GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for , Michael Price and Kyra Bennett

Name of Applicant

Address of site Price Bennett House, 40 Paradise Ave Avalon Beach

Declaration made by geotechnical engineer or engineering geologist or coastal engineer (where applicable) as part of a geotechnical report

I, Shyam Ghimire *on behalf of* CEC-Geotechnical

(Insert Name) (Trading or Company Name)

on this the ____________________ certify that I am a geotechnical engineer or engineering geologist or coastal engineer as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above organisation/company to issue this document and to certify that the organisation/company has a current professional indemnity policy of at least $10million.

I:

Please mark appropriate box

- X have prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009
- X am willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009
- X have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with Section 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. I confirm that the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy for Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.
- X have examined the site and the proposed development/alteration in detail and I am of the opinion that the Development Application only involves Minor Development/Alteration that does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.
- X have examined the site and the proposed development/alteration is separate from and is not affected by a Geotechnical Hazard and does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.
- X have provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: Geotechnical Assessment Report GR24140

Report Date: 15/10/2024

Author: Shyam Ghimire

Author's Company/Organisation: CEC-Geotechnical Pty Ltd

Documentation which relate to or are relied upon in report preparation:

A set of Architectural Plans including site plans, prepared by TKD Architects, Job references include AR.DA.1200, AR.DA.1400, AR.DA.1401, AR.DA.2000, AR.DA.2001, AR.DA.2002, AR.DA.3100, AR.DA.3101, AR.DA.3400.

• Survey Plan of prepared by CMS Surveyors, Reference No. 21152

I am aware that the above Geotechnical Report, prepared for the abovementioned site is to be submitted in support of a Development Application for this site and will be relied on by Pittwater Council as the basis for ensuring that the Geotechnical Risk Management aspects of the proposed development have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature ……………………………………………………………

Name …… Shyam Ghimire ……………………………………

Chartered Professional Status…… Professional Registered Engineering Geologist

Membership No. …… (RPgeo10300) Geotechnical Engineering

Company…… CEC-Geotechnical Pty Ltd ……

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER
FORM NO. 1(a) - Checklist of Requirements For Geotechnical Risk Management Report for Development Application

Development Application for Michael Price and Kyra Bennett
Name of Applicant
Address of site Price Bennett House, 40 Paradise Ave Avalon Beach

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Geotechnical Report. This checklist is to accompany the Geotechnical Report and its certification (Form No. 1).

Geotechnical Report Details:

Report Title: Geotechnical Assessment Report GR24140
Report Date: 15/10/24
Author: Shyam Ghimire
Author's Company/Organisation: CEC-Geotechnical

Please mark appropriate box

- Comprehensive site mapping conducted yes 17/07/24
  (date)
- Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
- Subsurface investigation required
  - No Justification ……not required as development is minor, and it will not impact in the stability……
  - Yes Date conducted ……………………
- Geotechnical model developed and reported as an inferred subsurface type-section
- Geotechnical hazards identified
  - Above the site yes report section 3.
  - On the site
  - Below the site
  - Beside the site
- Geotechnical hazards described and reported
- Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
  - Consequence analysis yes section 4 and 5
  - Frequency analysis
- Risk calculation
- Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
- Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified conditions are achieved.
- Design Life Adopted:
  - 100 years
  - Other ………50 years………
    specify
- Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
- Additional action to remove risk where reasonable and practical have been identified and included in the report.
- Risk assessment within Bushfire Asset Protection Zone.

I am aware that Pittwater Council will rely on the Geotechnical Report, to which this checklist applies, as the basis for ensuring that the geotechnical risk management aspects of the proposal have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated, and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature ……………………
Name ………Shyam Ghimire………
Chartered Professional Status………Professional Registered Engineering Geologist
Membership No. ….(RPgeo10300) Geotechnical Engineering
Company………CEC-Geotechnical Pty Ltd………

CEC Geotechnical

GEOTECHNICAL ASSESSMNET REPORT

Client – Michael Price

Project Title – 40 Paradise Avenue, Avalon Beach

Project Type – Proposed Alteration & Addition

Project No. – GR24140

Date Issued – 15/10/2024

Description of Services – Geotechnical Assessment Report

Document Control

Report Title: Geotechnical Site Classification Report

Report No: GR24140

Copies	Recipient
1. Final Copy (PDF – Sent via email)	Michael Price

Author	Technical Reviewer
	
Diego Espinosa Moreno Geotechnical/Environmental Engineer	**Shyam Ghimire** Principal Engineering Geologist

Revision	Details	Date	Amended By
	Original	15.10.2024	

T: (02) 9630 0121 **Email:** info@cec-au.com

M: (+61) 493 473 621 **Address:** 4/83 Grose St, North Parramatta NSW 2151

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1. Introduction

1.1 Background

CEC Geotechnical Pty Ltd was engaged by the client to conduct a geotechnical investigation at **40 Paradise Ave, Avalon Beach**. The objective of this report is to determine the subsurface ground condition, in order to provide a site classification in accordance with "*AS 2870-2011*" and to conduct a land slip risk assessment at the proposed alterations and additions.

1.2 Provided Information

- A set of Architectural Plans including site plans, prepared by TKD Architects, Job references include AR.DA.1200, AR.DA.1400, AR.DA.1401, AR.DA.2000, AR.DA.2001, AR.DA.2002, AR.DA.3100, AR.DA.3101, AR.DA.3400.
- Survey Plan of prepared by CMS Surveyors, Reference No. 21152

1.3 Proposed Development

With reference to the information provided by the client, it is understood that the proposed development will comprise of the alterations and additions to the existing dwelling.

1.4 Objectives

The objective of this report include:

- Slope stability assessment;
- Site Classification;
- Allowable bearing capacities;
- General geotechnical recommendations;

1.5 Scope of Works

The geotechnical site investigation was carried out on 17/07/2024 by an experienced geotechnical engineer in accordance with "*AS 1289*". The scope of works included:

- Desktop Study including a review of existing concept drawings, architectural plans, survey plan, geology and topography of the site and neighbouring properties.
- Site walkover
- Assessment of the existing slope including measurement of the ground slope and assessment of any structural and geotechnical defects that might be a cause of ground movements.
- Drilling 3 boreholes (BH01 - BH03) by hand auger (location found in Appendix A and logs found in Appendix B)
- Dynamic Cone Penetration (DCP) testing in accordance with Australian Standards "*AS 1289*"
- Site classification in accordance with Australian Standards "*AS 2870-2011".*

1.6 Constraints

This report was produced based on a limited geotechnical investigation in line with the requirements of "*AS 2870-2011*, If a more detailed geotechnical investigation regarding soil reactivity is available, it should be provided to CEC Geotechnical Pty Ltd. In addition, any details related to the site's history should be supplied.

This classification is based on the findings in this investigation, including visual-tactile identification of the soil profile combined with the author's local knowledge and experience. If the site conditions change from those of the original investigation, the findings of this report may be void.

2. Desktop Assessment

2.1 General Site Description

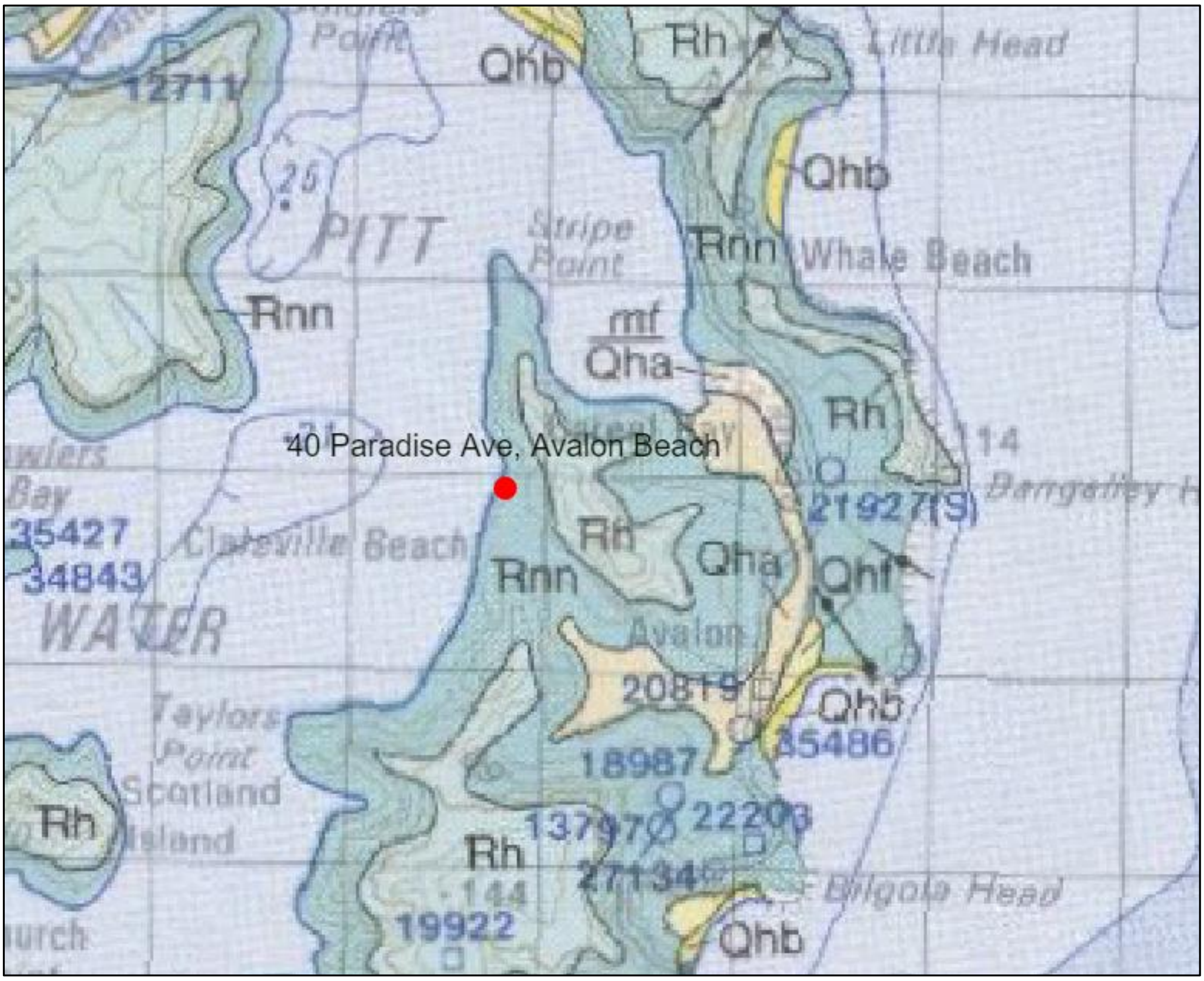
The site is located within the Local Government Area (LGA) of Northern Beaches Council and is registered as Lot 132 Section A DP1010865 and is covering an area of 1076m^2. During the site visit it was observed that there was two existing single-storey dwelling situated on the site, surrounded by grass.

Figure 1: Site Location (40 Paradise Ave, Avalon Beach)

2.2 Geological Description

From survey information site is sloping to the south; however, no survey data was available at the time preparing the report. The 1:100,000 scale Geological Series Map of the Sydney region indicates that the subject site is underlain by Newport Formation **(Rnn)**, which consists of interbedded laminite, shale, and quartz to lithic quartz sandstone.

Figure 2: 1:100,000 scale Geological Series Map of the Sydney Region



3. Geotechnical Investigation

3.1 Subsurface Conditions

The results of the investigation indicate that the subsurface profile at the test locations generally comprises Silty CLAY underlain by weathered SANDSTONE. Based on the borehole information, a summary of subsurface conditions is presented below. The borehole locations and bore hole logs are presented in Appendix A and B.

Table 1: Subsurface Conditions

Unit	Description	BH1 (m)*	BH2 (m)*	BH03 (m)*
Unit - 1 Topsoil	SILT OL: soft to firm, low plasticity, brown	0 – 0.3	0 – 0.4	0 – 0.3
Unit – 2 Fill	SILT OL: low plasticity, soft, dark grey	-	-	0.3 – 0.35
Unit - 3 Residual	Silty CLAY CI: firm, medium plasticity, dark grey brown	0.3 – 0.8	0.4 – 0.6	-
Unit - 4 Residual	Silty CLAY CI: stiff, medium plasticity, dark grey brow	0.8 – 1.5	0.6 – 0.8	-
Unit - 5 Residual	Silty CLAY CI: very stiff to hard, medium plasticity, brown	1.5 – 1.6	0.8 – 0.9	-

**Depths below ground level (BGL) at the location of each borehole. This may vary depending on other areas of the site.*
BH01, BH02 and BH03 met refusal at depths of 1.6m, 0.9m and 0.35m respectively.

3.2 Site Classification

Due to the presence of services, trees and topsoil, the overall site is classified as **Class P** in accordance with "*AS 2870 2011*". Once topsoil/fill is removed, this site will then be classified as **Class S** in accordance with "AS 2870-2011". Class S is indicative 0 - 20mm movement from moisture changes.

3.3 Design Parameters

The following allowable bearing pressures can be adopted for the units listed in the table below. These bearing pressures apply where typically footings are found minimum 300mm into the specified material.

Table *2* Geotechnical Design Parameters

Material Description	Depth (m)*	Allowable Bearing Capacity (kPa)
Unit 2: Fill Silt OL	0.3	0
Unit 3: Residual Silty CLAY (firm)	0.5	100
Unit 4: Residual Silty CLAY (stiff)	0.8	150
Unit 5: Residual Silty CLAY (very stiff to hard)	1.5	200

**Approximate depth below ground level based on borehole logs completed during geotechnical investigation.*
Note: Unit 1 Topsoil design parameters are not applicable.

3.4 Landslide Risk Assessment

3.4.1 General Description

The general stability of a site is governed by factors such as slope angles, depth of sub-surface material, drainage, movements of groundwater and surface runoff and potential sliding planes (interface of rock/soil and joints and faults within the bedrock).

Some indicators of ground movement/landslip include:

- Rotation, tilting or bending of trees or shrubs,
- Cracks in the ground parallel to the slope,
- Signs of slumping,
- Leaking pipes, such as water and sewer line,
- Bulging and tilting of retaining structures,
- Cracked or rotated brick piers and concrete surfaces; and
- Differential settlement.

3.4.2 Observations

The following were observed during the site inspection:

- The overall slope is less than 5 degrees.
- No signs of structural defects that could be associated with ground slip.
- No tension cracks on the ground surface.
- No signs of slumping or landslip within the site.
- No damages or deteriorations that could potentially be associated with ground slip or ground movement.
- No signs of movement in trees & shrubs.
- No sign of cracks in sewer line.
- The soil was generally moist, however, there were no signs of surface water ponding or seepage throughout the property.

4. Discussion and Recommendations

4.1 Risk Assessment of Property Loss

Based on the topography and the ground conditions, the following possible hazards have been identified for landslide mechanisms:

- Soil creep
- Shallow slip
- Deep seated slide
- Near surface slumping
- Detached rock blocks within the site

The assessed risk levels of the hazards with the existing conditions are summarised in Table 3. In this assessment, the potential effects of instability on the adjoining properties, including effects on the land, buildings, and associated structures within the adjoining properties were considered.

Table 2: Assessed Risk to Property – Current State of the Property

Potential Hazard	Qualitative Measures of Likelihood	Qualitative Measures of Consequences to Property	Qualitative Risk Analysis – Level of Risk to Property
Shallow Slip	Unlikely	Insignificant	Very Low
Deep seated slide	Unlikely	Minor	Very Low
Soil creep	Unlikely	Minor	Very Low
Near surface slumping	Rare	Insignificant	Low
Detached Rock blocks within the site	Unlikely	Minor	Very Low

The overall slope instability risk of the site under existing conditions is assessed to be **"Very Low"** resulting from potential down-slope soil creep. According to *"AGS 2007c"*, the "**Very Low Risk Level**" is acceptable and manageable by normal slope maintenance procedures.

4.2 Risk Assessment of Life Loss

The risk assessment is carried out as per the AGS (2007) guidelines for the present condition without any ground stabilisation and adding engineering works as shown in Table 3.

Table 3: Risk to Life

Mode of Failure	Likelihood of Occurrence	Indicative Annual Probability	Probability of Spatial	Temporal Factor	Vulnerability	Individual Risk (per annum)
Shallow Slip failure/ Near surface slumping	Rare (E)	10^{-5}	0.2	0.66	0.1	$1.32*10^{-6}$
Deep seated/ Soil creep	Rare (E)	10^{-5}	0.5	0.66	0.5	$1.65*10^{-6}$

The AGS guidelines outline that the post-development tolerable loss of life risk for the "existing slopes" is 1 x 10^{-6}/ annum. Based on our calculations in Table 3, the risk is less than the criteria and therefore the risk is negligible.

5. Conclusion and Geotechnical Recommendations

5.1 Risk on Property and Life

The overall slope instability risk of the site under existing conditions is assessed to be **"Low to Very Low"**. According to "*AGS 2007c*", the "Very Low Risk Level" is acceptable and manageable by normal slope maintenance procedures.

The AGS guidelines recommend that post-development tolerable loss of life risk for the person most at risk for the "existing slopes" is 1 x 10^{-6}/ annum. From CEC-Geotechnical calculations this level of risk is acceptable for long term.

For more information, please refer to Appendix B, titled *"Some Guidelines for Hillside Construction"* adapted from the Journal of the Australian Geomechanics Society, volume 42, Number 1, dated March 2007.

5.2 Sub-grade Preparation

- Fill should be compacted close to its optimum moisture content (+/- 2%) during compaction.
- The compaction method and equipment shall suit the filled material. The compaction of soil shall be tested by a NATA accredited laboratory and Geotechnical Inspection and Testing Authority (GITA) to ensure it meets the requirements of "*AS 3798-2007 Guidelines on earthworks for commercial and residential developments*".
- Any organic materials (including topsoil) within the proposed building envelope are to be removed.
- The site should be proof rolled after an initial site scrape to unveil any soft spots. Any soft areas are to be removed and backfilled with compacted fill material as described in "*AS 2870-2011*", cl 6.4.2.

5.3 Conditions of the Recommendations

- The descriptions of the soils encountered in the boreholes follow those outlined in "*AS 1726-2017*", Geotechnical Site Investigations. Colour descriptions can vary with soil moisture content and individual interpretation.
- The advice given in this report assumes that the test results are representative of the overall subsurface conditions. However, it should be noted that actual conditions in some parts of the building site may differ from those found in the boreholes. If excavations reveal soil conditions significantly different from those shown in our attached Borehole Log(s), CEC Geotechnical shall be consulted and the excavations shall be stopped immediately.
- Depths mentioned in this report are measured from the surface during testing and may vary accordingly if any filling or excavation works are carried out. The description of the foundation material has been provided for ease of recognition over the whole building site.
- Any sketches in this report should be considered as only approximate pictorial evidence of our work. Therefore, unless otherwise stated, any dimensions or slope information should not be used for any building cost calculations and/or positioning of the building. Dimensions on logs are correct.

6. Further Geotechnical Recommendations

CEC Geotechnical should be engaged at the following stages:

- If soil conditions encountered differ significantly from those described within this report.
- If the proposed development is altered significantly from what has been assessed and described within this report.
- To confirm safe batter angles and excavation methods during construction.
- To confirm founding materials and allowable bearing capacity.
- If the site conditions at the time of construction differ from those described in this report, then CEC Geotechnical shall be contacted. The owner/builder will be responsible for any fees associated with this additional work.

7. Limitations

This report and its associated recommendations have been prepared exclusively for our client who is named on the front page of this report and is the only intended entity to benefit from this report. CEC Geotechnical notes that reliance on the information provided in this report by any third party will be at their own risk. It should be noted that the analysis and conclusions made in this report may rely on works by other consultants and entities and hence, should these documents and investigations be incorrect, CEC Geotechnical must be made aware and the results of this report may be void.

For and on behalf of CEC Geotechnical Pty Ltd

Diego Espinosa Moreno

Geotechnical/Environmental Engineer
B.E, M.E.

Shyam Ghimire

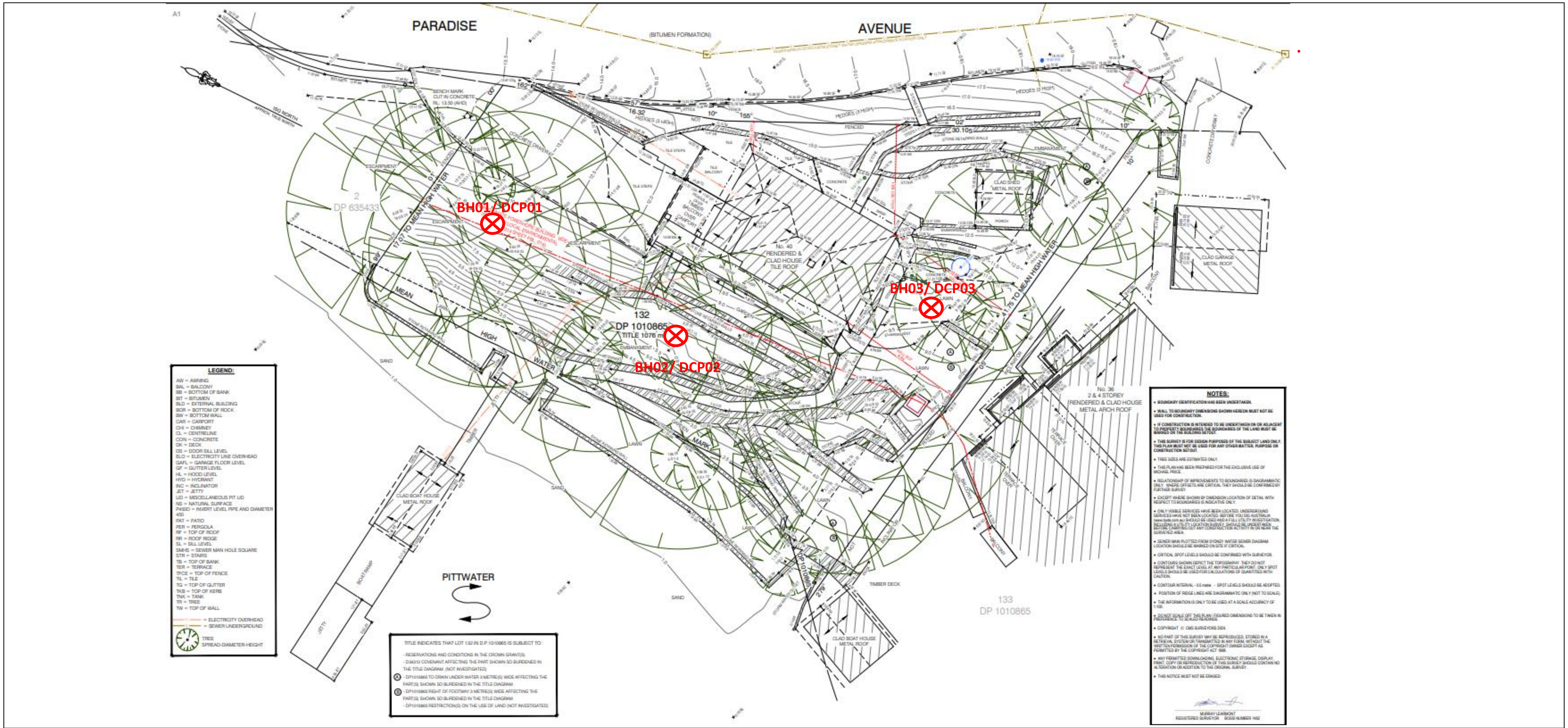
Principal Engineering Geologist
B.Sc. M.sc RPgeo(Geotechnical)10300

References

- *"AS 2870 (2011)"*, Residential Slab and Footings – Construction
- Australian Geomechanics Society (2007) – Practice notes guidelines for landslide risk management 2007,
- Australian Geomechanics Journal, Vol 42, No. 1 AS 1726 - 2017 Geotechnical Site Investigation
- Geological Series Sheet 9131 Geological Series Map of the Sydney Region

APPENDIX A – Site Plan

CEC Geotechnical



CEC GEOTECHNICAL

Drawn	**AS**	**CLIENT: MICHAEL PRICE** **SITE ADDRESS: 40 PARADISE AVE, AVALON BEACH**	**Figure**	**1**
Checked	**SG**		**Title**	**Site Plan**
Date	**31/07/2024**			
Scale @ A3	**NTS**		**Job No**	**GR24140**

APPENDIX B – Bore Hole Logs and DCP Test Results

CEC Geotechnical
U4 83, Grose Street, North Parramatta, NSW 2151
Phone: (02) 9630 0121

Geotechnical Log - Borehole

BH1

UTM	:	Drill Rig	: Hand Auger /DCP	Job Number	: GR24140
Easting (m)	: 0.00	Driller Supplier	:	Client	: Michael Price
Northing (m)	: 0.00	Logged By	: AS	Project	: Proposed Development
Ground Elevation	: Not Surveyed	Reviewed By	:	Location	: 40 Paradise Ave, Avalon Beach NSW
Total Depth	: 1.6 m BGL	Date	: 17/07/2024	Loc Comment	:

Drilling Method	DCP graph	Depth (m)	Water	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Testing	Consistency/Density	Well Diagram
Hand Auger	1, 1, 2	0.3		Top Soil		OL	Top soil SILT OL: soft to firm, low plasticity, brown, organic, slightly moist.	SLM		S-F	
	2, 2, 3, 3, 5	0.8		Residual		CI	Residual Silty CLAY CI: firm, medium plasticity, dark grey brown, organic, slightly moist.			F	
	8, 8, 11, 13, 14, 15, 15	1.5		Residual		CI	Residual Silty CLAY CI: stiff, medium plasticity, dark grey brown, organic, slightly moist.			St	
	terminated			Residual		CI	Residual Silty CLAY CI: very stiff to hard, medium plasticity, brown, organic, slightly moist.			VSt-H	

BH1 refusal at 1.6m

CEC Geotechnical

U4 83, Grose Street, North Parramatta, NSW 2151

Phone: (02) 9630 0121

Geotechnical Log - Borehole

BH2

UTM	:	**Drill Rig**	: Hand Auger /DCP	**Job Number**	: GR24140
Easting (m)	: 0.00	**Driller Supplier**	:	**Client**	: Michael Price
Northing (m)	: 0.00	**Logged By**	: AS	**Project**	: Proposed Development
Ground Elevation	: Not Surveyed	**Reviewed By**	:	**Location**	: 40 Paradise Ave, Avalon Beach NSW
Total Depth	: 0.9 m BGL	**Date**	: 17/07/2024	**Loc Comment**	:

Drilling Method	DCP graph	Depth (m)	Water	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Testing	Consistency/Density	Well Diagram
Hand Auger	1 1 2 2	0.4		Top Soil		OL	Top soil SILT OL: soft, low plasticity, dark grey, organic, slightly moist.	SLM		S	
	4 4 5 5	0.8		Residual		CI	Residual Silty CLAY CI: firm to stiff, medium plasticity, brown, organic, slightly moist.			F-St	
	Refusal			Residual		CI	Residual Silty CLAY CI: stiff to very stiff, medium plasticity, brown, organic, slightly moist.			St-VSt	

BH2 refusal at 0.9m

CEC Geotechnical

U4 83, Grose Street, North Parramatta, NSW 2151
Phone: (02) 9630 0121

Geotechnical Log - Borehole

BH3

UTM	:	Drill Rig	: Hand Auger /DCP
Easting (m)	: 0.00	Driller Supplier	:
Northing (m)	: 0.00	Logged By	: CEC Geotechnical
Ground Elevation	: Not Surveyed	Reviewed By	: AS
Total Depth	: 0.35 m BGL	Date	: 17/07/2024

Job Number	: GR24140
Client	: Michael Price
Project	: Proposed Development
Location	: 40 Paradise Ave, Avalon Beach NSW
Loc Comment	:

Drilling Method	DCP graph	Depth (m)	Water	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Testing	Consistency/Density	Well Diagram
				Top Soil		OL	Top soil SILT OL: soft, low plasticity, dark grey, organic, slightly moist.	SLM		S	
		0.3		Fill		OL	Fill SILT OL: low plasticity, soft, dark grey, organic, slightly moist.				

BH3 refusal at 0.35m

Depth scale: 1, 2, 3, 4

CEC Geotechnical

EXPLANATION OF NOTES, ABBREVIATIONS & TERMS USED ON BOREHOLE AND TEST PIT LOGS - SOIL DESCRIPTION (AS1726 - 2017)

SOIL CLASSIFICATION SYSTEM

Coarse Grained Soil

GW	Well graded gravels, gravel-sand mixtures, little or no fines
GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines, uniform gravels
GM	Silty gravels, Gravel-sand-silt mixtures
GC	Clayey gravels, gravel-sand-clay mixtures
SW	Well-graded sands, gravelly sands, little or no fines
SP	Poorly-graded sands, gravelly sand, little or no fines
SM	Silty sands, sand-silt mixtures
SC	Clayey sands, sand-clay mixtures

Fine Grained Soils

ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or silts with low plasticity
CL, CI	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays
OL	Organic silts and organic silty clays or low plasticity
MH	Inorganic silts, micaceous or diatomaceous fine sand for silty soils
CH	Inorganic clays of high plasticity
OH	Organic clays of medium to high plasticity, organic silts
PT	Peat, humus, swamp soils with high organic contents

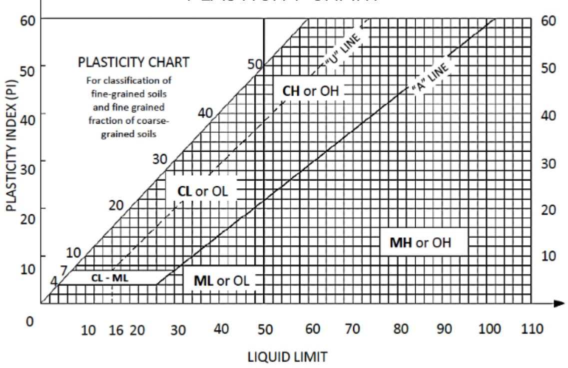
First Letter: G = Grave, S = Sand, M = Silt, C = Clay; Second Letter: W = Well graded, P = Poorly-graded, M = Mixture, O = Organic, L = Low plasticity, H = High plasticity
Soils may be a combination of multiple soil classifications where borderline

PARTICLE SIZE

Soil	Major Division	Sub-Division	Particle Size (mm)
Coarse	Boulders		>200
	Cobbles		63 – 200
	Gravel	Coarse	20 – 63
		Medium	6 – 20
		Fine	2.36 – 6
	Sand	Coarse	0.6 – 2.36
		Medium	0.2 – 0.6
		Fine	0.075 – 0.2
Fine	Silt		0.002 – 0.075
	Clay		<0.002

0.075 mm is the approximate minimum particle size discernible by eye

PLASTICITY CHART



MOISTURE CONDITION

Coarse	D	Dry	Sands and gravels are free flowing.
	M	Moist	Soils are darker than in the dry condition and may feel cool. Sands and gravels tend to cohere.
	W	Wet	Soils exude frere water. Sands and gravels tend to cohere
Fine	PL	Plastic Limit	Moisture content of fine grained soils are described; as below plastic limit (<PL), near to plastic limit (=PL), above plastic limit(>PL), near to the liquid limit (=LL), or above the liquid limit (>LL)
	LL	Liquid Limit	

CONSISTENTCY AND DENSITY

Fine Grained Soils

			Pocket Penetrometer Reading (kPa)
VS	Very Soft	Exudes between fingers when squeezed	<25
S	Soft	Can be moulded by light finger pressure	20 – 50
F	Firm	Can be moulded by strong finger pressure	50 – 100
St	Stiff	Cannot be moulded by fingers. Can be indented by thumb	100 – 200
VSt	Very Stiff	Can be indented by thumb nail	200 – 400
H	Hard	Can be indented by thumb nail with difficulty	>400

Coarse Grained Soils

		Density Index %	'N' Value
VL	Very Loose	≤15	0 – 4
L	Loose	15 – 35	4 – 10
MD	Medium Dense	35 – 65	10 – 30
D	Dense	65-85	30 – 50
VD	Very Dense	>85	>50

SECONDARY OR MINOR SOIL COMPONENTS

Designation of Components	In Coarse Grained Soils				In Fine Grained Soils	
	% Fines	Terminology	% Accessory Coarse Fraction	Terminology	% Sand/gravel	Terminology
Minor	≤5	'trace' clay/silt	≤15	'trace' sand/gravel	≤15	'trace' sand/gravel
	5 – 12	'with' clay/silt	15 – 30	'with' sand/gravel	15 – 30	'with' sand/gravel
Secondary	>15	Prefix silty or clayey	>30	Prefix sandy or gravelly	>30	Prefix sandy or gravelly

CEC Geotechnical

EXPLANATION OF NOTES, ABBREVIATIONS & TERMS USED ON BOREHOLE AND TEST PIT LOGS - SOIL DESCRIPTION (AS1726 - 2017)

STRENGTH OF INTACT ROCK

Symbol	Term	Point Load Index, (I_{s50}) MPa	Field Guide to Strength
VL	Very Low	$0.03 \le I_{s50} < 0.1$	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; pieces up to 30 mm thick can be broken by finger pressure
L	Low	$0.1 \le I_{s50} < 0.3$	Easily scored with knife; indentations 1 mm to 3 mm after firm blow with pick point; core 150mm long and 50 mm diameter can be broken by hand; sharp edges of core friable
M	Medium	$0.3 \le I_{s50} < 1.0$	Readily scored with knife; core 150 mm long and 50 mm diameter can be broken by hand with difficulty
H	High	$1.0 \le I_{s50} < 3$	Core 150 mm long and 50 mm diameter cannot be broken by hand but can be broken by single firm blow of pick; rock rings under hammer
VH	Very High	$3 \le I_{s50} < 10$	Hand held specimen breaks with pick after more than one blow; rock rings under hammer
EH	Extremely High	$10 \le I_{s50} <$	Specimen requires many pick blows to break intact rock, rock rings under hammer

Material with rock strength less than "Very Low" is to be described using soil properties

DEGREE OF ROCK WEATHERING

<table>
<tr><th colspan="2">Term</th><th colspan="2">Symbol</th><th>Definition</th></tr>
<tr><td colspan="2">Residual Soil</td><td colspan="2">RS</td><td>Soil derived from the weathering of rock; the mass structure and material fabric are no longer evident the soil has not been significantly transported.</td></tr>
<tr><td colspan="2">Extremely Weathered</td><td colspan="2">XW</td><td>Material is weathered to such an extent that it has soil properties, i.e. it either disintegrates or can be remoulded in water. Fabric of original rock still visible.</td></tr>
<tr><td>Highly Weathered</td><td rowspan="2">Distinctly Weathered</td><td>HW</td><td rowspan="2">DW</td><td>Rock strength is changed by weathering. The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognizable. Some minerals are decomposed to clay minerals. Porosity may be increased by leach, or may be decreased due to deposition or weathering products in pores.</td></tr>
<tr><td>Moderately Weathered</td><td>MW</td><td>The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognizable, but shows little or no change of strength from fresh rock.</td></tr>
<tr><td colspan="2">Slightly Weathered</td><td colspan="2">SW</td><td>Rock is slightly discoloured but shows little or no change of strength from fresh rock.</td></tr>
<tr><td colspan="2">Fresh</td><td colspan="2">FR</td><td>Rock shows no sign of decomposition or staining.</td></tr>
</table>

Distinctly Weathered is to be used when it is not possible to differentiate between highly and moderately weathered.

Extremely Weathered material is to be described using soil properties

ROCK MASS PROPERTIES

Term	Separation of Stratification Planes	Term	Description
Thinly laminated	< 6 mm	Fragmented	Primarily fragments < 20 mm length and mostly of width < core diameter
Laminated	6 mm to 20 mm	Highly fractured	Core lengths generally less than 20 mm to 40 mm with occasional fragments
Very thinly bedded	20 mm to 60 mm		
Thinly bedded	60 mm to 200 mm	Fractured	Core lengths mainly 30 mm to 100 mm with occasional shorter and longer pieces
Medium bedded	0.2 m to 0.6 m	Slightly fractured	Core lengths generally 0.3 m to 1.0 m with occasional longer and shorter sections
Thickly bedded	0.6 m to 2.0 m		
Massive	> 2 m	Unbroken	Core has no fractures

DEFECT TYPES AND DESCRIPTIONS

Defect Type

BR	Bedding parting
JT	Joint
SR	Sheared surface
SZ	Sheared zone
SS	Sheared seam
CS	Crushed seam
IS	Infill seam
XS	Extremely Weathered Seam

Defect Shape

PL	Planar
ST	Stepped
CR	Curved
IR	Irregular
UN	Undulating

Surface Roughness

VR	Very rough
RO	Rough
SM	Smooth
PO	Polished
SL	Slickenside

Defect Coatings

CL	Clean
ST	Stained
VN	Veneer
CT	Coating

Vertical Boreholes – The dip of the defect is given from the horizontal

Inclined Boreholes – The angle of the defect is given from the core axis

APPENDIX C – Qualitative Terminology for Use in Assessing Risk to Property

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		**Implied Indicative Landslide Recurrence Interval**		**Description**	**Descriptor**	**Level**
Indicative Value	**Notional Boundary**					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		**Description**	**Descriptor**	**Level**
Indicative Value	**Notional Boundary**			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

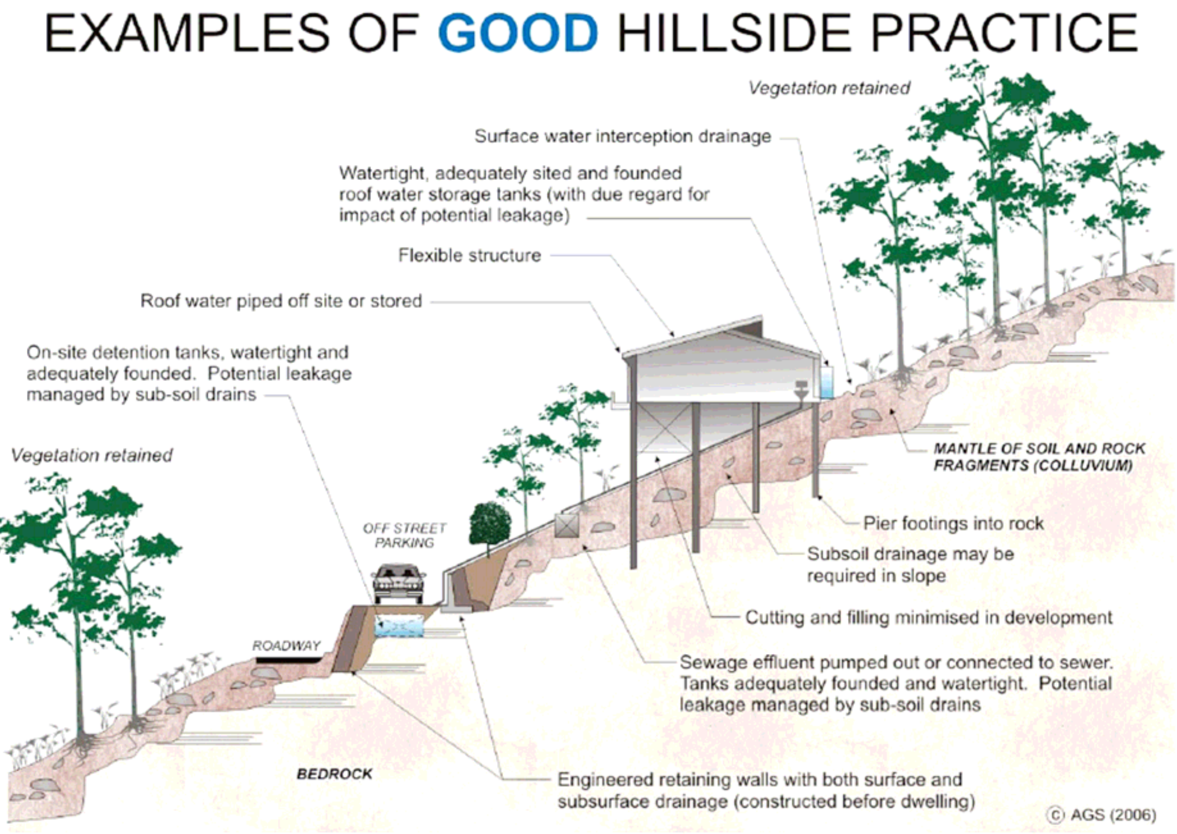
(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

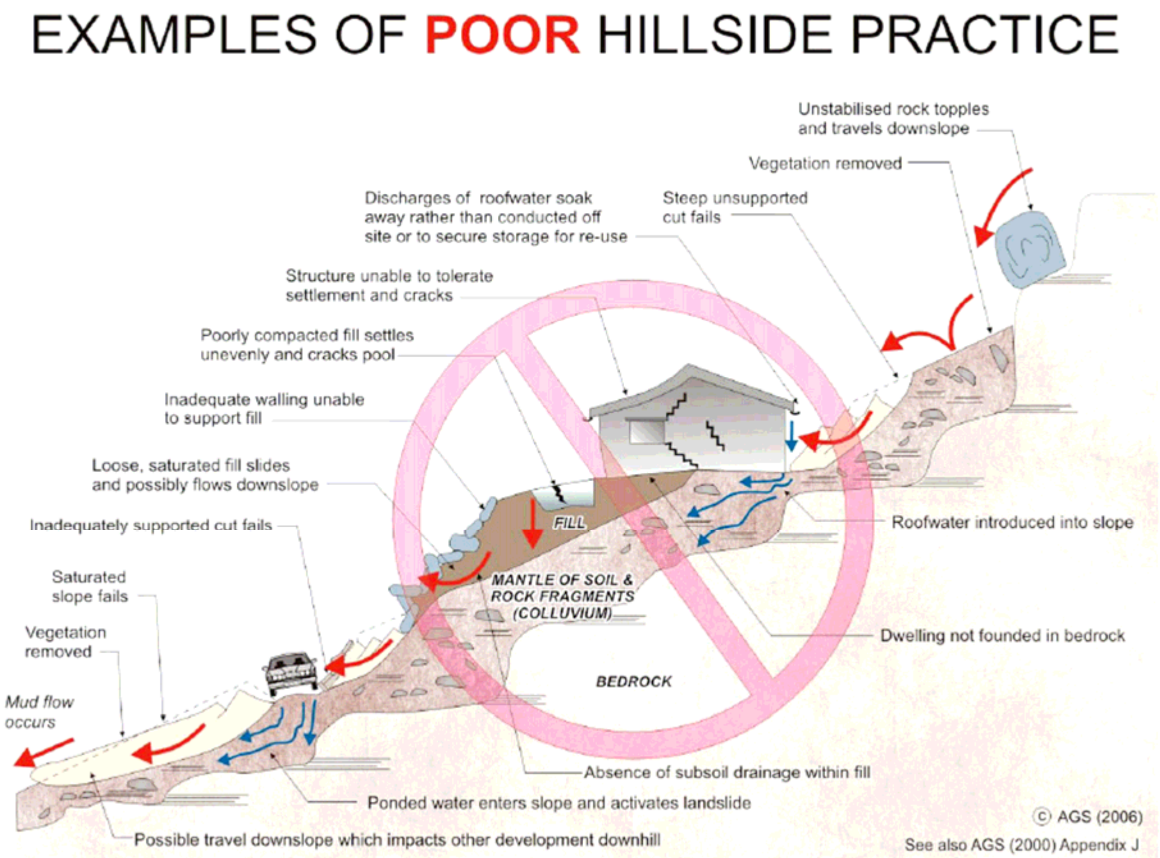
(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

APPENDIX D – Guidelines for Hillside Construction

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	


EXAMPLES OF GOOD HILLSIDE PRACTICE
Vegetation retained
Surface water interception drainage
Watertight, adequately sited and founded roof water storage tanks (with due regard for impact of potential leakage)
Flexible structure
Roof water piped off site or stored
On-site detention tanks, watertight and adequately founded. Potential leakage managed by sub-soil drains
Vegetation retained
OFF STREET PARKING
ROADWAY
MANTLE OF SOIL AND ROCK FRAGMENTS (COLLUVIUM)
Pier footings into rock
Subsoil drainage may be required in slope
Cutting and filling minimised in development
Sewage effluent pumped out or connected to sewer. Tanks adequately founded and watertight. Potential leakage managed by sub-soil drains
BEDROCK
Engineered retaining walls with both surface and subsurface drainage (constructed before dwelling)
© AGS (2006)


EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Loose, saturated fill slides and possibly flows downslope
Inadequately supported cut fails
Saturated slope fails
Vegetation removed
Mud flow occurs
FILL
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Roofwater introduced into slope
Dwelling not founded in bedrock
BEDROCK
Absence of subsoil drainage within fill
Ponded water enters slope and activates landslide
Possible travel downslope which impacts other development downhill
© AGS (2006)
See also AGS (2000) Appendix J

APPENDIX E – Site Classification General Information

Foundation Maintenance and Footing Performance: A Homeowner's Guide

BTF 18 replaces Information Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

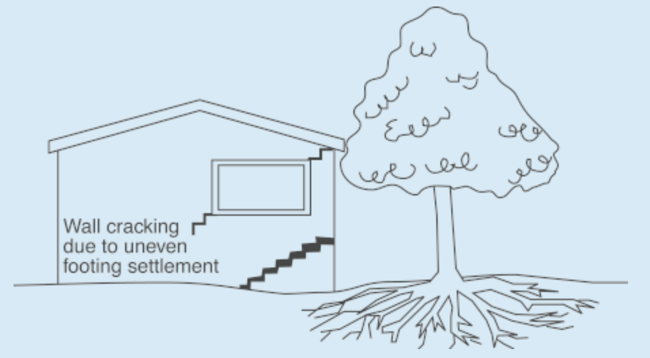
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

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

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

Trees can cause shrinkage and damage



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

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

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

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

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

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

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

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

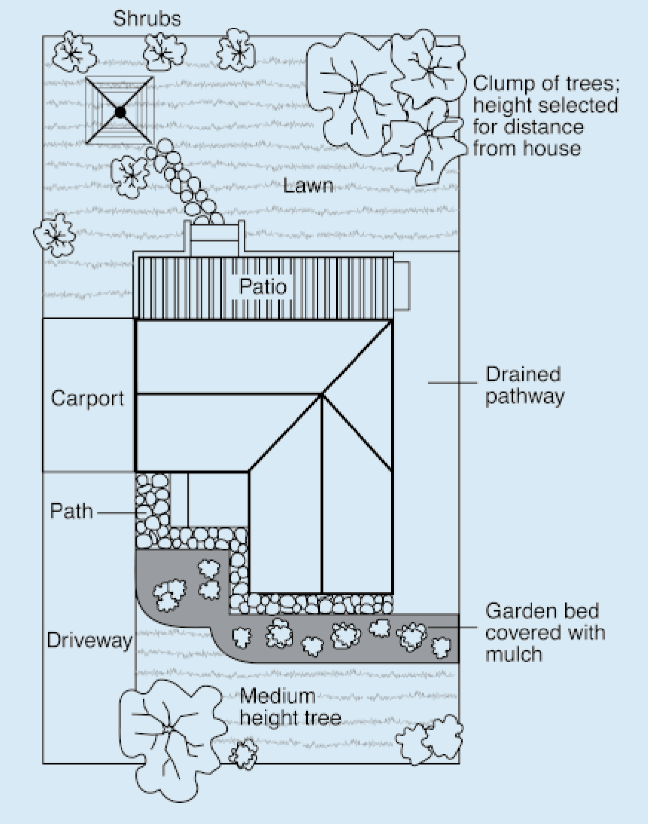
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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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