Landslide Risk Assessment for Lot 19 in DP8698, 77 Central Road, Avalon Beach 2107

Prepared For: Nicole & Joel Schuberg
C/O-Mathieson Architects

Reference: SG24-1170

Date: 18th October 2024

Controlled Document

Distribution and Revision Register

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Revision Control		
Document No.	**Revision No.**	**Issue Date**
SG24-1170	0	28-10-2024

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1 INTRODUCTION

At the request of Mathieson Architects, on behalf of Nicole & Joel Schuberg, Sydney Geotech Pty Ltd (SG) has conducted a Landslide Risk Assessment (LRA) at 77 Central Road, Avalon Beach 2107.

In accordance with the Northern Beaches Council LGA, under the Geotechnical Riak Management Policy for Pittwater – 2009 (Pittwater Local Environmental Plan 2014), the proposed development has been identified as H2 on the Pittwater Geotechnical Hazard Map. As such, this landslide risk assessment aims to determine the risk to life and property pertaining to the construction of the proposed.

1.1 Proposed Development

Proposed works include the demolition of the existing house and the construction of a new five-bedroom house, pool, and driveway.

1.2 Standards & Guidelines

This report shall be prepared in accordance with:

- AS1726-2017 'Geotechnical site investigations';
- AS2870-2011 'Residential slabs and footings';
- AS3798-2017 'Guidelines on earthworks and commercial residential developments';
- Geotechnical Riak Management Policy for Pittwater - 2009;
- AGS 2007 – 'Australian Geomechanics Society's guidelines for Landslide Risk Management (LRM)';
- Relevant council policies and guidelines

1.3 Scope of Works

The scope of works includes provision of the following;

- Desktop review;
- Review of Dial Before You Dig (DBYD);
- Drilling of appropriate number of boreholes;
- In-situ testing including Dynamic Cone Penetrometer (DCP) testing; and
- Preparation of a Landslide Risk Assessment.

1.4 Context of Report

This report is to be read in its entirety and individual sections should not be reviewed to provide any level of information independently. Each section of the report relates to the rest of the document and as such is to be read in conjunction, including its appendices and attachments. Particular attention is drawn to the limitations of inherent site investigations and the importance of verifying the subsurface conditions inferred herein.

2 DESKTOP STUDY

A range of online sources in conjunction with Sydney Geotech Pty Ltd available files were accessed for the purpose of this report. Appendix B displays the relevant desktop information.

2.1 Soil Landscapes

<u>Warriewood (Swamp)</u>

Level to gently undulating swales, depressions and infilled lagoons on Quaternary sands. Local relief <10 m, slopes <3%. Water table at <2 m. Mostly cleared of native vegetation.

2.2 Geology

Holocene silty to peaty quartz sand. Medium to fine marine sand with podzols.

Figure 1 Geology Map of The Area

2.3 Dominate Soils

Loose, speckled, dark grey loamy sand.

This is dark grey loamy sand with loose apedal single-grained structure and sandy fabric. It generally occurs as topsoil (A1 horizon). This material consists of a speckled mixture of dark organic materials and clean quartz sand grains. The colour ranges from brownish-grey to brownish-black to black with increasing organic matter. The pH ranges from strongly acid (pH 4.5) to neutral (pH 7.0) and lime has often been applied. This material is often water repellent. Roots are abundant and charcoal fragments are often present, but there are no stones.

Bleached massive sand.

This is bleached sand with apedal single-grained structure and sandy fabric. It commonly occurs as an A2 horizon. This material is composed almost entirely of clean quartz sand grains that have been compacted over time. It is weakly coherent with apedal massive structure when moist and non-cohesive with loose apedal single-grained structure when dry. The surface condition is loose. Dry colours are bleached and moist colour ranges from light grey to dull yellow orange. The pH ranges from moderately acid (pH 5.5) to neutral (pH 7.0). Charcoal and stones are absent whilst roots are few.

Pale mottled massive sand.

This is commonly saturated pale mottled sand with apedal single-grained structure and sandy fabric. This material occurs as deep subsoil usually below the water table (B horizon). Texture varies from sand to less commonly clayey sand. This material has apedal massive structure and sandy fabric. It is usually weakly cohesive. The colour varies from dull yellow to brownish-grey and grey, yellow or brown mottles are common with depth. The pH ranges from moderately acid (pH 5.5) to neutral (pH 7.0). Roots are rare and charcoal and stones are absent.

Black sticky peat.

This is commonly saturated, black organic rich silt loam or silty clay loam with apedal massive structure. It generally occurs as topsoil in low lying areas or as a buried soil (P or D horizon). Fibrous plant remains dominate this material which is moderately sticky and distinctly spongy. The colour is commonly black or brownish-black due to the organic material present. It may become extremely hardsetting when dry. The pH ranges from strongly acid (pH 4.5) to moderately acid (pH 5.5). Roots are common and stones are absent.

Brown soft iron pan.

This is commonly brown, iron-stained, sand to loamy sand with apedal massive structure and sandy fabric. It commonly occurs as subsoil above the water table (B horizon). Fabric is occasionally earthy. This material consists of quartz sand grains coated and weakly cemented with yellow to red sesquioxides. It requires up to a moderate force to disrupt. Colour varies from dull yellow orange to brown. Dark orange, yellow and brown mottles are common. The pH ranges from moderately acid (pH 5.5) to neutral (pH 7.0). Roots are rare and stones and charcoal fragments are absent.

Dark brown soft organic pan.

This is dark brown sand to loamy sand with apedal massive structure and sandy fabric. It usually occurs as subsoil (B horizon). Fabric is occasionally earthy. This material consists of quartz sand grains coated and weakly cemented with black organic aluminium compounds. It requires up to a moderate force to disrupt. The colour ranges from black to dark brown. The pH ranges from moderately acid (pH 5.5) to neutral (pH 7.0). Stones and charcoal are absent, and roots are rare.

2.4 Planning

With reference to the Pittwater Local Environmental Plan 2014 the subject site is mapped as:

- Land Zoning - R2: Low Density Residential.
- Heritage – No.
- Biodiversity – Yes.
- Acid Sulfate Soils – Class 4 & 5.
- Landslip – Yes: H2.

3 METHODOLOGY

3.1 Fieldwork

A site visit was made on Friday 27th September 2024 by an engineering geologist from SG. A preliminary walkover of the site was conducted during the site visit. The fieldwork consisted of the drilling of three (3) boreholes up to 3.00m depth (limit of investigation). The boreholes were drilled utilising a Ute Mounted Drill Rig with 100mm solid flight auger attachments.

Figure 2 Ute Mounted Drill Rig

Dynamic Cone Penetrometer (DCP) tests were undertaken next to each borehole location. Appendix A displays the location of the excavated boreholes and DCP testing undertaken.

4 SITE CLASSIFICATION

The classification of a site involves several geotechnical factors such as depth of bedrock, the nature and extent of subsurface soils and any specific problems (slope instability, soft soils, deleterious materials, filling, reactivity of the soils etc.).

The front of the site presented moderate slopes between 10-18°. In accordance with AS 2870 (2011) – 'Residential slabs and footings' the site is classified 'Class P'. The natural soil profile presented clayey sands and sandy clays up to a minimum 3.0m depth and can be classified Class H1 with a characteristic soil movement (Ys) of 40-60 mm. An appropriate footing system should be designed in accordance with the above code. The possibility of additional movements, due to abnormal moisture variations, should be minimised by proper "site management" procedures as provided on the attached CSIRO Sheet.

It should be noted that if controlled fill is used as foundation material the site may also be re-classified (if applicable) if assessed in accordance with engineering principles. Good engineering principles are provided in Australian standard 3798-2007 'Guidelines on earthworks for commercial and residential developments' compaction and certification methods All relevant construction notes to AS2870-2011; Section 3 Standard Designs apply.

5 LANDSLIDE RISK ASSESSMENT

The objectives of the landslide risk assessment are to verify the site conditions and local geology, evaluating the effect of the proposed scope of works on the stability of the site in relation to risk to life and property, and to deliver guidance and recommendations relating to the necessity for further investigation.

5.1 Site Conditions

The site and desktop inspection suggest the subject site is built upon natural swamp clayey sands and sandy clays. The site is a survey calculated 1306m^2 in area and presented an elongated rectangular shaped block. At the time of the inspection, the site presented and existing residential dwelling, numerous outhouses, managed lawns and small garden areas.

Figure 3 Site Location (SixMaps and SG Site Photographs)

The site slopes moderately to gently from north to south (front to rear of site). No outcropping of rock or floaters were present. The typical cross section of the local soil landscape is displayed in Figure 4. A schematic cross section of the site is presented in Figure 5.

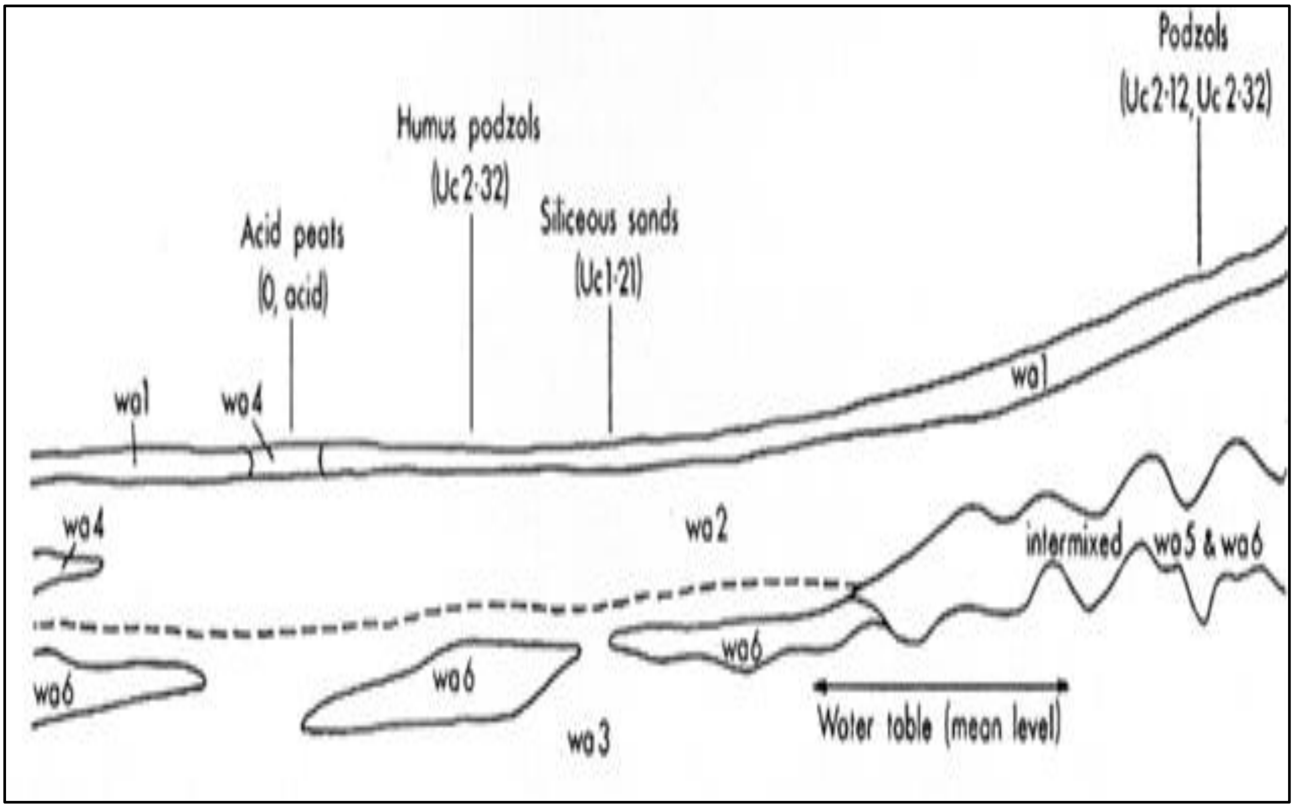


Figure 4 Schematic Cross-Section of the Warriewood Soil Landscape - Occurrence and Relationship of the Dominant Soil Materials

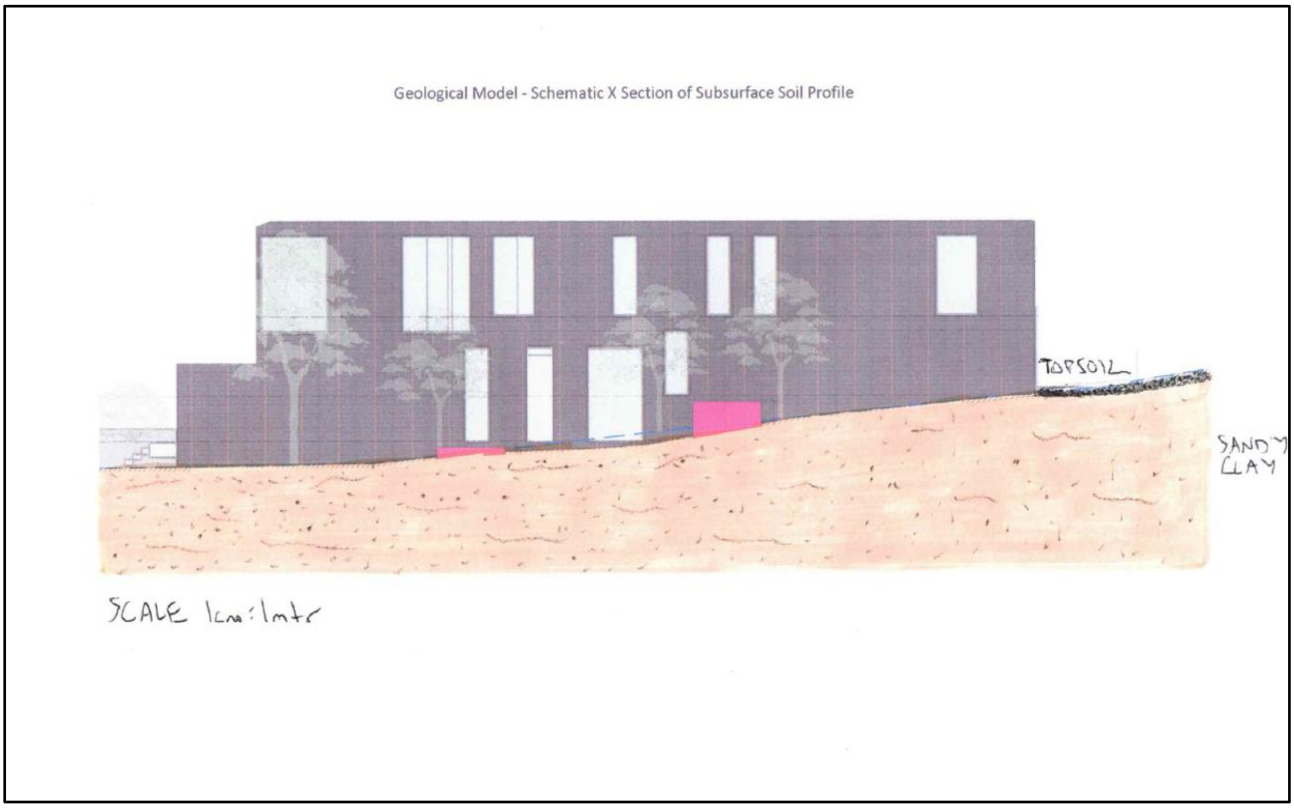


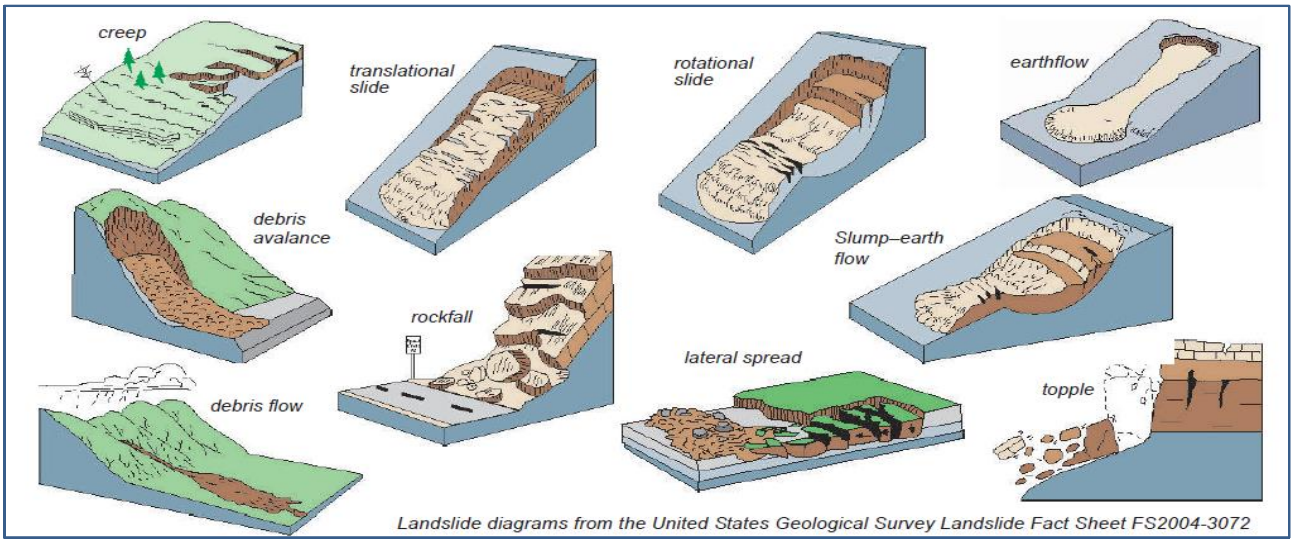
Figure 5 Schematic Cross Section of Site Conditions

5.2 Slope Instability

Assessing the stability of a slope (i.e., Landslide Risk Assessment) requires careful consideration of a wide range of inputs by an experienced and suitably qualified professional. The primary outcome of a Landslide Risk Assessment is to identify signs of stress in the landscape, the potential, and mechanisms (Figure 6) for distress to form, the likelihood of distress causing a landslide and the risk to life and property a landslide will cause.

The most common considerations are:

- The slope of the land
- Local and broad topography
- Cut and fill
- Existing vegetation (type, density, and existing slip evidence)
- Cleared vegetation
- Soil moisture changes (rain, flow paths and non-natural sources)
- Foundation type



Landslide diagrams from the United States Geological Survey Landslide Fact Sheet FS2004-3072

Figure 6 Landslide Mechanisms

The Australian Geomechanics Society published quantitative measures for performing a Risk Analysis (Australian Geomechanics Vol 42 No 1, 2007). This approach has been adopted for assessing the risk of a landslide to property and life.

NOTE: This assessment only investigates the risk associated with the proposed demolition of existing structures and construction of a new residence. It does not consider the current risk state of the site and its surrounds, nor any structures or infrastructure.

5.3 Slope Stability Assessment

In accordance with the Geotechnical Riak Management Policy for Pittwater – 2009 the site is mapped Geotechnical Hazard "H2". The Australian Geomechanics (Volume 42 No1 March 2007) provides a table of slope descriptions as illustrated below.

Table 1 Slope Descriptions (AGS 2007)

Appearance	Slope Angle	Maximum Gradient	Slope Characteristics
Gentle	0° - 10°	1 on 6	Easy walking.
Moderate	10°- 18°	1 on 3	Walkable. Can drive and manoeuvre a car on driveway
Steep	18°- 27°	1 on 2	Walkable with effort. Possible to drive straight up or down roughened concrete driveway, but cannot practically manoeuvre a car.
Very Steep	27°- 45°	1 on 1	Can only climb slope by clutching at vegetation, rocks etc.
Extreme	45°- 64°	1 on 0.5	Need rope access to climb slope
Cliff	64°- 84°	1 on 0.1	Appears vertical. Can abseil down.
Vertical or Overhang	84° - 90±°	Infinite	Appears to overhang. Abseiler likely to lose contact with the face.

The below figure displays the slope intensity of the site and associated slope angle/gradient in accordance with AGS (2007) and Table 1 above.

Figure 7 Map of Site Slope Constraints

The overall slope of the site consists of moderate to gentle slopes. The moderate slopes exist primarily at the front of the site adjacent to Central Road at approximately 12-15°. The gentle sloping ground extends across the rest of the site at <5°. Approximate slopes are mapped in Figure 7 above.

Loose sands, clayey sands and soft fill are highly susceptible to concentrated flow erosion. The removal of the ground cover (e.g., by bush fire and clearing) can result in severe sheet erosion and minor riling. Rock floaters or other loose cobbles or boulders appear stable if not disturbed, however construction disturbance due to vibration can trigger sudden movement and lead to unpredictable rock falls.

This assessment assumes that the proposed will be founded onto natural clay/sand soils, or engineered fill, although it is likely that the depth will vary within the excavated footprint. The slope assessment only investigates the effect of the construction of the newly proposed will have on the site and the respective risk to property and life. The risk to property includes the total value of the entire construction.

The primary failure modes considered in this assessment is ‘shallow rotational slides.’ The risk matrix adopted is displayed below. Specific values for the consequence and likelihood are shown in Appendix F.

Table 2 Matrix Summary

LIKELIHOOD	CONSEQUENCE				
	1	**2**	**3**	**4**	**5**
A	VH	VH	VH	H	M/L
B	VH	VH	H	M	L
C	VH	H	M	M	VL
D	H	M	L	L	VL
E	M	L	L	VL	VL
F	L	VL	VL	VL	VL

VERY HIGH (VH)
HIGH (H)
MEDIUM (M)
LOW (L)
VERY LOW (VL)

6 DISCUSSION AND RECOMMENDATIONS

Appendix F presents the outputs for the 'Landslide Susceptibility' and risk to property and life relating to the proposed. Table 3 below displays the relationship between the output from Appendix G and the susceptibility of the site to landslides.

Table 3 Landslide Susceptibility Relationship

Output	Susceptibility
<0.2	Very Low
0.2 – 0.6	Low
>0.6 – 2.0	Moderate
>2.0 – 6.0	High
>6.0	Very High

The landslide risk assessment (Appendix F) displays an output of **0.03** and a **very low** susceptibility to landslides relating to the construction of the proposed.

Table 4 gives recommended descriptors for landslide risk zoning using life loss criteria. These are based on annual individual risk for the person most at risk (Australian Geomechanics Vol 42 No 1 March 2007 Pg22).

Table 4 Recommended descriptors for risk zoning using life loss criteria (AGS 2007c)

Annual Probability of Death of the Person Most at Risk in the Zone	Risk Zoning Descriptors
>10 $^{-3}$/annum	Very High
10 $^{-4}$ to 10 $^{-3}$/annum	High
10 $^{-5}$ to 10 $^{-4}$/annum	Moderate
10 $^{-6}$ to 10 $^{-5}$/annum	Low
>10 $^{-6}$/annum	Very Low

Risk to Life – Very Low - $R_{(LoL)}$=(4.25^{-6}/annum). Acceptable. Manage by normal slope maintenance procedures.

For property loss risks the risk matrix AGS (2007c) is reproduced in Table 5 below.

Table 5 recommended descriptors for risk zoning using property loss criteria (AGS 2007c)

Likelihood		Consequences to property (With indicative approximate cost of damage) (1)				
	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 (2)
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: (1) As a percentage of the value of the property. (2) L Low, M Medium, H High, VL very low, VH very high

Risk to Property – Low. Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.

It is advised that the slopes are primarily monitored for shallow slides, soil creep and to a lesser extent rock fall (irrespective of whether the proposed is constructed). Particular attention should be made to any loose unconsolidated surface material and soft soils during the construction period. If warning signs of slope failure are noticed during and after heavy rain periods the relevant authorities should be notified and action to stabilise the affected area using a retaining wall, sediment fencing, or other suitable means should be implemented.

The following recommendations must be adhered to and are explicitly provided for the existing conditions currently observed at the time the site inspection was made:

- New footings should be founded into minimum stiff to very stiff clays subject to structural engineer's advice. Loose sediment, floaters, and other unsuitable soil materials (soft soils, uncontrolled fill etc.) should be removed in order to expose the consolidated subsurface strata.
- Cut and fill should be avoided where possible to minimise slope disturbance. Where fill is placed, it should be placed under geotechnical supervision and in accordance with good engineering principles. The weight of fill should be considered especially on steeper sloping areas or areas of cut.
- All retaining walls must have gravel, geotextile material and drainage installed professionally.
- Drainage within construction and retained areas must be built in order to mitigate periods of high intensity rainfall and/or rainfall events characteristic of local climate behaviour.
- All retaining walls over 1.0m must be designed by a suitably qualified and experienced engineer.
- All soft soil areas must be retained as soon as possible after cut/fill operation. This may require piles or shotcrete subject to appropriate engineering advice.
- Ground cover should be maintained whenever possible. If erosion is identified, a sediment and erosion control plan should be determined and actioned.
- The practice notes in Appendix H should be followed at all times.

This assessment is based solely on the proposed alterations and additions:

- Being designed and constructed by suitably experienced and qualified professionals.
- The footings being founded into minimum stiff natural soils or engineered material in accordance with AS 2870 'Residential Slabs and Footings'; and
- Having a design life equivalent to the design life of the development. A design life of at least 50 years would be considered to be reasonable for permanent structures used by people and in agreement with AS 2870 'Residential Slabs and Footings'.

Based on the assessment and assumptions presented, and that the above measure will be implemented and applied to the construction methodology in order to maintain the low risk to life and property, the site is **suitable** for the proposed development. It should be noted that it is common for construction methodology measures to be amended or modified during construction. Therefore, it is recommended that a geotechnical professional be consulted during the construction phase of the project when required.

7 LIMITATIONS

Scope of Services

This report has been prepared for the Client in accordance with the Terms of Agreement between the Client and Sydney Geotech Pty Ltd.

Reliance on Data

Sydney Geotech Pty Ltd has relied upon data and other information provided by the Client and other individuals. Sydney Geotech Pty Ltd has not verified the accuracy or completeness of the data, except as otherwise stated in the report. Recommendations in the report are based on the data.

Sydney Geotech Pty Ltd will not be liable for incorrect recommendations should any data, information or condition be incorrect or have been concealed, withheld, misrepresented, or otherwise not fully disclosed.

Geotechnical Investigation

Findings of Geotechnical Investigations are based extensively on judgment and experience. Geotechnical reports are prepared to meet the specific needs of individual clients. This report was prepared expressly for the Client and expressly for the Clients purposes.

This report is based on a subsurface investigation, which was designed for project-specific factors. Unless further geotechnical advice is obtained this report cannot be applied to an adjacent site nor can it be used when the nature of any proposed development is changed.

Limitations of Site investigation

As a result of the limited number of sub-surface excavations or boreholes there is the possibility that variations may occur between test locations. The investigation undertaken is an estimate of the general profile of the subsurface conditions. The data derived from the investigation and laboratory testing is extrapolated across the site to form a geological model. This geological model infers the subsurface conditions and their likely behavior regarding the proposed development.

The actual conditions at the site might differ from those inferred to exist.

No subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies.

Time Dependence

This report is based on conditions which existed at the time of subsurface exploration. Any construction operations at or adjacent to the site, and natural events such as floods, or groundwater fluctuations may also affect subsurface conditions, and thus the continuing adequacy of a geotechnical report.

Sydney Geotech Pty Ltd should be kept appraised for any such events and should be consulted for further geotechnical advice if any changes are noted.

Avoid Misinterpretation

A geotechnical engineer or engineering geologist should be retained to work with other design professionals explaining relevant geotechnical findings and reviewing the adequacy of their plans and specifications relative to geotechnical issues. No part of this report should be separated from the Final Report.

Sub-surface Logs

Sub-surface logs are developed by geoscientific professionals based upon their interpretation of field logs and laboratory evaluation of field samples. These logs should not under any circumstances be redrawn for inclusion in any drawings.

Geotechnical Involvement During Construction

During construction, excavation frequently exposes subsurface conditions. Geotechnical consultants should be retained through the construction stage, to identify variations if they are exposed.

Report for Benefit of Client

The report has been prepared for the benefit of the Client and no other party. Other parties should not rely upon the report or the accuracy or completeness of any recommendations and should make their own enquiries and obtain independent advice in relation to such matters.

Sydney Geotech Pty Ltd assumes no responsibility and will not be liable to any other person or organisations for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisations arising from matters dealt with or conclusions expressed in the report.

Other limitations

Sydney Geotech Pty Ltd will not be liable to update or revise the report to consider any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

Other Information

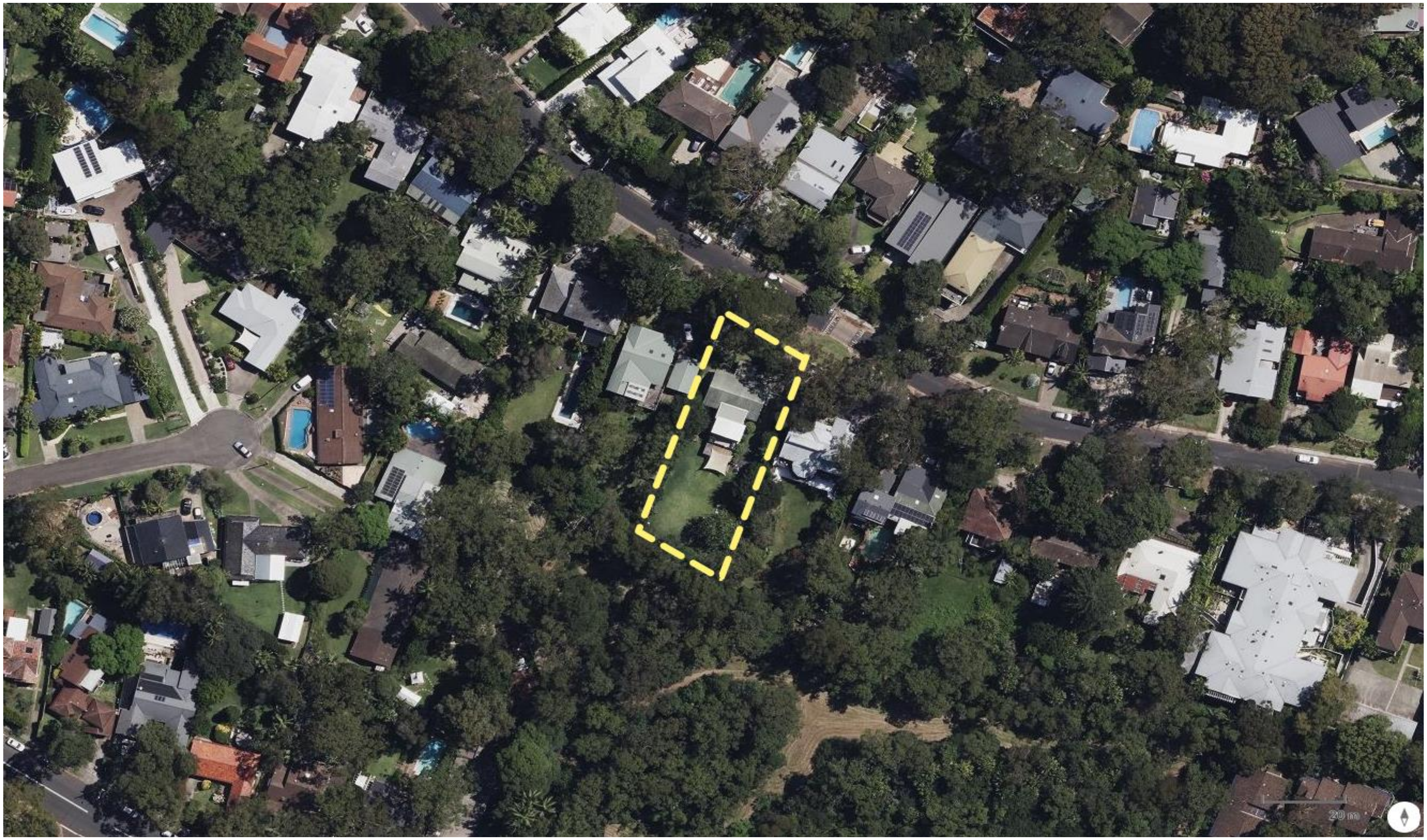
For further information reference should be made to "Guidelines for the Provision of Geotechnical Information in Construction Contracts" published by the Institution of Engineers Australia, 1987.

8 REFERENCES

- AS 1726 (2017) – 'Geotechnical site investigations'.
- AS 2870 (2011) – 'Residential slabs and footings'.
- AS 3798 (2007) – Guidelines on earthworks for commercial and residential developments'.
- AS 4678 (2002) – 'Earth retaining structures'.
- Australian Geomechanics Vol 42 No 1, 2007.
- Practice Note Guidelines for Landslide Risk Management 2007.
- Council policies, guidelines, and requirements.
- NSW Resources and Geoscience: Sydney 1:100k Geological Series Sheet 9130 (Edition 1) 1983.
- NSW Spatial Information Exchange (https://maps.six.nsw.gov.au/).
- NSW Espade (https://www.environment.nsw.gov.au/eSpade2WebApp).
- NSW Planning Portal (https://www.planningportal.nsw.gov.au/spatialviewer/#/find-a-property/address).
- Geotechnical Riak Management Policy for Pittwater – 2009
- Pittwater Local Environmental Plan 2014
- Northern Beaches Council Guidelines.
- Mathieson Architects: Concept Plans for 77 Central Road, Avalon Beach 2107, Rev B, 03 July 2024.
- Donovan Associates: Contour Plan for LOT 19 DP 8698 77 CENTRAL ROAD AVALON BEACH, NSW, Job Ref 0427/335149, DWG No. 335149, 17.08.2020

Appendix A – Site and Borehole Locations

Site Location

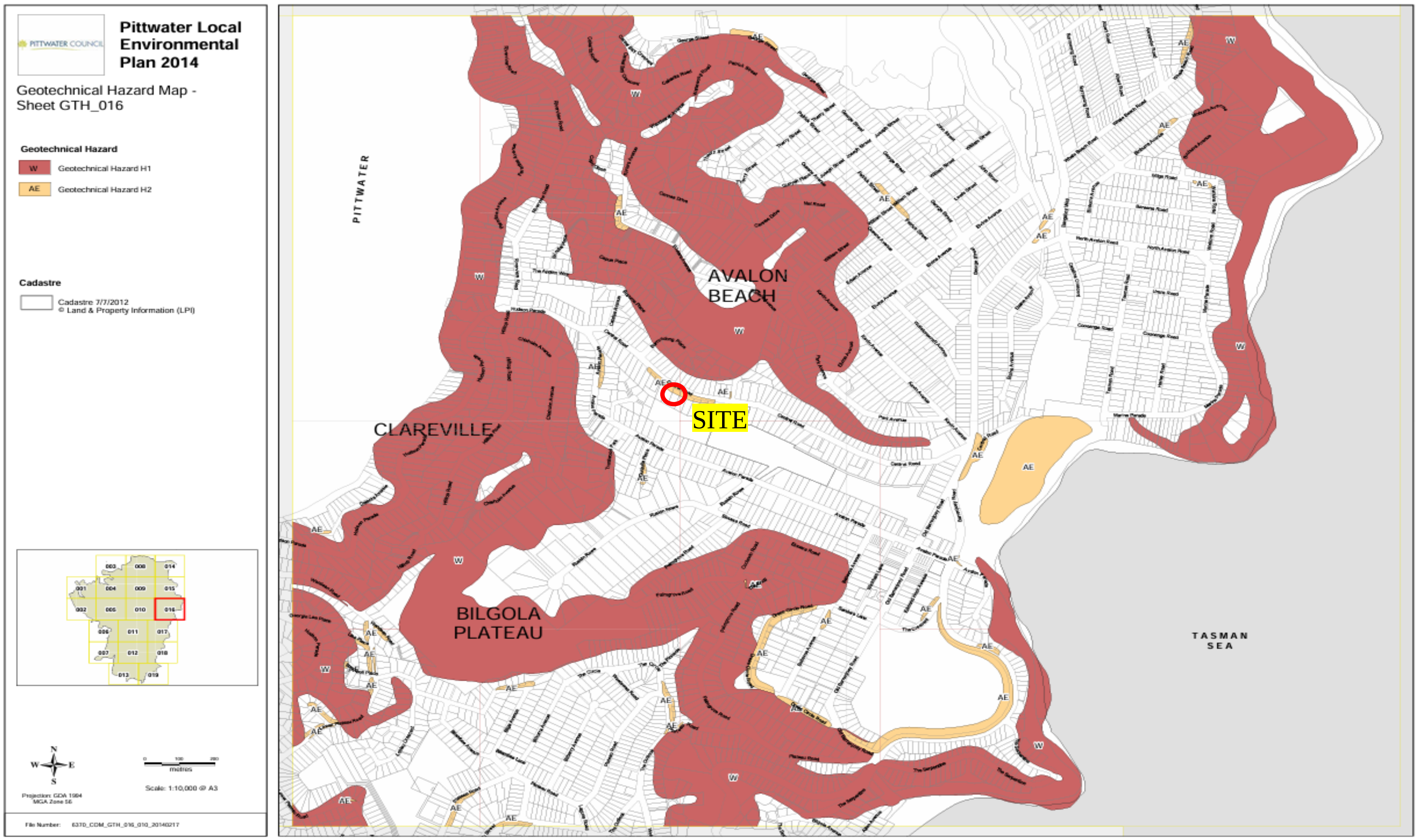


Borehole/DCP Location

Note: Borehole/DCP locations are approximate. Borehole size is not to scale.

Appendix B – Desktop Review

Geotechnical Hazard H2



Appendix C – Geotechnical Explanatory Notes

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Explanatory Notes

Soil Description

In engineering terms soil includes every type of uncemented or partially cemented inorganic material found in the ground. In practice, if the material can be remoulded by hand in its field condition or in water it is described as a soil. The dominant soil constituent is given in capital letters, with secondary textures in lower case. The dominant feature is assessed from the Unified Soil Classification system and a soil symbol is used to define a soil layer as follows:

UNIFIED SOIL CLASSIFICATION

The appropriate symbols are selected on the result of visual examination, field tests and available laboratory tests, such as, sieve analysis, liquid limit and plasticity index.

USC Symbol	Description
GW	Well graded gravel
GP	Poorly graded gravel
GM	Silty gravel
GC	Clayey gravel
SW	Well graded sand
SP	Poorly graded sand
SM	Silty sand
SC	Clayey sand
ML	Silt of low plasticity
CL	Clay of low plasticity
OL	Organic soil of low plasticity
MH	Silt of high plasticity
CH	Clay of high plasticity
OH	Organic soil of high plasticity
Pt	Peaty Soil

MOISTURE CONDITION

Dry – Cohesive soils are friable or powdery
Cohesionless soil grains are free-running

Moist – Soil feels cool, darkened in colour
Cohesive soils can be moulded
Cohesionless soil grains tend to adhere

Wet – Cohesive soils usually weakened
Free water forms on hands when handling

For cohesive soils the following codes may also be used:

MC>PL Moisture Content greater than the Plastic Limit.
MC~PL Moisture Content near the Plastic Limit.
MC<PL Moisture Content less than the Plastic Limit.

PLASTICITY

The potential for soil to undergo change in volume with moisture change is assessed from its degree of plasticity. The classification of the degree of plasticity in terms of the Liquid Limit (LL) is as follows:

Description of Plasticity	LL (%)
Low	<35
Medium	35 to 50
High	>50

COHESIVE SOILS – CONSISTENCY

The consistency of a cohesive soil is defined by descriptive terminology such as very soft, soft, firm, stiff, very stiff and hard. These terms are assessed by the shear strength of the soil as observed visually, by the pocket penetrometer values and by resistance to deformation to hand moulding.

A Pocket Penetrometer may be used in the field or the laboratory to provide approximate assessment of unconfined compressive strength of cohesive soils. The values are recorded in kPa, as follows:

Strength	Symbol	Pocket Penetrometer Reading (kPa)
Very Soft	VS	< 25
Soft	S	20 to 50
Firm	F	50 to 100
Stiff	St	100 to 200
Very Stiff	VSt	200 to 400
Hard	H	> 400

COHESIONLESS SOILS – RELATIVE DENSITY

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Relative density terms such as very loose, loose, medium, dense and very dense are used to describe silty and sandy material, and these are usually based on resistance to drilling penetration or the Standard Penetration Test (SPT) ‘N’ values. Other condition terms, such as friable, powdery or crumbly may also be used.

The Standard Penetration Test (SPT) is carried out in accordance with AS 1289, 6.3.1. For completed tests the number of blows required to drive the split spoon sampler 300 mm are recorded as the N value. For incomplete tests the number of blows and the penetration beyond the seating depth of 150 mm are recorded. If the 150 mm seating penetration is not achieved the number of blows to achieve the measured penetration is recorded. SPT correlations may be subject to corrections for overburden pressure and equipment type.

Term	Symbol	Density Index	N Value (blows/0.3 m)
Very Loose	VL	0 to 15	0 to 4
Loose	L	15 to 35	4 to 10
Medium Dense	MD	35 to 65	10 to 30
Dense	D	65 to 85	30 to 50
Very Dense	VD	>85	>50

COHESIONLESS SOILS PARTICLE SIZE DESCRIPTIVE TERMS

Name	Subdivision	Size
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 μm to 2.36 mm
	medium	200 μm to 600 μm
	fine	75 μm to 200 μm

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Rock Description

The rock is described with strength and weathering symbols as shown below. Other features such as bedding and dip angle are given.

ROCK QUALITY

The fracture spacing is shown where applicable and the Rock Quality Designation (RQD) or Total Core Recovery (TCR) is given where:

$$\text{RQD (\%)} = \frac{\text{Sum of Axial lengths of core} > \text{100mm long}}{\text{total length considered}}$$

$$\text{TCR (\%)} = \frac{\text{length of core recovered}}{\text{length of core run}}$$

ROCK STRENGTH

Rock strength is described using AS1726 and ISRM - Commission on Standardisation of Laboratory and Field Tests, "Suggested method of determining the Uniaxial Compressive Strength of Rock materials and the Point Load Index", as follows:

Term	Symbol	Point Load Index $I_{s(50)}$ (MPa)
Extremely Low	EL	<0.03
Very Low	VL	0.03 to 0.1
Low	L	0.1 to 0.3
Medium	M	0.3 to 1
High	H	1 to 3
Very High	VH	3 to 10
Extremely High	EH	>10

ROCK MATERIAL WEATHERING

Rock weathering is described using the following abbreviation and definitions used in AS1726:

Abbreviation	Term
RS	Residual soil
XW	Extremely weathered
DW	Distinctly weathered
SW	Slightly weathered
FR	Fresh

DEFECT SPACING/BEDDING THICKNESS

Measured at right angles to defects of same set or bedding.

Term	Defect Spacing	Bedding
Extremely closely spaced	<6 mm	Thinly Laminated
	6 to 20 mm	Laminated
Very closely spaced	20 to 60 mm	Very Thin
Closely spaced	0.06 to 0.2 m	Thin
Moderately widely spaced	0.2 to 0.6 m	Medium
Widely spaced	0.6 to 2 m	Thick
Very widely spaced	>2 m	Very Thick

DEFECT DESCRIPTION

Type:	**Description**
B	Bedding
F	Fault
C	Cleavage
J	Joint
S	Shear Zone
D	Drill break

Planarity/Roughness:

Class	Description
I	rough or irregular, stepped
II	smooth, stepped
III	slickensided, stepped
IV	rough or irregular, undulating
V	smooth, undulating
VI	slickensided, undulating
VII	rough or irregular, planar
VIII	smooth, planar
IX	slickensided, planar

The inclination if defects are measured from perpendicular to the core axis.

WATER

▽ Water level at date shown ◁ Partial water loss

▷ Water inflow ◀ Complete water loss

Groundwater not observed: The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

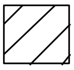
Groundwater not encountered: The borehole/test pit was dry soon after excavation; however groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

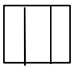
Graphic Symbols for Soils and Rocks

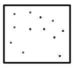
Typical symbols for soils and rocks are as follows. Combinations of these symbols may be used to indicated mixed materials such as clayey sand.

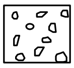
Soil Symbols

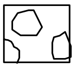
Main components

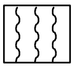
 CLAY

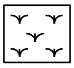
 SILT

 SAND

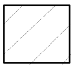
 GRAVEL

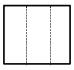
 BOULDERS / COBBLES

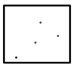
 TOPSOIL

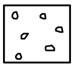
 PEAT

Minor Components

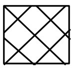
 Clayey

 Silty

 Sandy

 Gravelly

Other

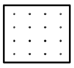
 FILL

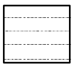
 BITUMEN

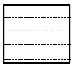
 CONCRETE

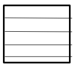
Rock Symbols

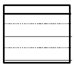
Sedimentary Rocks

 SANDSTONE

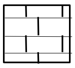
 SILTSTONE

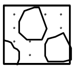
 CLAYSTONE, MUDSTONE

 SHALE

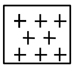
 LAMINITE

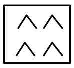
 COAL

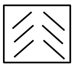
 LIMESTONE

 CONGLOMERATE

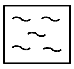
Igneous Rocks

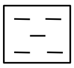
 GRANITE

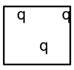
 BASALT

 UNDIFFERENTIATED IGNEOUS

Metamorphic Rocks

 SLATE, PHYLLITE, SCHIST

 GNEISS

 QUARTZITE

Engineering Classification of Shales and Sandstones in the Sydney Region – A Summary Guide

The Sydney Rock Class classification system is based on rock strength, defect spacing and allowable seams as set out below. All three factors must be satisfied.

CLASSIFICATION FOR SANDSTONE

Class	Uniaxial Compressive Strength (MPa)	Defect Spacing (mm)	Allowable Seams (%)
I	>24	>600	<1.5
II	>12	>600	<3
III	>7	>200	<5
IV	>2	>60	<10
V	>1	N.A.	N.A.

CLASSIFICATION FOR SHALE

Class	Uniaxial Compressive Strength (MPa)	Defect Spacing (mm)	Allowable Seams (%)
I	>16	>600	<2
II	>7	>200	<4
III	>2	>60	<8
IV	>1	>20	<25
V	>1	N.A.	N.A.

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UNIAXIAL COMPRESSIVE STRENGTH (UCS)

For expedience in field/construction situations the uniaxial (unconfined) compressive strength of the rock is often inferred, or assessed using the point load strength index (Is_{50}) test (AS 4133.4.1 - 1993). For Sydney Basin sedimentary rocks the uniaxial compressive strength is typically about 20 x (Is_{50}) but the multiplier may range from about 10 to 30 depending on the rock type and characteristics. In the absence of UCS tests, the assigned Sydney Rock Class classification may therefore include rock strengths outside the nominated UCS range.

DEFECT SPACING

The terms relate to spacing of natural fractures in NMLC, NQ and HQ diamond drill cores and have the following definitions:

Defect Spacing (mm)	Terms Used to Describe Defect Spacing[1]
>2000	Very widely spaced
600 - 2000	Widely spaced
200 - 600	Moderately spaced
60 - 200	Closely spaced
20 - 60	Very closely spaced
<20	Extremely closely spaced

[1]After ISO/CD14689 and ISRM.

ALLOWABLE SEAMS

Seams include clay, fragmented, highly weathered or similar zones, usually sub-parallel to the loaded surface. The limits suggested in the tables relate to a defined zone of influence. For pad footings, the zone of influence is defined as 1.5 times the least footing dimension. For socketed footings, the zone includes the length of the socket plus a further depth equal to the width of the footing. For tunnel or excavation assessment purposes the defects are assessed over a length of core of similar characteristics.

Source: Based on Pells et al (1978), as revised by Pells et al (1998).

Pells, P.J.N, Mostyn, G. and Walker, B.F. - Foundations on Sandstone and Shale in the Sydney Region. Australian Geomechanics Journal, No 33 Part 3, December 1998.

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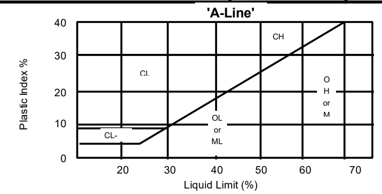
Summary of Soil Logging Procedures

Coarse Material: grain size - colour - particle shape - secondary components - minor constituents - moisture condition - relative density - origin - additional observations.

Fine Material: plasticity - colour - secondary components - minor constituents - moisture w.r.t. plasticity - consistency - origin - additional observations.

Guide to the Description, Identification and Classification of Soils

Major Divisions				SYMBOL	Typical Names
> 200mm	BOULDERS				
60 to 200mm	COBBLES				
COARSE GRAINED SOILS	More than 50% by dry mass less than 60mm is greater that 0.076mm	GRAVEL / Gravelly Soils	More than 50% of coarse fraction > 2.36mm	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
				GP	Poorly graded gravels and gravel-sand mixtures, little or no fines, uniform gravels.
				GM	Silty gravels, gravel-sand-silt mixtures.
				GC	Clayey gravels, gravel-sand-clay mixtures
		SANDS / Sandy Soils	More than 50% of coarse fraction < 2.36mm	SW	Well-graded sands, gravelly sands, little or no fines.
				SP	Poorly graded sands and gravelly sands; little or no fines, uniform sands.
				SM	Silty sands, sand-silt mixtures.
				SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	More than 50% by dry mass less than 60mm is less than 0.076mm	Liquid Limit < 50%		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts
				CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays.
				OL	Organic silts and organic silty clays of low plasticity.
		Liquid Limit > 50%		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
				CH	Inorganic clays of high plasticity, fat clays.
				OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS				Pt	Peat and other highly organic soils.



Grain sizes			
Gravel		Sand	
Coarse -	63 to 20mm	Coarse -	2.36 to 0.6mm
Medium -	20 to 6 mm	Medium -	0.6 to 0.2mm
Fine -	6 to 2.36mm	Fine -	0.2 to 0.075mm

GEOLOGICAL ORIGIN:-

Fill - artificial soils / deposits
Alluvial - soils deposited by the action of water
Aeolian - soils deposited by the action of wind
Topsoil - soils supporting plant life containing significant organic content
Residual - soils derived from insitu weathering of parent rock.
Colluvial - transported debris usually unsorted, loose and deposited

Field Identification of Fine Grained Soils - Silt or Clay?

Dry Strength - Allow the soil to dry completely and then test its strength by breaking and crumbling between the fingers. High dry strength - Clays; Very slight dry strength - Silts.

Toughness Test - the soil is rolled by hand into a thread about 3mm in diameter. The thread is then folded and re-rolled repeatedly until it has dried sufficiently to break into lumps. In this condition inorganic clays are fairly stiff and tough while inorganic silts produce a weak and often soft thread which may be difficult to form and readily breaks and crumbles.

Dilatancy Test - Add sufficient water to the soil, held in the palm of the hand, to make it soft but not sticky. Shake horizontally, striking vigorously against the other hand several times. Dilatancy is indicated by the appearance of a shiny film on the surface of the soil. If the soil is then squeezed or pressed with the fingers, the surface becomes dull as the soil stiffens and eventually crumbles. These reactions are pronounced only for predominantly silt size material. Plastic clays give no reaction.

Descriptive Terms for Material Portions

COARSE GRAINED SOILS		FINE GRAINED SOILS	
% Fines	*Term/Modifier*	*% Coarse*	*Term/Modifier*
< 5	Omit, or use "trace"	< 15	Omit, or use "trace"
> 5, < 12	"with clay/silt" as applicable	> 15, < 30	"with sand/gravel" as applicable
> 12	Prefix soil as "silty/clayey"	> 30	Prefix as "sandy/gravelly"

Moisture Condition

for non-cohesive soils:

Dry -	runs freely through fingers.
Moist -	does not run freely but no free water visible on soil surface.
Wet -	free water visible on soil surface.

for cohesive soils:

MC > PL	Moisture content estimated to be greater than the plastic limit.
MC ~ PL	Moisture content estimated to be approximately equal to the plastic limit. The soil can be moulded
MC < PL	Moisture content estimated to be less than the plastic limit. The soil is hard and friable, or powdery.

The plastic limit (PL) is defined as the moisture content (percentage) at which the soil crumbles when rolled into threads of 3mm dia.

Consistency - For Clays & Silts

Description	*UCS (kPa)*	*Field guide to consistency*
Very soft	< 25	Exudes between the fingers when squeezed in hand
Soft	25 - 50	Can be moulded by light finger pressure
Firm	50 - 100	Can be moulded by strong finger pressure
Stiff	100 - 200	Cannot be moulded by fingers. Can be indented by thumb.
Very stiff	200 - 400	Can be indented by thumb nail
Hard	> 400	Can be indented with difficulty by thumb nail
Friable	-	Crumbles or powders when scraped by thumbnail

Relative Density for Gravels and Sands

Description	*SPT "N" Value*	*Density Index (ID) Range %*
Very loose	0 - 4	< 15
Loose	4 - 10	15 - 35
Medium dense	10 - 30	35 - 65
Dense	30 - 50	65 - 85
Very dense	> 50	> 85

Summary of Rock Logging Procedures

Description order: constituents - rock name - grain size - colour - weathering - strength - minor constituents - additional observations.
- minor constituents - moisture w.r.t. plasticity - consistency - origin - additional observations.

Definition - Sedimentary Rock	
Conglomerate	more than 50% of the rock consists of gravel (> 2mm) sized fragments
Sandstone	more than 50% of the rock consists of sand (0.06 to 2mm) sized grains
Siltstone	more than 50% of the rock consists of silt sized granular particles and the rock is not laminated
Claystone	more than 50% of the rock consists of clay or mica material and the rock is not laminated
Shale	more than 50% of the rock consists of clay or silt sized particles and the rock is laminated

Weathering		
Residual Soil	RS	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a change in volume but the soil has not significantly transported.
Extremely Weathered	EW	Rock is weathered to such an extent that it has 'soil' properties; ie. it either disintegrates or can be remoulded, in water
Distinctly Weathered	DW	Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron-staining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Slightly Weathered	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh	FR	Rock shows no sign of decomposition or staining.

Stratification			
thinly laminated	< 6mm	medium bedded	0.2 - 0.6m
laminated	6 - 20mm	thickly bedded	0.6 - 2m
very thinly bedded	20 - 60mm	very thickly bedded	> 2m
thinly bedded	60mm - 0.2m		

Discontinuities

order of description: depth - type - orientation - spacing - roughness / planarity - thickness - coating

	Type	Class	Roughness/Planarity	Class	Roughness/Planarity
B	Bedding	I	rough or irregular, stepped	VI	slickensided, undulating
F	Fault	II	smooth, stepped	VII	rough or irregular, planar
C	Cleavage	III	slickensided, stepped	VIII	smooth, planar
J	Joint	IV	rough or irregular, undulating	IX	slickensided, planar
S	Shear Zone	V	smooth, undulating		
D	Drill break				

Rock Strength

Term		Is (50)	Field Guide
Extremely Low	EL		Easily remoulded by hand to a material with soil properties.
		0.03	
Very low	VL		May be crumbled in the hand. Sandstone is "sugary" and friable
		0.1	
Low	L		A piece of core 150 mm long x 50 mm dia. may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.
		0.3	
Medium	M		A piece of core 150 mm long x 50 mm dia. can be broken by hand with considerable difficulty. Readily scored with knife.
		1	
High	H		A piece of core 150 mm long x 50 mm dia. core cannot be broken by unaided hands, can be slightly scratched or scored with knife.
		3	
Very High	VH		A piece of core 150 mm long x 50 mm dia. May be broken readily with hand held hammer. Cannot be scratched with pen knife.
		10	
Extremely High	EH		A piece of core 150 mm long x 50 mm dia. Is difficult to break with hand held hammer. Rings when struck with a hammer.

* - rock strength defined by point load strength (Is 50) in direction normal to bedding

Degree of fracturing	
fragmented	The core is comprised primarily of fragments of length less than 20mm, and mostly of width less than the core diameter
highly fractured	Core lengths are generally less than 20mm - 40mm with occasional fragments.
fractured	Core lengths are mainly 30mm - 100mm with occasional shorter and longer lengths
slightly fractured	Core lengths are generally 300mm - 1000mm with occasional longer sections and shorter sections of 100mm – 300mm.
unbroken	The core does not contain any fracture.

- spacing of all types of natural fractures, but not artificial breaks, in cored bores.

The fracture spacing is shown where applicable and the Rock Quality Designation is given by:

$$RQD\ (\%) = \frac{\text{sum of unbroken core pieces 100 mm or longer}}{\text{total length considered}}$$

Appendix D – Bore Hole Logs

SYDNEY GEOTECH
GEOTECHNICAL CONSULTING + DRILLING

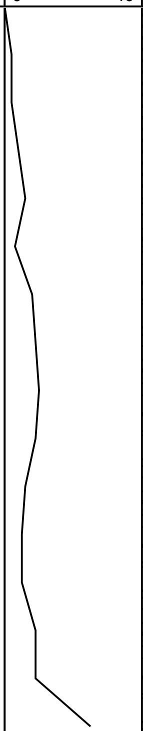
GEOTECHNICAL BOREHOLE / TESTPIT BH01

PROJECT NUMBER SG24-1170
PROJECT NAME Landslip Investigation
CLIENT Mathieson Architects
ADDRESS 77 Central Road Avalon Beach 2107

DRILLING DATE 27-09-24
DRILLING COMPANY Sydney Geotech
DRILLER BH
DRILLING METHOD Ute Mounted Auger
TOTAL DEPTH 3.00m

COORDINATES E: 344357 N: 6277390
COORD SYS GDA2020 MGA56
SURFACE ELEVATION ~12 m AHD
LOGGED BY BH
CHECKED BY BH

COMMENTS

Depth (m)	Penetrometer (kPa)	Dynamic Cone Penetrometer (Blows per 100mm) 0 – 40	Graphic Log	USCS	Material Description	Moisture	Consistency	Additional Observations
0 – 0.4				CL-CH	FILL: Admix sandy loams, orange & brown, gravels	Moist to Very Moist	Soft; Stiff	FILL: Uncontrolled
0.4 – 3.0 (0.5, 1, 1.5, 2, 2.5)	160; 300; 250			SC	NATURAL: Sandy CLAY, medium plasticity, contains organic pan, dark grey, fine grained, moisture content =< plastic limit Orange, red & grey below 1.4m Trace fine to medium gravels		Stiff; Very Stiff	SWAMP Holocene silty to peaty quartz sand and clay loams
3					Termination Depth: 3.00m limit of investigation.			

SYDNEY GEOTECH
GEOTECHNICAL CONSULTING + DRILLING

GEOTECHNICAL BOREHOLE / TESTPIT BH02

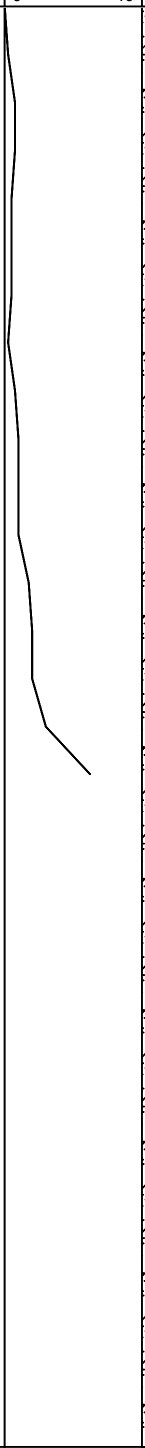
PROJECT NUMBER SG24-1170
PROJECT NAME Landslip Investigation
CLIENT Mathieson Architects
ADDRESS 77 Central Road Avalon Beach 2107

DRILLING DATE 27-09-24
DRILLING COMPANY Sydney Geotech
DRILLER BH
DRILLING METHOD Ute Mounted Auger
TOTAL DEPTH 3.00m

COORDINATES E: 344365 N: 6277402
COORD SYS GDA2020 MGA56
SURFACE ELEVATION ~12.7 m AHD
LOGGED BY BH
CHECKED BY BH

COMMENTS

Depth (m)	Penetrometer (kPa)	Dynamic Cone Penetrometer (Blows per 100mm) 0–40	Graphic Log	USCS	Material Description	Moisture	Consistency	Additional Observations
0				SC	NATURAL: Sandy CLAY, medium plasticity, contains organic pan, dark grey, fine grained, moisture content =< plastic limit	Moist to Very Moist	Soft	SWAMP Holocene silty to peaty quartz sand and clay loams
0.5					Grey, mustard green below 0.6m			
							Stiff	
1								
	180				Red. orange & grey below 1.4m Trace fine to medium gravels			
1.5	250						Very Stiff	
2								
2.5								
3					Termination Depth: 3.00m limit of investigation.			



SYDNEY GEOTECH

GEOTECHNICAL CONSULTING + DRILLING

GEOTECHNICAL BOREHOLE / TESTPIT BH03

PROJECT NUMBER SG24-1170
PROJECT NAME Landslip Investigation
CLIENT Mathieson Architects
ADDRESS 77 Central Road Avalon Beach 2107

DRILLING DATE 27-09-24
DRILLING COMPANY Sydney Geotech
DRILLER BH
DRILLING METHOD Ute Mounted Auger
TOTAL DEPTH 3.00m

COORDINATES E: 344366 N: 6277421
COORD SYS GDA2020 MGA56
SURFACE ELEVATION ~15.5 m AHD
LOGGED BY BH
CHECKED BY BH

COMMENTS

Depth (m)	Penetrometer (kPa)	Dynamic Cone Penetrometer (Blows per 100mm) 0 – 40	Graphic Log	USCS	Material Description	Moisture	Consistency	Additional Observations
				OL-OH	TOPSOIL: Loamy Sand, grey, grass & roots	Moist to Very Moist	Soft	SWAMP Holocene silty to peaty quartz sand and clay loams
				SC	NATURAL: Sandy CLAY, medium plasticity, contains organic pan, dark grey, fine grained, moisture content =< plastic limit			
0.5								
					Orange, red & grey below 0.6m		Stiff	
1	200							
					Trace gravels below 1.1m			
1.5	350							
							Very Stiff	
2					Predominantly red below 2.0m			
2.5								
3					Termination Depth: 3.00m limit of investigation.			

Appendix E – Dynamic Cone Penetrometer Results

SOIL STRENGTH AND CONSOLIDATION TESTS – DETERMINATION OF THE PENETRATION RESISTANCE OF A SOIL WITH A DYNAMIC CONE PENETROMETER

Test No	BH03								
BGL (mm)	0								
Depth (m)									
0.0-0.1	1	1.4-1.5	7						
0.1-0.2	1	1.5-1.6	5						
0.2-0.3	1	1.6-1.7	8						
0.3-0.4	1	1.7-1.8	10						
0.4-0.5	2	1.8-1.9	12						
0.5-0.6	5	1.9-2.0	11						
0.6-0.7	10		20						
0.7-0.8	12		LOI						
0.8-0.9	6								
0.9-1.0	5								
1.0-1.1	4								
1.1-1.2	5								
1.2-1.3	5								
1.3-1.4	6								

Note: LOI – Limit of investigation.

Test method: AS 1289 6.3.2	**Tip:** Cone Tip	**Drop:** 510mm

SOIL STRENGTH AND CONSOLIDATION TESTS – DETERMINATION OF THE PENETRATION RESISTANCE OF A SOIL WITH A DYNAMIC CONE PENETROMETER

Test No	BH01				Test No	BH02			
BGL (mm)	0				BGL (mm)	0			
Depth (m)									
0.0-0.1	2	1.4-1.5	25		0.0-0.1	1	1.4-1.5	12	
0.1-0.2	2		LOI		0.1-0.2	3	1.5-1.6	20	
0.2-0.3	4				0.2-0.3	3		LOI	
0.3-0.4	6				0.3-0.4	2			
0.4-0.5	3				0.4-0.5	2			
0.5-0.6	8				0.5-0.6	2			
0.6-0.7	9				0.6-0.7	1			
0.7-0.8	10				0.7-0.8	3			
0.8-0.9	9				0.8-0.9	4			
0.9-1.0	6				0.9-1.0	4			
1.0-1.1	5				1.0-1.1	4			
1.1-1.2	5				1.1-1.2	7			
1.2-1.3	9				1.2-1.3	8			
1.3-1.4	9				1.3-1.4	8			

Note: LOI – Limit of investigation.

Test method: AS 1289 6.3.2	**Tip:** Cone Tip	**Drop:** 510mm

Appendix F – Landslide Risk Assessment

SYDNEY GEOTECH

GEOTECHNICAL CONSULTING + DRILLING

SUMMARY	LEVEL	FACTOR
A. Natural Site Conditions		
(1) Natural surface slope		
<5º	L	0.1
(2) Slope shape/appearance		
Planar/convex	M	0.9
(3) Site geology		
Sedimentary rocks	M	1
(4) Soil profile		
Residual Soil - bedrock 1 to 3m	M	0.9
(5) Regional position on hillside		
Upper 1/3 of slope	M	0.9
(6) Evidence of groundwater		
No evidence	L	0.7
(7) Evidence of slope instability		
No sign of instability	L	0.8
B. Earthworks (proposed/existing)		
(8) Cut depth		
1 to 3m	M	1.5
(9) Cut batter angle		
<30º	L	0.5
(10) Cut batter support		
Engineered concrete/masonry wall	L	0.5
(11) Fill depth		
<1m	M	1.1
(12) Fill batter angle		
<30º	L	0.5
(13) Fill batter support		
Engineered concrete/masonry wall	L	0.8
(14) Type of fill		
Compacted but not certified	M	1
C. Construction (proposed/existing)		
(15) Waster water system (sewerage etc)		
Fully sewered	M	0.8
(16) Storm water disposal		
To the kerb or council system	M	0.7
(17) Expandable/mechanical pipes		
Specifically engineer designed and inspected	L	0.8
(18) Footing system		
As per AS2870-2011	H	1.2
(19) The foundation strata		
Residual soil	L	1
(20) In-ground tanks		
3 to 6m from footing	H	1.5
(21) Landscaping		
Non-AS2870-2011 compliant	H	1.5
(22) Upslope boulder/flow events		
No action taken	H	4
OUTPUT = (1X2X3X4 ETC)		**0.03259**

Risk to Life Assessment

Method based on AGS 2007 Guildlines

SYDNEY GEOTECH
GEOTECHNICAL CONSULTING + DRILLING

PROJECT DETAILS

Project	77 Central Road Avalon Beach 2107	Job. No.	SG24-1170
Author	BH	Created	16/10/2024

C

STEP 1 : ENTER SITE AND DESIGN DATA

Hazard Type | **Shallow Rotational Slide**

$P_{(H)}$ Annual probability of landslide: **0.001**

INDICATIVE VALUE	RECURRENCE INTERVAL	DESCRIPTION	DESCRIPTOR	LEVEL
10^{-1}	10 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
4.0E+00	100 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	1000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	10,000 years	The enent might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	100,000 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

$P_{(S:H)}$ Probablity of spatial impact impacting building location taking into account travel distance and travel direction: **1.70**

LOW (L)

FACTOR	DESCRIPTION	UNITS	VALUE
W_1	Likely slide/fall width	m	**5**
W_2	Width of allotment / investigation area	m	**22.5**
W_3	Width of dwelling / investigation element	m	**22.5**
L_{1Min}	Minimum run-out length	m	**1**
L_{1Max}	Maximum run-out length	m	**20**
L_2	Length of allotment / investigation area	m	**20**
L_3	Length of dwelling / investigation element	m	**20**
L_{PMin}	Probability of runout being 0 - 1 m long	(0 - 1)	**1.00**
L_{PMax}	Probability of runout being 5 - 20 m long	(0 - 1)	**0.70**
W_F	Cummulative Width Factor	(0 - 1)	**1.00**
$L_{F\ Min}$	Likelihood of downslope strike on risk element for minimum run-out distance	(0 - 1)	1.00
$L_{F\ Max}$	Likelihood of downslope strike on risk element for maximum run-out distance	(0 - 1)	1.00
$L_{F\ Design}$	Likelihood of downslope strike (integrated) on risk element run-out distance	(0 - 1)	**1.70**

$P_{(T:S)}$ Temporal spatial probability given the spatial impact: **0.05**

FACTOR	DESCRIPTION	UNITS	VALUE
T_1	Percentage of time person(s) are on-site	%	100%
T_2	Percentage of dwelling / element that person(s) occupy	%	5%

$V_{(D:T)}$ Vulnerability of the individual (ie. probability of loss of life given the impact): **0.05**

CASE	DESCRIPTION	RANGE IN DATA	RECOMMENDED VALUE	COMMENTS
Person in open space	If struck by a rockfall	0.1 - 0.7	0.50	May be injured but unlikely to cause death
	If buried by debris	0.8 - 1.0	1.00	Death by asphyxia almost certain
	If not buried	0.1 - 0.5	0.10	High chance of survival
Person in a vehicle	If vehicle is buried / crushed	0.9 - 1.0	1.00	Death is almost certain
	If the vehicle is damaged only	0.0 - 0.3	0.30	High chance of survival
Persons in building	If the building collapses	0.9 - 1.0	1.00	Death is almost certain
	If the building is inundated with debris and the person is buried	0.8 - 1.0	1.00	Death is highly likely
	If the debris strikes the building only	0.0 - 0.1	0.05	Very high chance of survival

STEP 2 : RISK EVALUATION

$R_{(LoL)}$ Risk (annual probability of loss of life of an individual): **4.25E-06**

Risk Assessment | **Acceptable. Manage by normal slope maintenance procedures.**

Risk to Property Assessment

Method based on Australian Geomechanics Vol. 42 No 1, March 2007

SYDNEY GEOTECH
GEOTECHNICAL CONSULTING + DRILLING

PROJECT DETAILS

Project	77 Central Road Avalon Beach 2107	Job. No.	SG24-1170
Author	BH	Created	16/10/2024

STEP 1 : LIKELIHOOD

LEVEL	D			
INDICATIVE VALUE	**RECURRENCE INTERVAL**	**DESCRIPTION**	**DESCRIPTOR**	**LEVEL**
10^{-1}	10 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	100 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	1000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	10,000 years	The enent might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	100,000 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

STEP 2 : CONSEQUENCE

LEVEL	4		
INDICATIVE VALUE	**DESCRIPTION**	**DESCRIPTOR**	**LEVEL**
200%	Structure completely destroyed or large scale damage requiring major engineering works for stabilisation.	CATASTOPHIC	1
60%	Extensive damage to most of structure, or extending beyond site boundaries requiring significant stabilisation works	MAJOR	2
20%	Moderate damage to some of structure, or significant part of site requiring large stabilisation works.	MEDIUM	3
5%	Limited damage to part of structure, or part of site requiring some reinstatement/stabilisation works.	MINOR	4
1%	Little damage.	INSIGNIFICANT	5

STEP 3 : Risk Matrix

LIKELYHOOD	CONSEQUENCE				
	1	**2**	**3**	**4**	**5**
A	VH	VH	VH	10	L-M
B	VH	VH	H	L-M	L
C	VH	H	M	L-M	VL
D	H	M	L	L	VL
E	M	L	L	VL	VL
F	L	VL	VL	VL	VL

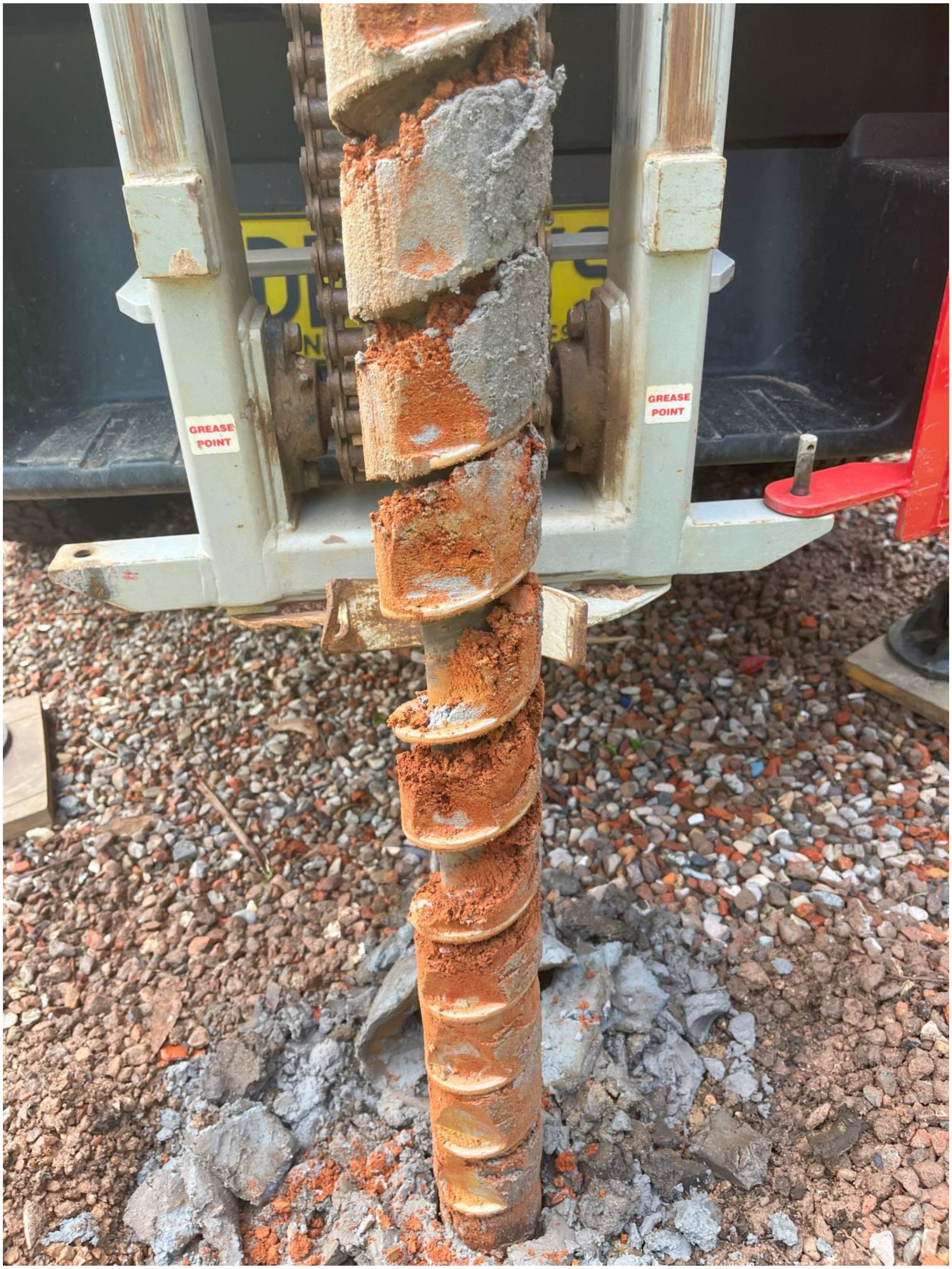
LOW (L)	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.

Appendix G – Site Photographs

Site Photographs


SYDNEY GEOTECH CONSULTING + DRILLING


DD 88 YS

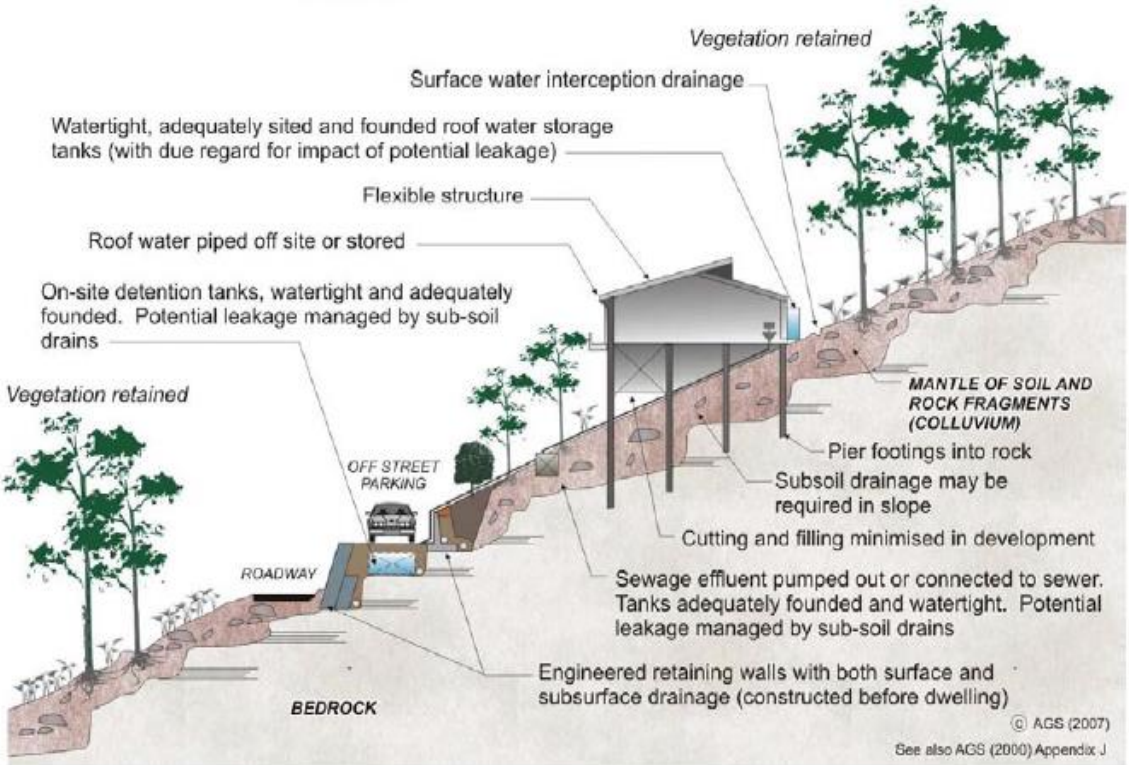

GREASE POINT
GREASE POINT


GREASE POINT
GREASE POINT

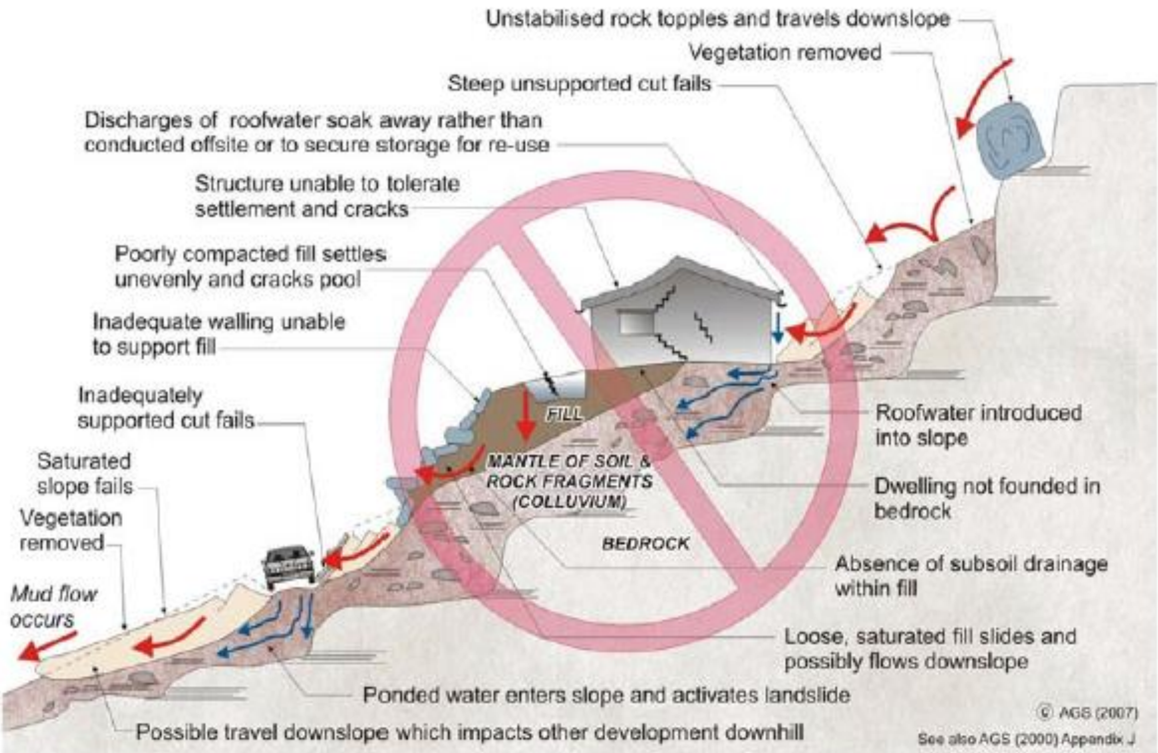
Appendix H – Practice Note Guidelines

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF GOOD HILLSIDE CONSTRUCTION PRACTICE



EXAMPLES OF POOR HILLSIDE CONSTRUCTION PRACTICE



Appendix I – CSIRO-Foundation Maintenance and Footing Performance

FOUNDATION MAINTENANCE AND FOOTING PERFORMANCE

Understanding and preventing soil-related building movement

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

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 home owner 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.

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. Table 1 below is a reproduction of Table 2.1 from Australian Standard AS 2870-2011, Residential slabs and footings.

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 may be the province of the builder and should be taken into consideration as part of the preparation of the site for construction.

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, from AS 2870). 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.

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.

TABLE 1. GENERAL DEFINITIONS OF SITE CLASSES.

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

Source: Reproduced with the permission of Standards Australia Limited © 2011. Copyright in AS 2870-2011 Residential slabs and footings vests in Standards Australia Limited.

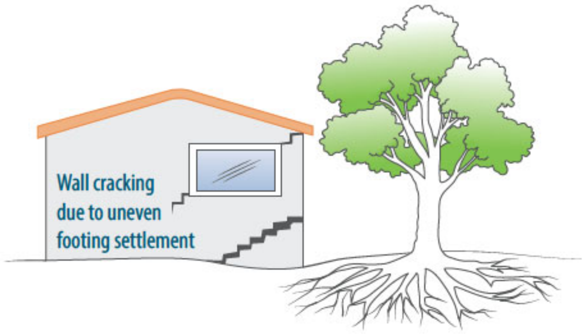


FIGURE 1 Trees can cause shrinkage and damage.

- 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 through absorption. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Shrinkage usually begins on the side of the building where the sun's heat is greatest.

EFFECTS OF UNEVEN SOIL MOVEMENT ON STRUCTURES

EROSION AND SATURATION

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

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

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

SEASONAL SWELLING/SHRINKAGE IN CLAY

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

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

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

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

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

MOVEMENT CAUSED BY TREE ROOTS

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

COMPLICATIONS CAUSED BY THE STRUCTURE ITSELF

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

EFFECTS ON FULL MASONRY STRUCTURES

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

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

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

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

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

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

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

EFFECTS ON FRAMED STRUCTURES

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

EFFECTS ON BRICK VENEER STRUCTURES

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

WATER SERVICE AND DRAINAGE

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

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

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

SERIOUSNESS OF CRACKING

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. Table 2 below is a reproduction of Table C1 of AS 2870-2011.

AS 2870-2011 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

PREVENTION AND 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 may be regarded as an area for an expert consultant.

PROTECTION OF THE BUILDING PERIMETER

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

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

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.

TABLE 2. CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS.

Description of typical damage and required repair	Approximate crack width limit	Damage category
Hairline cracks	<0.1 mm	0 – Negligible
Fine cracks which do not need repair	<1 mm	1 – Very Slight
Cracks noticeable but easily filled. Doors and windows stick slightly.	<5 mm	2 – Slight
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 – Moderate
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted.	15–25 mm but also depends on number of cracks	4 – Severe

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Warning: Although this Building Technology Resource 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, and mould.
- 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.

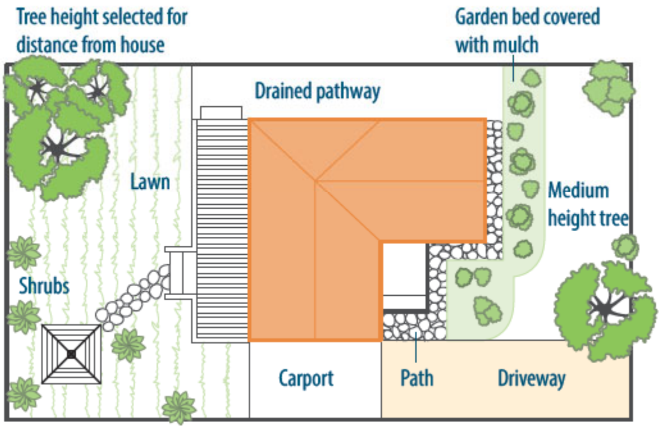

FIGURE 2 Gardens for a reactive site.

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 home owner 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.

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For information about CSIRO testing services visit www.csiro.au/en/work-with-us/services
ISBN 9781486312962 (print)/9781486312979 (digital) © CSIRO 2021
(replaces Building Technology File 18, 18-2011 and Information Sheet 10/91)

TERMS AND CONDITIONS: BUILDING TECHNOLOGY RESOURCES