VISIONENGINEERS

Slope & Stability Report

Three Two Story Units

On A Vacant Block

Council: Newcastle City Council

Applicant: Plan Vision – (02) 4954 2422

Revision: 0

Date Issued:

Contents

1. Introduction

Vision Engineers was engaged by Plan Vision Australia on behalf of their Client, REMOVED, to undertake a Slope Stability Assessment at REMOVED. Architectural Plans have been prepared and provided by Plan Vision Australia (917-6187, 30/09/2017). The proposal is for three two story units each with a garage and tree bedrooms. Further to this, the Pier and beam construction is to conform to 'Standard Designs' type under Section 3 of AS2870 Residential Slabs & Footings.

A site visit was undertaken on Wednesday 9th May 22, 2018. This site visit and report describes the surface and subsurface conditions encountered at the site and provides the following:

1. A site classification in accordance with *AS 2870-2011, Residential Slabs and Footings* (herein referred to as *AS 2870-2011*) for the site of the proposed additions to the existing residence;
2. Determine the existing soil subsurface profile within the site, including groundwater levels;
3. A slope stability assessment for the site;
4. Comments on geotechnical development guidelines in relation to site earthworks, structures and foundations, retaining walls, and drainage;
5. Discussion of footing alternatives, including founding levels and recommendations on allowable bearing pressures, for the proposed additions to the existing residence;
6. provide excavation conditions for the site;

Note that this Report has been issued solely for the subject lot and is non-transferrable to adjacent or nearby lots in any way or form. Vision Engineers is not responsible for the misuse of the information within this report.

2. Site Information

2.1 Site Description

The development in the immediate context of the site includes single dwellings, dual occupancies, unit developments, rental housing and private-owned housing, along with public community open space.

The residential area is situated within a developed area, with no obvious undeveloped lots nearby.

68 Minmi Road, Wallsend is situated on the South side of a slope

Figure Removed.

Figure 1: Immediate Context (Source: Google maps)

2.2 Site Vegetation

Vegetation at the site consists of short to medium length grass across the site and small to large trees, including a large tree on the neighbours property.

2.3 Site Features – Existing Topography

The lot trends approximately to the south at an approximate decline of 15-25°.

Cut or fill was not encountered on the site and drainage is by way of overland flow combined with surface infiltration.

2.4 Site Features – Existing Development

There was no existing development on the site at the time of assessment with the exception of the 'colorbond' metal boundary fencing.

2.5 Proposal – Design Features

To develop 3 x two storey units on a vacant block, each with a singe garage and 3 bedrooms.

2.6 Site Geology and Soil Landscapes

Reference to the 1:250,000 Newcastle Geological Map indicates that the site lies within the Newcastle Coal Measures, which are noted to include conglomerate, sandstone, tuff, shale and coal.

The site falls within the Gateshead Landscape as identified on the "Soil Landscapes of the Newcastle 1:100 000 Sheet" published by the Department of Land and Water Conservation.

The Gateshead Landscape is an erosional landscape characterised by undulating to rolling rises on Permian conglomerate, shale and sandstone in the Awaba Hills. The Gateshead Landscape contains slopes between 5-15% on local reliefs to 100m consists of predominantly cleared woodland and open forest.

3. Site Investigations

3.1 Fieldwork & Laboratory Testing

A subsurface investigation was conducted, consisting of 3 Push tube (drill rig) (BH1), (BH2) & (BH3) by Vision Engineers, on Wednesday 9th May, 2018. The Push tube (drill rig) and DCP tests were undertaken at the locations shown on the site plan presented in **Appendix A** of this report.

- **BH1 –** The push tube (drill rig) encountered dark brown silt, topsoil with organic matter, and laight brown clayey silt to a depth of 1.6m beneath ground level (bgl) after that the push tube (drill rig) experienced refusal on weathered rock. The borehole was hence terminated at a depth of 1.6m bgl.
- **BH2 -** The push tube (drill rig) encountered dark brown silt, topsoil and organic matter, and orange clay to a depth of 1.05m bgl after that the push tube (drill rig) experienced refusal on weathered rock. The borehole was hence terminated at a depth of 1.05m bgl.
- **BH3**- The push tube (drill rig) encountered dark brown silt, topsoil and organic matter, and mottled red, white, tan sandy clay and clay to a depth of 1.05m bgl after that the push tube (drill rig) experienced refusal on weathered rock. The borehole was hence terminated at a depth of 1.05m bgl.

The push tube (drill rig) results are made available in **Appendix B** of this Report.

3.2 Subsurface Conditions

A summary of the soil subsurface profiles encountered in each borehole can be seen below in Table 1.

Borehole	Depth (m)	Topsoil or Fill Material	Natural Material	Bedrock
BH1	1.6	200mm Dark brown topsoil with organic matter	1400mm light brown, red, orange sandy clay with traces of gravel	>400 weathered rock
BH2	1.05	150mm Dark brown topsoil with organic matter	900mm orange clay and weathered rock	>950mm weathered rock
BH3	1.05	200mm Dark brown topsoil with organic matter	850mm mottled tan, white, red sandy clay	>950mm weathered rock

Table 1 – Summary of soil subsurface profiles.

3.3 Bedrock

It is inferred that there is bedrock of weathered rock at approximately 1.05 - 1.6m below natural ground level.

4. Slope Stability

4.1 Slope Stability

The purpose of the slope stability assessment is to determine the degree of risk of slope movement and whether the building development would be likely to suffer damage as a result of any slope instability due to landslide.

For the purpose of this report, landslide is the movement downhill of material comprising the hillside.

Landslide is brought about through the development of shear failure surfaces within the soil mass. The subsequent movement can be rapid enough to pose a threat of damage, or actual damage, well within the expected lifetime of the building development. This landslide movement is to be distinguished from land creep, which takes place slowly over long periods of time and may affect gentle as well as steep slopes.

The agents of land creep are varied and include the action of rainwater, temperature variation, tree roots and soil organisms.

If landslide occurs within the soil under a building structure, the effect is to produce both vertical and horizontal deformation of the building foundations. This may evidence itself as cracks in brickwork which become more severe over time.

The extent of structural damage would depend upon local site conditions, soil characteristics and prevailing climatic conditions.

There is always some degree of risk associated with hillside construction when compared with construction on flat land. It is not practically possible to make an assessment which would categorically class a hillside site as either safe or unsafe, however, a range of risk classifications can be considered as follows –

	Risk Level	Example Implications
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 the 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 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.

Table 1 - *Risk Level Implications (Practice Note Guidelines for Landslide Risk Management, 2007).*

- **NOTE:** * 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.
- *Tolerable Risks* are risks within a range that society can live with so as to secure certain benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible(1)
- *Acceptable Risks* are risks which everyone affected is prepared to accept. Action to further reduce such risk is usually not required unless reasonably practicable measures are available at low cost in terms of money, time and effort(1)

(1) Commentary on Practice Note Guidelines For Landslide Risk Management 2007, Section C8.2.

4.2 Impact of Building Development on Slope Stability

Any building development carried out on a hillside may have an adverse effect on the site's potential for landslip. It is essential that suitable design features are incorporated in hillside development to minimize adverse landslip effects. This is addressed later in this report for the particular site conditions encountered on this property.

4.3 Evidence of Slope Instability

There is no visible evidence of slope instability on the subject lot or surrounding lots.

4.4 Stability Assessment

4.4.1 General Assessment – Underlying Features

The site is assessed as having a **very low risk** of slope instability in its present condition of development. The loads imposed on the subsoil by future proposed development are expected to cause no slope instability if the foundation of the structure is upon rock. Due to this, the slope stability of the subject lot in its developed state is deemed to be at **very low risk** of slope instability.

4.4.2 Local Assessment – Construction - Features

The carrying out of minor cut-fill operations (ie cut-fill operations in which less than 900mm of material is displaced) on site would not change the recommendations of this report provided the constraints noted below are incorporated into the design. It is recommended however that the slopes on the existing batters not be made steeper in any cut-fill operations undertaken on the subject lot.

4.5 Mine Subsidence

68 Minmi Road, Wallsend is not in a mine subsidence.

5. Site Classification

5.1 General

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

Soil reactivity classifications are determined using AS2870 – 2011 "Residential Slabs and Footings". Classifications are based on the potential shrink/swell movement due to changes in moisture content. **Table 2** shows site classification types.

Class	Foundation
A	Most sand and rock sites with little to no ground movement from moisture change
S	Slightly reactive clay sites, which may experience slight ground movement from moisture changes
M	Moderately reactive clay 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 clay sites, which may experience extreme ground movement from moisture changes
P	Problem sites, which include soft soils such as soft clay, silt or loose sands, landslip, mine subsidence, collapsing soils, soils subject to erosion and fill sites greater than 0.8m for sand and 0.4m for material other than sand

Table 2 – Classification based on site reactivity

Reactive sites are sites consisting of clay soils that swell on wetting and shrink on drying, resulting in ground movements that can damage lightly loaded structures. The amount of ground movement is mainly related to the physical properties of the clay and environmental factors such as climate, vegetation and watering.

A higher probability of damage can occur on reactive sites where abnormal moisture conditions occur, due to factors such as:

- growth of trees too close to a footing or removal of trees prior to construction;
- lack of maintenance of site drainage, failure to repair plumbing leaks and excessive or irregular watering of gardens;
- unusual moisture conditions caused by removal of structures, ground covers (pavements), drains, dams, etc.

The growth of trees too close to footings can result in damage to footings and structures on reactive sites due to drying of the clay soils at substantial distances. Appendix B of *AS 2870-2011* indicates that to reduce but not eliminate the possibility of damage, trees should be restricted to a distance from the building of ¾ × the mature height for Class M sites and 1 × the mature height for Class H1 and Class H2 sites. Where rows or groups of trees are present, the distance from the building should be increased.

Appendix H of *AS 2870-2011* indicates that the maximum lateral reach of the drying influence of a group of trees should be taken as 1.5 × the design height of the group of trees and for a group of four or more trees in a row as 2 × the design height of the group of trees.

In regard to the performance of footings systems, AS 2870-*2011* states "Buildings supported by footing systems designed and constructed in accordance with this Standard on a normal site which is –

(a) not subject to abnormal moisture conditions; and

(b) maintained such that the original site classification remains valid and abnormal moisture conditions do not develop; are expected to experience usually no damage, a low incidence of damage Category 1 and an occasional incidence of damage Category 2". Damage categories are defined in Appendix C of *AS 2870-2011*, which is reproduced in CSIRO information sheet *BTF 18, Foundation Maintenance and Footing Performance: A Homeowner's Guide*.

5.3 Site Classification

Based upon the push tube (drill rig) excavation and the DCP tests undertaken on the subject lot, the subsoil can be classed as '**Class M**', for foundation design purposes due to the shallowness of bedrock. However, if any part of the structural foundations bears onto rock, then all the structural foundations **SHALL** bear upon competent bedrock at all points across the proposed development in order to prevent differential settlement. In areas where there is retained fill, the foundations should pier down to competent soil in accordance with the Australian Standard AS2870: *Residential Slabs and Footings*. The site classification is based on the subsurface profile and a visual assessment of the site.

This site classification has not included the effects of poor site drainage, leaking plumbing and exceptional moisture. Induced movements such as those that could follow removal of trees prior to construction have also not been included.

It is the responsibility of the design engineer to ensure that AS2870 is applicable to the proposed development.

6. Recommendations

6.1 Report Limitations

The extent of testing associated with this assessment is limited to the visual assessment of the site and surrounding area and the borehole logs and variations in ground conditions may occur.

Vision Engineers does not provide unqualified warranties nor does Vision Engineers assume liability for the site conditions not recorded in this report. Vision Engineers should be contacted immediately should subsurface conditions be found to differ from those described in this report.

This report has note included an assessment of the slope stability of the site, an assessment of ground conditions for the purpose of retaining wall parameters or an investigation of mine subsidence at the site.

This report and all associated documentation has been prepared solely for the use of the listed client.

The use of this report by other parties not listed on this report shall be at the own risk of those parties. Any ensuing liabilities resulting from the use of this report by other parties cannot be transferred to Vision Engineers.

Please also refer to General Notes in the Appendix.

6.2 Excavation During Construction

It is expected that excavation of the residual soils and weathered rock could be achieved using conventional earthmoving equipment like backhoes and excavators. Boreholes for pile construction could be drilled using a 12 tonne excavator or backhoe with an attached auger.

Excavations in excess of 1.0m depth external to the excavation for the proposed development must be supported by an engineered designed retaining wall.

Unretained cuts in soil must be battered in accordance with the requirements of the Building Code of Australia, but in no case should be steeper than 2H:1V and must be protected from erosion. Unretained cuts in competent rock must be battered in accordance with the requirements of the Building Code of Australia, but in no case should be steeper than 1H:4V and must be protected from erosion.

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

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

Tiered batter slopes must be separated by a minimum distance of 1.5m. Separation distances must not contain a slope in excess of 20H:1V.

It is recommended that the maximum excavation height not exceed 3m without further geotechnical investigation and approval.

Excavations should be undertaken as per AS3798-2007 “Guidelines on Earthworks for Commercial and Residential Development”.

Figure 2 below diagrammatically shows the above excavation guidelines.

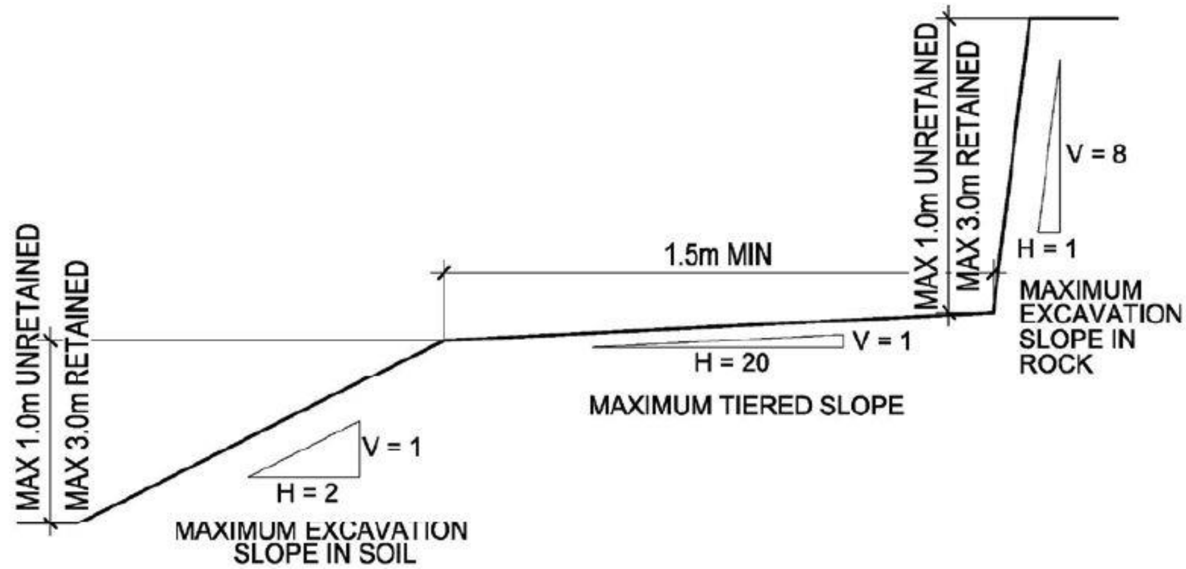


Figure 2: Diagram of excavation guidelines

6.3 Filling

Fill in excess of 1.0m must be retained by an engineer designed retaining wall.

Unretained fill less than 1.0m in depth should be battered in accordance with the requirements of the Building Code of Australia, but in no case should be steeper than 2H:1V and must be protected from erosion.

Fill should be placed in maximum 200mm deep layers and be compacted to 100% maximum dry relative density for cohesive material or 70% relative density for non-cohesive (sand) material, and generally in accordance with the requirements of AS3798: *Guidelines for Earthworks for Commercial & Residential Developments.*

Where fill is placed on slopes greater than 8H:1V, the natural surface should be benched prior to the placement of fill material.

Tiered batter slopes must be separated by a minimum distance of 1.5m. Separation distances must not contain a slope in excess of 20H:1V.

It is recommended that the maximum filling height not exceed 3m without further geotechnical investigation and approval.
Figure 3 below diagrammatically shows the above fill guidelines

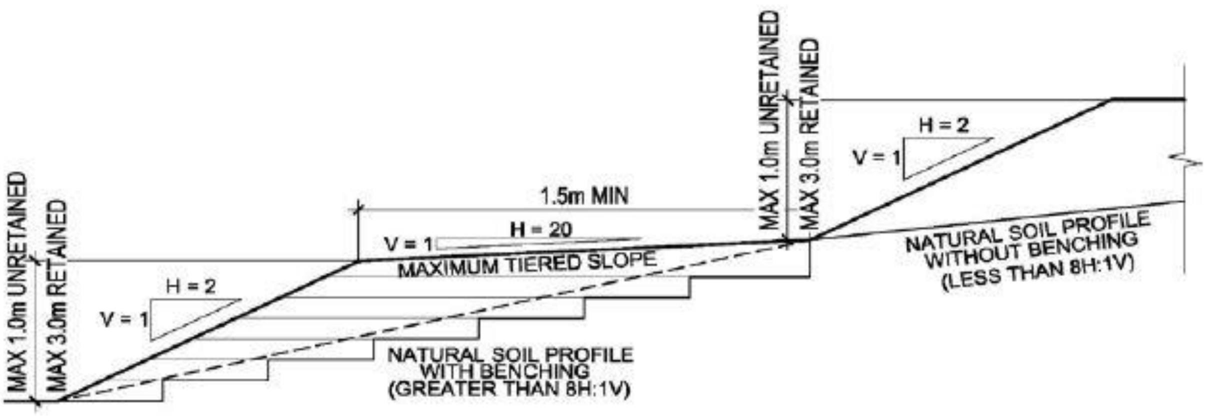


Figure 3: Diagram of excavation guidelines

6.4 Structural Foundations

The push tube (drill rig) and DCP readings indicate that the natural ground has an **adequate bearing capacity** to support future development. Due to the apparent shallowness of bedrock, it is recommended that the structural foundations and footings for the proposed development bear directly onto the underlying bedrock.

It is advised that foundations for any future **proposed structures** be designed to the site classification of "**M**" as defined within AS2870, and where the structural foundations do not bear directly on bedrock, should pier to it.

The site is suitable for footing systems such as waffle pod, strip footings or stiffened raft slab footing system supported on firm natural material, founded below any existing topsoil, slopewash or fill on the site. For a waffle pod system the footing would need to be piered to the rock layer and Vision Engineers anticipates that a stiffened raft footing is likely to be approximately at the bedrock layer if any minor cut/fill operations are undertaken.

The footing systems must be designed by a structural engineer in accordance with engineering principles and AS 2870 - 2011 "Residential Slabs and Footings" for no less than the minimum requirements for a Class H1 site.

Vibrations caused during the driving of piles and the proximity of neighbouring buildings should be considered.

A geotechnical engineering inspection is recommended prior to pouring of recommended foundations.

6.5 Retaining Walls

The construction of any new retaining walls should be designed by a practicing structural engineer. It is essential that retaining wall foundations are fully embedded in natural (non-filled) ground and the foundation subsoil and be designed as fully drained. A geotechnical engineer must inspect the subgrade and footing excavation prior to placement of concrete in order to verify the findings of this report.

7. Wind Speed Assessment

Vision Engineers have assessed the subject site in accordance with AS4055 - 2012 *Wind loads for housing.* This assessment has determined that for the subject site an 'N2' design wind speed is applicable.

The design engineer shall confirm that the proposed structure is within the limitations as specified in AS4055 or where required undertake a wind speed assessment based on AS1170.2 – 2011 *Wind actions*.

Vision Engineers notes that a detailed wind speed assessment in accordance with AS1170.2 may result in a design wind speed lower than 'N2'.

8. Conclusion

A site investigation was undertaken on Wednesday 9th May, 2018 to carry out a site subsoil classification in accordance with AS2870: *Residential Slabs and Footings* and to assess the slope stability of the subject lot in its current state and following the proposed development. The findings from this subsoil investigation is summarised below.

The site **in its current state** is assessed as having a **very low risk** of slope instability, and landslip assessed as being **unlikely**. Provided the recommendations above are incorporated in the design of the proposed development upon the subject lot, the assessment for the developed block will remain in the **very low risk** bracket, with landslip being **unlikely**.

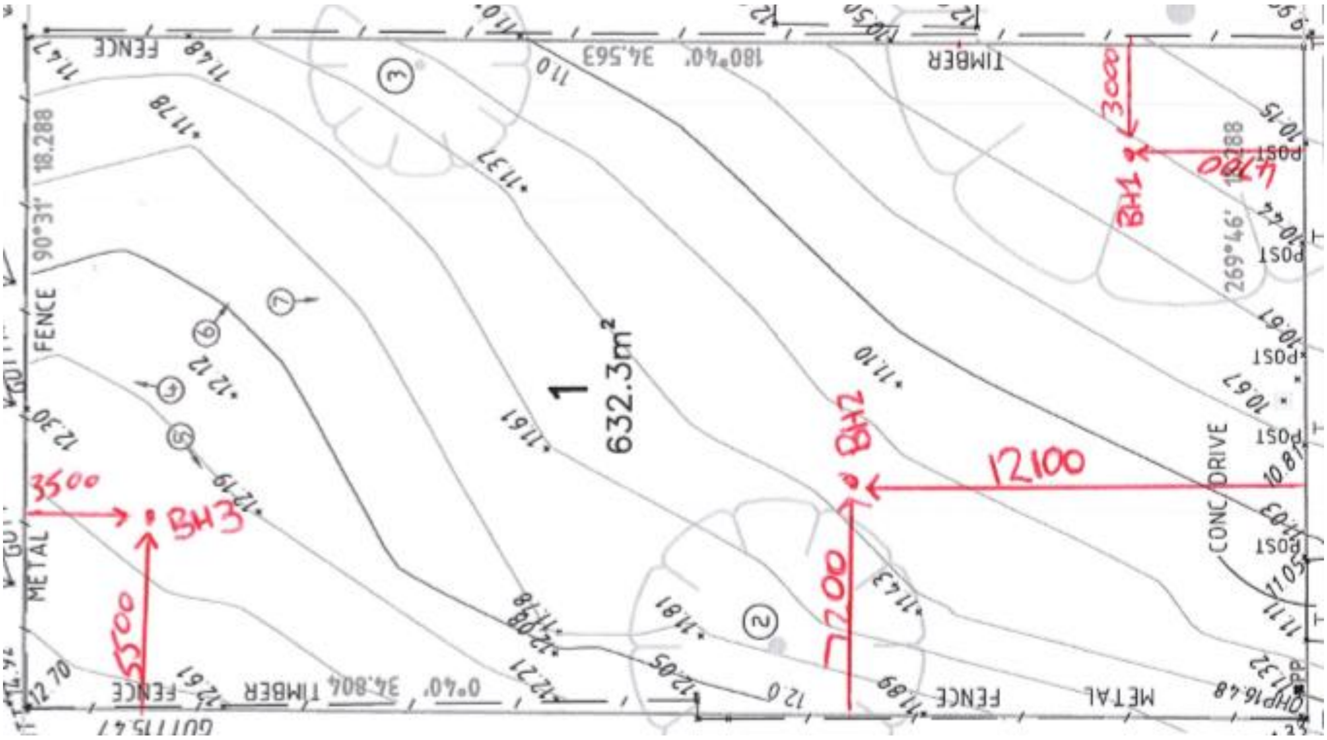
Vision Engineers have determined that for the subject site an 'N2' design wind speed is applicable, in accordance with AS4055 *Wind loads for housing.*

The subject lot has been classified as "**Class M**", as defined in AS2870 for foundation design.

It is the responsibility of the design engineer to ensure that the proposed development is within the limitations of A2870 and AS4055.

If landslip or slope instability is observed on the subject site please contact Vision Engineers for a secondary assessment to confirm if the assessment contained within this report is still valid.

9. Appendix A – *Site Map*



10. Appendix B – *Borelogs*

Definitions

Moisture	Clays	Sands	Methods
D = Dry	VS = Very Soft	VL = Very Loose	PTM = Push Tube (Drill Rig)
M = Moist	S = Soft	L = Loose	PTH = Push Tube (Hand Gear)
W = Wet	F = Firm	MD = Medium Dense	HA = Hand Augur
	VSt = Very Stiff	D = Dense	
	H = Hard	VD = Very Dense	

Water
E = Water Encountered
NE = Water Not Encountered

GEOTECHNICAL BOREHOLE LOG - BH1

VISIONENGINEERS

Drawing Number: 917-6187
Project:
Client:
Date:
Logged By: MWA

Borehole Information			Profile Description			
Depth	Method	Water	Classification Symbol	Description, Structure and additional Observations	Moisture	Consistency
0.05 0.1 0.15 0.2	PTM	NE	OL	Silt, topsoil, organic matter, dark brown	D	L
0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6	PTM	NE	ML	Clayey silt with traces of gravel, light brown	D	L
0.65 0.7 0.75 0.8 0.85 0.9 0.95 1 1.05 1.1 1.15 1.2	PTM	NE	CH	Clay, mottled light brown, red	D	VSt
1.25 1.3 1.35 1.4 1.45 1.5 1.55 1.6	PTM	NE	CI	Sandy clay, mottled light, dark brown, orange with traces of gravel	D	S
1.65 1.7 1.75 1.8 1.85 1.9 1.95 2				Terminated at 1.6m on Weathered rock LIMIT OF INVESTIGATION		

GEOTECHNICAL BOREHOLE LOG - BH2

VISIONENGINEERS

Drawing Number: 917-6187
Project:
Client:
Date:
Logged By: MWA

Borehole Information			Profile Description			
Depth	Method	Water	Classification Symbol	Description, Structure and additional Observations	Moisture	Consistency
0.05 0.1 0.15	PTM	NE	OL	Silt, topsoil,organic matter, dark brown	D	L
0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65	PTM	NE	CH	Clay, orange	M	VSt
0.7 0.75 0.8 0.85 0.9 0.95 1 1.05	PTM	NE		Weathered rock		
1.1 1.15 1.2 1.25 1.3 1.35 1.4 1.45 1.5 1.55 1.6 1.65 1.7 1.75 1.8 1.85 1.9 1.95 2				Termination at 1.05m on weathered sandstone LIMIT OF INVESTIGATION		

GEOTECHNICAL BOREHOLE LOG - BH3

Drawing Number: 917-6187
Project:
Client:
Date:
Logged By: MWA

Borehole Information			Profile Description			
Depth	Method	Water	Classification Symbol	Description, Structure and additional Observations	Moisture	Consistency
0.05						
0.1	PTM	NE	OL	Silt, topsoil, organic matter, dark brown	D	L
0.15						
0.2						
0.25						
0.3						
0.35						
0.4						
0.45						
0.5						
0.55	PTM	NE	CL	Clay, mottled tan, white, red	M	S
0.6						
0.65						
0.7						
0.75						
0.8						
0.85						
0.9						
0.95	PTM	NE	CL	Sandy clay, Mottled red, white, tan	M	L
1						
1.05						
1.1				Termination at 1.05m on Weathered rock		
1.15				LIMIT OF INVESTIGATION		
1.2						
1.25						
1.3						
1.35						
1.4						
1.45						
1.5						
1.55						
1.6						
1.65						
1.7						
1.75						
1.8						
1.85						
1.9						
1.95						
2						

11. Appendix C – *General Notes*

11.1 Introduction

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

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

11.2 Engineering Reports

Vision Engineers engineering reports are prepared by qualified personnel and are based on information obtained, and on modern engineering standards of interpretation and analysis of that information. Where the report has been prepared for a specific design proposal the information and interpretation may not be relevant if the design proposal is changed. If the design proposal or construction methods do change, **Vision Engineers** request that it be notified and will be pleased to review the report and the sufficiency of the investigation work.

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

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

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

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

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

11.3 Misinterpretation of Reports

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

11.4 Engineering Logs

Vision Engineers uses subcontractors for fieldwork. Field logs are developed by accredited geotechnicians. Final engineering logs are developed by the Geotechnical Engineer based upon interpretation of field logs and laboratory evaluation of field samples. Only final engineering logs are
included in geotechnical engineering reports. To minimize the likelihood of engineering log misinterpretation, give contractors ready access to the complete geotechnical engineering report.

11.5 Site Inspection

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

11.6 Changes in Conditions

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

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

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

11.7 Ground Water

Unless otherwise indicated the water levels given on the engineering logs are levels of free water or seepage in the test hole recorded at the given time of measuring.

This may not accurately represent actual ground water levels, due to one or more of the following:

- In low permeability soils, ground water although present may enter the hole slowly, or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent prior weather changes. They may not be the same at the time of construction as indicated at the time of investigation.

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

11.8 Foundation Depth

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

11.9 Engineering Logs

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

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

11.10 Investigation Methods

Vision Engineers both conducts engineering fieldwork and outsources fieldwork to accredited subcontractors. All fieldwork is conducted as per AS 1726. The following is a summary of drilling methods currently used by **Vision Engineers** and its subcontractors, and some comments on their use and application.

Test Pits: These are excavated using a backhoe or tracked excavator, allowing close examination of insitu soil if it is safe to descend into the pit.

Hand Auger: The soil sample is obtained by screwing a 75mm Auger into the ground by hand.

Push Tube: The soil sample is obtained by pushing an approximately 50mm diameter tube into the ground via machine (vehicle mounted or hand held). The sample is less disturbed than other methods mentioned here.

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

Hand Penetrometers: Hand Penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and recording the number of blows for successive 100mm increments of penetration. Hand penetrometers tests are carried out as per AS 1289.5.3.2 and AS 1289.5.3.3

Sampling: Sampling is carried out during drilling or excavation to allow engineering examination, and laboratory testing of the soil or rock. Disturbed samples taken during drilling or excavation provide information on colour, type, inclusions and some information on strength and structure.

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

Laboratory Testing: Laboratory testing where specified is carried out by NATA accredited laboratories.

12. Appendix D - *Limitations to AS2870 and AS4055*

Limitations to AS2870

The limitations of **AS2870:** ***Residential Slabs and Footings*** designs are listed at the beginning of the code under **Section 3: Standard Designs**. An extract from the code is below that lists these limitations and hence qualifies the relevance of the structural foundation design recommendations of this Report to **Standard Designs**.

For proposals that do not meet **AS2870** code limitations for standard designs, designs should then be based on proven structural engineering principles and be carried out by suitably experienced qualified structural engineer in accordance to relevant Australian Standards.

SECTION 3 STANDARD DESIGNS

3.1 SELECTION OF FOOTING SYSTEMS

3.1.1 Selection procedure

Standard deemed-to-comply designs shall be in accordance with Clauses 3.2 to 3.6. These designs shall not apply to—

(a) Class E or Class P sites;

(b) buildings longer than 30 m;

(c) slabs containing permanent joints (e.g. contraction or control joints);

(d) two-storey construction with a suspended concrete floor at the first floor level except in accordance with Clause 3.9;

(e) two-storey construction in excess of the height limitations (see Clause 1.8.60);

(f) support of columns or fireplaces not complying with Clause 3.10;

(g) buildings incorporating wing walls or masonry arches unless they are detailed for movement in accordance with TN 61;

(h) construction of three or more storeys; or

(i) single-leaf earth or stone masonry walls greater than 3 m in height.

On moderately and highly reactive sites, the entire footing system for a single building shall comprise only one standard design.

These designs shall not apply to construction using concrete strengths of 32 MPa and greater.

3.1.2 Design for single-leaf masonry, mixed construction and earth wall construction

The proportions for the selected footing system for single-leaf masonry, mixed construction and earth wall construction shall comply with Clause 3.1.1 using the equivalent construction set out in Table 3.1.

Figure 4. Extract from AS2870-2011, Section 3: Standard Designs, pg 26.

Limitations to AS4055

The limitations of **AS4055** are listed at the beginning of the code in **Section 1: Scope and General**. An extract from the code is shown below to qualify the relevance of this Report to the proposed design.

If the proposed development does not meet these limitations, the site wind classification to **AS4055** contained within this report is **not suitable for use in design** and **AS1170.2**: *Structural Design Actions – Wind Actions* is the relevant standard to be used in the structural design.

1.2 LIMITATIONS

For the purpose of this Standard, the following conditions (geometric limits) shall apply (see Figure 1.1):

(a) The distance from ground level to the underside of eaves shall not exceed 6.0 m from ground level to the highest point of the roof, neglecting chimneys shall not exceed 8.5 m.

(b) The width (*W*) including roofed verandas, excluding eaves, shall not exceed 16.0 m, and the length (*L*) shall not exceed five times the width.

(c) The roof pitch shall not exceed 35°.

The tables in Section 5 are based on floor to ceiling height of 2.4 m and a floor depth of 0.3 m (floor level down to ceiling below).

Figure 5. Limitations of AS4055-2006, Section 1: Scope and General, pg 4.

13. Appendix E - *CSIRO's Foundation Maintenance & Footing Performance*

Foundation Maintenance and Footing Performance: A Homeowner's Guide

CSIRO

BTF 18 replaces Information Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

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

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

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

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

Trees can cause shrinkage and damage

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

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

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

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

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

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

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

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

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

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

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

Effects on framed structures

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

Effects on brick veneer structures

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

Water Service and Drainage

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

Plumbing

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

Ground drainage

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

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

Protection of the building perimeter

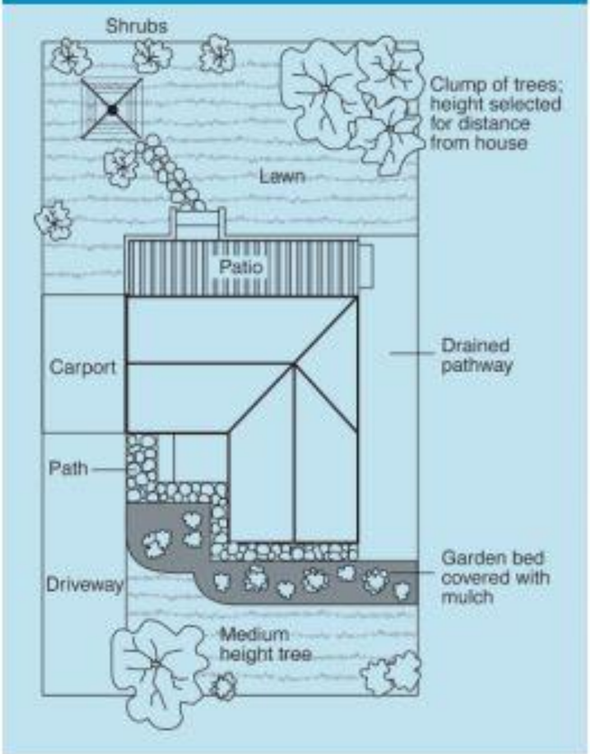
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

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

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

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

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

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

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

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

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

Remediation

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

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

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14. Appendix F - *Excerpt from Practice Note Guidelines for Landslide Risk Management 2007 on Terminology*

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

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

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

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

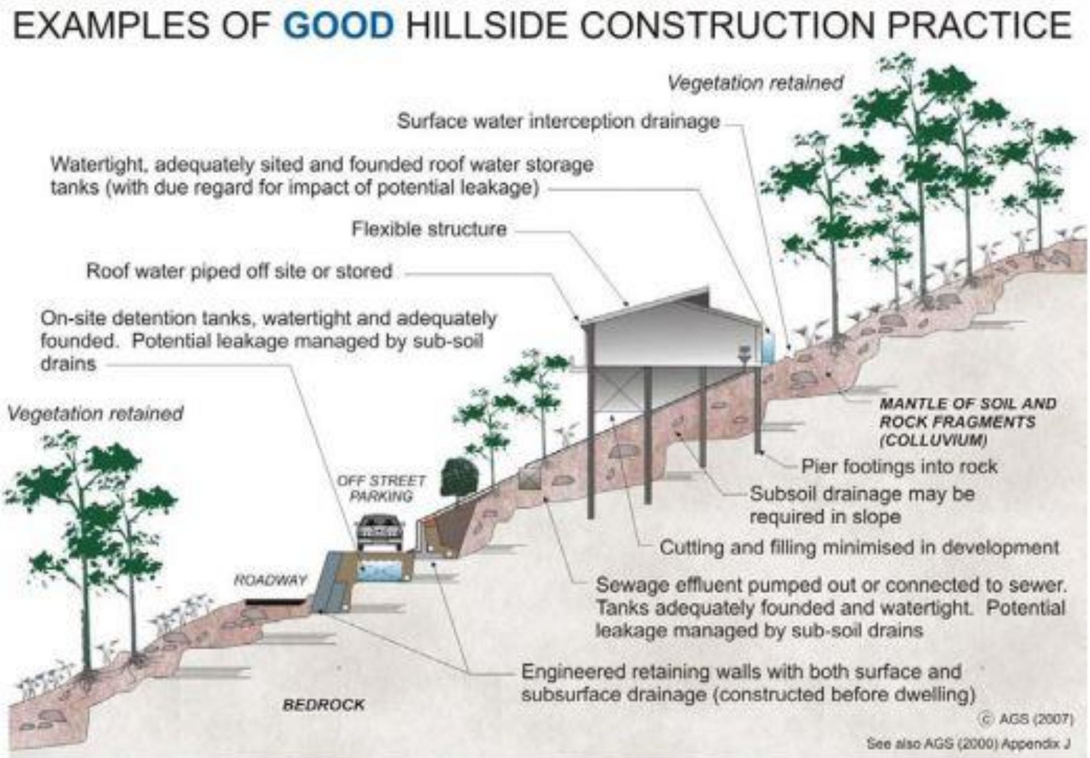
Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
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.

15. Appendix G - *Guidelines for Hillside Construction*

HILLSIDE CONSTRUCTION PRACTICE

Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.



WHY ARE THESE PRACTICES GOOD?

Roadways and parking areas - are paved and incorporate kerbs which prevent water discharging straight into the hillside (GeoGuide LR5).

Cuttings - are supported by retaining walls (GeoGuide LR6).

Retaining walls - are engineer designed to withstand the lateral earth pressures and surcharges expected, and include drains to prevent water pressures developing in the backfill. Where the ground slopes steeply down towards the high side of a retaining wall, the disturbing force (see GeoGuide LR6) can be two or more times that in level ground. Retaining walls must be designed taking these forces into account.

Sewage - whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground.

Surface water - from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfil the same purpose (GeoGuide LR5).

Surface loads - are minimised. No fill embankments have been built. The house is a lightweight structure. Foundation loads have been taken down below the level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide LR3). If you are uncertain whether your site has rock near the surface, or is essentially a soil slope, you should engage a geotechnical practitioner to find out.

Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

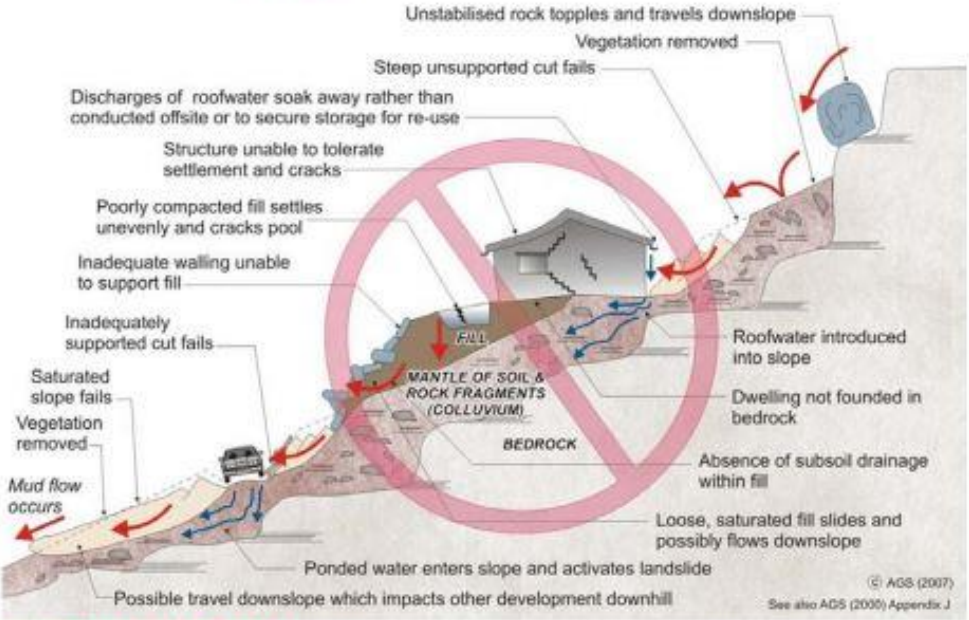
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing can result in a rise in water table with a consequent increase in the likelihood of a landslide (GeoGuide LR5). An exception may have to be made to this rule on steep rock slopes where trees have little effect on the water table, but their roots pose a landslide hazard by dislodging boulders.

Possible effects of ignoring good construction practices are illustrated on page 2. Unfortunately, these poor construction practices are not as unusual as you might think and are often chosen because, on the face of it, they will save the developer, or owner, money. You should not lose sight of the fact that the cost and anguish associated with any one of the disasters illustrated, is likely to more than wipe out any apparent savings at the outset.

ADOPT GOOD PRACTICE ON HILLSIDE SITES

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF POOR HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

Roadways and parking areas - are unsurfaced and lack proper table drains (gutters) causing surface water to pond and soak into the ground.

Cut and fill - has been used to balance earthworks quantities and level the site leaving unstable cut faces and added large surface loads to the ground. Failure to compact the fill properly has led to settlement, which will probably continue for several years after completion. The house and pool have been built on the fill and have settled with it and cracked. Leakage from the cracked pool and the applied surface loads from the fill have combined to cause landslides.

Retaining walls - have been avoided, to minimise cost, and hand placed rock walls used instead. Without applying engineering design principles, the walls have failed to provide the required support to the ground and have failed, creating a very dangerous situation.

A heavy, rigid, house - has been built on shallow, conventional, footings. Not only has the brickwork cracked because of the resulting ground movements, but it has also become involved in a man-made landslide.

Soak-away drainage - has been used for sewage and surface water run-off from roofs and pavements. This water soaks into the ground and raises the water table (GeoGuide LR5). Subsoil drains that run along the contours should be avoided for the same reason. If felt necessary, subsoil drains should run steeply downhill in a chevron, or herring bone, pattern. This may conflict with the requirements for effluent and surface water disposal (GeoGuide LR9) and if so, you will need to seek professional advice.

Rock debris - from landslides higher up on the slope seems likely to pass through the site. Such locations are often referred to by geotechnical practitioners as "debris flow paths". Rock is normally even denser than ordinary fill, so even quite modest boulders are likely to weigh many tonnes and do a lot of damage once they start to roll. Boulders have been known to travel hundreds of metres downhill leaving behind a trail of destruction.

Vegetation - has been completely cleared, leading to a possible rise in the water table and increased landslide risk (GeoGuide LR5).

DON'T CUT CORNERS ON HILLSIDE SITES - OBTAIN ADVICE FROM A GEOTECHNICAL PRACTITIONER

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments ' National Disaster Mitigation Program.