Geotechnical Site Investigation

Lot. 40 / DP15762

136 Narrabeen Park Parade

Mona Vale NSW 2103

Submitted To
Metricon Homes Pty Ltd
Building E, Level 4, 32 Lexington Drive
BAULKHAM HILLS, NSW 2153

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Document Revision History

Date	Rev	Author	Approved by	Comments
25/03/2020	0	Raj Singh	Scott Emmett	First Edition
30-Jul-21	1	Dave Fisher	Scott Emmett	First Revision

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Practice Note Guidelines For Landslide Risk Management 2007, Australian Geoguide LR8 (Construction Practice)

REFERENCED STANDARDS:

AS 1726-2017, Geotechnical site investigations, Standards Australia, Sydney, Retrieved from SAI Global

AS 2159-2009, Piling-Design and Installation, Standards Australia, Sydney, Retrieved from SAI Global

AS 2870-2011, Residential slabs and footings, Standards Australia, Sydney, Retrieved from SAI Global

AS 3798-2007, Guidelines on earthworks for commercial and residential developments, Standards Australia, Sydney, Retrieved from SAI Global

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1 Introduction

In March 2020, Intrax Consulting Engineers completed a geotechnical investigation for a proposed double storey residential development at Lot. 40, No. 136, Narrabeen Park Parade, Mona Vale, NSW, 2103. The investigation was carried out in accordance with the email fee proposal commissioned by Metricon Homes Pty Ltd and a version of this report (Rev 0) was submitted on 22 March 2020.

This report (Rev 1) outlines the geotechnical site investigation carried out on 12 March 2020, and incorporates comments on proposed alterations to a proposed retaining wall along the northern portion of the north western site boundary. This revision of the report supersedes Rev 0.

Council previously requested a landslip report due to the development requiring excavation for the proposed driveway more than 1 meter in height. This report includes the results of the site investigation works, as well as updated comments on risk of landslide in accordance with Northern beaches council and Australian Geomechanics Society "Practice Note Guidelines for Landslide Risk Management 2007", landslide Risk assessment guidelines. We understand that revision to the plans of the proposed retaining wall will now require excavation to a depth of up to about 2m adjacent to the northern portion of the north western boundary.

2 Project and Site Description

2.1 Project Description

The development is a new double storey dwelling as outlined in the architectural drawings prepared by Metricon Homes (Job number 704711, Dated 25/09/2019) which were provided to us by Metricon. Excavation to depths of up to approximately 2m are required to construct a retaining wall adjacent to the northern portion of the north western site boundary.

2.2 Site Description

The site is situated to the south west of Narrabeen Park Parade, Mona Vale and covers an area of about 594.4m^2.

The site is bound by Narrabeen Park Parade to the north east, and by residential dwellings to the north, south and west. At the time of the initial investigation, the site was occupied by a single storey residential dwelling with detached carport. The site slopes down toward the south west. A brick retaining wall was present along the north western boundary of the site, near the existing driveway. The retaining wall appeared to be in a good condition.

The surface soils generally comprise of Silty Sand topsoil fill.

Site conditions on the date of the initial fieldwork are visible in the attached photography in Appendix B with the site features indicated in the site plan, refer Appendix A.

3 Method of Investigation

3.1 Desktop Assessment

Geological maps from the Geological Survey of New South Wales (NSW), aerial photography and our local experienced were used to assess the anticipated site conditions and the area geology.

3.2 Fieldwork

The fieldwork consisted of visual inspection of the site and its surroundings by one of Intrax Senior Geotechnical Engineers. Boreholes were drilled using hand auger equipment to a depth of 1.2m. The approximate locations of the boreholes are shown on the attached site plan in Appendix A. The subsurface materials were visually classified in accordance with AS1726-2017: Geotechnical Site Investigation.

Dynamic Cone Penetrometer (DCP) tests were conducted adjacent to borehole 1 and borehole 2.

4 Results of Investigation

4.1 Desktop Assessment

Investigation of geological maps from the Geological survey of NSW has identified the expected site geology is Triassic aged group Newport Formation and Garie Formation Narrabeen Group (Rn, undifferentiated) which comprises interbedded laminite, shale and quartz to lithic quartz sandstone, minor red claystone north of Hawkesbury River. Clay pellet sandstone (Garie Fm) south of Hawkesbury River. This geology was consistent with the visual identification of material on site. An extract of the local geological map is provided below.

Figure 1: Extract of local geology from 1:100,000 Sydney Map

4.2 Subsurface Conditions

From previous study, the boreholes revealed the substrata typically consisted of the following soil profile. Variation from this profile existed across the site, refer to borehole logs in Appendix A for details.

TOPSOIL FILL	Silty SAND, fine to medium grained, dark brown mottled, root material, moist, loose
RESIDUAL	CLAY, medium to high plasticity, red mottled brown yellow

4.2.1 Ground Water

Groundwater was not intersected within 1.2 metres of the existing ground surface during borehole drilling.

Substrata conditions encountered are such that infiltration and occurrence of perched water at the interface between different material layers should not be disregarded.

5 Slope Instability

A landslide hazard assessment of the existing slopes has been carried out in accordance with the Australian Geomechanics Society Landslide Risk Management Concepts and Guidelines, 2007.

A copy of this document can be found at www.australiangeomechanics.org. Appendix C of the document describes the terminology used.

5.1 Proposed Development

As mentioned in section 2.1 of the report, the development comprises a double storey residential dwelling and requires excavation up to about 2m depth for construction of a proposed retaining wall.

5.2 Previous Instability

Indicators of instability within soil or rock beneath the site can include, but are not limited to:

- Creep – observed by tilting of structures including trees, fences.
- Hummocky disturbed ground in or at the base of slopes.
- Tension cracks in or at the top of slopes.

The borehole encountered clayey fill over residual soil (clay).

5.3 Site Features Relating to Slope Instability

The following site features are assessed to be relevant for assessment of risk to slope instability:

- Excavation up to about 2m in height near the northern corner of the site.

5.4 Possible Landslide Hazards

Based on our assessment of the site, possible landslide hazards considered applicable to the existing slope are as follows:

Table 1: General Possible Failure Mechanisms for Landslide

Possible Failure Mechanisms Description	Description of Failure Mechanism
Rotational/ Translational Landslide	This mode of failure is characterised by a curved or relatively flat failure surface. Should rotational/translational failure occur at this site, the plane of failure would likely be at an angle of approximately 45° from the toe of any over-steep cuts.
Creep	Slow downhill movement of landmass due to steep slopes, groundwater conditions and other factors.

5.5 Hazard Identification

Based on the site features noted above, the following instability mechanisms are considered relevant for the proposed work:

- Failure of over-steep excavation for the proposed driveway.

5.6 Risk Assessment

In accordance with Appendix – C Qualitative Measures of Consequences to property, the anticipated consequences of the identified landslide hazards are explained in the report from section 5.6.1 to 5.6.5.

The level of risk to property has been determined using the Qualitative Risk Analysis Matrix.

5.6.1 Failure of proposed excavation of the driveway

Based on the supplied drawings, it is understood that excavation will be carried out near the northern corner of the site to achieve the proposed design levels.

Based on engineering judgement, provided that the excavation is appropriately benched, battered or propped, the probability of failure of unsupported cuttings during excavation is assessed to be possible, with an indicative value of approximate annual probability 0.001. The consequences of this instability are assessed to be Medium to High. Hence, the risk to the property or life is assessed to be **moderate to high.** This risk may be reduced to **Low** by adopting the safe batter angles provided in *section 6.4 Excavation and Retention* of this report, or by installing appropriate, engineer designed propping to support the face of the excavation.

6 Discussion and Recommendations

6.1 General

The generalised subsurface profile within the boreholes may be represented by topsoil fill overlying residual clay.

6.2 Excavation and Retention

6.2.1 Dilapidation Surveys

It is recommended that dilapidation reports be undertaken on the adjacent buildings prior to commencing work on the site to document any existing defects so that any claims for damage due to excavations or other construction related activities can be accurately assessed.

6.2.2 Retention Design Parameters

The following parameters established from Rankine's theory would be valid in the design of a retention system. These values assume that the soil being retained/supported has horizontal surface.

Table 2: Geotechnical soil and retention design parameters

Material Description	Unit weight (kN/m³)	Undrained Cohesion, Cu (kPa)	Friction angle (°)	Ka#	Kp#	Ko#
TOPSOIL FILL	16	-	25	0.41	2.46	0.58
Residual - clay	18	150	28	0.36	2.77	0.53

**Approximate depth based on borehole logs completed during geotechnical investigation*
#K_a, K_p and K_o are the active, passive and at-rest earth pressure coefficients.

The above parameters assume that the level of the water table is below the bottom of the excavation by the use of adequate drainage and that any adjacent surcharge loads are superimposed.

It is suggested that design of permanent retaining structures be based on an average bulk unit weight for the retained material of 18kN/m³ and on a triangular distribution. In order to maximise the rigidity of the retaining wall, 'at rest' Ko earth pressure conditions may be adopted.

6.2.3 Site Excavation

During the excavation of the site following prolonged rain periods, seepage water may be present in the excavation. The zone of influence that the work has on the surface of the excavation during construction is at an angle of 45° from the toe of the excavation, or at a distance of 0.5H horizontal from the toe of the excavation, where H is the depth of the excavation.

It is recommended that where any footings are to be constructed next to existing underground services (sewers, etc), then these footings should be founded and designed taking into account the above parameters.

This office recommends the following excavation methodology;

1. Any upper FILL, TOPSOIL and SILT layers must battered to not steeper than 33 degrees with the horizontal all around the excavation perimeter or temporarily retained.
2. Any residual clay soils or extremely weathered rock must be battered at not steeper than 45 degrees with the horizontal or temporarily retained.
3. Any distinctly weathered rock may be battered at 60 degrees with the horizontal or temporarily retained.
4. Steeper batter angles may be adopted following approval from a suitability experienced geotechnical engineer/engineering geologist, and adoption of an inspection regime by a qualified geotechnical engineer/engineering geologist.
5. Inspections are to be completed by this office following any of the below events during construction:
    - Following rainfall events in excess of 30mm over a 24-hour period.
    - At any sign of instability including but not limited to:
        - Water seepage through the excavation face
        - Material observed at the base of the excavation
        - Tension cracks observed at the surface
6. Excavations adjacent to existing structures, property boundaries or services (were batters cannot be achieved during horizontal distance constraints) are to be retained prior to excavation via use of an in-situ retaining wall system (e.g. non-contiguous pile wall).

Table 3: Safe batter angles

Material Description	Safe Batter (V:H)	
	Short Term	Long Term
Clayey Fill	1:1.5	1:2
Residual - Clay	1:1	1:1.5

Excavation for the proposed retaining wall will initially encounter Silty Clay fill and residual CLAY. There is a possibility that extremely weathered rock may be encountered as well. Removal of fill, clay and extremely weathered rock should be readily carried out using conventional earthmoving equipment, such as a hydraulic excavator or backhoe.

It is unlikely that excavation of sandstone rock would require some techniques such as use of hydraulic impact hammers. However, if rock hammers are to be used, such works will need to be completed carefully as there may be direct transmission of ground vibration to existing structures. We recommend that at the commencement of using rock hammer for excavation, a geotechnical engineer visit the site to review the excavation methods being employed by the contractor. An experienced consultant may be required to carry out quantitative vibration monitoring to confirm that vibrations are within tolerable limits. If during the use the use of a rock hammer the transmitted vibrations are found to be excessive, then alternative excavation equipment would be recommended by the geotechnical engineer. This may include the use of a smaller hammer of the use of lower vibration emitting equipment.

6.3 Drainage

The following drainage measures should be implemented to reduce the risk of slope instability:

- Subsoil drains should be provided behind all retaining walls.
- Roof drainage and drainage from hardstand areas should be collected and directed to the site drainage system in a manner that does not reduce the site stability. Stormwater from other hardstand areas may be discharged from the site via pipes into designated council drainage paths and not allowed to flow on to exposed earth.

The layout of drains should be designed by a qualified Civil Engineer.

6.4 Inspections (Hold Points)

Intrax **must** be engaged at the following stages:

1. In the event soil conditions encountered differ significantly from those described within this report.
2. If project design is altered significantly from drawings reviewed and outlined or project described within this report

Intrax should be engaged at the following stages:

1. To confirm safe batter angles and excavation construction during construction.

Limitations of Report

1. The recommendations in this report are based on the following:
    a. Information about the site & its history, proposed site treatment and building type conveyed to us by the client and or their agent
    b. Professional judgements and opinions using the most recent information in soil testing practice that is available to us.
    c. The location of our test sites and the information gained from this and other investigations.

    Should the client or their agent neglect to supply us with correct or relevant information, including information about previous buildings, trees or past activities on the site, or should changes be made to the building type, size and or/position, this report may be made obsolete, irrelevant or unsuitable. In such cases, Intrax will not accept any liability for the consequences and Intrax reserves the right to make an additional charge if more testing or a change to the report is necessary.
2. The recommendations made in this report may need to be reviewed should any site works disturb any soil 200mm below the proposed founding depth.
3. The descriptions of the soils encountered in the boreholes follow those outlined in AS1726-2017; Geotechnical Site Investigations. Colour descriptions can vary with soil moisture content and individual interpretation.
4. If the site conditions at the time of construction differ from those described in this report then Intrax must be contacted so a site inspection can be carried out prior to any footing being poured. The owner/builder will be responsible for any fees associated with this additional work.
5. This report assumes that the soil profile observed in the boreholes are representative of the entire site. If the soil profile and site conditions appear to differ substantially from those reported herein, then Intrax should be contacted immediately and this report may need to be reviewed and amended where appropriate. The owner/builder will be responsible for any fees associated with this additional work.
6. The user of this report must take into account the following limitations. Soil and drilling depths are given to a tolerance of +/- 200mm.

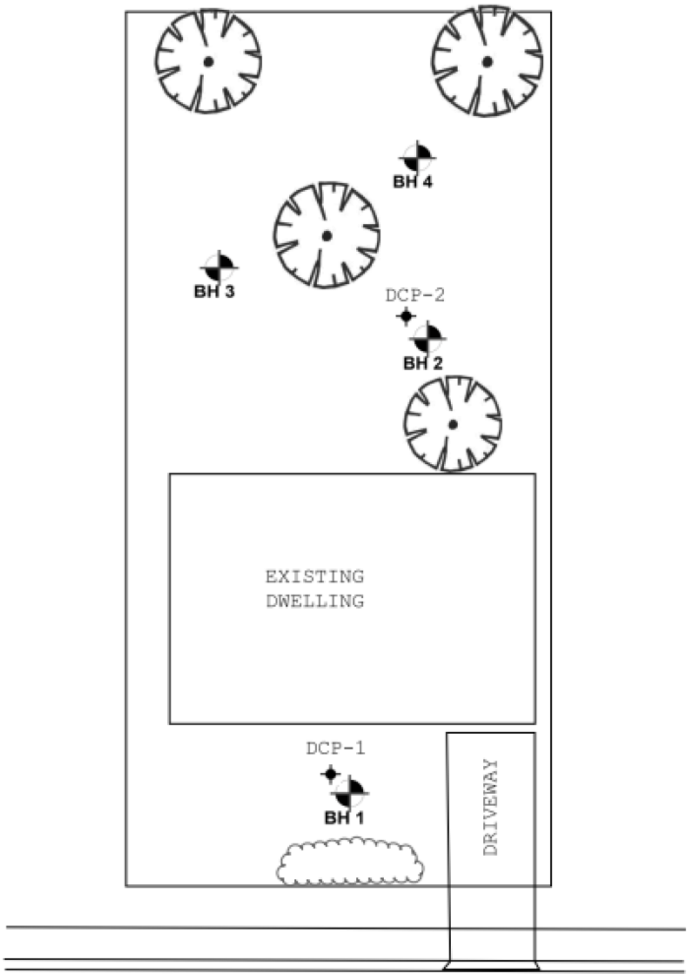
    It must be understood and a condition of acceptance of this report is that whilst every effort is made to identify fill material across the site, difficulties exist in determining fill material, in particular, for example, well compacted site or area derived fill, when utilising a small diameter auger. Consequently Intrax emphasises that we will not be responsible for any financial losses, consequential or otherwise, that may occur as a result of not accurately determining the fill profile across the site.
7. Finally, no responsibility will be taken for this report if it is altered in any way or is not reproduced in full.

Appendix A

Site Plan and Borehole Logs

Site Plan

Site Address: Lot. 40, No. 136, Narrabeen Park Parade, Mona Vale, Nsw, 2103



Client: Metricon Homes Pty Ltd	Scale (A4): Not to scale
Project: Lot. 40, No. 136, Narrabeen Park Parade, Mona Vale, NSW, 2103	Date: 01.11.2019
	Sheets: 1
Drawing: Site Plan	Project No. 130018 — Ver. 1

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Borehole Log: **BH1** **Sheet:** **1 of 1**

Client: Metricon Homes Pty Ltd — Drill Rig: Hand Auger

Project: Proposed Residential Dwelling — Logged: RS

Location: No. 136, Narrabeen Park Parade, Mona Vale, NSW — Date: 12/08/2019

Method	Depth (metres)	DCP blows count	Material Description	Soil Classification	Moisture	Consistency / Density	Structure, Origin, Water and Additional Observations	Disturbed Samples (D)
MA	0.50		Silty CLAY, medium plasticity, dark brown mottled black orange, root material, trace sand gravel	CI	>PL		FILL	D at 0.5m
	1.00		CLAY, high plasticity, pale grey brown mottled orange, root material, trace gravel	CH	>PL		NATURAL	D at 1.0m D at 1.3m
	1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00		Groundwater was not encountered BH1 terminated at 1.3m depth					

This borehole log is to be read in conjunction with the explanatory notes appended to the set of logs. This borehole log is not be reproduced without the full inclusion of all explanatory notes.

Borehole Log: **BH2** **Sheet:** **1 of 1**

Client: Metricon Homes Pty Ltd Drill Rig: Hand Auger

Project: Proposed Residential Dwelling Logged: RS

Location: Lot. 40, No. 136, Narrabeen Park Parade, Mona Va Date: 12/08/2019

Method	Depth (metres)	DCP blows count	Material Description	Soil Classification	Moisture	Consistency / Density	Structure, Origin, Water and Additional Observations	Disturbed Samples (D)
MA	0.50		Silty CLAY, medium plasticity, dark brown mottled black orange, root material, trace sand gravel	CI	>PL		FILL	D at 0.5m
	1.00		CLAY, high plasticity, pale grey brown mottled orange, root material, trace gravel	CH	>PL		NATURAL	D at 1.0m
	1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00		Groundwater was not encountered BH2 terminated at 1.2m depth					

This borehole log is to be read in conjunction with the explanatory notes appended to the set of logs. This borehole log is not be reproduced without the full inclusion of all explanatory notes.

Borehole Log: BH3 **Sheet:** 1 of 1

Client: Metricon Homes Pty Ltd Drill Rig: Hand Auger

Project: Proposed Residential Dwelling Logged: RS

Location: Lot. 40, No. 136, Narrabeen Park Parade, Mona Va Date: 12/08/2019

Intrax

Method	Depth (metres)	DCP blows count	Material Description	Soil Classification	Moisture	Consistency / Density	Structure, Origin, Water and Additional Observations	Disturbed Samples (D)
MA	0.50		Silty CLAY, medium plasticity, dark brown mottled black orange, root material, trace sand gravel	CI	>PL		FILL	
	1.00		CLAY, high plasticity, pale grey brown mottled orange, root material, trace gravel	CH	>PL		NATURAL	
	1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00		Groundwater was not encountered BH3 terminated at 1.2m depth					

This borehole log is to be read in conjunction with the explanatory notes appended to the set of logs. This borehole log is not be reproduced without the full inclusion of all explanatory notes.

Borehole Log: BH4 **Sheet:** 1 of 1

Client: Metricon Homes Pty Ltd Drill Rig: Hand Auger

Project: Proposed Residential Dwelling Logged: RS

Location: Lot. 40, No. 136, Narrabeen Park Parade, Mona Va Date: 12/08/2019

Intrax

Method	Depth (metres)	DCP blows count	Material Description	Soil Classification	Moisture	Consistency / Density	Structure, Origin, Water and Additional Observations	Disturbed Samples (D)
MA	0.50		Silty CLAY, medium plasticity, dark brown mottled black orange, root material, trace sand gravel	CI	>PL		FILL	
	1.00		CLAY, high plasticity, pale grey brown mottled orange, root material, trace gravel	CH	>PL		NATURAL	
	1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00		Groundwater was not encountered BH4 terminated at 1.2m depth					

This borehole log is to be read in conjunction with the explanatory notes appended to the set of logs. This borehole log is not be reproduced without the full inclusion of all explanatory notes.

Appendix B

Site Photography

Appendix C

CSIRO BTF "Foundation Maintenance and Footing Performance: A Homeowner's Guide"

Practice Note Guidelines For Landslide Risk Management 2007

Australian Geoguide LR8 (Construction Practice)

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).

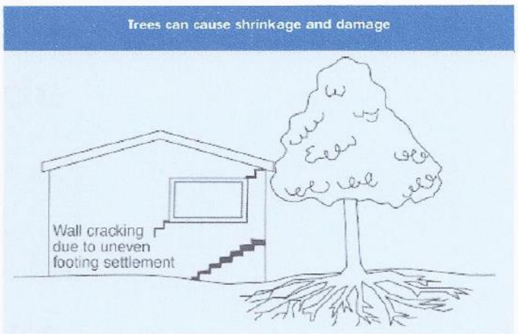
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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.



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

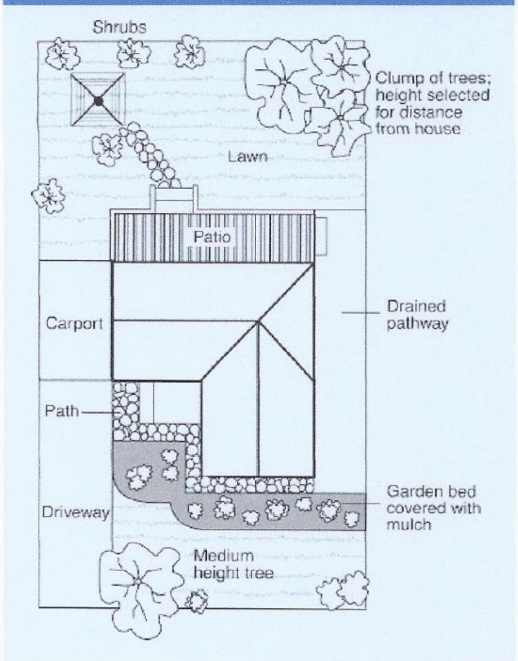
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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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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.

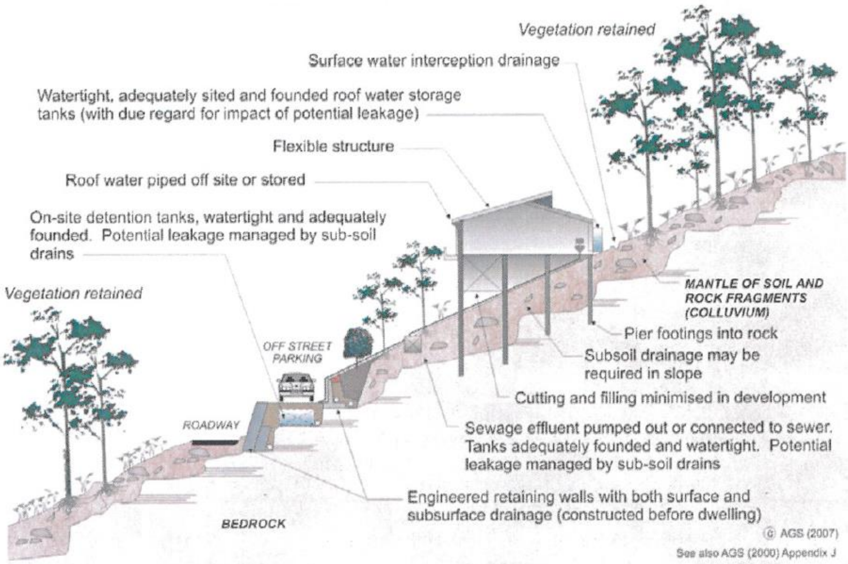
Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

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.

EXAMPLES OF **GOOD** HILLSIDE CONSTRUCTION PRACTICE



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.

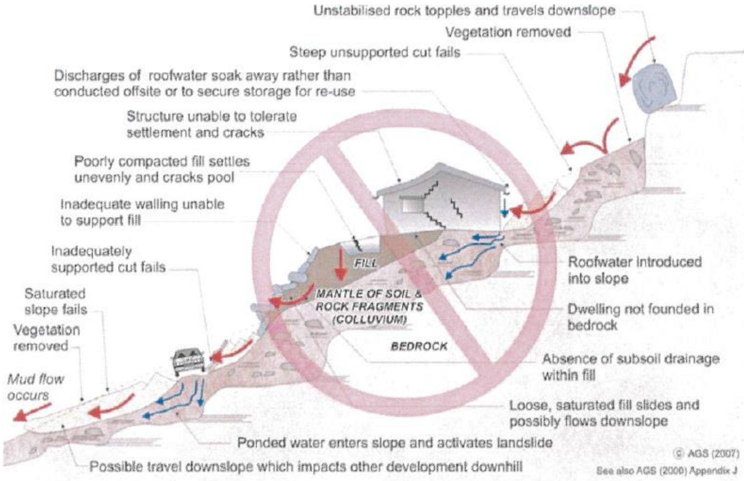
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing 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.