Ref: 210027-001-Rev0
Date: 22 June 2021

Mr Christian Stevens (c/o A Grade Pools),
19A Philip Road,
Mona Vale
NSW 2103

By email to: Blake Gaffney (agradepools@outlook.com)
CC:

Preliminary Geotechnical Assessment – Swimming Pool
19A Philip Road, Mona Vale, NSW 2103

Dear Mr Stevens,

1. Introduction

This letter report contains a preliminary geotechnical assessment undertaken by GeoReports Pty Ltd (GeoReports) to inform Development Approval (DA) and assist with design and construction of a new swimming pool at the above site (the Subject Site). The scope, deliverables and conditions relating to GeoReports services were defined in our emailed proposal of 11 June 2021, and your acceptance of 14 June 2021.

The following information was made available to GeoReports for this assessment:

- Landscape and Site Plans by A Grade Landscapes, Issue 1, dated 24 March 2021 (1 Sheet); and
- Detail and Level Survey Plan by Helensburgh Surveying Services, Ref. 21-064, dated May 2021 (1 Sheet).

2. Scope of Work

GeoReports has been engaged to provide preliminary geotechnical assessment at the subject site as they relate to the proposed swimming pool and ancillary works, in accordance with the Northern Beaches Council development controls (Geotechnical Risk Management Policy (GRMP) for Pittwater, No. 178).

In adverse circumstances, the Council GRMP can require prescriptive levels of geotechnical investigation and reporting including minimum levels of subsurface investigation and quantitative slope risk assessment. Where conditions are favourable and verified by preliminary geotechnical assessment (this report), a detailed geotechnical report may not be necessary (See Table 1).

Table 1 – Assessment requirements – Conditions not requiring a detailed Geotechnical Report

GRMP Criteria (Not Requiring Detailed Report)	Applicability / Comment
The proposed works involve a minor development, minor alterations and/or development separate from a Geotechnical Hazard*	✓ Minor works; See below for geotechnical hazard assessment
The proposed works are separate from the primary development*	✓ Swimming pool is separate from the primary development
The property is located in Geotechnical Hazard Zone 3	✓ The Site is H3 (outside H1 and H2) - See Figure 1

*- Requires due consideration of level of investigation required and consideration of risk to Life and to Property as part of the Preliminary Geotechnical Assessment (refer to following sections).

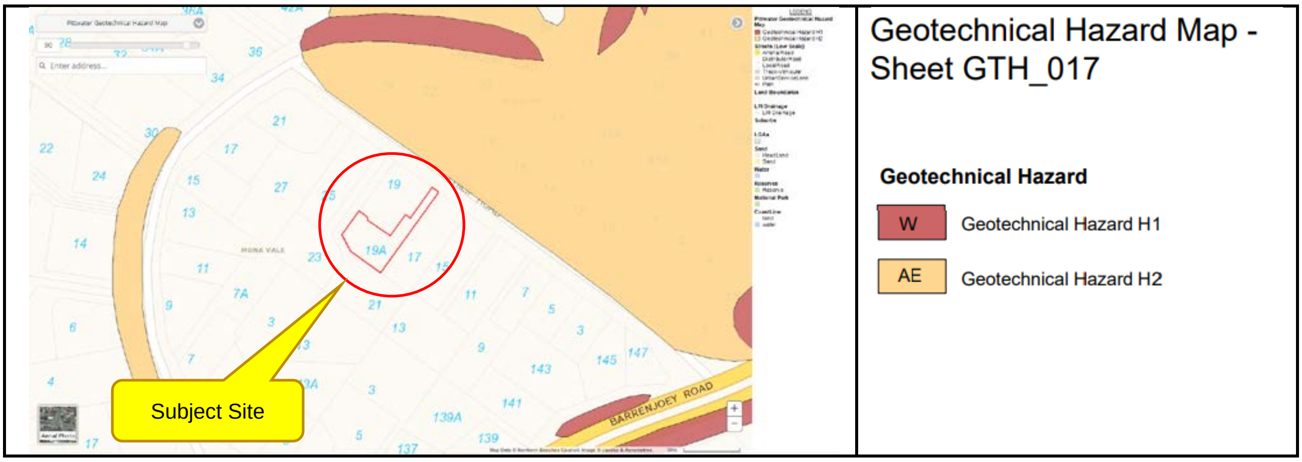


Figure 1 –Geotechnical Hazard Classification
(Source: Northern Beaches Council / GeoReports)

Based on this screening approach, this report is required to provide a preliminary assessment of geotechnical conditions relevant to the proposed works with due consideration of level of investigation required and presence of geotechnical hazards including consideration risk to life and to property.

Geology and Soil Landscape

The New South Wales Seamless Geology dataset (version 1.1) shown in Figure 2 indicates that the Subject is underlain by Narrabeen Group which consists of Interbedded laminate, shale and quartz to lithic quartz sandstone.

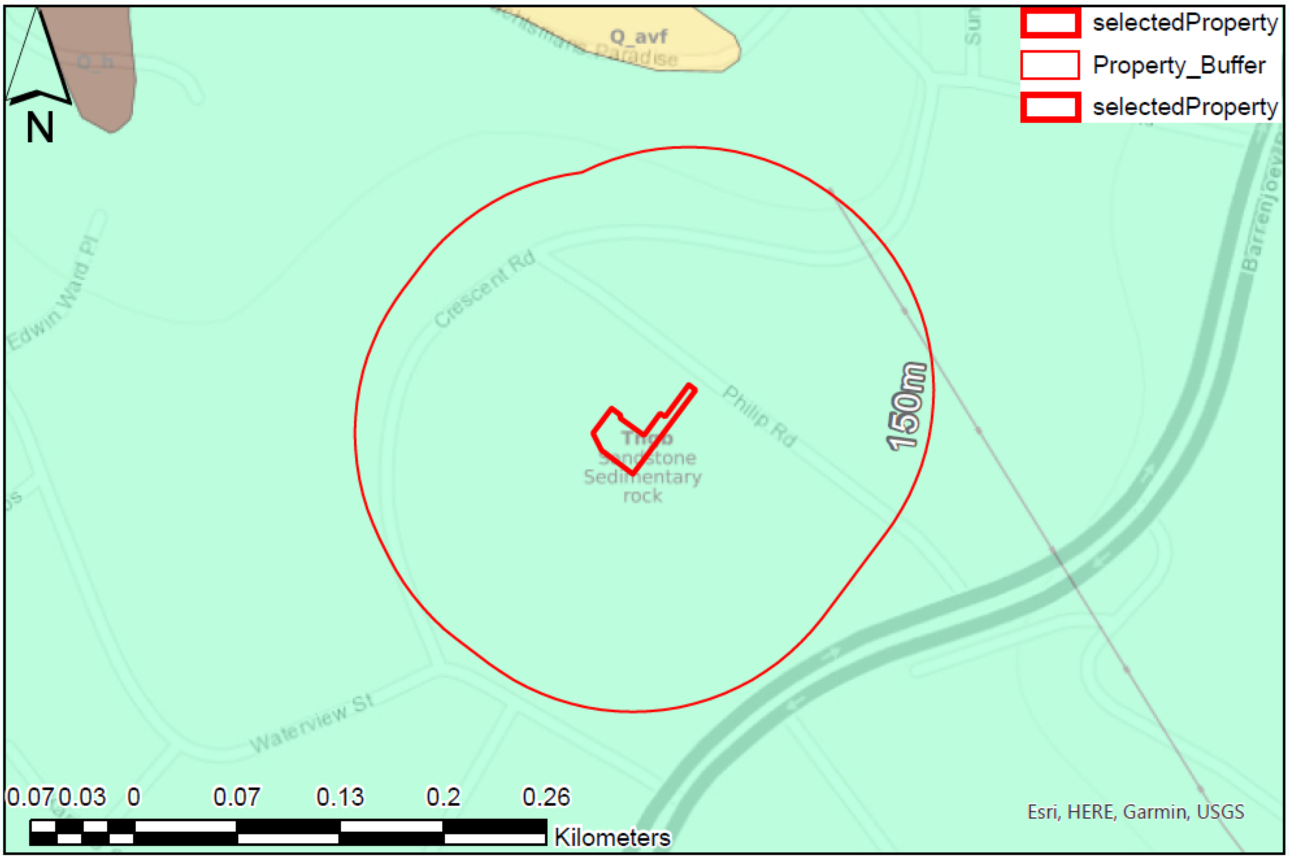


Figure 2: Mapped Geology
(Source: Geoscience Australia)

Published mapping data by the NSW Government indicates that soils developed on this lithology at the Subject Site are associated with the Erina soil landscape unit (See Figure 3) which occur on undulating to rolling rises and low hills on fine-grained sandstones and claystones of the Narrabeen Group. These erosional soils are typically 1 to 2m deep and typically consist of sand-rich topsoil horizons, becoming clay-dominant with depth and containing sub-angular sandstone rock fragments. Identified limitations of these soils include moderate reactivity, high soil erosion hazard, low wet-strength and seasonal waterlogging of footslopes.

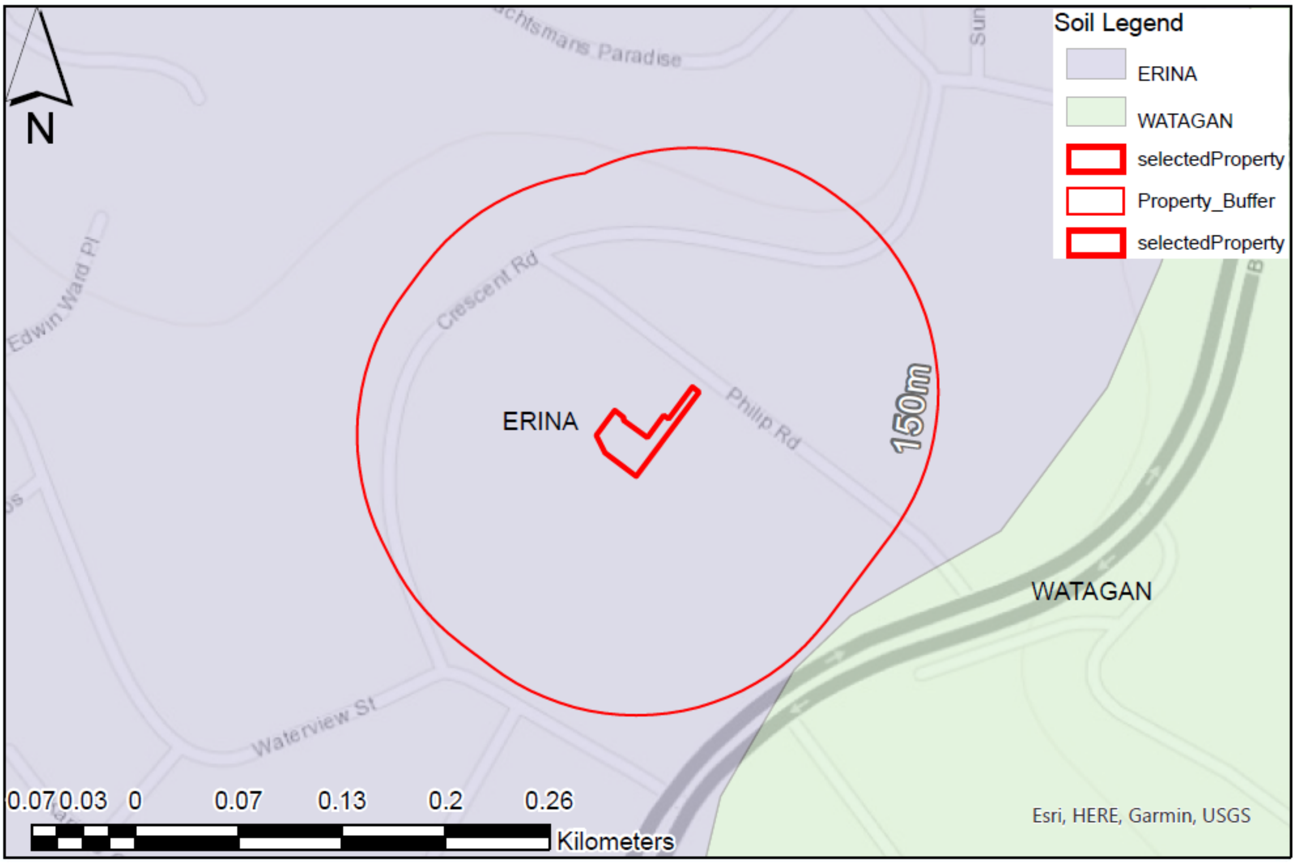


Figure 3: Soil Landscape
(Source: Office of Environment and Heritage)

3. Geotechnical Field Observations and Preliminary Assessment

A Principal Geotechnical Engineer from GeoReports undertook a walkover at the Subject Site on 17 June 2021 to document site features and conditions. The visit took place on a dry day without rainfall in the preceding week; no springs or free groundwater were observed at the site. A summary of observations, photographs and field sketches are presented below and attached.

- The battle-axe property is located near the crest of a rounded ridge above Philip Road and contains a two-storey brick and tile residence surrounded by garden to rear, concrete driveway / gardens at front and paved footpaths on each side. No rock outcrop was observed on the property.
- The residence is founded on a platform which has been cut about 1.3m into surrounding land along the southern boundary. There is evidence of minor filling settling around the northern corner of the house and along a sloping easement boundary between the northern brick-paved path which is about 600mm above an adjacent concrete driveway to the north. We understand that the path and retaining wall shown in Photograph 1 (above) are to be reinstated and upgraded as part of landscaping work.
- The house is in generally good condition with no evidence of external cracking or movement. A concrete slab under the existing pergola is paved with terracotta tiles and one minor existing crack was observed extending across several tiles near the centre of the tiled area.
- The location of the proposed pool is currently surface by a near level turfed lawn area, surrounded on three sides (South, West, North) by garden beds retained by low sandstone wall edging (to 200mm height) and 1.8m high timber fencing in fair condition. The Eastern edge of the pool will be

immediately adjacent to the tiled concrete slab (described above) and also adjacent to a column footing supporting a pergola structure.

- A plan showing the site topography is presented in Figure 4, below and indicates that the elevation falls about RL 40m to RL 38m AHD across the central portion of the block (approximately 10% or 6º average slope angle).
- A marked-up plan showing key features is presented as Figure 5, below, and includes locations of numbered photographs which are shown in Table 1. Sections through the site showing excavation extents in relation to site features are shown in Figure 6 (plan) and Figure A1 (attached, sections).

Figure 4: Topography (Source: Mecone Mosaic)

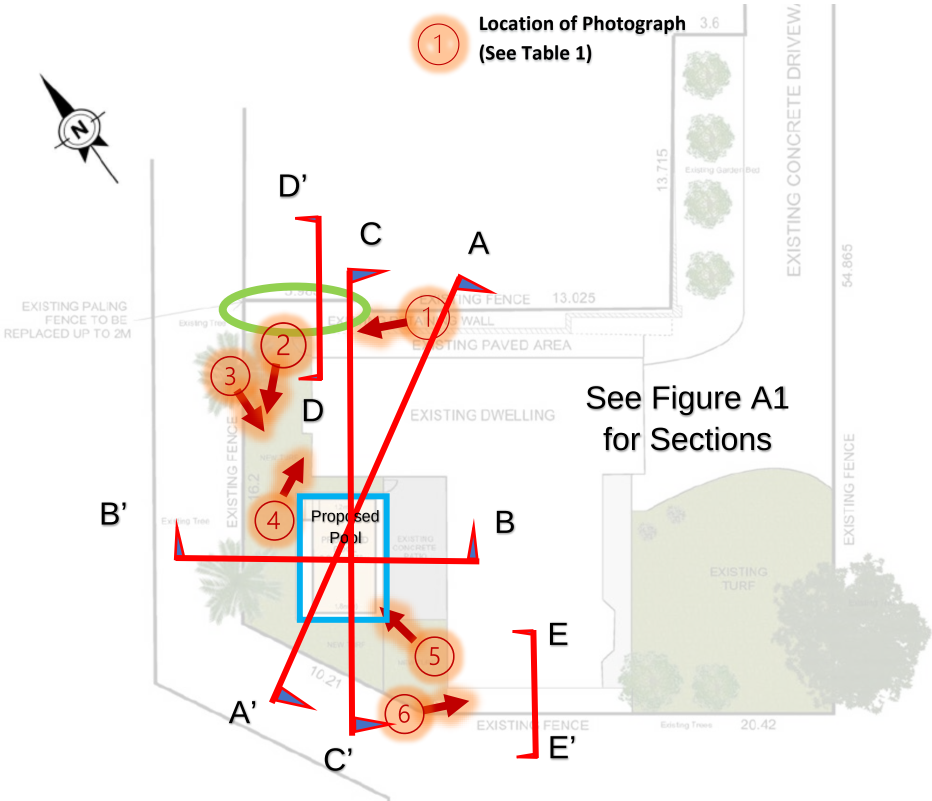
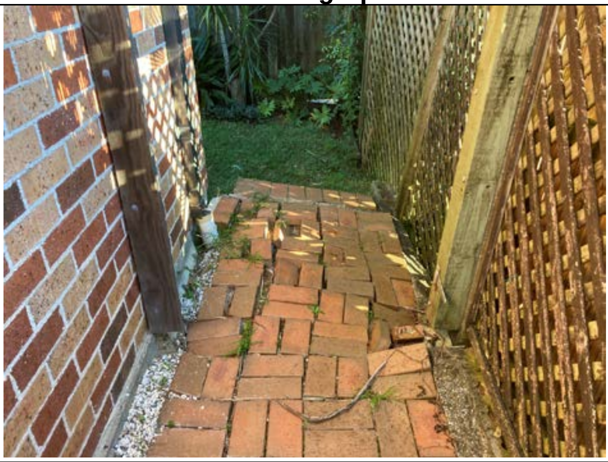


Figure 5: Key plan showing numbered photographs (Table 1) and Sections (Figure A1, attached)

Table 1 – Numbered Photographs



1 – Path and low wall to be reinstated

2 – View across pool footprint

3 – View across pool footprint towards paving

4 – Historic fill settlement surrounding house

5 – View across paving towards pool area

6 – Concrete wall beside house

Photographs 1 to 6 – Site Photos

4. Discussion and Recommendations

Based on our review of available information and site visit, we consider that there are no geotechnical slope stability hazards immediately affecting the location of the proposed swimming pool. However, the following key points will need to be considered and addressed during design and construction.

4.1. Investigation Requirements

It is likely that the uppermost 2m below existing ground in the vicinity of the proposed pool will comprise topsoil, reworked site-won fill (thickening to north) overlying clayey residual soils possibly transitioning into extremely to distinctly weathered sedimentary bedrock.

We consider that appropriate retaining measures can be implemented at the site without necessarily requiring additional pre-DA subsurface investigation, based on the assumed ground conditions (above) and providing that suitable excavation support measures are implemented to provide a relatively stiff support for surrounding structures (see below).

Construction stage inspections may be used in-lieu of investigations to confirm that design requirements for allowable bearing capacity have been achieved for the pool structure or otherwise to advise on piering requirements according to structural drawings.

4.2. Temporary Excavation Support

Due to the presence of adjacent slab, and nearby house and pergola footings, pro-active and pre-emptive excavation support measures must be implemented during excavation to provide relatively stiff excavation support to limit movements at adjacent structures. Examples of suitable shoring systems are shown below in Figure 6 (Refer https://www.coates.com.au/ for further information).

	
Slide Rail Systems with king posts	Lightweight aluminium shoring shields

Figure 6: Shoring Systems

Ground movements surrounding excavations are likely, and unless adequately controlled may adversely impact nearby slabs and structures which rely on ground for support. For excavations within a 1H:1V envelope extending below the underside of slabs and footings, we recommend use of pre-support systems installed ahead of excavations which provide continuous face support and can provide positive strutting pressure (such as hydraulic bracing).

In the event that pre-construction investigations are undertaken (optional) and/or construction stage pot-holing or limited exploratory excavations identify more favourable ground conditions such as shallow bedrock, then it may be possible to review excavation support requirements. Any reduced excavation support measures would be subject to additional construction stage inspections by an appropriately qualified and experienced geotechnical engineer and appropriate management of the ground stability and movement risks identified below.

4.3. Risk to Property / Life

Due to the minor nature of the proposed works and the geotechnical setting (Hazard Class H3; no hazards identified), GeoReports considers that a detailed geotechnical report and associated quantitative risk assessment is not required.

However, to address Council requirements to consider geotechnical risks as they relate to potential impacts of the works on people and adjacent assets, a qualitative risk assessment has been undertaken using the principles adapted from the Australian Geomechanics Society (AGS) Practice Note Guidelines for Landslide Risk Management (LRM), 2007[1] which provides a recognised framework for the characterisation, risk classification and treatment of ground stability related risks in Australia. The AGS LRM process involves desktop and site assessment, hazard identification, assessment of risk to property and life by considering likelihood and consequence of the hazards identified. Based on the desktop and site assessment described above, relevant hazards have been identified in Table 2. An extract from Appendix C of the AGS LRM is

[1] Australian Geomechanics Journal 42(1):63-109 · March 2007

shown in Appendix A, defining the relationship between consequence, likelihood and risk, along with definitions for risk terminology used.

Table 2 – Risk Summary and Recommendations

Hazard / Element	Current Risk* to…		Recommended Mitigation Measure	Residual Risk* to…	
	Property	Life*		Property	Life*
1. Footpath, slope and bdy retaining wall at northern corner of house**	Low	Acceptable	Reinstate retaining wall and extend along full easement boundary	Very Low	Acceptable
2. Pool excavation impact on Structures within Site	Moderate	Tolerable	Install suitable temporary excavation support	Low	Acceptable
3. Pool excavation impact on Structures surrounding site	Low	Acceptable	Install suitable temporary excavation support	Very Low	Acceptable
4. Ongoing fill settlement at northern house corner**	Low	Acceptable	Periodically inspect, monitor (short term), re-level area	Low	Acceptable
5. Concrete retaining wall, southern boundary**	Low	Tolerable	Periodically inspect, monitor (short term), Remediate (Long Term)	Low	Tolerable

*- A guide to risk terminology is attached in Appendix A
**- Item unrelated to the proposed swimming pool works

Additional general recommendations for good construction practice on sloping sites and property maintenance are provided in Appendices A and B, respectively.

This report identifies a range of geotechnical features and issues requiring specific design and construction measures and post-approval review and inspections. Appropriate consideration has been given to Council's GRMP to support the Development Approval process, and it is our opinion, having examined the site and the proposed development in detail that that the proposed work involves Minor Development/Alteration which is separate from existing structures in an H3 zoned area which does not require a Detailed Geotechnical Report. On this basis, a Council Form 1 has been completed and is attached as Appendix C.

5. Further Assessments

Post-approval review and inspections by suitably qualified geotechnical engineer must be undertaken to verify the following:

- Construction Certificate review of structural drawings of the pool structure including geotechnical notation (appropriate for completion of Council Form 2) which sets out:
  - Suitable foundation material requirements (material type, preparation requirements);
  - Minimum allowable bearing pressures;
  - Suitable details for any permanent retaining walls (complying with AS4678-2002 Australian Standard for Earth-retaining structures); and
  - Temporary excavation support requirements in accordance with this report (unless approved otherwise by investigation, pot-holing or limited excavation).
- Construction stage inspection and approval (appropriate for completion of Council Form 3) to confirm that:
  - Installed temporary excavation support meets the requirements set out in this report and on approved drawings (unless otherwise approved); and
  - Foundation preparation and allowable bearing capacity for all new structural footings meets requirements shown on approved structural drawings; and
  - Any permanent as-built retaining structures meet the requirements set out in this report and on approved drawings.

6. Limitations

This assessment is limited in scope and coverage and is not designed or capable of identifying all subsurface conditions, which can vary even over short distances and with time. The advice given in this assessment is based on the assumption that the assessment and fieldwork assessment are representative of the overall ground conditions. However, it should be noted that actual conditions in some parts of the site might differ from those found. If excavations reveal ground conditions significantly different from those shown in our findings, GeoReports must be consulted.

The scope and the coverage of services are described in the assessment and are subject to restrictions and limitations. GeoReports has not performed a complete assessment of all possible conditions or circumstances that may exist at the site. If a service or issue is not expressly indicated as being considered, then do not assume it has been addressed. If a matter is not addressed, do not assume that any determination has been made by GeoReports with regards to it.

Where data has been supplied by the client or a third party, it is assumed that the information is correct unless otherwise stated. No responsibility is accepted by GeoReports for incomplete or inaccurate data supplied by others.

Any drawings or figures presented in this report should be considered only as pictorial evidence of our work. Therefore, unless otherwise stated, any dimensions should not be used for accurate calculations or dimensioning.

7. References

- Colquhoun G.P., Hughes K.S., Deyssing L., Ballard J.C., Phillips G., Troedson A.L., Folkes C.B. & Fitzherbert J.A. 2019. New South Wales Seamless Geology dataset, version 1.1, Geological Survey of New South Wales, NSW Department of Planning and Environment, Maitland.
- Office of Environment and Heritage, 2019, Soil Landscapes of Central and Eastern NSW - v2, NSW Office of Environment and Heritage, Sydney.
- Geological Series Sheet 9130, Map of the Sydney region, scale 1:100,000
- Australian Geomechanics Journal Landslide Risk Management (LRM) Guidelines, Vol 42, No.1, March 2007
- https://www.mecone.com.au/mosaic/
- AS 4678-2002 Australian Standards for Earth-retaining structures

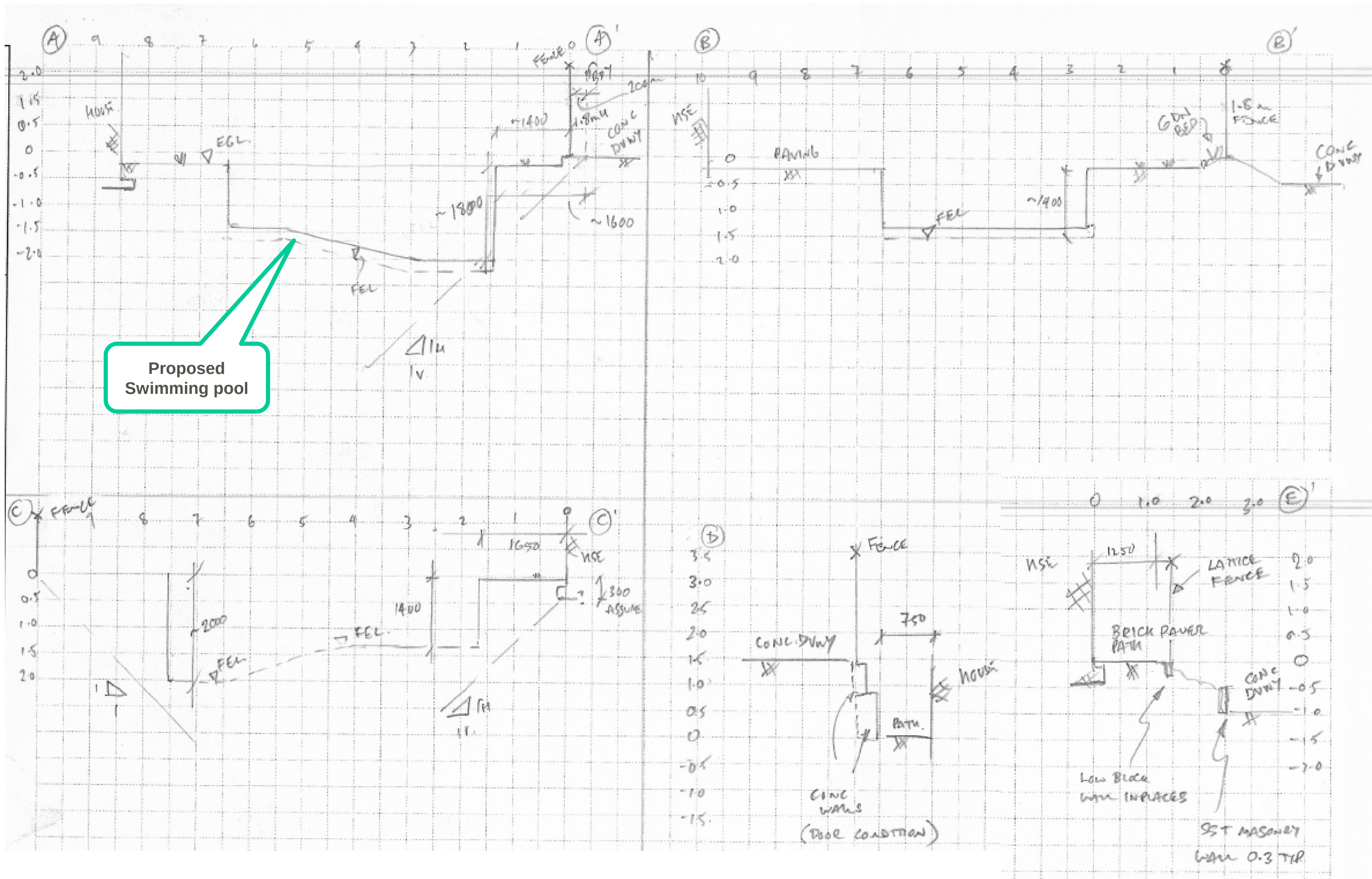
8. Closure

Please feel free to contact Philip Davies on 0409 33 22 34 to discuss any aspect of this report.

On behalf of GeoReports Pty Ltd,

Philip Davies BEng (Hons), MSc, DIC, CPEng, MIEAust, NER
Managing Director

Attached:
Appendix A – LRM Information and Guidelines for Good Hillside Construction Practice
Appendix B – Homeowners Guide to Foundation Maintenance (CSIRO)
Appendix C – Northern Beaches Council Form 1



	CLIENT	Christian Stevens		PROJECT	19A Philip Road, Newport	A4
GeoReports	DRAWN	PD	DATE 21/06/2021	TITLE	Sections A to E	
	CHECKED	HD	DATE 21/06/2021			
	SCALE	N.T.S		PROJECT No 210027	Reference 210027-001	FIGURE A1

Appendix A – LRM Information and Guidelines for Good Hillside Construction Practice

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.

Figure A2 – Risk Management Framework (Source: AGS LRM Guidelines)

LANDSLIDE RISK

Concept of Risk

Risk is a familiar term, but what does it really mean? It can be defined as *"a measure of the probability and severity of an adverse effect to health, property, or the environment."* This definition may seem a bit complicated. In relation to landslides, geotechnical practitioners (GeoGuide LR1) are required to assess risk in terms of the likelihood that a particular landslide will occur and the possible consequences. This is called landslide risk assessment. The consequences of a landslide are many and varied, but our concerns normally focus on loss of, or damage to, property and loss of life.

Landslide Risk Assessment

Some local councils in Australia are aware of the potential for landslides within their jurisdiction and have responded by designating specific "landslide hazard zones". Development in these areas is often covered by special regulations. If you are contemplating building, or buying an existing house, particularly in a hilly area, or near cliffs, go first for information to your local council.

Landslide risk assessment must be undertaken by a geotechnical practitioner. It may involve visual inspection, geological mapping, geotechnical investigation and monitoring to identify:

- potential landslides (there may be more than one that could impact on your site)
- the likelihood that they will occur
- the damage that could result
- the cost of disruption and repairs and
- the extent to which lives could be lost.

Risk assessment is a predictive exercise, but since the ground and the processes involved are complex, prediction tends to lack precision. If you commission a landslide risk assessment for a particular site you should expect to receive a report prepared in accordance with current professional guidelines and in a form that is acceptable to your local council, or planning authority.

Risk to Property

Table 1 indicates the terms used to describe risk to property. Each risk level depends on an assessment of how likely a landslide is to occur and its consequences in dollar terms. "Likelihood" is the chance of it happening in any one year, as indicated in Table 2. "Consequences" are related to the cost of repairs and temporary loss of use if a landslide occurs. These two factors are combined by the geotechnical practitioner to determine the Qualitative Risk.

TABLE 2: LIKELIHOOD

Likelihood	Annual Probability
Almost Certain	1:10
Likely	1:100
Possible	1:1,000
Unlikely	1:10,000
Rare	1:100,000
Barely credible	1:1,000,000

The terms "unacceptable", "may be tolerated", etc. in Table 1 indicate how most people react to an assessed risk level. However, some people will always be more prepared, or better able, to tolerate a higher risk level than others.

Some local councils and planning authorities stipulate a maximum tolerable level of risk to property for developments within their jurisdictions. In these situations the risk must be assessed by a geotechnical practitioner. If stabilisation works are needed to meet the stipulated requirements these will normally have to be carried out as part of the development, or consent will be withheld.

TABLE 1: RISK TO PROPERTY

Qualitative Risk		Significance - Geotechnical engineering requirements
Very high	VH	**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.
High	H	**Unacceptable** without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable level. Work would cost a substantial sum in relation to the value of the property.
Moderate	M	**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 possible.
Low	L	**Usually acceptable** to regulators. Where treatment has been needed to reduce the risk to this level, ongoing maintenance is required.
Very Low	VL	**Acceptable**. Manage by normal slope maintenance procedures.

Risk to Life

Most of us have some difficulty grappling with the concept of risk and deciding whether, or not, we are prepared to accept it. However, without doing any sort of analysis, or commissioning a report from an "expert", we all take risks every day. One of them is the risk of being killed in an accident. This is worth thinking about, because it tells us a lot about ourselves and can help to put an assessed risk into a meaningful context. By identifying activities that we either are, or are not, prepared to engage in we can get some indication of the maximum level of risk that we are prepared to take. This knowledge can help us to decide whether we really are able to accept a particular risk, or to tolerate a particular likelihood of loss, or damage, to our property (Table 2).

In Table 3, data from NSW for the years 1998 to 2002, and other sources, is presented. A risk of 1 in 100,000 means that, in any one year, 1 person is killed for every 100,000 people undertaking that particular activity. The NSW data assumes that the whole population undertakes the activity. That is, we are all at risk of being killed in a fire, or of choking on our food, but it is reasonable to assume that only people who go deep sea fishing run a risk of being killed while doing it.

It can be seen that the risks of dying as a result of falling, using a motor vehicle, or engaging in water-related activities (including bathing) are all greater than 1:100,000 and yet few people actively avoid situations where these risks are present. Some people are averse to flying and yet it represents a lower risk than choking to death on food. Importantly, the data also indicate that, even when the risk of dying as a consequence of a particular event is very small, it could still happen to any one of us any day. If this were not so, no one would ever be struck by lightning.

Most local councils and planning authorities that stipulate a tolerable risk to property also stipulate a tolerable risk to life. The AGS Practice Note Guideline recommends that 1:100,000 is tolerable in newly developed areas, where works can be carried out as part of the development to limit risk. The tolerable level is raised to 1:10,000 in established areas, where specific landslide hazards may have existed for many years. The distinction is deliberate and intended to prevent the concept of landslide risk management, for its own sake, becoming an unreasonable financial burden on existing communities. Acceptable risk is usually taken to be one tenth of the tolerable risk (1:1,000,000 for new developments and 1:100,000 for established areas) and efforts should be made to attain these where it is practicable and financially realistic to do so.

TABLE 3: RISK TO LIFE

Risk (deaths per participant per year)	**Activity/Event Leading to Death** (NSW data unless noted)
1:1,000	Deep sea fishing (UK)
1:1,000 to 1:10,000	Motor cycling, horse riding , ultra-light flying (Canada)
1:23,000	Motor vehicle use
1:30,000	Fall
1:70,000	Drowning
1:180,000	Fire/burn
1:660,000	Choking on food
1:1,000,000	Scheduled airlines (Canada)
1:2,300,000	Train travel
1:32,000,000	Lightning strike

More information relevant to your particular situation may be found in other AUSTRALIAN GEOGUIDES:

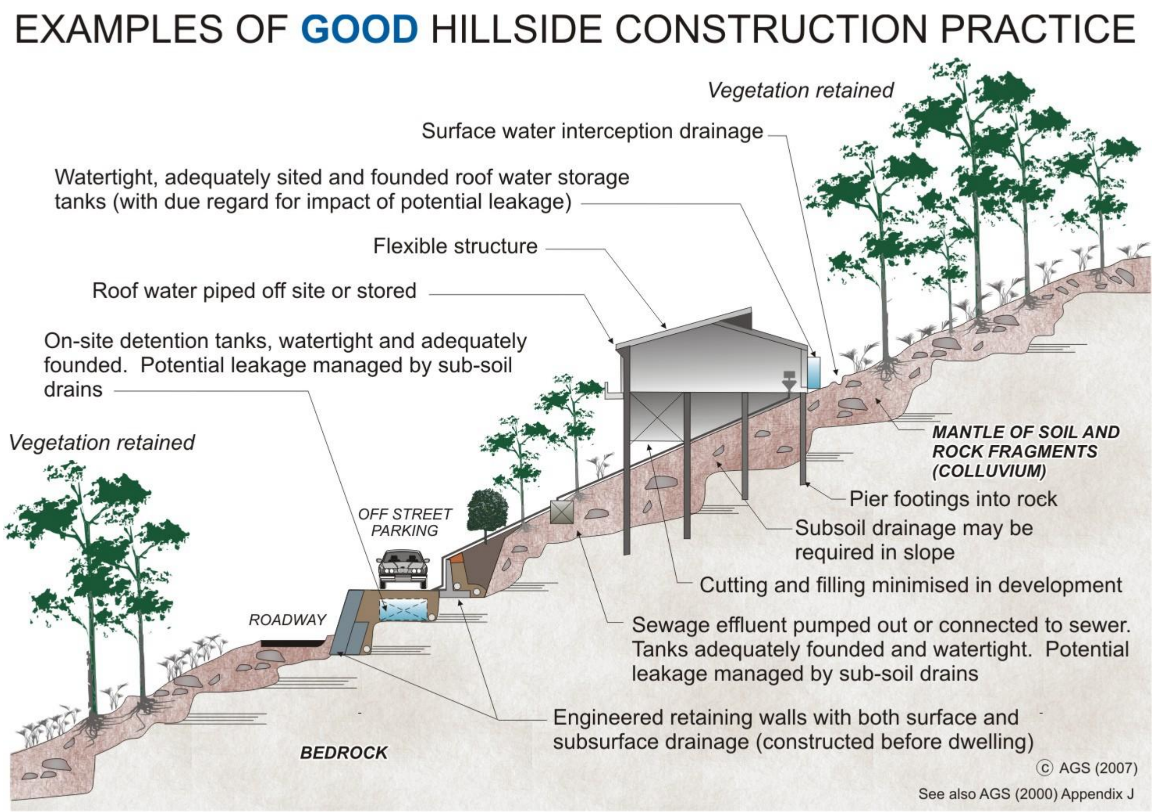
- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
  GeoGuide LR10 - 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.

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.



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.

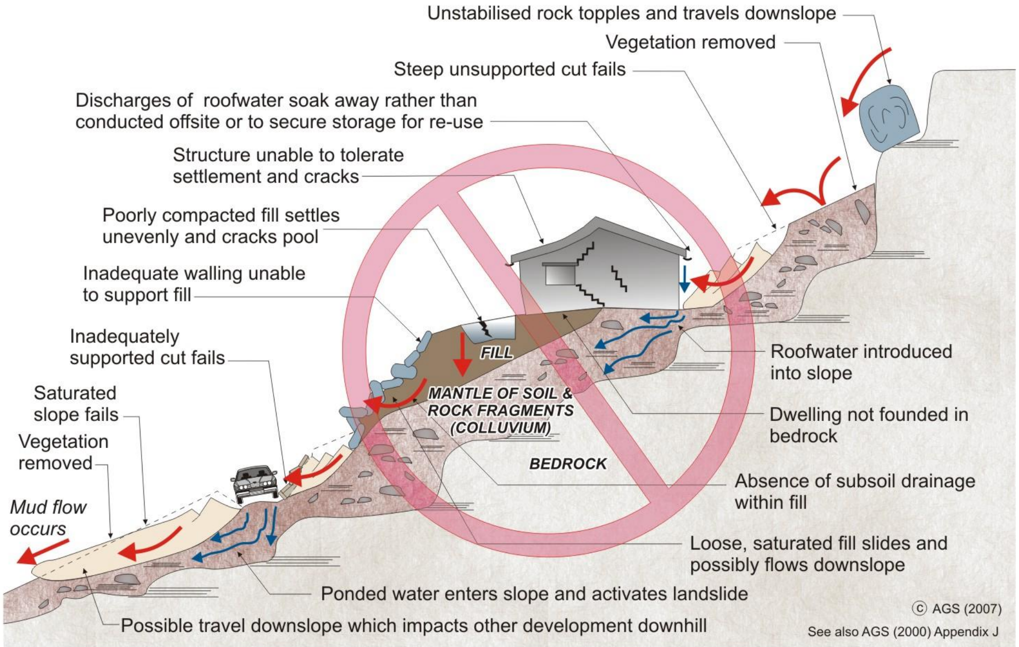
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing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

Appendix B - Homeowners Guide to Foundation Maintenance (CSIRO)

Foundation Maintenance and Footing Performance: A Homeowner's Guide

CSIRO

BTF 18 replaces Information Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

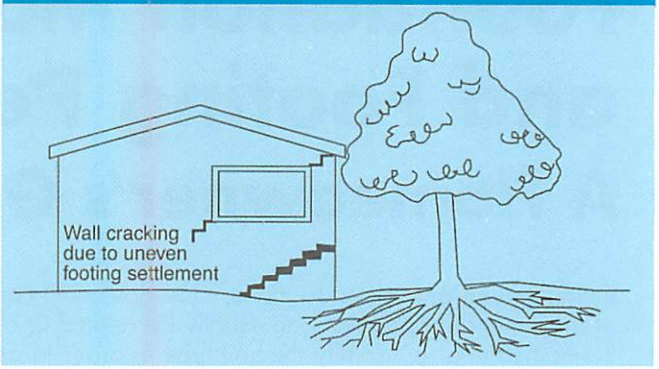
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

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

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

Trees can cause shrinkage and damage



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

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

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

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

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

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

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

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

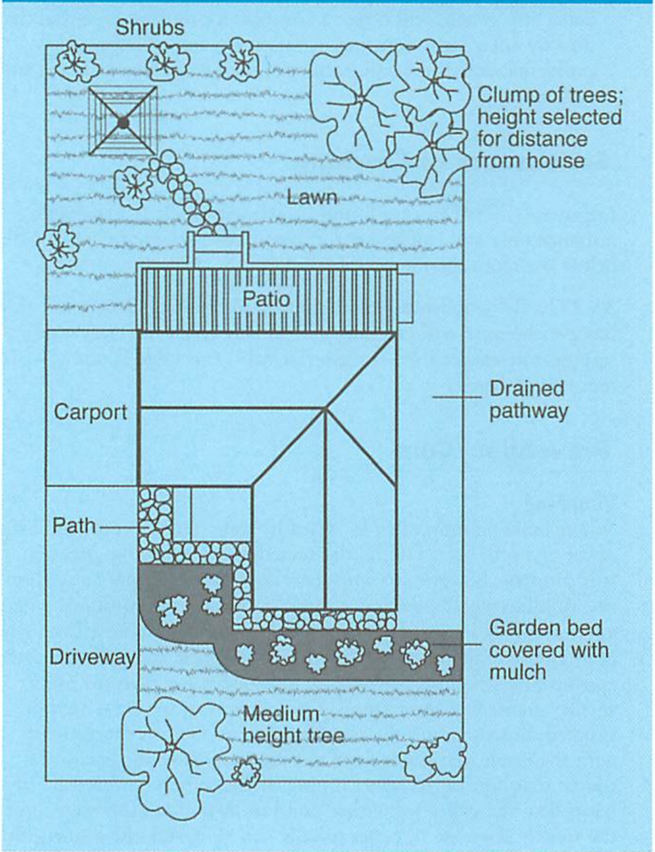
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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

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BUILDING TECHNOLOGY file

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A builder's guide to preventing damage to dwellings

Part 1 – Site investigation and preparation

THE PROBLEMS

History

Many homes in Australia suffer from one or more of the several maladies that result from conditions that could have been prevented had the engineer and/or builder undertaken thorough site investigation and subsequent site preparation. This work is just as important as employing sound practice in construction – in fact, at law it is increasingly seen as part of sound building practice. The result is that a reasonably competent builder is now expected to know more about building movement caused by foundation soils than was the case before the landmark legal battles of the middle 1990s.

The growth of consumerism has led to the notion that a consumer can rely on the builder to be competent in all matters related to construction. We know that the builder relies on the competence of specialists and professionals, but in the end it is the builder's duty to the customer to ensure that the building is not adversely affected by defective foundations. There are many builders who are sufficiently competent in soils to carry out the level of elementary investigation required for most small sites. For them, this document may serve as a checklist for their initial inspection and a reminder that if they discover any soil problems, they should engage a suitably qualified engineer. For those builders who are not familiar with site investigation, this document is designed to give the rudiments of soils as they affect housing in most parts of Australia, and to help the practitioner on the road toward an understanding of the issues. Such builders, while in the process of learning, would be wise to engage an expert engineer for site investigation prior to finalisation of the engineering design drawings.

The predominant practice in residential construction is for the builder to ignore the soil except for the provision of bearing surfaces for footings. In fact, Clause 3.2 of AS 1684 requires the site to be clear of tree roots etc. and to be well drained. AS 2870 requires soil classification and gives a brief description of the allowable methods. AS 3798 details a number of issues that should be covered in a site investigation. All of these standards have been incorporated into the Building Code of Australia (BCA). Because the BCA has been adopted by every relevant jurisdiction in the nation, the law requires the builder to abide by the provisions in the standards or have an engineered solution accepted that will meet the performance requirements of the BCA.

Results of soil problems

The upshot of all the above is that no longer are defects such as falls in floor levels, cracking in floor tiles, cracking in concrete slabs, cracking in walls and ceilings (especially cornices), squeaky flooring, binding doors and windows, deflecting roof slopes, and cracked mortar bedding to ridge and hip caps believed to be caused by a natural phenomenon beyond the responsibility of the builder. The builder should therefore carry out proper site investigation and prepare the site accordingly.

Water problems

The principal enemy is water – either flowing, ponding, seeping by gravitational force, migrating by capillary action or in the air as vapour. Any masonry product that can absorb water can be damaged by it or by the chemicals carried with water; any permeable mortar is also susceptible; timber will decay in contact with water or vapour; gypsum plasterboard decomposes; steel is obviously also vulnerable.

Aside from direct damage to building elements, water very commonly causes damage to buildings indirectly by working on the foundation soil – erosion, subsidence, swelling and shrinkage of soil by absorption and shedding of moisture.

Buildings with subfloor voids, such as found when timber or steel frame floors are constructed, also suffer from high humidity in the subfloor when water flows or ponding exist. This can encourage decay of the timber, cup the floorboards and raise the humidity level in the living space.

This introduces another dimension of the problems created by water – that of living organisms. The presence of water attracts insects including termites. In turn, predators such as spiders are also attracted. Perhaps the most insidious and serious hazard is introduced by dust mites and some types of fungus, that have been shown to greatly increase the incidence of respiratory ailment symptoms in susceptible occupants.

Slab-on-ground construction is also subject to water incursion problems. The added problem this method has is the ease with which water can gain access to the cavity via weepholes. Once in the cavity, it creates a damp environment which is very slow to dry, transferring moisture to the inner leaf walls and timber finishes and creating high humidity in the living space.

Vegetation problems

The other source of instability to structures that this BTF deals with is vegetation and organic matter. Tree roots can cause upheaval when growing and subsidence when decomposed, as well as creating uneven moisture content by taking in water. Organic material generally in the subsoil is not stable and does not properly compact, therefore making a poor foundation for a structure.

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 cohesive. Quite often foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Cohesive soils are either clay or silt. Clay soils are by far the more common and are subject to saturation and swell/shrink problems.
As most buildings suffering continuing 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 following table is reproduced from AS 2870.

TABLE 2.1 GENERAL DEFINITIONS OF SITE CLASSES	
Class	**Foundation**
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites* 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 (see Clause 2.4.6)
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

* For examples of clay sites classified as Class S, refer to Appendix D.

SOIL PROBLEMS

Rock
Excluding movement caused by seismic events, monolithic rock is not subject to movement problems. However, there are things to watch for:

- Footings may be founded on boulders or 'floaters' which can move due to erosion of soil around them.
- Rock is susceptible to water migration via faults and between strata. Many dwellings founded on sandstone suffer from water in the subfloor.

Granular soils
There are a number of problems to be avoided:

- These soils are not cohesive and can be susceptible to local shear failure when not confined. For this reason, building on sand dunes is inadvisable.
- Sandy soils are prone to erosion so service trenches, pipes, surface water and ground water flows can be hazards.
- Organic material left in the soil may be eaten by termites, leaving a void which will be filled by surrounding granular soil, thus reducing the bearing capacity of the foundation in that area.
- Sand expands when damp – surface tension will adhere water to grains, thus expanding the volume. Conversely, when saturated, sand is at its lowest volume. The fact that these changes occur means that care must be exercised to ensure that sand is well-compacted when constructing footings.

Silt
The chief risk presented by silt is its susceptibility to erosion, so the hazards that apply to granular soils may also apply to silt.

Clay
Most clays provide good residential foundations when dry, but most clays react significantly to the introduction of water:

- Local shear failure is not uncommon when soft clays are wet.
- When saturated, virtually any clay substantially loses its bearing capacity.
- The cohesive quality of clay makes it slower to compress under load than other soil types.
- A small volume of water can have a significant effect on clay.
- Clay absorbs and sheds water slowly.

CAUSES OF MOVEMENT

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

- Immediate settlement takes place 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 largely take place during the first few months after construction, but has been known to take many years in exceptional cases.

Erosion
All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay, particularly 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.

Seasonal swelling & shrinkage of soil
As can be seen in the table above, all clays react to the presence of water by slowly absorbing it, making the soil increase in volume. The degree of increase varies considerably in various 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 significant 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. This can occur through saturation of clay, failure of a damp reactive clay when attempting to raise a footing that is being acted on by a superior downward force, or any soil that loses its compaction.

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.

In addition, roots that are left in the ground after the tree is felled can be eaten by termites and/or destroyed by decay. This leaves a void which can turn into a watercourse and/or cause subsidence under or adjacent to the footings.

SITE INVESTIGATION

Factors
The factors that need to be investigated are:

- Soil classification.
- Soil condition.
- Watertable.
- Ground slope.
- Trees, shrubs and organic material.
- Service trenches.
- Water run-off.

Soil classification test
AS 2870 requires that the soil to be used as foundation for construction be classified. The requirement is that the soil be classified not by its geotechnic type, but by its reactivity. Reactivity can be defined as the change in volume brought about in the soil by the introduction or removal of water – in other words, the swell and shrinkage. Soil classes A, S, M, H and E cover the range of reactivity, and P is used where soil has abnormalities that do not allow normal classification. In some long-established areas, information on soil class may be obtained from buildings adjacent to the site, where the buildings are footed on lightly stiffened strip footings or slabs-on-ground. AS 2870 Tables 2.2, C1 and C2 are a guide to determining soil class by measuring differential movement or masonry cracking.

This easy classification method should, however, be regarded as the exception rather than the rule, because the majority of new buildings are constructed in areas where adjacent buildings, if they exist, are not sufficiently well established to enable sound data to be taken. In years gone by, local councils assumed some responsibility for providing soil classification to applicants for developments, but local authorities are increasingly divesting themselves of this type of service and, in any case, council area classifications do not necessarily apply to specific sites. Therefore, the job falls back on the engineer and the builder to ascertain the soil class which will determine the footing and masonry design.

It is desirable to inspect the site before clearing and/or excavation, because although the ground may be covered with topsoil, organic material or vegetation, there may be valuable evidence that will not be apparent after excavation. Usually, test pits or boreholes can, without difficulty, be dug to reach the depth required by Clause 2.3.3 and Table 2.4 of AS 2870, reproduced below.

> ***2.3.3 Depth of investigation*** *The soil profile shall be examined to a minimum depth equal to 0.75 times the depth of the suction change, H_s, as given in Table 2.4, but not less than 1.5 m, unless rock is encountered or in the opinion of the classifier, further drilling is unnecessary for the purpose of identifying the soil profile in accordance with Clause 2.2.1(a).*

TABLE 2.4
RECOMMENDED SOIL SUCTION CHANGE PROFILES FOR CERTAIN LOCATIONS

Location	Change in suction at the soil surface (Δu) pF	Depth of design suction change (H_s) m
Adelaide	1.2	4.0
Albury/Wodonga	1.2	3.0
Brisbane/Ipswich	1.2	1.5–2.3 (see Note)
Hobart	1.5	2.0
Hunter Valley	1.5	2.0
Launceston	1.2	2.0
Melbourne	1.2	1.5–2.3 (see Note)
Newcastle/Gosford	1.5	1.5
Perth	1.2	3.0
Sydney	1.5	1.5
Toowoomba	1.2	1.8–2.3 (see Note)

NOTE: The variation in H_s depends largely on climatic variation.

This investigation is necessary if correct soil classification has not been ascertained by other means. For a Class 1 building, a single test hole is usually sufficient for soil classification. However, if at a predominantly clay site, the clay extends to the bottom of the borehole, or if abnormalities are apparent, further investigation will be required. This may need to be carried out or followed up by a suitably qualified engineer and, in the case of clay soil, some laboratory analysis may be needed. In any case, while soil class may be ascertained by one borehole, a better picture of class and condition will emerge if investigation extends to the footprint extremities, particularly on sloping sites. For most purposes, a manually dug test pit is more useful than a borehole, but if boreholes are to be used, 400 mm diameter gives good vision.

The site investigation will also incorporate examination of the surface for cracking, gilgais, grades, identification of tree species and their locations relative to the proposed building, signs of ponding, saturation or erosion, condition of the road, kerbs, gulleys, surrounding land as to water run-off, and filled trenches carrying services such as stormwater, sewer, telephone, gas, electricity.

There is a trend, particularly in the case of standard designs like project homes, for engineers to assume a soil class when designing a structure, then visit the site when the footings excavation is under way in order to verify their assumption or, if the soil turns out to be less stable, order more and/or deeper piers. This practice has shortcomings:

- The engineer tends to rely on the excavation contractor to report on issues instead of carrying out his/her own tests.
- It is usually not possible to ascertain the difference between S, M and H class soils by a site inspection undertaken soon after excavation has been carried out, particularly where imported fill is used.
- In the event of a change being deemed necessary, the ensuing instructions become ad hoc corrective measures rather than holistic design considerations which would be worked through if the design were undertaken with the site's characteristics in mind.
- The instructions inevitably mean that the consumer pays for a variation due to 'latent conditions' that were within the builder's power to discover.
- Site drainage characteristics and requirements are never addressed.

This is not to say that the engineer should not visit the site to view the footings excavations, but rather to point out that this is not the time to be designing the structure.

Soil condition

When assessing the condition of soil for use as foundation material, the primary concerns are moisture content, depth of watertable, evidence of surface and ground water flows or moisture migration, and voids which may cause subsidence and/or act as ducts for water flows.

Ignoring any topsoil, which will be skimmed off before construction, the walls of the test pit will give an indication of the moisture content of the soil:

- Dry sand will tend not to hold its shape when squeezed.
- Moist or wet sand will tend to hold its shape when squeezed.
- Dry clay, even soft clay, tends to be firm.
- Moist clay tends to be plastic.
- Saturated clay tends to be boggy.

The next sign to look for is seepage, which will usually but not always emanate from the uphill side of the hole. The depth, compaction, amount of flow and type of soil should be noted. It should be realised that seepage or any other form of moisture migration may not show itself immediately and, where testing for moisture migration, it may be necessary to seal the top of the pit and leave it for several days or longer.

Watertable

A hole that is 1.5 m or more deep is likely to show the watertable, especially in deforested or built-up areas. The watertable becomes important where it is high and can affect the ability of the soil surface to dry out and, in the case of clay, to achieve a reasonably even moisture content throughout the footprint.

Ground slope

The fall of the land is important for two reasons:

- In order to achieve even settlement and maintain equilibrium across the structure, it is essential to found it on similar soil throughout. With a sloping site this can become difficult because strata may not be consistently deep around the footprint; they may not, in fact, even be continuous as the slope continues down. It is not unusual for a slope to cut through strata and in this event it is essential for the designer to know beforehand because it may affect the whole approach to footings.
- Either because of discontinuous strata or because of the necessity to cut at the uphill elevation, water flows often reach the surface adjacent to the footings or in the subfloor.

For both the above reasons it is advisable to dig holes at the upper and lower extremities, first to check for a satisfactory common soil, then to look for seepage. To check for water surfacing within the footprint, it is only necessary to inspect and walk on the soil. Another sign may be profusion of vegetation or a different type of vegetation.

Trees, shrubs & organic material

It is important to mark on a site plan the location of any tree, large shrub or stump within or adjacent to the footprint. It is not unusual for arborists to grub out stumps after felling but leave major roots. The same result can occur when trees are removed by a machine. It is essential to ensure that the stump and significant roots are removed and the soil is compacted in the void. The excavator should be instructed to remove any organic material while cutting or skimming. In addition, particularly where a sandy foundation exists, it is good practice to probe the subsoil in the immediate area around where a stump has been removed. A good tool to use is a 1 m length of 6–10 mm round reinforcement bar. Driven with a hammer, this will discover not only tree roots, but floaters and voids or poorly compacted areas. In some cases, poorly compacted areas are composed of leaves and other decayed vegetable matter. This material must not be left under or adjacent to the location of any footings as it will reduce in volume and cause a void.

Service trenches

It is not unusual to find that trenches that are dug to house services are not well backfilled or compacted. Often the trench is used as a repository for trade spoil. Where a subsoil water flow picks up such a trench, a watercourse is provided where water may be delivered alongside or even under footings. Typically, sewer and stormwater pipes run adjacent to and/or under footings. Where building additions are being constructed it is important to check around existing service trenches that may carry water to the proposed construction. Of course, it is also imperative to ensure that trenches dug for the new project are properly located, backfilled and compacted, but this topic is dealt with in BTF 20. During the site investigation, other than any pre-existing domestic service trenches, the following are some of the possible problems:

- Trenches under the footpath or roadway for telephone cables, gas, electricity, stormwater or sewer all have risers to the surface. Often, water can gain access to the trench from around the riser or manhole, then flow along or pond in the trench until finding a way to flow out, through the proposed domestic feed, or just by permeating the soil in the area.
- Street stormwater gullies can also be vulnerable, particularly older ones with brickwork in their structure.
- The possibility of leaking water, stormwater or sewer piping should not be ignored.

Where the new structure is downhill from these water sources, moisture can surface under the building or at the external footing where the soil has been cut. Builders sometimes believe that running agricultural pipe around the external side of the footing excavation solves the problem. This is not always the case, because some systems in common use may collect only a moderate percentage of the water, particularly when not expertly installed. In fact, this practice often delivers water directly to the footing area.

Water run-off

Surface water must not be allowed to flow to the building. A thorough inspection of the topography is necessary in order to properly allow for finished ground falls and water run-off collection. Particularly on a sloping site, the finished falls can be critical to the maintenance of good drainage.

REMEDIAL MEASURES

Other than the exception of water flow through rock faults, which is very difficult to stop, almost all of the problems above can be addressed by correct drainage of the soil or, in the case of poor existing trenches, removal of poor ballast material then refilling and compacting.

Correct drainage is an engineering matter and, unless very straightforward, should be the province of a suitably qualified person, however in essence the job is to prevent water from coming into contact with the building or entering the soil within the footprint and its environs.

The object of good ground drainage should be to exclude all possible water from the building, the foundation and its area of influence. There is a notion that reactive clays should be kept at a constant moisture content in order to provide equilibrium. Irrigation systems have been developed to try to provide constant moisture content to subfloor areas, but these can fail because there are other factors involved, i.e.:

- A building creates its own environment and predominant weather conditions will either create moisture flow toward the centre of the subfloor or away from it. This influence is never evenly distributed but varies with several factors.
- Solar influence dries some areas more rapidly than others.
- Ground slope or other factors can result in uneven water content at various parts of the perimeter.

These and other naturally occurring factors mean that the irrigation system would have to be very sophisticated indeed in order to keep all the foundation soil and immediately adjacent soil at the same stage of volumetric expansion.

In practice, the best solution in all but extreme cases is to drain the ground and surface water away from the building and keep the foundations dry. In reactive clay this is likely to result in cracking due to some shrinkage, and this needs to be redressed, but once this has been remedied and providing the drainage system is kept in working order, the building will remain stable.

This document has covered the bulk of the issues that a builder should deal with in regard to discovery of pre-existing conditions that can affect the stability of the foundation soil. There are also several construction do's and don'ts that the builder must know about and put into practice in order to make sure that the building itself does not contribute to instability of the soil and resultant movement in the structure. These matters are dealt with in BTF 22.

FURTHER READING

AS 1684, *Residential Timber-Framed Construction*, Standards Australia, Sydney, 1999.

AS 2870, *Residential Slabs and Footings – Construction*, Standards Australia, Sydney, Amdt 2, 2003.

AS 3798, *Guidelines on Earthworks for Commercial and Residential Developments*, Standards Australia, Sydney, 1996.

BTF 22, *A Builder's Guide to Preventing Damage to Dwellings: Part 2 – Sound Construction Methods*, CSIRO, Highett, Victoria, 2003.

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A builder's guide to preventing damage to dwellings

Part 2 – Sound construction methods

THE PROBLEMS

Site water problem identification

It is essential to investigate the site and prepare it in such a way that ground and surface water are prevented from entering the building footprint, whether the building has suspended floors or is footed on a ground slab. Site investigation methods are dealt with in BTF 19, which should be read prior to reading this BTF. It is also recommended that BTF 18 be read as additional information on this subject.

Legal considerations

Good site drainage always addresses both surface and ground water flows. Lack of attention to potential building movement caused by moisture migration can be a costly oversight for the builder, who may be found liable for damage long after any statutory warranty has expired. The Building Code of Australia (BCA) has not made site drainage mandatory, although it does set out acceptable construction practice in Volume 2, Clause 3.1.2, to be used where a local drainage authority deems it necessary. This makes for uncertainty in the minds of builders as to their responsibilities, but the courts tend to view the builder as the expert and, where some foreseeable damage occurs, it is usually found that the builder should have used methods that would have prevented the damage.

Where site investigation has revealed that there is existing or potential erosion problem, or where reactive clay subsoil is present, the builder is wise to give written advice to the owner and strongly recommend that ground drainage be installed. Where the owner declines in writing, some jurisdictions are known to have accepted that it is within the contractor's rights to continue the project. However, ground drainage is an area where contractors ignore or try to side-step at their own peril.

As to water entering a building, the BCA is quite clear. It is the task of the builder to prevent rainwater from entering a building, even when the rainwater is propelled by a storm of a magnitude that would only be expected to occur, on average, once in a hundred years. What is not so obvious to many is that water should not be allowed to enter the cavity, which is there not as a drain or repository for water that enters through openings, but as a break between the outer and inner leaves of exterior walls to prevent water from permeating through as it used to do when buildings were constructed of 230 mm solid brickwork. When water enters the cavity in volume, a wet, dark and enclosed environment is set up that can result in serious consequences for the health and amenity of the occupants.

Water problems in buildings are usually cumulative, resulting from several oversights rather than from a single source. This BTF is designed as a general checklist of commonly occurring flaws in construction methods, to help the builder deliver a product that will be durable, weatherproof and provide a healthy environment.

SURFACE AND GROUND WATER PREVENTION

It is no longer acceptable for a builder to claim that building movement is outside his or her power to prevent. The subsoil of land that is available for building development normally has an allowable bearing capacity well in excess of the loads imposed by class 1a buildings. The movement problems that are experienced by buildings are very often brought about by the failure of the builder and designers to deal with site water.

Surface and ground water that is allowed within the footprint of the building causes erosion and foundation soil movement, which in turn causes an exacerbation of cracking in slabs; cracking and failure in masonry and finishes; doming and dishing of floors; cupping and lifting of timber flooring; decay to timber members; degradation of metals and mortar; doming and dishing of roofs, leading to breakage of tiles and degradation of mortar beds.

Surface drainage methods

The basis of good surface water drainage is to:

- Have the finished exterior ground level at the building perimeter a minimum of 150 mm below finished floor level, ground floor cavity flashing weepholes or subfloor vents, whichever are the lowest. However, where a slab is used as part of a termite management system, 75 mm at the top of the slab edge must be visible or able to be made visible.
- In the finished ground, provide a 1:20 fall away from the building for at least the first metre. Nothing that needs to be watered, including lawn, should be within this graded area and it should preferably be a hard surface.

The above requirements mean that thought may need to be given to finished floor level etc. before the plans go to council.

Where there is natural topography that leads to surface water being encouraged toward the building, a dish or other surface drain should be installed and connected to the stormwater system through a pit.

Ground water drainage methods

If it is desired to keep the soil dry in areas other than the building footprint, it should be realised that this other drainage may not be sufficient to prevent water entering the footprint, and additional drainage for the building may be necessary. It should be understood that ground drainage is a complex subject, often requiring the expertise of an engineer who is suitably competent in hydrology and geotechnics. For anything other than straightforward problems, even drainers or builders experienced in installing ground drainage should engage a consultant to assist in the design. This section is therefore intended to give reminders to already competent people, and to assist others toward a rudimentary understanding to help them discuss the issues with a consultant. In addition, it is essential for a builder or drainer to comply with the minimum requirements of BCA Volume 2, Clause 3.1.2, and AS 3500.3.2, Sections 6–8, unless installing a system certified by an engineer.

The first step is to investigate the depth and volume of the subsoil flow of water. Test pits, particularly on the uphill perimeter of the footprint should be dug as outlined in BTF 19. It is, however, important to remember that ground drainage problems are not restricted to sloping sites. Some of the most susceptible sites are on flat land, particularly where the area is ringed by higher ground. In addition, as explained in BTF 18, where warm, wet summers and colder, dry winters are experienced, the building itself will tend to cause inward water migration.

In any case, the minimum depth of drainage should comply with BCA Volume 2, Clause 3.1.2.4, that the top of the drain be a minimum of 400 mm below ground and 100 mm below the adjacent footing. This means that the trench should be dug at a safe distance from the footing to ensure that the foundation is not affected. If this is not practicable, temporary measures to support the trench walls may be needed and/or the strength of the pipe material may need to be increased. It is important to remember that in clay the allowable angle between the external bottom corner of the footing and the nearest part of the bottom of the trench is usually 45°, whereas the normally applicable angle for compact granular soil is 30°. These may be exceeded where the trench fill is well compacted and the piping is non-compressible, but supervision by a competent engineer is normally necessary for soil classification and strength issues. A good working arrangement is to locate the trench toward the edge of the area that is graded away from the building to allow run-off of surface water.

Having discovered the required depth, the next step is to establish whether it is above the depth of the local authority's stormwater system, to determine the method of dispersal of the captured water. It must be borne in mind that the BCA's minimum fall for ground drainage is 1:300, and a silt arrestor requires a minimum drop of 50 mm from the invert of the inlet to the inner roof of the outlet. If the depth of the ground drainage is too low for the council system, councils may allow a soakage pit for any naturally occurring ground water, so that the drainage can divert the water from the uphill side of the building to the downhill side. The builder should confirm this with the council.

Next, the type of drainage should be determined. For general purposes, a geocomposite system using 90 mm slotted stormwater pipe with fabric sock and geofabric perimeter material is adequate, however suppliers can advise on other systems. It is desirable in any ground drainage system and essential where the fall is shallower than 1:100 to install inspection openings to enable the system to be flushed out. These should be at changes of direction greater than 45° and at the connection to the stormwater system. Where practicable, pits make the ideal inspection opening, particularly when configured as silt arrestors.

Drainage to rock substrates
BTF 19 discusses the special drainage problems with rock foundations. While a solid rock foundation remains stable regardless of water flows, water damage to building elements and high subfloor relative humidity can have potentially serious consequences. When the ground floor is to be suspended, and particularly when using timber framing and/or flooring, drains should be cut around the perimeter where water can otherwise enter the subfloor. Totally preventing water entering the subfloor area can be impracticable because of faults and interstrata gaps. Where water flows on rock foundations cannot be prevented, the design should allow for an open subfloor and an increased minimum clearance between the floor and the ground, commensurate with the volume of water experienced. If a completely open subfloor is impracticable, openings should be as large as possible, particularly where subfloor walls would otherwise dam water. Watercourses should be cut out to divert water if this is beneficial to the aim of removing water as soon as possible. A mechanical ventilation system may need to be installed as an augmentation to the measures discussed above, but when relied upon without sufficient other precautions, such a system may be inadequate.

Subfloor ponding
When constructing dwellings with suspended floors, it is essential to grade the subfloor area so that no depressions remain that can allow water to pond. With rock foundations it may be necessary to use concrete to fill depressions.

Dampproof courses
Ground moisture usually carries salts and other chemicals. When moisture migrates through masonry by capillary action, some chemicals may be transported. It is often these chemicals that attack the building elements. Different dampproof course (DPC) materials are susceptible to different chemicals.

It is not always possible to predict the nature of pollutants to which the underside of a DPC will be exposed. This is one of the reasons that moisture should be kept away from the building. DPCs that have poor plasticity or develop poor plasticity through exposure to water and chemicals, are unsuited for use where building movement cannot be totally prevented, because they tend to break. When a DPC is discontinuous it allows water to penetrate the gap. This is one common way that rising damp occurs in buildings constructed in the modern era.

The safest suggestion for overcoming the problem of lack of durability in DPCs for applications where high moisture content is expected, is to double up, perhaps using two different types, one on top of the other.

Antcapping
Antcapping should never be used as a DPC unless is has been tested and designed for this purpose. Galvanising will break down over time when in constant contact with moisture, particularly when salts are present. It is essential to isolate the antcapping from any water in the masonry by using a DPC between. The galvanising should also be checked for quality and any cuts or damage should be coated with cold galvanising, because even when the antcapping is isolated from direct contact with water, constant high humidity in the air will tend to attack the steel. Once corrosion has eaten through the metal, termites are given a path of entry to the building. This is not a rare condition.

RAINWATER PREVENTION

In addition to surface and ground water considerations, there are several issues of construction that builders must address in order to prevent rainwater from entering the building.

Rainwater is not only a problem when it enters the living area as water, but also when it is allowed into the cavities and voids and onto building members that can degrade or decay. In addition, rainwater has a more insidious danger in that it gives life to fungus and promotes pests like dust mites – these conditions are conducive to illness in people who are abnormally susceptible to breathing disorders.

Builders and tradespeople often attempt to make a building weatherproof by the use of sealants. It should be realised that sealants cannot be regarded as a durable solution to most weatherproofing problems. Durability can only be attained by sound construction method.

Ridge capping
Mortar bedding to ridge capping is permeable, even with flexible pointing applied over it. Water can migrate through the bedding and pond on the tile above the bedding. Any condensation tends to perpetuate the moisture and, in addition, where summers are warm and wet and winters are cold and dry the tendency is for moisture to be drawn in. The above factors tend to create an overflow of water that may drip into the roof space or run down the soffit of the tiling, decaying battening or framing and/or eventually damaging fastenings. This flow adds to flows caused by the natural absorption of water through tiles and any wind-driven rain that penetrates the gaps between tiles. These are the flows that lead to inundation of the roof. Weepholes should be created in the beds at the depressions in tiles to allow water to flow to the top surface of the tiles.

Where footing movement occurs, usually due to the action of water on the foundation soil, the roof moves. Cut and pitched roofs will dome and dish in the same way that floors do, because of the uneven rise and fall of reactive clay soils. This movement causes a stress on rigid members of the roof structure such as mortar beds to hips, ridges and verges, which hog and sag, tending to crack the mortar and/or the tiles. When 1:2 cement: sand mortar pointing is used, this will retard the cracking, but it will eventually crack and when it does, the water entry will increase accordingly. On truss roofs the effect is less but still sufficient to cause cracking. If there is no footing movement, the pointing tends to last many years. Where some movement is expected, it is recommended that flexible pointing be used.

Sarking
In general, roof tiles are of marginal suitability for installing on a roof slope of less than 18° and should never be used where the pitch is lower than 15° For other roof slopes below 25°, the manufacturer's recommendations should be checked before

installing a particular profile. Where flat profile tiles are to be used on a roof that has a pitch below 25° or where any tiles are to be used on a roof below 20°, sarking should be installed to prevent water entering the roof void. Where the common rafter length is greater than 4500 mm and sarking is not fitted to the whole slope, the table shown below (source: AS 2050, Table 5) should be consulted and sarking may have to be fitted to the lower end of the slope.

SARKING REQUIREMENTS IN RELATION TO PITCH/RAFTER LENGTH

Roof (degrees of pitch)	Maximum rafter length without sarking (mm)
≥18<20	4500
≥20<22	5500
≥22	6000

In addition, on any slope with a pitch of 20° or less, an anti-ponding board should be installed between the bottom batten and the oversail to ensure that the sarking does not sag sufficiently to create ponding, or allow rainwater into the eaves or structural elements.

Guttering too high

The front bead of eaves guttering is usually higher than the highest point of the rear vertical face that sits against the fascia board. A common mistake where there is a long run to the downpipe, is to install the guttering with the front bead level with or above the top of the fascia so as to allow for fall to the downpipe. The reasons why this is an error are:

- Where there is a roof overhang, this allows water to overflow onto the eaves lining. In the case of framed external leaf walls, the rainwater is fed into the frame.
- Where there is no overhang and extruded bricks are used for the external leaf, the overflowing water spills into the core holes and saturates the brickwork from within.
- Where water cannot feed entirely into the extruded brickwork or where pressed clay bricks are used, rainwater falls directly into the cavity if one is present.

This is one of the reasons that the BCA calls for downpipes at a maximum of 12 m intervals. Such intervals mean that 6 m should be the maximum distance away from a downpipe for any part of the guttering. The minimum fall for eaves gutters is 1:500, so gutters can be installed with a 12 mm fall from the highest point to the downpipe.

Section 3 of AS 3500.3.2 requires that the front bead of the guttering is lower than the top of the fascia, so as to allow overflow and prevent rainwater entering the building. A process contained in AS 3500.3.2, Appendices G and H, is used to determine how much lower the front bead of the guttering must be than the top of the fascia board. Appendix G also contains some examples of acceptable alternatives.

Roof flashings

All metal materials on a roof should be compatible. Lead flashings should not be used with Colorbond/Zincalume roofing. Galvanic action will degrade the zinc and cause corrosion that will lead to roof leakage. In the event that re-roofing introduces Colorbond/Zincalume to a roof that has existing lead flashings, the lead should be coated on both sides using a suitable paint. Other incompatibilities are listed in AS 3500.3.2, Tables 4.2 and 4.3.

Rainwater spreaders

Where water is collected by guttering to an upper roof and deposited onto a lower roof via a spreader, the lower slope is called upon to carry an additional volume of water – sometimes too great a volume. It must be realised that tile systems are designed to prevent water entry in accordance with the performance requirements of the BCA Volume 2, Clause 2.2.1 (b), which states: '*(b) Surface water, resulting from a storm having an average recurrence interval of 100 years must not enter the building.*'

When rainwater is gathered from a large catchment and concentrated by a spreader on another catchment, the volume of water on that catchment may well be above the capacity of the tiling to cope, particularly in a case where wind is tending to drive the rain up the slope. This type of overloading cannot be taken into account by tile designers or building designers. If it is intended to use a rainwater spreader on a tiled roof, the tile manufacturer should be consulted. Spreaders may also create a local guttering overflow.

Another even more serious problem is caused by the practice of locating a spreader on a flashing. This allows the combination of wind and the proximity of the flashing and the tile to push water up and over the top of the tile, then into the roof space. This practice should never occur. If a spreader is allowable on a roof slope, it should always be well below any flashing, but the best practice is to run the water from the upper roof to the ground by a downpipe.

Roof/wall interfaces

Where a roof meets a cavity wall and the wall then becomes internal, such as a garage abutting a two-storey dwelling, a tray flashing is necessary to carry water to an external wall cavity flashing. Where the roof slopes away from the wall this can be a horizontal combination of overflashing and cavity flashing. The most important consideration is the provision of a positive method of transferral from the tray flashing to the standard floor-level cavity flashing so that no water can escape.

Where the roof slopes along the wall the combination overflashing/cavity flashing is stepped. A requirement of this is that the 'uphill' end of the cavity flashing be turned up to ensure that water follows the steps down to the standard floor-level cavity flashing. Other information is available in BCA Volume 2, Clause 2.2.4.10.

Cavity flashings

Brickwork is permeable. A single leaf of brickwork will allow water to migrate from the exterior to the cavity. This is the main reason that a cavity is necessary. In fact, when significant wind-driven rain falls against single-leaf brickwork, water can be plainly seen running down the internal face.

More and more is being learned about the problems associated with water that is trapped in the cavity. This water can quickly accumulate, but because it is not exposed to sunlight, it can take a significant time to dissipate. Water in a cavity is not just harmful to building elements, but it also promotes fungal growth and creates an ideal environment for termites, other insects, spiders and mites, including dust mites, which are known to be harmful to people who are susceptible to respiratory ailments. In addition, the humidity that is created can transfer moisture into the inner leaf of walling that is measurable on the internal face. This is particularly true in southern exposure rooms and is undesirable, particularly in living or bedroom areas.

Because cavity flashings are bedded into the masonry during the building of the wall, mortar is dropped into the flashing as the wall rises. These droppings accumulate and harden. Because of their height inconsistency, water will inevitably be dammed in the cavity. Also, weepholes become partially or fully blocked by these mortar droppings, further reducing the possibility that water will escape.

Mortar droppings should be cleaned out of the flashing before they become difficult to remove, at least once a day during the bricklaying process. As the wall rises and cleaning by hand becomes impracticable, a hose can be used, provided that the mortar beds at the flashing level are sufficiently cured to resist deterioration by the water. Anything that bridges the cavity between the inner and outer leaves of walling and allows the transfer of water to the inner leaf must be removed.

Another common defect is that the flashing does not extend to the outer edge of the external leaf. The function of a cavity flashing is to gather water and direct it to the external face of the brickwork. It usually also acts as a DPC whose function is to prevent vertical moisture migration (either up or down). A DPC or flashing that does not extend to the outer edge of the brickwork will allow migration down by gravity or up by capillary action.

If the brickwork is to be cement rendered, the flashing should be continuous to the face of the render. A neat way to overcome this is to create a v-joint at the flashing, then cut the flashing off at the inner extremity of the v-joint. This method creates a control joint that will prevent unsightly cracking of the render.

Weepholes
AS 3700, Clause 12.7.2.3, requires that weepholes are formed immediately above the cavity flashing and that mortar is removed from the joint so that the opening is clean and the flashing is exposed. This is to ensure the free flow of water from the cavity. It is not uncommon to find blocked weepholes, recessed DPCs and fouled cavity flashings all on the same job.

Window and door openings
The popularity of unevenly faced bricks has led to a problem at openings. The problem arises where brickwork reveals do not present a straight line against windows, and is exacerbated by the fact that these bricks are generally not suited to flush mortar bedding. Consequently, it is common to see gaps at window/reveal interfaces caused by brick unevenness and raked joints. Such gaps mean that the building envelope is not weatherproof within the requirements of the BCA.

It should be realised that the cavity is not envisaged as a part of a water removal system, but is there to prevent moisture permeation from the outer skin to the inner skin. It may also act as a last line of defence in the event of an extraordinary event, however the idea that a builder should leave gaps in the building envelope through which water can penetrate into the cavity is in direct conflict with the objectives and requirements of the BCA. An external wall that routinely allows water to enter the cavity, turns that cavity into a hazard to the building elements, and to the health and amenity of the occupants. It is the job of the builder to make the envelope weatherproof. The construction system must prevent significant volumes of water entering the cavity.

In the case of window and door reveals, the bricklayer, while being mindful of the danger of ceramic growth, should not rake or iron the joint past the leading edge of the frame. In some cases where gaps must be left because long walls make ceramic growth a hazard, or where the brick profile is badly uneven, storm moulds should be installed, and bedding should be left flush with the leading edge of the storm mould.

It is also common to see cases where an overwide cavity creates insufficient overlap between the window and the brickwork reveal. Where this occurs, storm moulds are also called for.

Window gaskets
When fitted to brick veneer construction, windows need to be clear of the brickwork sill so as to allow for timber shrinkage in the frame. The usual allowance is 5–10 mm clearance to ground floor windows and a minimum of 15 mm on the second storey. For this purpose, aluminium window assemblies are fitted with neoprene gaskets to bridge the gap between the window frame and the brickwork sill. As with reveals, the brickwork sill should have joints left flush from the leading edge of the gasket to the rear edge of the sill. Commonly, little attention is paid to seating the gasket to provide a waterproof surface. Mortar is left on top of sill bricks which, when timber shrinkage reduces or closes the gap, pushes the gasket up and away from the brick and allows water to enter the cavity. Mortar should be cleaned off the top of bricks while laying. In addition, bricklayers commonly turn the ends of gaskets down into the perpends at the sill/ reveal joints. This is poor practice, as it leaves a gap above the gasket where water can gain entry to the cavity and which also encourages water into the mortar where the gasket turns down. These gaskets should be cleanly cut off flush with the reveal and the mortar should be flush with the sill brickwork. If the reveal bed aligns with the gasket there is no reason that the gasket cannot be bedded into it.

Sills and thresholds
Where brickwork sills are significantly sloped, it is common to find that the bricks are cut to have a minimal overlap with the gasket. These gaskets need a minimum 15 mm overlap with the sill bricks where the sill is at 30° to the horizontal. For lesser angles the necessary overlap increases.

Brickwork patio and other door thresholds are often laid without any fall away from the building. This will always result in water entering the cavity. Some bricklayers fill the cavity in at the doorway to prevent water incursion, but this does not work and only inhibits the operation of the flashing. The builder must provide the bricklayer with sufficient height to allow for weepholes to be continued across the doorway as necessary, and for either a soldier course sill with sufficient fall or room to lay a sloped tiling threshold.

Subfloor vents
In dwellings having suspended ground floors, particularly where timber floor framing is used, adequate cross-flow ventilation must be installed to counteract condensation. BCA Volume 2, Section 3.4.1, gives minimum ventilation standards that are deemed to satisfy the performance requirements. The required ventilation area is based on the perimeter length of the building and differs depending on:
- The zone in which the dwelling is located.
- The moisture content of the foundation soil.

It is also important to realise that where the floor is lower to the ground, there is less volume of air to dissipate the moisture that is transferred to it from the ground.

Landscaping
Two important aspects of landscaping that relate to water entry were introduced in the surface drainage section above, viz.:
- The finished exterior ground level at the building perimeter should be a minimum of 150 mm below finished floor level, ground floor cavity flashing weepholes or subfloor vents, whichever are the lowest. However, if paving is to be used around the building perimeter, the clearance may be 50 mm. Where a slab is used as part of a termite management system, 75 mm at the top of the slab edge must be visible or able to be made visible.
- The finished ground should have a 1:20 fall away from the building for at least the first metre. Nothing that needs to be watered, including lawn, should be within this graded area and it should preferably be a hard surface.

In addition, the landscaper should only install automatic watering systems where the beds that they service are lower than the base of the footings or where they are separated from the building by a properly engineered surface and ground water drainage system.

FURTHER READING/REFERENCED DOCUMENTS

AS 2050, *Installation of Roof Tiles*, Standards Australia, Sydney, 2002.
AS 3500.3.2, *Stormwater Drainage – Acceptable Solutions*, Standards Australia, Sydney, 1998.
AS 3700, *Masonry Structures*, Standards Australia, Sydney, 2001.
BTF 18, *Foundation Maintenance and Footing Performance – A Homeowner's Guide*, CSIRO, Highett, Victoria, 2001.
BTF 19, *A Builder's Guide to Preventing Damage to Dwellings: Part 1 – Site Investigation and Preparation*, CSIRO, Highett, Victoria, 2003.
Building Code of Australia (BCA) Volume 2, Australian Building Codes Board, Canberra, 1996.

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Appendix C – Northern Beaches Council Form 1

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for	CHRISTIAN STEVENS / A GRADE POOLS
	Name of Applicant
Address of site	19A PHILIP ROAD, MONAVALE NSW 2103

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

I, PHILIP DAVIES *on behalf of* GEOREPORTS PTY LTD
(Insert Name) (Trading or Company Name)

on this the 22 JUNE 2021 certify that I am a geotechnical engineer or engineering geologist or ~~coastal engineer~~ as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above organisation/company to issue this document and to certify that the organisation/company has a current professional indemnity policy of at least $10million.

I:

Please mark appropriate box

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

Geotechnical Report Details:

Report Title:	PRELIMINARY GEOTECHNICAL ASSESSMENT - SWIMMING POOL
Report Date:	22 JUNE 2021 (REV 0)
Author:	GEOREPORTS PTY LTD, PHILIP DAVIES
Author's Company/Organisation:	

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

AS NOTED IN REPORT

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

Signature ....[signature]........

Name .... PHILIP DAVIES

Chartered Professional Status........ CPENG, NER

Membership No. 2381700

Company........ GEOREPORTS PTY LTD