



Geotechnical Assessment

Project: Low Density Residential Development
60 Binalong Avenue, Allambie Heights.

Prepared for:

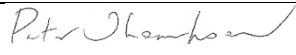
Hamish Humphreys
Gannet Developments
PO Box 7005
Warringah Mall, NSW, 2100

REF: AG 18011

2nd February, 2018

Geotechnical Assessment

For Proposed Low Density Residential Development at
60 Binalong Road, Allambie Heights, NSW

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Limitations

This report has been prepared for Hamish Humphreys c/o Gannet Developments in accordance with Ascent Geotechnical Consulting's (Ascent) Fee Proposal dated 30th January, 2018.

The report is provided for the exclusive use of Gannet Developments for the specific development and purpose as described in the report. This report must not be used for purposes other than those outlined in this document or applied to any other projects.

The information contained within this report is considered accurate at the time of issue with regard to the current conditions onsite as identified by Ascent and the documentation provided by others.

The report should be read in its entirety and should not be separated from its attachments or supporting notes. It should not have sections removed or included in other documents without the approval of Ascent.

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1 Overview

1.1 Background

This report presents the findings of a geotechnical assessment carried out at 60 Binalong Avenue, Allambie Heights, undertaken by Ascent Geotechnical Consulting (Ascent). This assessment has been prepared to accompany a Development Application (DA) with Northern Beaches Council.

The author of this report attended the site on the 1st February, 2018, to conduct a detailed site inspection and preliminary subsurface investigation.

1.2 Proposed Development

Details of the proposed development are outlined in a series of Architectural drawings prepared by Walsh² Architects, sheets DA000, DA005, DA010, DA015, DA020, DA050, DA100 - DA104, DA200, DA201, DA300, DA301, DA400, DA500, DA502, DA503, DA900 & DA901 Issue A, dated 21st January, 2018:-

The proposed works comprise the following:

- Demolition of existing structures, clearing of vegetation and site preparation,
- Construction of a new part two-level low density residential development, incorporating; basement carpark, internal lift and OSD storage tank.
- The proposed development will take place on an approximately 1708m² residential block being Lots 2211 & 2223 in D.P. 752038 – 60 Binalong Road, Allambie Heights.

1.3 Relevant Instruments

This geotechnical assessment has been prepared in accordance with the following relevant guidelines and standards:

- Northern Beaches Council – Warringah Local Environment Plan (WLEP) 2011 – (Current Version for 1st September, 2017) & Warringah Development Control Plan (WDCP) 2011.
- Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007)
- Australian Standard 1726:2017 Geotechnical Site Investigations.
- Australian Standard 2870:2011 Residential Slabs and Footings.
- Australian Standard 1289.6.3.2:1997 Methods of Testing Soils for Engineering Purposes.

1.4 Geotechnical Reporting Principles

This report has been developed based on the proposed development and the site-specific conditions to ensure that the site, surrounding area and proposed development adhere to the above-mentioned planning controls and the following stipulations:

- Geotechnically stable,
- Suitable for the proposed development,

- Both property and life will be protected,
- Provide recommendations to ensure that the existing rock formations and substrate on site are capable of withstanding:
 - The proposed loads to be imposed,
 - The extent of the proposed excavation, including any recommendations for shoring works that may be required to ensure the stability of the excavation,
 - Protection of adjoining properties,
 - The provision of appropriate subsoil drainage to prevent impact on the existing subsurface flow conditions.
- Details demonstrating the development will conform to relevant Australian Standards and best Engineering Practice.

2 Site Description

2.1 Summary

A summary of site conditions identified at the time of our inspection is provided in the table below (Table 1.).

Table 1: Summary of site conditions.

Parameter	Description
Site Visit	Ben Morgan - Ascent Geotechnical – 1/02/2018
Address	60 Binalong Road, Allambie Heights - Lots 2211 & 2223 in D.P. 752038
Site Area m ² (approx.)	1708m ² (by Title)
Council Mapped Landslip Risk Zones	A & B - WLEP Landslip Risk Map LSR_008
Site Classification	A - In accordance with AS 2870:2011.
Existing development	Two, two-storey dilapidated stone and clad cottages
Aspect	South
Average gradient & RL (AHD)	~10 degrees across the site, ~RL 82 at NW corner to RL 76 SE corner
Vegetation	Dense overgrown garden beds, lawn areas, established medium to large trees and shrubs.
Neighbouring environment	Residentially developed to the south. Jennifer Ave and Nargong Rd to the north, Council Reserve to the east.



Image 1: Site location – Red Pin (Google Maps)

2.2 Fieldwork

A site investigation was undertaken on the 1st February, 2018 which included a visual assessment of the property and its surrounds, and a preliminary subsurface investigation.

Three Dynamic Cone Penetrometer (DCP) tests were conducted to determine the relative density of the subgrade, and the depth to weathered bedrock. The tests were conducted to the Australian Standard for ground testing: AS 1289.6.3.2 – 1997. The locations of the tests are shown on the site plan provided and the results of the tests are as follows:

Table 2: Network Geotechnics DCP test results.

DEPTH (m)	NUMBER OF BLOWS		
	Conducted using a 9kg hammer, 510mm drop & conical tip.		
	DCP 1	DCP 2	DCP 3
0.0 to 0.3	4	2	5
0.3 to 0.6	7	6	5/
0.6 to 0.9	13	4/	
0.9 to 1.2	14/		
	Refusal @ 1.10m on weathered rock	Refusal @ 0.65m on weathered rock	Refusal @ 0.50m on weathered rock

DCP 1: Refusal @ 1.10m double bouncing on bedrock. White impact dust on damp tip.

DCP 2: Refusal @ 0.65m double bouncing on bedrock. White-yellow impact dust on dry tip.

DCP 3: Refusal @ 0.50m double bouncing on bedrock. White impact dust on dry tip.

No significant groundwater or seepage was identified during our testing.

NOTE: The equipment chosen to undertake ground investigations provides the most cost-effective method for understanding the subsurface conditions. Our interpretation of the subsurface conditions is limited to the results of testing undertaken and the known geology in the area. While every care is taken to accurately identify the subsurface conditions on-site, variation between the interpreted model presented herein, and the actual conditions onsite may occur. Should actual ground conditions vary from those anticipated, we would recommend the geotechnical engineer be informed as soon as possible to advise if modifications to our recommendations are required.

2.3 Geology and Geological Interpretation

The Sydney 1:100,000 Geological Sheet 9130 (NSW Dept. Mineral Resources, 1983) indicates that the site is underlain by Wianamatta Group Hawkesbury Sandstones (Rh) comprising medium to coarse grained quartz sandstone and very minor shale and laminate lenses.

Outcropping sandstone was identified in the subfloor area of the existing structure, in the creek bed to the east of the property and on the road reserve opposite the block on the western side of Binalong Avenue.

3 Geotechnical Assessment

3.1 Site Classification

Due to the relatively shallow sandy soils and Hawkesbury Sandstone bedrock, the site is classified as **Class "A"** in accordance with AS 2870:2011.

3.2 Ground Water

The property is located toward the top of a moderate slope that rises to the crest of the ridge near Roosevelt Avenue to the north. Normal ground water seepage is expected to move downslope through the soil profile along the interface with underlying bedrock, also exploiting any cracks joints or fissures that may be present in the rocks surface.

Due to the position of the block relative to the slope and the underlying geology, no significant standing water table is expected to influence the site.

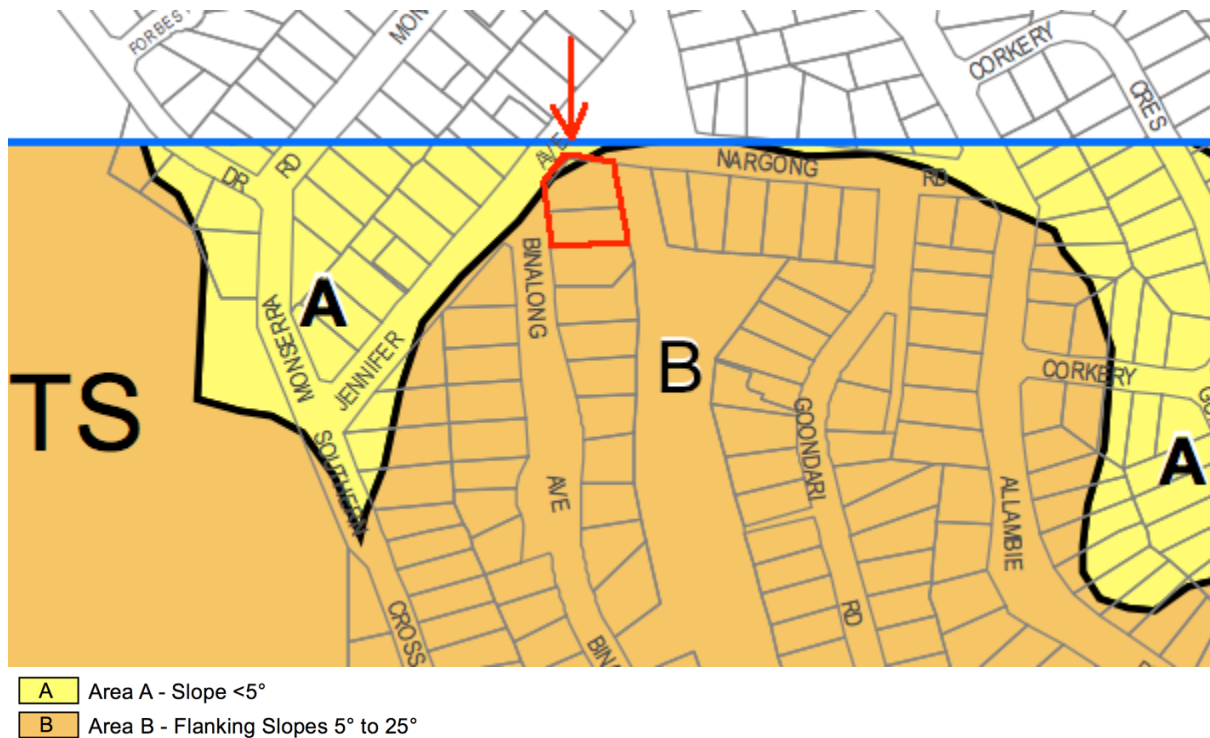
3.3 Surface Water

Overland or surface flows entering the site from the adjoining areas were not identified at the time of our inspection, however normal overland runoff could enter the site from above during heavy or extended rainfall. The majority of surface flow from above will be captured by the gutter and drain systems for Jennifer Avenue and Nargong Road.

3.4 Slope Instability

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

- No evidence of significant soil creep, tension cracks or other indicators of slope instability were identified at the time of our inspection.
- The proposed residential development will be situated on land that is gently to moderate sloped with a maximum gradient of ~10 degrees.
- The property is classified category 'A & B' in Northern Beaches Council WLEP Landslip Risk Map LSR_008 (**Image 2:** Below. Site indicated by red arrow)



3.5 Geotechnical Hazards and Risk Analysis

The slope across the location of the proposed residential development has an average gradient of >10 degrees. The soil profile is comprised of shallow sandy soils, over weathered sandstone bedrock confirmed by ground testing. Provided all footings for the proposed secondary dwelling are taken to and socketed a minimum of 300mm into competent sandstone bedrock, the likelihood of the slope failing is assessed as '**UNLIKELEY**', the consequences of such a failure are assessed as '**MINOR**'. The risk to property is '**LOW**'. The existing conditions and proposed development, including excavations for footings and minor levelling are considered to constitute an '**ACCEPTABLE**' risk to life and a '**LOW**' risk to property provided that the recommendations outlined in **Section 3.6** are adhered to.

The proposed works are not considered to present a significant risk to the integrity of any council infrastructure or assets, including, but not limited to Binalong Ave, Jennifer Ave & Nargong Rd reserves.

3.6 Recommendations

The proposed development is considered to be suitable for the site. No significant geotechnical hazards will result from the completion of the proposed development provided the recommendations presented in **Table 3** are adhered to.

Table 3: Geotechnical Recommendations.

Recommendation	Description
Soil Excavation	<p>Construction of the proposed development will require excavations to an approximate maximum depth of 4.5m from current surface levels. It is anticipated that the cut will be through shallow sandy soils before weathered rock is encountered at depths of between 0.2 - 1.2m across the site.</p> <p>Provided these unconsolidated materials are battered back to a minimum of 45 degrees they will stand unsupported for a short period until permanent support is in place.</p> <p>If permanent batters are proposed, the unsupported batter must not be steep in gradient than 35 degrees, and should be supported by geotextile fabric, and planted with soil binding vegetation.</p>
Rock Excavation	<p>All excavation recommendations as outlined below should be read in conjunction with Safe Work Australia's '<i>Excavation Work – Code of Practice</i>', published March, 2015.</p> <p>Due to the depth of excavation required, proximity to Council infrastructure and adjoining properties, it is strongly recommended that an excavation contractor with demonstrable experience in this type of project be engaged to undertake the proposed works with the appropriate care and diligence.</p> <p>The cuts required for the construction of the basement car park and OSD tank will extend to approximately RL 76.9, requiring excavation to approximate maximum depths of ~ 4.5m from current surface levels. The bulk of the cuts are expected be through competent Hawkesbury Sandstone bedrock.</p> <p>It is essential that any excavation through rock that cannot be readily achieved with a bucket excavator or ripper should be carried out initially using a rock saw to minimise the vibration impact and disturbance on the adjoining properties. Any rock breaking must be carried out only after the rock has been sawed and in short bursts (2-5 seconds) to prevent the</p>

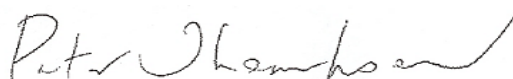
	<p>vibration amplifying. The break in the rock from the saw must be between the rock to be broken and the closest adjoining structure.</p> <p>All excavated material is to be removed from the site in accordance with current Office of Environment and Heritage (OEH) regulations.</p>
Vibrations	<p>The Australian Standard AS2670.2-1990 "Evaluation of human exposure to whole-body vibrations – continuous and shock induced vibrations in buildings (1-80 Hz)" suggests a day time limit of 8 mm/s component PPV for human comfort is acceptable.</p> <p>We would suggest allowable vibration limits be set at 5mm/s PPV. It is expected that rock hammers with an approximate weight of 600-800kg will be adequate to operate within these tolerances.</p>
Excavation Support	<p>While it is anticipated the bulk of the cut face will stand unsupported at sub vertical or vertical angles permanently, we would recommend the retaining structure to support the proposed cut is to be installed as soon as possible after the excavation is complete. The cut batter of any unconsolidated portion of the cut, if exposed for an extended period, is to be covered to prevent loss of moisture in dry weather and to prevent excess moisture in wet weather. Upslope runoff must be diverted from the cut faces by sandbag mounds or similar diversion works. Temporary support may be necessary depending upon the material encountered in the cuts, the likelihood of heavy rain and the length of period before permanent support is installed.</p>
Sediment and Erosion Control	<p>Appropriate design and construction methods shall be required during site works to minimise erosion and provide sediment control. In particular, any stockpiled soil will require erosion control measures, such as siltation fencing and barriers, to be designed by others.</p>
Footings	<p>Visual inspection and our testing indicated shallow sandy soils overlying weathered Hawkesbury Sandstone bedrock across the site. All footings are to be taken to, and if piered, socketed a minimum of 300mm into the underlying sandstone bedrock. The allowable bearable pressure is 1.2 MPa.</p> <p>Note: The local geology is comprised of benches of Hawkesbury Sandstone. Subsequently depth to rock under the existing soil profile on site may alter significantly across short distances. This variability should be anticipated and accounted for in the design and construction of any new foundations. We recommend that Ascent be contacted immediately if conditions onsite are outside of those expected.</p>

Retaining Structures	Any retaining structures to be constructed as part of the site works are to be backfilled with suitable free-draining materials wrapped in a non-woven geotextile fabric (i.e Bidim A34 or similar), to prevent the clogging of the drainage with sediment.
Fills	No significant filling is proposed.
Stormwater Disposal	Any stormwater collected from hard surfaces is to be collected and piped to the council stormwater network through any storage tanks or on-site detention that may be required by the regulating authorities.
Inspections	<p>We would recommend that Ascent be engaged for a site meeting with the project manager and excavation contractor to discuss and approve proposed excavation methodology and equipment before bulk excavations commence.</p> <p>We would recommend that Ascent inspect the excavation face at hold points of 1.5m drops to ensure the competency of the rock strata and advise if any temporary or permanent support is required.</p> <p>It is essential that the foundation materials of all footing excavations be inspected and approved by Ascent before steel reinforcement and concrete is placed.</p>

For and on behalf of, **Ascent Geotechnical Consulting Pty Ltd,**



Ben Morgan BSc Geol.
Engineering Geologist



Peter Thompson CPEng MIEAust
Senior Civil/Geotechnical Engineer

4 References

NSW Department of Mineral Resources (1983), Sydney Australia 1: 100,000 Geological Series Sheet 9130.

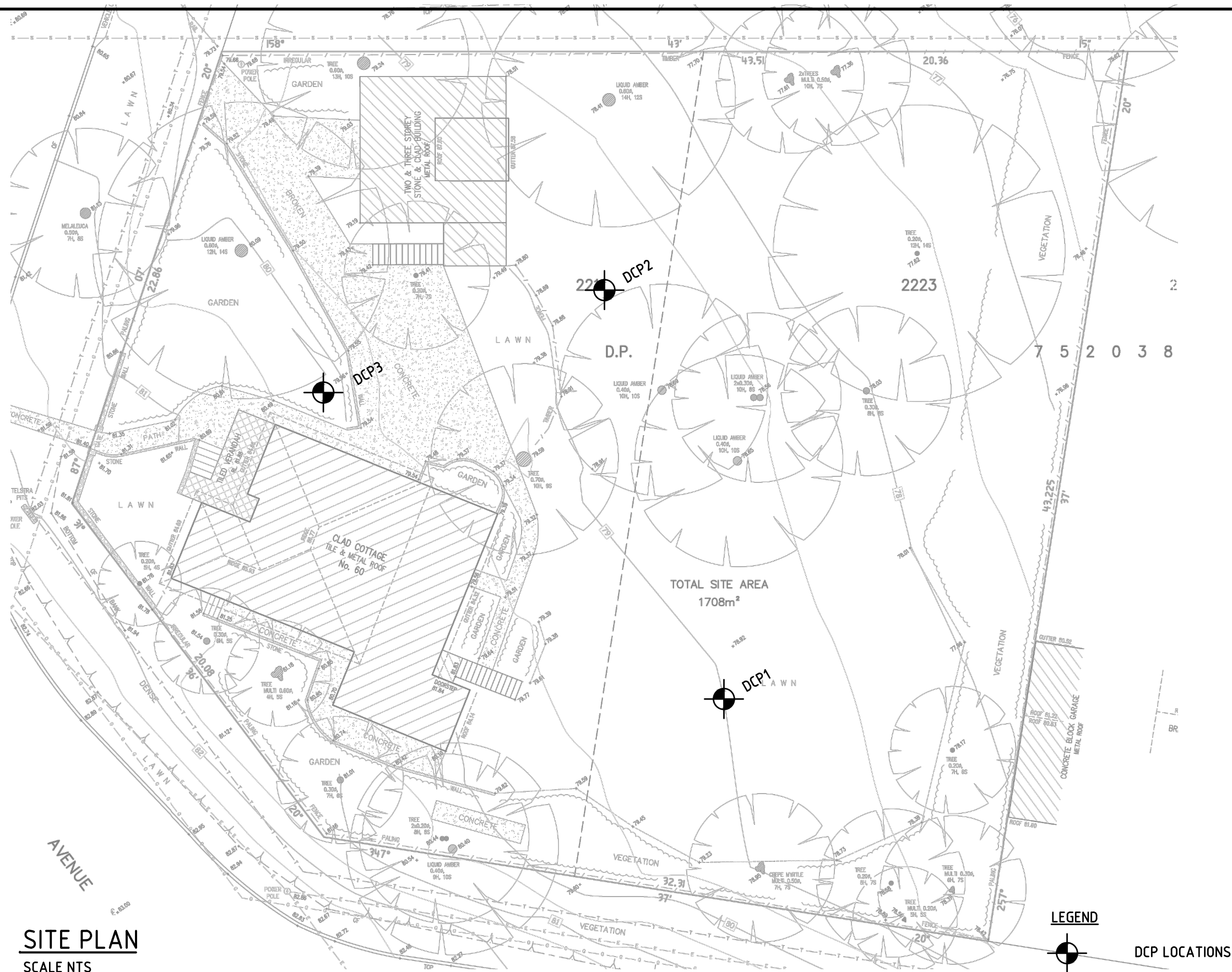
Australian Geomechanics Society (March 2007), *Landslide Risk Management*, Australian Geomechanics 42 (1).

Australian Standard 1726:2017 Geotechnical Site Investigations.


Australian Standard 2870:2011 Residential Slabs and Footings.

Australian Standard 1289.6.3.2:1997 Methods of Testing Soils for Engineering Purposes.

Australian Standard AS2670.2:1990 Evaluation of Human Exposure to Whole-Body Vibrations – Continuous and Shock Induced Vibrations in Buildings (1-80 Hz).



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ASCENT
GEOTECHNICAL CONSULTING

ABN: 71621428402
MIE Aust. CP Eng. NER
Ben: 0448 255 537
Ben@ascentgeo.com.au
Doug@ascentengineers.com.au
PO BOX 37
Manly NSW 1655

CLIENT:
GANNET DEVELOPMENTS

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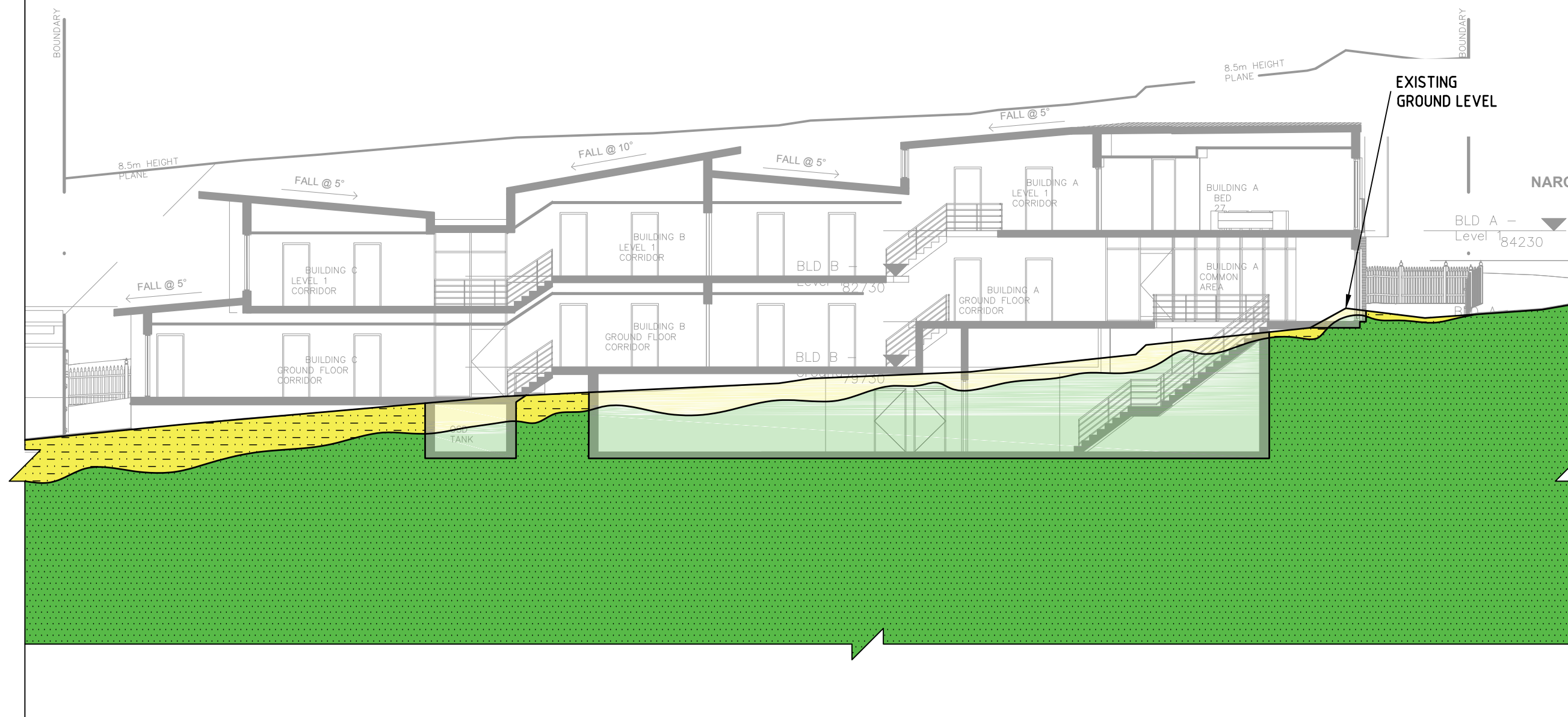
ADDRESS:
**60 BINALONG AVE
ALLAMBE HEIGHTS NSW**

DRAWING TITLE:
SITE PLAN

DATE: 02/02/2018

SCALE: AS SHOWN @ A3

DRAWING NO:
AG18011- S1




LEGEND

- SANDY SOIL
- HAWKESBURY SANDSTONE

BASE SECTION BY
WALSH ARCHITECTS
REF: DA200
DATE: 21/01/18

INTERPRETED SUBSURFACE SECTION ONLY.
ACTUAL GROUND CONDITIONS MAY VARY.

INTERPRETED GEOLOGICAL SECTION
SCALE: NTS

					<div><p>ASCENT</p><p>GEOTECHNICAL CONSULTING</p></div>	<p>ABN: 71621428402 MIE Aust. CP Eng. NER Ben: 0448 255 537 Ben@ascentgeo.com.au Doug@ascentengineers.com.au PO BOX 37 Manly NSW 1655</p>	CLIENT:	<p>ADDRESS:</p> <p>60 BINALONG AVE ALLAMBE HEIGHTS NSW</p>	DATE:	02/02/2018
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General Notes About This Report

Introduction

These supporting notes have been prepared by Ascent Geotechnical Consultants (AGC) to assist our clients interpret and understand the limitations of this report. Not all sections below are necessarily relevant to this report.

Limitations

Geotechnical reports are based on information gained from limited sub-surface site testing and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of the information on which they rely.

This report has been prepared for this specific project's design proposal. This report should not be relied upon for any other project or if the design proposal of this project changes without the prior knowledge of AGC.

Subsurface Conditions

Subsurface conditions can change with time and can vary significantly between test locations and over very short distances. That actual interface between the materials may be far more gradual or abrupt than interpreted. Therefore, actual conditions in areas not tested may differ from those predicted since no subsurface investigation, no matter how comprehensive, can reveal all subsurface details and anomalies.

Groundwater

Groundwater levels indicated in our subsurface testing are recorded at specific times. The groundwater levels recorded will depend on ground permeability, seepage and environmental variations.

Site inspections

Ascent Geotechnical Consultants will always be please to provide engineering inspection services for aspects of work relating to this report. This may range from standard foundation material inspections for footings, to a full-time engineering presence on site or through one stage of the development. Ascent Geotechnical Consultants are familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction.

Anomalies

If the ground or groundwater conditions onsite prove to differ from those described in this report we would recommend that Ascent Geotechnical Consulting be contacted as a matter of priority. It is far easier and less costly to address these issues if they are addressed early on in the project.

Foundation Maintenance and Footing Performance: A Homeowner's Guide



BTF 18
replaces
Information
Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

Tree root growth

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

Erosion and saturation

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

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

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 graded 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



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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

The information in this and other issues in the series was derived from various sources and was believed to be correct when published.

The information is advisory. It is provided in good faith and not claimed to be an exhaustive treatment of the relevant subject.

Further professional advice needs to be obtained before taking any action based on the information provided.

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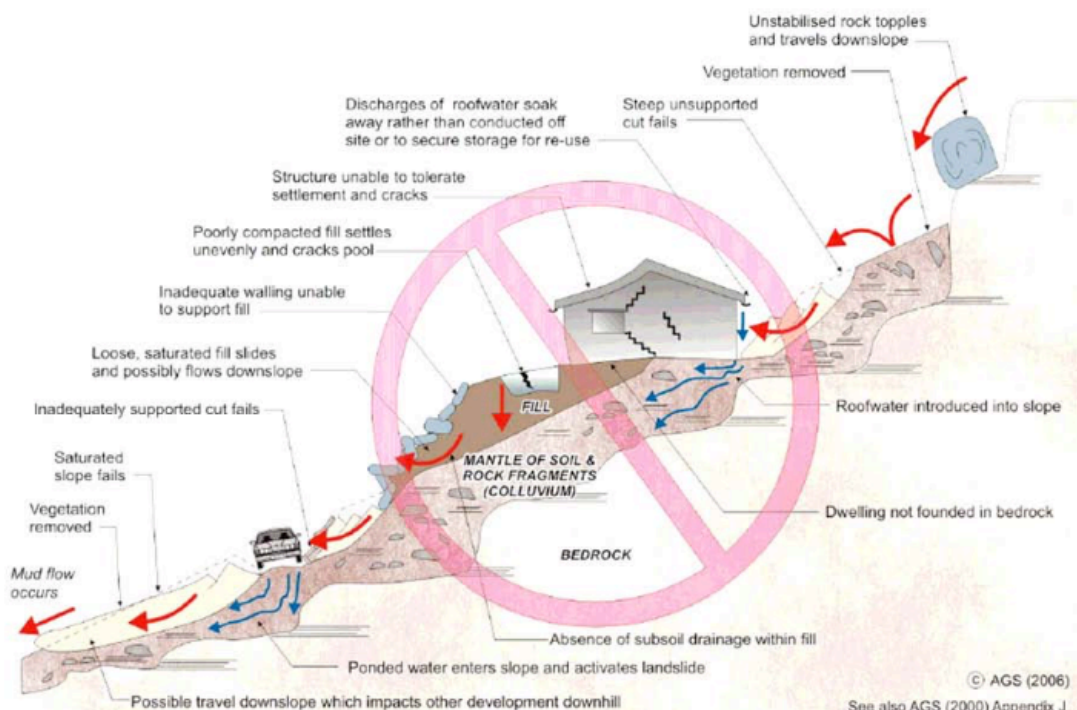
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EXAMPLES OF **GOOD** HILLSIDE PRACTICE



EXAMPLES OF **POOR** HILLSIDE PRACTICE



PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007
APPENDIX C: LANDSLIDE RISK ASSESSMENT
QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

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

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007
APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	1: CATASTROPHIC 200%	2: MAJOR 60%	3: MEDIUM 20%	4: MINOR 5%	5: INSIGNIFICANT 0.5%
A – ALMOST CERTAIN	10 ⁻¹	VH	VH	VH	H	M or L (S)
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.