ASCENTGEO
GEOTECHNICAL CONSULTING

Geotechnical Assessment

Project: Duplex
35 Moore Road, Freshwater NSW

Prepared for:
Bill Derrin

Ref: AG 25207
22 May 2025

ASCENTGEO
GEOTECHNICAL CONSULTING

WHAT TO DO WITH THIS REPORT

While your geotechnical assessment report may be a statutory requirement from council in support of your development application, it also contains information important to the structural design and construction methodology of your project. Therefore, it is critical that all relevant parties are provided with a copy of this report.

We suggest you give a copy of your geotechnical assessment report to:

Your Architect/Building Designer
Your Certifier
Your Excavation Contractor
Your Structural/Stormwater/Civil Engineer
Your Project Manager
Your Builder

We would also suggest that if any of your project team have questions regarding the contents of this report, that we be contacted for clarification.

NEXT CRITICAL STAGES

Keep in mind that you will need AscentGeo again at different stages of your project. This may include:

Review or endorsement of structural plans/architectural plans for a Construction Certificate
Foundation/Footing inspection during construction
Excavation hold point inspection, usually at hold points not exceeding 1.5m drops
Final inspection and certification for an Occupation Certificate upon completion of works

GENERAL ADVICE

If after reading this report you have any questions, are unsure what to do next or when you need to get in touch, please reach out to us.

Given AscentGeo can't be on site the whole time, we recommend that you or/and your builder take a lot of progress photos, especially during excavation. Many of the potential problems that may pop up can be resolved if we have clear photos of the work that's been done.

A lot can change on site during a construction project: some of these changes are normal and innocuous, while others can be symptoms of larger or more serious issues. For this reason, it's important to contact us to discuss any changes you notice on site that you aren't sure about. This could include but not be limited to changes to ground or surface water, movement of structures, and settlement of paths or landscaping elements.

We're here to help.

The AscentGeo Team

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AG 25207
22 May 2025

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Geotechnical Assessment

For **Proposed Duplex** at

35 Moore Road, Freshwater NSW

Document Status			Approved for Issue	
Version	**Author**		**Reviewer**	**Date**
1	C.young Cameron Young BEnvSci Geol MAIG		Ben Morgan BScGeol MAIG RPGeo	22.05.2025
Document Distribution				
Version	**Copies**	**Format**	**To**	**Date**
1	1	PDF	Bill Derrin	22.05.2025

Limitations

This report has been prepared for Bill Derrin, in accordance with AscentGeo's fee proposal dated 7 May 2025.

The report is provided for the exclusive use of the property owner and their nominated agents for the specific development and purpose as described in the report. This report must not be used for purposes other than those outlined in the report 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 on site as identified by AscentGeo 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 express approval of AscentGeo.

Contents

Appendix A:	Site plan/ground test locations and geological cross section
Appendix B:	Site photos
Appendix C:	Engineering logs
Appendix D:	General notes
	CSIRO Publishing, 2012. 'Foundation Maintenance and Footing Performance: A Homeowners Guide', Sheet BTF-18.
	Australian GeoGuide LR8, 2007. 'Examples of Good/Bad Hillside Construction Practice'.
	Australian Geomechanics, 2007. 'Practice Note Guidelines for Landslide Management', Appendix C: Qualitative Terminology.

1 Overview

1.1 Background

This report presents the findings of a geotechnical assessment carried out at 35 Moore Road, Freshwater (the 'Site'), by AscentGeo. This geotechnical assessment has been prepared to meet Northern Beaches Council lodgement requirements for a Development Application (DA), as well as informing detailed structural design and construction methodology.

1.2 Proposed Development

The proposed development will take place on Lot 15, Sec 1 in DP7022, being 35 Moore Road, Freshwater.

Details of the proposed development are outlined in a series of architectural drawings prepared by Action Plans, drawing numbers DA00 – DA31, dated 21 May 2025.

We understand the proposed works comprise the following:

- Demolition of existing structures, site clearing, basement excavation and footings preparation
- Construction of new two storey duplex dwelling with basement carpark
- Associated hard and soft landscaping.

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 and 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
- Australian Standard 3798–2007 Guidelines on Earthworks for Commercial and Residential Developments.

2 Site Description

2.1 Summary

A summary of site conditions identified at the time of our assessment is provided in Table 1.

Table 1. Summary of existing site conditions

Parameter	Description
Site visit	Cameron Young, Engineering Geologist – 15/5/2025
Site address	35 Moore Road, Freshwater – Lot 15, Sec 1 in DP7022
Site area m^2 (approx.)	385.2m^2 (by NSW explorer calc.)
Existing development	Two storey rendered apartment with brick garage.
Slope Aspect	North-east
Average gradient	~10 degrees
Vegetation	Lawn areas, small shrubs and trees.
Retaining structures	Low level rendered walls in fair condition. Mass concrete wall along rear boundary appears to be in good condition, however the foundation materials of this wall are unknown. Timber sleeper wall in good condition.
Neighbouring environment	Residentially developed to the north, east, south and west. Moore Road to the north.

Figure 1. Site location – 35 Moore Road, Freshwater NSW (© SIX Maps NSW Gov)

2.2 Site Description

The subject site is situated in a residential area, has a rectangular shape and is bounded by residential dwellings to the northeast and southwest, a mixed commercial/ residential structure to the southeast and Moore Road to the northeast. The site is on a gently sloping ground with a gradient of ~10 degrees, with northeasterly aspect (falling to its frontage). A site plan is included in Appendix A.

The existing building at the site is a two-storey rendered apartment building with a grassed front yard and larger grassed backyard areas. Along the rear boundary of the site is a mass concrete wall, approx. 1m high, the wall appears to be in good condition, however the foundation materials on this wall are unknown. A timber sleeper wall in the central portion of the site appears to retain sandy fill and appears to be in good condition.

Sandstone bedrock is outcropping on the site. Where visible, the sandstone is heavily weathered with closely spaced horizontal bedding defects. The surface of the outcropping rock is very low strength and can be scoured with a pen under medium hand pressure. The surface of the outcrop was moist, but no individual points of significant seepage were observed.

The photos presented in Appendix B show the general conditions of the site on the day of the site visit conducted by AscentGeo.

2.3 Geology and Geological Interpretation

The Geological Survey of New South Wales (GSNSW) Seamless Geology Project Version 2.4, May 2024, accessed via Minview, indicates that the site is underlain by Middle Triassic Hawkesbury Sandstone (Tuth). The Hawkesbury rock is typically comprised of medium to course-grained quartz sandstones, minor shale and laminite lenses.

The soil profile consists of shallow uncontrolled fill and silty topsoil (O & A Horizons), sand (B Horizon) and weathered bedrock (C Horizon). Based on our observations and the results of testing on site, we expect weathered sandstone bedrock to be found within 0.6 to 2.5 metres below current surface levels across the area of the proposed works potentially deeper where filling has been carried out, and it may be locally deeper near the inside of rock benches which may exist at this site.

Note: The local geology is comprised predominantly of sandstone. The sandstone bedrock is often found in benched terraces, subsequently ground conditions 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.

2.4 Fieldwork

A site visit and investigation were undertaken on 15 May 2025, which included a geotechnically focused visual assessment of the property and its surrounds; geotechnical mapping; photographic documentation; and a limited subsurface investigation including hand auger borehole and Dynamic Cone Penetrometer (DCP) testing.

Hand Auger Borehole Testing

Two hand auger boreholes (BH01 & BH02) tests were drilled at the approximate locations shown on the site plan to visually identify the subsurface material. Engineering logs of the hand auger boreholes are presented in Appendix C.

Dynamic Cone Penetrometer (DCP) Testing

Four (4) DCP tests were carried out to assess the in situ relative density of the shallow soils and the depth to weathered rock. These tests were carried out in accordance with the Australian Standard for ground testing: AS 1289.6.3.2–1997 'Methods of testing soils for engineering purposes.'

The location of these tests is shown on the site plan provided in Appendix B and a summary of the test results is presented below in Table 2, with the full details presented in the engineering logs in Appendix C.

Table 2. Summary DCP test results

Test	Summary
DCP 1	Refusal @ 1.3m Bouncing on inferred bedrock. Brown sand on dry tip.
DCP 2	Refusal @ 1.2m Bouncing on inferred bedrock. Brown sand on dry tip.
DCP 3	Refusal @ 0.6m Bouncing on inferred bedrock. Brown sand on moist tip.
DCP 4	Refusal @ 2.5 Bouncing on inferred bedrock. Orange dust on dry tip.

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

3 Geotechnical Assessment

3.1 Geological Model

Based on the results of our site assessment, ground testing, geological mapping and our experience in the area, the subsurface conditions encountered on site may be summarised as follows in Table 3.

Table 3. Interpreted geological model (mechanical core drilling to confirm rock composition and strength)

Unit	Material Type	Material description
1	Topsoil/Fill	Paving and tiled areas. Stone paths. Silty Sand disturbed fill and topsoil.
2	Sand	Medium grained quartz sand. Generally loose.
3	Class V* Sandstone	Extremely weathered sandstone bedrock. Typically occurring near the uppermost metre (~) of bedrock.
4	Class IV* Sandstone	Mainly low strength sandstone bedrock with closely to moderately spaced defects resulting in blocky weathering. Typically encountered in the uppermost 2m (~) of bedrock profile.
5	Class III* Sandstone	Medium strength, massively bedded sandstone with isolated but persistent sub-vertical joints. Depth to this quality of rock is unconfirmed.

* Pells, PJN, Mostyn, G & Walker, F, 1998 (Dec). 'Foundations on sandstone and shale in the Sydney region'. *Australian Geomechanics Journal,* vol. 33, no. 3, pp. 17–29.

3.2 Site Classification

The presence of fill material necessitates a Site Classification of **"P"** as outlined in Table 4, below. For uniformity of performance, new footings comprising the same structural element should be founded on the same natural material. For the purposes of re-classification for footings on Unit 5 (described in Table 3 above), the Site may be re-classified as **"A"** in accordance with AS 2870–2011.

Table 4. Site classification table for residential slabs and footings (AS2870-2011)

Site Classification	Soil description	Expected range of movement
A	Most sand and rock sites with little or no ground movement from moisture changes.	
S	Slight reactive clay sites, which may experience only slight ground movement from moisture changes.	0–20mm
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes.	20–40mm
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes.	40–60mm
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes.	60–75mm

Site Classification	Soil description	Expected range of movement
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes.	>75mm
P	May consist of any of the above soil types, but in combination with site conditions produce undesirable foundations. P sites may also include fill, soft soils, mine subsidence, collapsing soils, prior or potential landslip, soils subject to erosion, reactive sites subject to abnormal moisture conditions, or sites which cannot be classified otherwise.	

3.3 Groundwater

No groundwater was encountered during testing at the time of our inspection.

Groundwater seepage during and after periods of inclement weather should be anticipated through permeable soil layers, close to the interface with weathered rock and from joints and discontinuities deeper in the weathered rock. Appropriate ground support measures should be utilised in soils overlying rock to manage any localised groundwater inflows and prevent ground loss due to saturated/fluidised sands.

There is a potential for natural intermittent perched groundwater to develop above shallow bedrock and/or above any other low permeability impervious horizons, such as clays in overlying soils or siltstone/shale bands in rock.

Whilst dedicated groundwater monitoring was not within the scope of this assessment, as a basement excavation is proposed, groundwater monitoring bores may be required to understand the potential for the local groundwater regime to be influenced by the proposed works, and to appropriately manage its interaction with proposed structures.

3.4 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 adjacent areas during heavy or extended rainfall. Appropriate surface water diversions should be implemented to prevent overland runoff entering the site from adjacent areas during heavy or extended rainfall.

3.5 Slope Instability

A landslide hazard assessment of the existing slope has been undertaken in general accordance with Australian Geomechanics Society's 'Practice Note Guidelines for Landslide Risk Management', published in March 2007.

- No evidence of significant soil creep, tension cracks or landslip instability were identified across the site or on adjacent properties as viewed from the subject site at the time of our inspection.
- Structures on the subject property, and on adjoining properties, including homes, and masonry walls, appeared to be in generally good condition at the time of our assessment as viewed from the subject site.

- Site gradients are gently sloping and the site is underlain by relatively shallow Hawkesbury Sandstone bedrock.
- The property is classified as **Area B** with reference to Northern Beaches Council WLEP – Warringah Landslip Risk Map (**Image 2**).

Image 2. Warringah Landslip Risk Map:
35 Moore Road, Freshwater NSW (© **NBC Maps**)

LEGEND
Warringah Landslip Risk Map
🟨 Area A - Slope less than 5 degrees
🟧 Area B - Flanking Slopes from 5 to 25 degrees
🟥 Area C - Slopes more than 25 degrees
🟩 Area D - Collaroy Plateau Area Flanking Slopes 5 to 15 degrees
🟦 Area E - Collaroy Plateau Area Slopes more than 15 degrees

3.6 Geotechnical Hazards and Risk Analysis

No significant geotechnical hazards were identified above, beside or below the subject site, including but not limited to the immediately adjoining residential properties, and the road reserve.

The scope of the proposed excavations on site, and the local geology make this site susceptible to instability during the proposed construction works. Careful control of all site works will be required during the installation of any required retention systems, excavations, and the construction of the proposed structures to maintain the stability of the block, and adjacent land.

Based on observation made during our site assessment, the following geological/geotechnical hazards have been identified in relation to the proposed works:

- **Hazard One:** Failure of the soil portion of the proposed basement excavations before permanent supporting basement walls are constructed.
- **Hazard Two:** Failure of the sandstone rock portion of the proposed basement excavations before permanent supporting basement walls are constructed

Table 5. Risk analysis summary

HAZARDS	**HAZARD ONE**	**HAZARD TWO**
TYPE	Failure of the soil portion of the proposed basement excavations before permanent supporting basement walls are constructed.	Failure of the sandstone rock portion of the proposed basement excavations before permanent supporting basement walls are constructed
LIKELIHOOD	'Possible' (10^{-3})	'Unlikely' (10^{-4})
CONSEQUENCES TO PROPERTY	'Minor' (5%)	'Medium' (12%)
RISK TO PROPERTY	'Moderate' (2×10^{-3})	'Low' (2×10^{-5})
RISK TO LIFE	4.5×10^{-4}/annum	6.3×10^{-7}/annum
COMMENTS	Following implementation of the recommendations outlined in Section 3.7, the above risk levels would reduce to 'Acceptable' levels within the site.	This level of risk to life and property is **'ACCEPTABLE'.**

3.7 Conclusion and Recommendations

The proposed development is considered to be suitable for the site. The existing conditions and proposed development are considered to constitute an '**ACCEPTABLE**' risk to life and a '**LOW**' risk to property ***provided that the recommendations outlined in Table 6 are adhered to during design and construction*****.**

Table 6. Geotechnical recommendations

Recommendation	**Description**
Dilapidation Reporting	We recommend that detailed dilapidation reporting be undertaken by others (typically by the structural engineer or building inspector). These should be prepared for the adjacent properties to the east, west and south before the demolition, and before installation of shoring/support systems or excavations commence on site. It may also be necessary to include dilapidation assessment of the road reserves, pavement and paths at front of the property that may be affected by construction related activities. The inspection and preparation of the report should be in accordance with Australian Standard 4349.1–2007.
Further Geotechnical Investigation	We recommend that further testing, in the form of at least two mechanical boreholes and the installation of at least one groundwater monitoring bore, should be carried out in the area of the proposed excavation to assess expected bedrock quality prior to commencement of bulk excavation. This should be undertaken following the demolition of the existing structure to allow access to the rear of the site.

Recommendation	Description
Soil Excavation	Soil excavation will be required as part of the basement excavation. It is anticipated that these excavations will encounter shallow uncontrolled fill and sandy topsoil, sand and weathered bedrock. The excavation of soil, clay and extremely weathered rock should be possible with the use of bucket excavators and rippers, or for piered footings, traditional auger attachments. Temporary unsupported batter slopes may be considered where setbacks from existing structures and property boundaries permits. For shallow excavations (<1.0m) in soil outside the zone if influence of existing footings formed no steeper than 1V:1.5H, they should remain stable without support for a short period until permanent support is in place. Unsupported batter slopes in sandy soil will be prone to erosion in inclement weather. See Excavation Support paragraph below for advice on support required for excavated soil materials.
Rock Excavation	All excavation recommendations as outlined below should be read in conjunction with Safe Work Australia's *Code of Practice: Excavation Work*, published in October 2018. 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, existing structures and any previously installed supporting systems. Any rock breaking must be carried out only after the rock has been sawed, and in short bursts (2–5 seconds), to prevent the vibration amplifying. The break in the rock from the saw must be between the rock to be broken and the closest adjoining structure. All excavated material is to be removed from the site in accordance with current Office of Environment and Heritage (OEH) regulations.
Vibrations	The Australian Standard 2670.1–2001 'Evaluation of human exposure to whole-body vibration General requirements. Part 1: General requirements', suggests a daytime limit of 5mm/s component PPV for human comfort is acceptable. In general, vibration criteria for human disturbance are more stringent than vibration criteria for effects on building contents and building structural damage. Hence, compliance with the more stringent limits dictated for human exposure, would ensure that compliance is also achieved for the other two categories. Furthermore, it is noted that this approach satisfies the requirements of Appendix J of AS 2187.2–2006 'Explosives – storage and use', which also limits PPV to 5mm/s for residential settings. As such, we would suggest that the recommendations for method and/or equipment presented in the table below be adopted to maintain an allowable vibration limit of 5mm/s PPV.

<table>
<tr><th>Recommendation</th><th>Description</th></tr>
<tr><td></td><td>
<table>
<tr><th rowspan="2">Distance from adjoining structure (m)</th><th colspan="2">Maximum Peak Particle Velocity 5mm/sec</th></tr>
<tr><th>Equipment</th><th>Operating Limit (% of Maximum Capacity)</th></tr>
<tr><td>1.5 – 2.5</td><td>Hand-operated jackhammer only</td><td>100</td></tr>
<tr><td>3.0 – 5.0</td><td>150kg rock hammer</td><td>100</td></tr>
<tr><td>5.0 – 10.0</td><td>300kg rock hammer
or 600kg rock hammer</td><td>100 (300kg)
or 50 (600kg)</td></tr>
</table>
<p>It may be necessary to move to smaller rock hammers or to rotary grinders or rock saws if vibration limits cannot be met. (Manufactures of the plant should be contacted for information regarding peak vibration output.)</p>
<p>The propagation of vibrations can be mitigated by pulsing the use of rock hammers, i.e. short bursts, utilising line sawing along boundaries.</p>
<p>The following procedures are recommended to reduce vibrations when rock hammers are used:</p>

Line sawing the perimeter of the excavation prior to any hammering.
Excavation using hydraulic rock hammers should commence away from likely critical areas.
Maintain rock hammer orientated towards the face and enlarge excavation by breaking small wedges off the face.
Use rock hammers in short bursts only to reduce amplification of vibrations.
Maintain a sharp moil on the hammer.

<p>We recommend use of excavation contractors with proven experience in similar work, with a competent supervisor who is aware of vibration damage risks. The contractor should be provided with a full copy of this report and have all appropriate statutory and public liability insurances.</p>
<p>We recommend that continuous vibration monitoring be carried out by an independent party during all percussive excavation works. AscentGeo can be engaged to assist with the management of vibration monitoring on request.</p>
</td></tr>
<tr><td>Excavation Induced Rock Movement</td><td>Locked in stresses are present in bedrock. During excavation of the basement, these stresses will be released, which may result in lateral movement, typically along existing sub-horizontal bedding planes. These lateral movements have the potential to cause cracking in adjacent buildings and services. Maximum movement will occur towards the top and centre of the face. Re-entrant corners within the perimeter of the excavation are likely to move more than the straight sides of the excavation. Lateral movements of the edge of the excavation may be in the order of 0.5 to 1 mm per metre depth of rock excavation (ie. between 5 mm and 10 mm for a 10 m deep excavation).</td></tr>
</table>

Recommendation	Description
	Most of the stress-relief movement is expected to be complete once bulk level has been reached. Consideration should be given to the locations of internal columns, connections with perimeter walls and other design issues so that future rock stress relief movements as a result of 'creep' or from reactivation of earlier movement as a result of subsequent adjacent excavations (i.e. basements of neighbouring residences) does not affect the new structure. A gap between the proposed excavation face and the new structure should be allowed for to account for such rock stress relief movement.
Excavation Support	Temporary support and/or underpinning of the adjoining structures and the concrete wall on the rear boundary may be required where these footings are not founded on Class III sandstone or better and where proposed excavations are located within 300mm of the zone of influence of the existing structure and adjoining footings (assumed as an envelope extending below and beyond the underside of the existing footing at 1V:1H). Any temporary or permanent retaining systems are to be designed in accordance with AS 4678–2002. Test pits to confirm the foundation materials of structures within the excavation zone of influence are to be dug prior to bulk excavation by the builder. The detail of underpinning and structural support required is to be designed by the structural engineer We recommend that the underpinning required be designed as stiff retaining structures, to prevent soil loss or movement occurring under the adjoining residences. Where practical soil material overlying bedrock may be battered back to the appropriate angle, as outlined above. Exposed soil batters should be covered to prevent excessive infiltration or evaporation of moisture and to prevent erosion. If underpinning is not possible and where batters cannot be achieved due to proximity to site boundaries and existing structures, support of the soft sediments overlying bedrock will be required prior to bulk excavation. This may be in the form of contiguous or closely spaced piles, or similar, as detailed by the structural engineer. Vertical or sub-vertical excavation through competent sandstone bedrock should stand unsupported permanently, subject to inspection and approval by AscentGeo. Where permanent sandstone excavations are required, drainage channels should be installed at the base of the excavations to adequately discharge any natural seepage that may occur. Should significant geological defects such as clay seems, joints or fractures be exposed as the works progress, works should be halted and AscentGeo should be contacted immediately to inspect and provide advice on the stability of the cut faces. We recommend the project anticipate and budget for bedrock stabilisation measures. Any necessary stabilisation measures will need to be specifically designed based on the orientation and nature of the bedrock defects identified during the hold point inspections.

<table>
<tr><th>Recommendation</th><th>Description</th></tr>
<tr><td></td><td>Hold point inspections of all vertical cuts, following installation of underpinning then at drops initially not exceeding 1.0m, should be carried out by AscentGeo to allow any adverse defects to be identified and, where required, remedial measures initiated.</td></tr>
<tr><td>Retaining Structures</td><td>Retention systems should be designed by a qualified structural engineer in accordance with Australian Standard AS 4678. The following geotechnical parameters can be used for preliminary design of shoring systems to be confirmed by further geotechnical investigation.
<table>
<tr><th colspan="3"></th><th colspan="3">Earth Pressure Coefficients</th></tr>
<tr><th>(Unit) Material</th><th>Bulk Unit Weight (kN/m^3)</th><th>Friction Angle (°)</th><th>Active K_a</th><th>At Rest K_0</th><th>Passive K_p</th></tr>
<tr><td>(Unit 1) Fill / Topsoil</td><td>18</td><td>29</td><td>0.38</td><td>0.60</td><td>2.00</td></tr>
<tr><td>(Unit 2) Sand</td><td>19</td><td>29</td><td>0.33</td><td>0.50</td><td>2.00</td></tr>
<tr><td>(Unit 3) Sandstone Class IV</td><td>23</td><td>35</td><td>0.25</td><td>0.40</td><td>4.00</td></tr>
</table>
Retention systems should be designed to prevent hydrostatic pressure from developing behind the wall. As such, retaining walls to be constructed as part of the site works are to incorporate back wall subsoil drainage pipes, and 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 fine-grained sediment.
Design of appropriate retention systems should consider potential surcharges from sloping land above the wall, soil creep, adjacent structures and footings, and construction related activities such as compaction of fill, traffic of vehicles and construction plant.</td></tr>
<tr><td>Footings</td><td>We recommend that all new footings are taken to and founded directly upon the underlying sandstone bedrock (Unit 5) using piers as required.
The allowable bearing pressure for footings seated at least 500mm into sandstone bedrock of at medium strength (Class III or better) is 1000kPa. Higher allowable bearing capacities may be achievable subject to lab testing of retrieved core samples & inspection and certification of excavated footings by AscentGeo. Further investigation in the form of mechanical bore holes should be undertaken if depth to Class III bedrock is a critical design parameter.
Pier footings should be of sufficient diameter to enable effective base cleaning to be carried out during construction. To mitigate the risk of differential settlement, it is essential that all footings are founded on competent bedrock of similar consistency. This may require excavation through sandstone</td></tr>
</table>

Recommendation	Description
	floaters, over excavation through weak rock or the relocation of planned footings. **It is essential that the foundation materials of all footing excavations be inspected and approved before steel reinforcement and concrete is placed. This inspection should be scheduled while excavation plant and operators are still on site, and before steel reinforcement has been fixed or the concrete booked.**
Fills	Any fill that may be required is to comprise local sand, clay, and weathered rock. Existing organic topsoil is to be cleared in preparation for the introduction of fill. Any new fill material is to be placed in layers not more than 250mm thick and compacted to not less than 95% of Standard Optimum Dry Density at plus or minus 2% of Standard Optimum Moisture Content. If supporting pavements or slabs, any new fill must be compacted to not less than 98% of Standard Optimum Dry Density at plus or minus 2% of Standard Optimum Moisture Content for the uppermost 300mm. All new fill placement is to be carried out in accordance with AS 3798–2007 'Guidelines on earthworks for commercial and residential developments'. Fill should not be placed on the site outside of the lateral extent of new engineered retaining walls. The retaining walls should be in place prior to the placement of new fill, with suitable permanent and effective drainage of backfill.
Sediment and Erosion Control	Appropriate design and construction methods shall be required during site works to minimise erosion and provide sediment control. In particular, siltation fencing, and barriers will be required and are to be designed by others.
Hydrogeology and Stormwater Drainage	While significant groundwater was not observed in rock faces on or near the site, minor seepage may be encountered in the excavations and intermittently in the long term into a drained / unsealed basement level. Any seepage that cannot be drained should be managed by sump and pump and be disposed of in accordance with council controls. All stormwater collected from hard surfaces is to be collected and piped directly to the council stormwater network through any storage tanks or on-site detention that may be required by the regulating authorities, and in accordance with all relevant Australian Standards, council controls and the detailed stormwater management plan by others.
Inspections	It is essential that AscentGeo inspect the cut faces of any excavation at hold points initially not exceeding 1.0m drops.

Recommendation	Description
	The foundation materials of all footing excavations be visually assessed and approved by AscentGeo before steel reinforcement and concrete is placed. **Failure to engage AscentGeo for the required hold point/excavation/ foundation material inspections will negate our ability to provide final geotechnical sign off or certification.** **Occasionally, the subsurface conditions may be found to be different (or may be interpreted to be different) from those outlined herein. Variation in groundwater conditions can also occur, especially after climatic changes. If variation from expected site conditions is encountered, we recommend that you immediately contact this office.**
Conditions Relating to Design and Construction Monitoring	To comply with Northern Beaches Council conditions and/or Private Certifier requirements it may be necessary at the following stages for AscentGeo to: ● Review the geotechnical content of all structural designs prior to the issue of Construction Certificate ● Complete the abovementioned excavation hold point and/or foundation material inspections during construction to ensure compliance to design with respect to stability and geotechnical design parameters ● By Occupation Certificate stage (project completion), AscentGeo must have inspected and certified excavation/foundation materials. A final site inspection will be required at this stage before the issue of the Occupation Certificate.

Should you have any queries regarding this report, please do not hesitate to contact the author of this report, undersigned.

For and on behalf of **AscentGeo,**

C.young

Cameron Young
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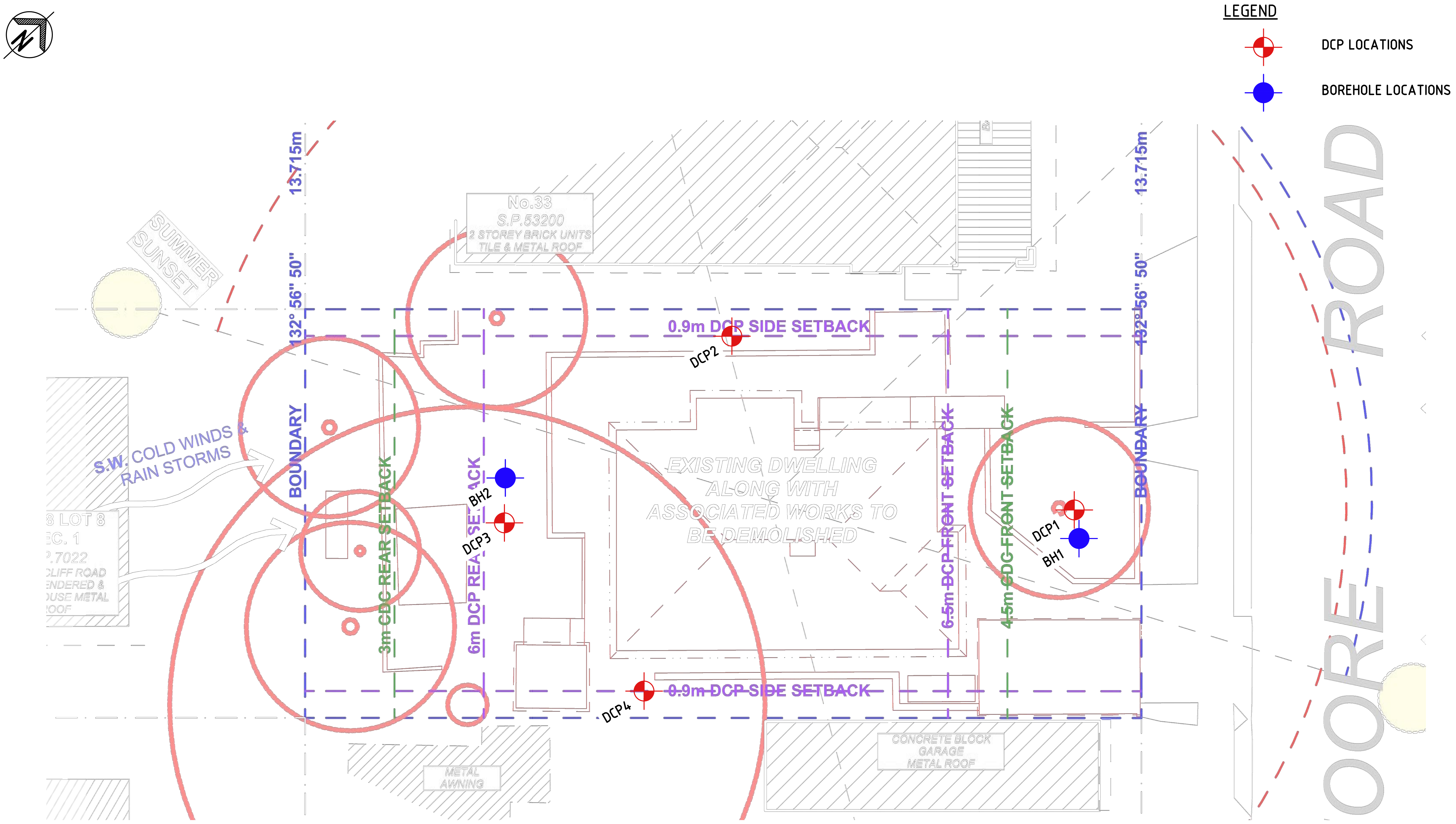
Appendix A

Site plans



SITE PLAN/GROUND TEST LOCATIONS

SCALE NTS

REV	DATE	REVISION DESCRIPTION	REV BY	CHCKD
A	21.05.25	PRELIMINARY ISSUE	VT	BM

ASCENTGEO
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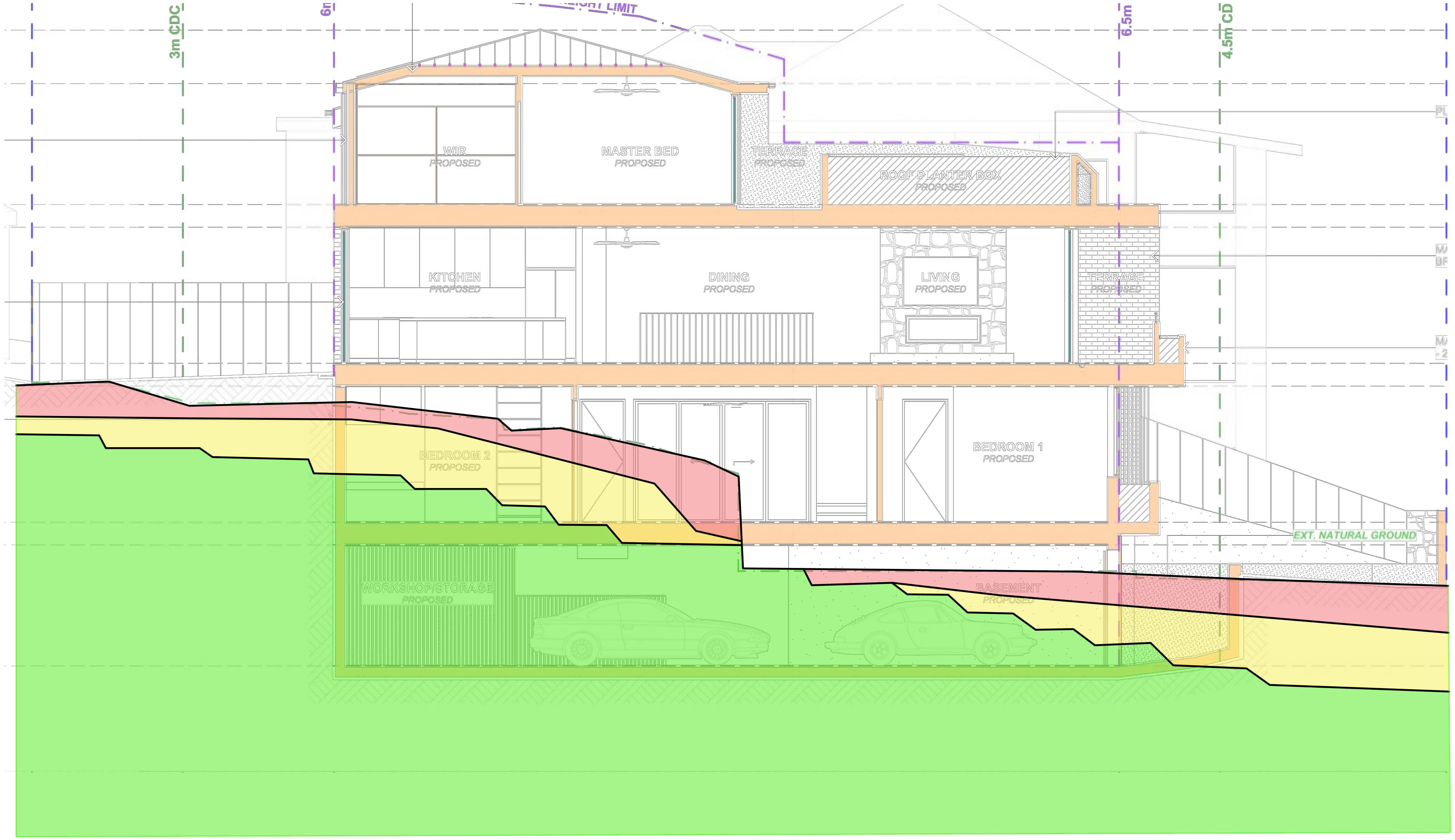
1457 Pittwater Road
North Narrabeen NSW 2101

CLIENT:
BILL DERRIN

SITE PLAN/GROUND TEST LOCATIONS
AT 35 MOORE ROAD
FRESHWATER NSW

DATE: 21/05/2025
SCALE: AS SHOWN @ A3
DRAWING TITLE: SITE PLAN
DRAWING NO: AG 25207- S1

INTERPRETED SUBSURFACE SECTION ONLY.
ACTUAL GROUND CONDITIONS MAY VARY.



LEGEND

🟥	UNCONTROLLED FILL / SILTY SAND TOPSOIL
🟨	SAND
🟩	HAWKESBURY SANDSTONE BEDROCK

INFERRED GEOLOGICAL SECTION

SCALE NTS

REV	DATE	REVISION DESCRIPTION	REV BY	CHCKD
A	21.05.25	PRELIMINARY ISSUE	VT	BM

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BILL DERRIN

INFERRED GEOLOGICAL SECTION
AT 35 MOORE ROAD
FRESHWATER NSW

DATE: 21/05/2025
SCALE: AS SHOWN @ A3
DRAWING TITLE: SECTION
DRAWING NO: AG 25207- S2

Appendix B

Site photos

Photo 1: Facing SW. Residence frontage

Photo 2: Facing SE. Residence rear

Photo 3: Facing SW along SE boundary

Photo 4: Facing SW along NW boundary

Appendix C

Bore Logs | DCP Test Results

Borehoe Log: BH01

PROJECT NUMBER AG 25207
PROJECT NAME Duplex
CLIENT Bill Derrin

DRILLING DATE 15/05/2025
METHOD HAND AUGER

ADDRESS 35 Moore Road
Freshwater NSW
Sheet 1 of 1

COMMENTS See plan for location

LOGGED BY CY

Depth (m)	Water	Graphic Log	Moisture	Material Description	USCS	Consistency	Additional Observations
	Dry		D/M	Topsoil: Silty SAND, poorly compacted, dark brown with trace of fine gravel, rootlets.	N/A	N/A	
0.2			M	SAND: medium grained. grey and pale yellow. Loose.	L	St	
0.4							
0.6							
0.8							
1							
1.2				Termination Depth at: 1.2 m Scraping on inferred bedrock			
1.4							
1.6							
1.8							
2							
2.2							
2.4							
2.6							
2.8							
3							
3.2							
3.4							
3.6							
3.8							
4							
4.2							
4.4							
4.6							
4.8							

produced by ESlog.ESdat.net on 15 May 2025

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Borehoe Log: BH02

PROJECT NUMBER AG 25207
PROJECT NAME Duplex
CLIENT Bill Derrin

DRILLING DATE 15/05/2025
METHOD HAND AUGER

ADDRESS 35 Moore Road
Freshwater NSW
Sheet 1 of 1

COMMENTS See plan for location

LOGGED BY CY

Depth (m)	Water	Graphic Log	Moisture	Material Description	USCS	Consistency	Additional Observations
	Dry		D/M	Topsoil: Silty SAND, poorly compacted, dark brown with trace of fine gravel, rootlets.	N/A	N/A	
0.2 0.4 0.6 0.8			M	SAND: medium grained. grey becoming orange. Loose.	L	St	Becomes wet towards the bedrock interface
1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8				Termination Depth at: 1.0 m Scraping on inferred bedrock			

Disclaimer Refer to report limitations

produced by ESlog.ESdat.net on 15 May 2025

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Dynamic Cone Penetration Test Report

Client:	Bill Derrin	**Job No:**	AG 25207
Project:	Duplex	**Date:**	15/5/2025
Location:	35 Moore Road, Freshwater	**Operator:**	CY
Test Procedure:	AS 1289.6.3.2 – 1997		

Test Data									
Test No: DCP 1		Test No: DCP 2		Test No: DCP 3		Test No: DCP 4		Test No:	
Test Location: Refer to Site Plan		Test Location: Refer to Site Plan		Test Location: Refer to Site Plan		Test Location: Refer to Site Plan		Test Location:	
RL:		RL:		RL:		RL:		RL:	
Soil Classification: P		Soil Classification: P		Soil Classification: P		Soil Classification: P		Soil Classification:	
Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows
0.0 – 0.3	3	0.0 – 0.3	7	0.0 – 0.3	6	0.0 – 0.3	2		
0.3 – 0.6	7	0.3 – 0.6	5	0.3 – 0.6	12 Rs	0.3 – 0.6	4		
0.6 – 0.9	12	0.6 – 0.9	14	0.6 – 0.9		0.6 – 0.9	8		
0.9 – 1.2	12	0.9 – 1.2	19 Rs	0.9 – 1.2		0.9 – 1.2	11		
1.2 – 1.5	15 Rs	1.2 – 1.5		1.2 – 1.5		1.2 – 1.5	14		
1.5 – 1.8		1.5 – 1.8		1.5 – 1.8		1.5 – 1.8	14		
1.8 – 2.1		1.8 – 2.1		1.8 – 2.1		1.8 – 2.1	21		
2.1 – 2.4		2.1 – 2.4		2.1 – 2.4		2.1 – 2.4	19		
2.4 – 2.7		2.4 – 2.7		2.4 – 2.7		2.4 – 2.7	21 Rs		
2.7 – 3.0		2.7 – 3.0		2.7 – 3.0		2.7 – 3.0			
3.0 – 3.3		3.0 – 3.3		3.0 – 3.3		3.0 – 3.3			
3.3 – 3.6		3.3 – 3.6		3.3 – 3.6		3.3 – 3.6			
3.6 – 3.9		3.6 – 3.9		3.6 – 3.9		3.6 – 3.9			
3.9 – 4.2		3.9 – 4.2		3.9 – 4.2		3.9 – 4.2			
4.2 – 4.5		4.2 – 4.5		4.2 – 4.5		4.2 – 4.5			
4.5 – 4.8		4.5 – 4.8		4.5 – 4.8		4.5 – 4.8			
DCP 1: Refusal @ 1.3m Bouncing on inferred bedrock. Brown sand on dry tip.		DCP 2: Refusal @ 1.2m Bouncing on inferred bedrock. Brown sand on dry tip.		DCP 3: Refusal @ 0.6m Bouncing on inferred bedrock. Brown sand on moist tip.		DCP 4 : Refusal @ 2.5 Bouncing on inferred bedrock. Orange dust on dry tip.			

	Weight:	9	kg
Remarks: No groundwater encountered.	Drop:	510	mm
	Rod Diameter:	16	mm

Rs = Solid ring/Hammer bouncing

Pr = Practical Refusal. Rods progressingly slowly through weathered bedrock.

D = Equipment dropping under own weight

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Appendix D

Information Sheets

General Notes About This Report

INTRODUCTION

These notes have been prepared by Ascent Geotechnical Consulting Pty Ltd (Ascent) to help our Clients interpret and understand the limitations of this report. Not all sections below are necessarily relevant to all reports.

SCOPE OF SERVICES

This report has been prepared in accordance with the scope of services set out in Ascent's proposal under Ascent's Terms and Conditions, or as otherwise agreed with the Client. The scope of work may have been limited by a range of factors including time, budget, access and/or site constraints.

RELIANCE ON INFORMATION PROVIDED

In preparing the report, Ascent has necessarily relied upon information provided by the Client and/or their Agents. Such data may include surveys, analyses, designs, maps and design plans. Ascent has not verified the accuracy or completeness of the data except as stated in this report.

GEOTECHNICAL AND ENVIRONMENTAL REPORTING

Geotechnical and environmental reporting relies on the interpretation of factual information, based on judgment and opinion, and is far less exact than other engineering or design disciplines.

Geotechnical and environmental reports are prepared for a specific purpose, development, and site, as described in the report, and may not contain sufficient information for other purposes, developments, or sites (including adjacent sites), other than that described in the report.

SUBSURFACE CONDITIONS

Subsurface conditions can change with time and can vary between test locations. For example, the actual interface between the materials may be far more gradual or abrupt than indicated.

Therefore, actual conditions in areas not sampled may differ from those predicted, since no subsurface investigation, no matter how comprehensive, can reveal all subsurface details and anomalies.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes or groundwater fluctuations can also affect subsurface conditions, and thus the continuing adequacy of a geotechnical report. Ascent should be kept informed of any such events, and should be retained to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

GROUNDWATER

Groundwater levels indicated on borehole and test pit logs are recorded at specific times. Depending on ground permeability, measured levels may or may not reflect actual levels if measured over a longer time period. Also, groundwater levels and seepage inflows may fluctuate with seasonal and environmental variations and construction activities.

INTERPRETATION OF DATA

Data obtained from nominated discrete locations, subsequent laboratory testing and empirical or external sources are interpreted by trained professionals in order to provide an opinion about overall site conditions, their likely impact with respect to the report purpose and recommended actions in accordance with any relevant industry standards, guidelines or procedures.

SOIL AND ROCK DESCRIPTIONS

Soil and rock descriptions are based on AS 1726 – 1993, using visual and tactile assessment, except at discrete locations where field and / or laboratory tests have been carried out. Refer to the accompanying soil and rock terms sheet for further information.

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This report shall not be reproduced either totally or in part without the permission of Ascent. Where information from this report is to be included in contract documents or engineering specification for the project, the entire report should be included in order to minimise the likelihood of misinterpretation.

FURTHER ADVICE

Ascent would be pleased to further discuss how any of the above issues could affect a specific project. We would also be pleased to provide further advice or assistance including:

- Assessment of suitability of designs and construction techniques;
- Contract documentation and specification;
- Construction advice (foundation assessments, excavation support).

Abbreviations, Notes & Symbols

SUBSURFACE INVESTIGATION

METHOD

Borehole Logs

AS#	Auger screwing (#-bit)
AD#	Auger drilling (#-bit)
B	Blank bit
V	V-bit
T	TC-bit
HA	Hand auger
R	Roller/tricone
W	Washbore
AH	Air hammer
AT	Air track
LB	Light bore push tube
MC	Macro core push tube
DT	Dual core push tube

Excavation Logs

BH	Backhoe/excavator bucket
NE	Natural exposure
HE	Hand excavation
X	Existing excavation

Cored Borehole Logs

NMLC	NMLC core drilling
NQ/HQ	Wireline core drilling

SUPPORT

Borehole Logs

C	Casing
M	Mud

Excavation Logs

S	Shoring
B	Benched

SAMPLING

B	Bulk sample
D	Disturbed sample
U#	Thin-walled tube sample (#mm diameter)
ES	Environmental sample
EW	Environmental water sample

FIELD TESTING

PP	Pocket penetrometer (kPa)
DCP	Dynamic cone penetrometer
PSP	Perth sand penetrometer
SPT	Standard penetration test
PBT	Plate bearing test
s_u	Vane shear strength peak/residual (kPa) and vane size (mm)
N*	SPT (blows per 300mm)
Nc	SPT with solid cone
R	Refusal

**denotes sample taken*

BOUNDARIES

_______	Known
_ _ _ _ _	Probable
---------	Possible

SOIL

MOISTURE CONDITION

D	Dry
M	Moist
W	Wet
Wp	Plastic Limit
Wl	Liquid Limit
MC	Moisture Content

CONSISTENCY

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
Fb	Friable

DENSITY INDEX

VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

USCS SYMBOLS

GW	Well graded gravels and gravel-sand mixtures, little or no fines
GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
GM	Silty gravels, gravel-sand-silt mixtures
GC	Clayey gravels, gravel-sand-clay mixtures
SW	Well graded sands and gravelly sands, little or no fines
SP	Poorly graded sands and gravelly sands, little or no fines
SM	Silty sand, sand-silt mixtures
SC	Clayey sand, sand-clay mixtures
ML	Inorganic silts of low plasticity, very fine sands, rock flour, silty or clayey fine sands
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays
OL	Organic silts and organic silty clays of low plasticity
MH	Inorganic silts of high plasticity
CH	Inorganic clays of high plasticity
OH	Organic clays of medium to high plasticity
PT	Peat muck and other highly organic soils

ROCK

WEATHERING

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
DW*	Distinctly Weathered
SW	Slightly Weathered
FR	Fresh

**covers both HW & MW*

STRENGTH

EL	Extremely Low
VL	Very Low
L	Low
M	Medium
H	High
VH	Very High
EH	Extremely High

ROCK QUALITY DESIGNATION (%)

$$= \frac{\underline{\text{sum of intact core pieces} > 100\text{mm}}}{\text{total length of section being evaluated}} \times 100$$

CORE RECOVERY (%)

$$= \frac{\underline{\text{core recovered}}}{\text{core llft}} \times 100$$

NATURAL FRACTURES

Type

JT	Joint
BP	Bedding plane
SM	Seam
FZ	Fractured zone
SZ	Shear zone
VN	Vein

Infill or Coating

Cn	Clean
St	Stained
Vn	Veneer
Co	Coating
Cl	Clay
Ca	Calcite
Fe	Iron oxide
Mi	Micaceous
Qz	Quartz

Shape

pl	Planar
cu	Curved
un	Undulose
st	Stepped
ir	Irregular

Roughness

pol	Polished
slk	Slickensided
smo	Smooth
rou	Rough

Soil & Rock Terms

SOIL

MOISTURE CONDITION

Term	Description
Dry	Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through the hand.
Moist	Feels cool and darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet	As for moist, but with free water forming on hands when handled.

For cohesive soils, moisture content may also be described in relation to plastic limit (W_P) or liquid limit (W_L). [>> much greater than, > greater than, < less than, << much less than].

CONSISTENCY

Term	c_u (kPa)	Term	c_u (kPa)
Very Soft	< 12	Very Stiff	100 - 200
Soft	12 - 25	Hard	> 200
Firm	25 - 50	Friable	-
Stiff	50 - 100		

DENSITY INDEX

Term	I_D (%)	Term	I_D (%)
Very Loose	< 15	Dense	65 – 85
Loose	15 – 35	Very Dense	> 85
Medium Dense	35 – 65		

PARTICLE SIZE

Name	Subdivision	Size (mm)
Boulders		> 200
Cobbles		63 - 200
Gravel	coarse	20 - 63
	medium	6 - 20
	fine	2.36 - 6
Sand	coarse	0.6 -2.36
	medium	0.2 - 0.6
	fine	0.075 - 0.2
Silt & Clay		< 0.075

MINOR COMPONENTS

Term	Proportion by Mass coarse grained	fine grained
Trace	≤ 5%	≤ 15%
Some	5 - 2%	15 - 30%

SOIL ZONING

Layers	Continuous exposures
Lenses	Discontinuous layers of lenticular shape
Pockets	Irregular inclusions of different material

SOIL CEMENTING

Weakly	Easily broken up by hand
Moderately	Effort is required to break up the soil by hand

SOIL STRUCTURE

Massive	Coherent, with any partings both vertically and horizontally spaced at greater than 100mm
Weak	Peds indistinct and barely observable on pit face. When disturbed approx. 30% consist of peds smaller than 100mm
Strong	Peds are quite distinct in undisturbed soil. When disturbed >60% consists of peds smaller than 100mm

ROCK

SEDIMENTARY ROCK TYPE DEFINITIONS

Rock Type	**Definition** (more than 50% of rock consists of….)
Conglomerate	… gravel sized (> 2mm) fragments
Sandstone	… sand sized (0.06 to 2mm) grains
Siltstone	… silt sized (<0.06mm) particles, rock is not laminated
Claystone	… clay, rock is not laminated
Shale	… silt or clay sized particles, rock is laminated

STRENGTH

Term	Is50 (MPa)	Term	Is50 (MPa)
Extremely Low	< 0.03	High	1 – 3
Very Low	0.03 – 0.1	Very High	3 – 10
Low	0.1 – 0.3	Extremely High	> 10
Medium	0.3 – 1		

WEATHERING

Term	Description
Residual Soil	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident
Extremely Weathered	Rock is weathered to such an extent that it has 'soil' properties, i.e. it either disintegrates or can be remoulded, in water. Fabric of original rock is still visible
Highly Weathered	Rock strength usually highly changed by weathering; rock may be highly discoloured
Moderately Weathered	Rock strength usually moderately changed by weathering; rock may be moderately discoloured
Distinctly Weathered	See 'Highly Weathered' or 'Moderately Weathered'
Slightly Weathered	Rock is slightly discoloured but shows little or no change of strength from fresh rock
Fresh	Rock shows no signs of decomposition or staining

NATURAL FRACTURES

Type	Description
Joint	A discontinuity or crack across which the rock has little or no tensile strength. May be open or closed
Bedding plane	Arrangement in layers of mineral grains of similar sizes or composition
Seam	Seam with deposited soil (infill), extremely weathered insitu rock (XW), or disoriented usually angular fragments of the host rock (crushed)
Shear zone	Zone with roughly parallel planar boundaries, of rock material intersected by closely spaced (generally < 50mm) joints and /or microscopic fracture (cleavage) planes
Vein	Intrusion of any shape dissimilar to the adjoining rock mass. Usually igneous

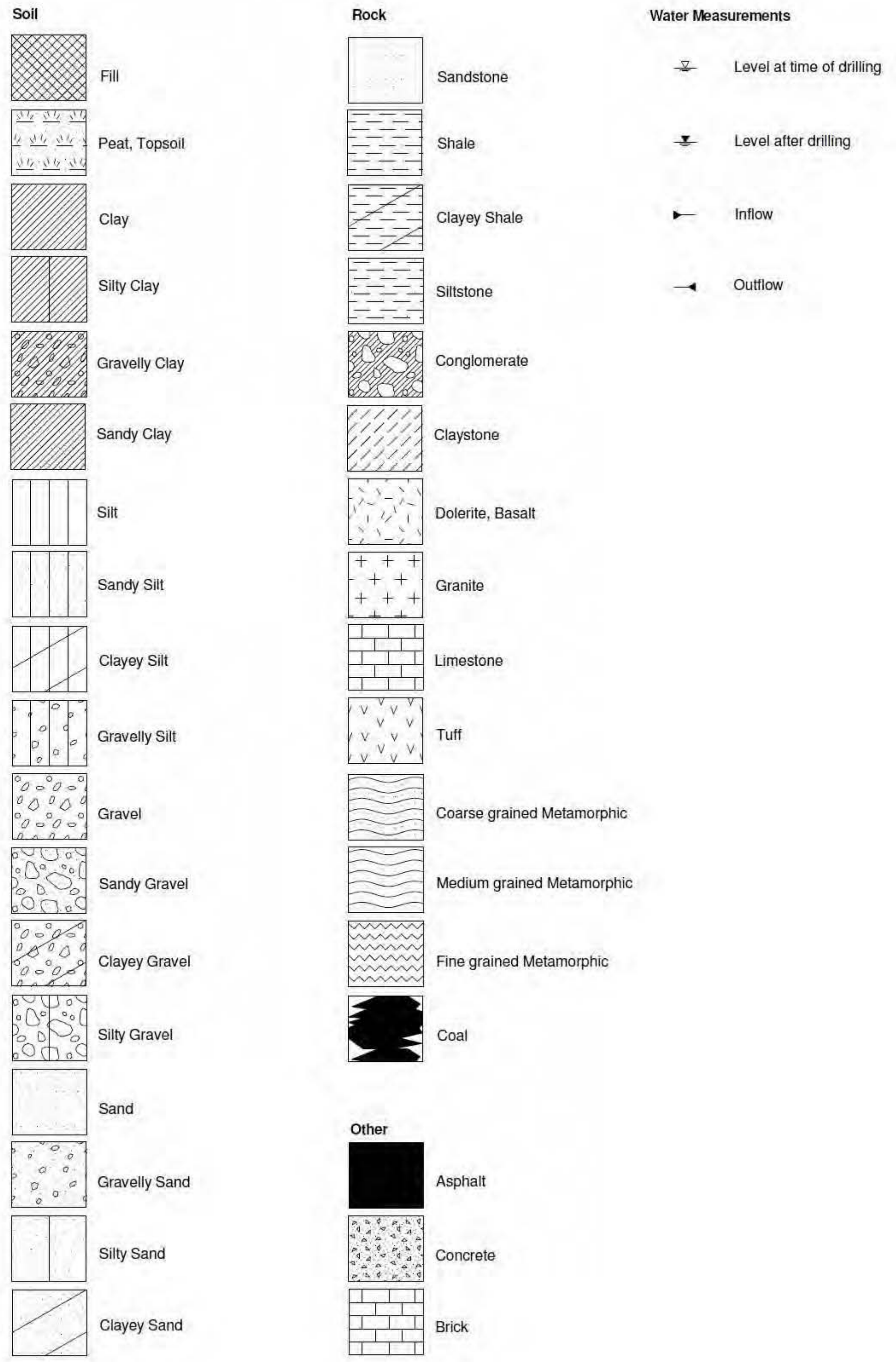
Shape	Description
Planar	Consistent orientation
Curved	Gradual change in orientation
Undulose	Wavy surface
Stepped	One or more well defined steps
Irregular	Many sharp changes in orientation

Infill or Coating	Description
Clean	No visible coating or discolouring
Stained	No visible coating but surfaces are discoloured
Veneer	A visible coating of soil or mineral, too thin to measure; may be patchy
Coating	Visible coating ≤ 1mm thick. Ticker soil material described as seam

Roughness	Description
Polished	Shiny smooth surface
Slickensided	Grooved or striated surface, usually polished
Smooth	Smooth to touch. Few or no surface irregularities
Rough	Many small surface irregularities (amplitude generally < 1mm). Feels like fine to coarse sandpaper

Note: soil and rock descriptions are generally in accordance with AS1726-1993 Geotechnical Site Investigations

Graphic Symbols Index



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.

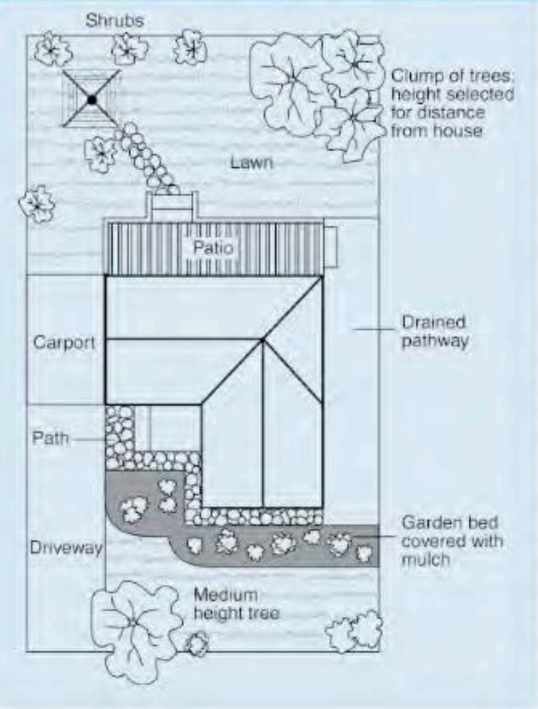
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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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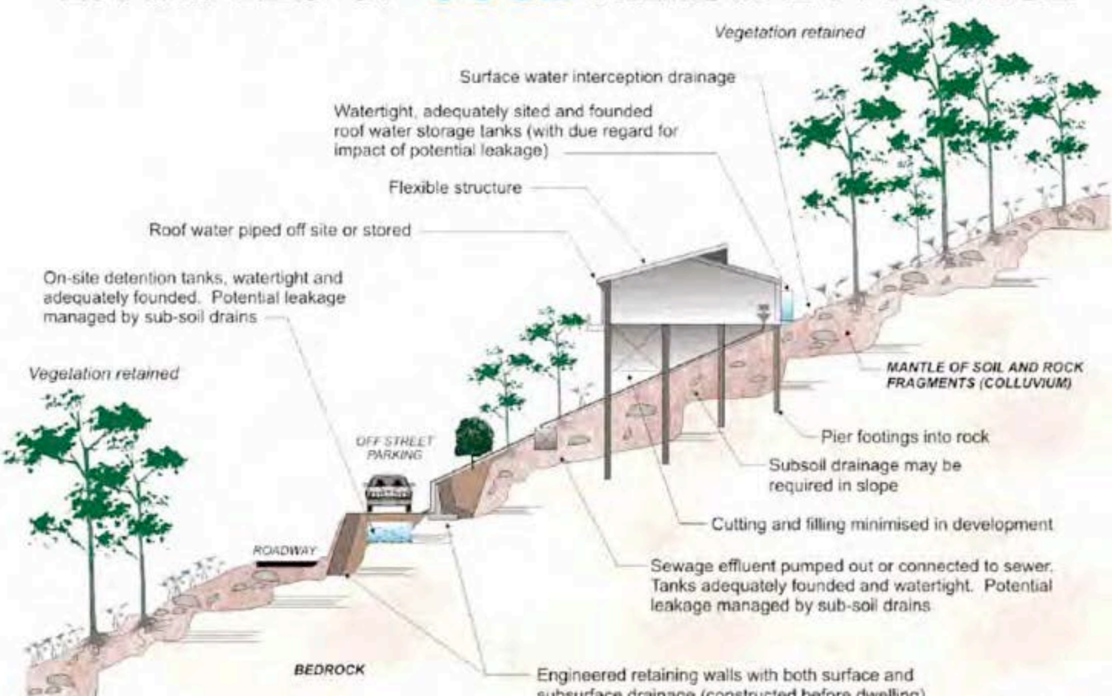
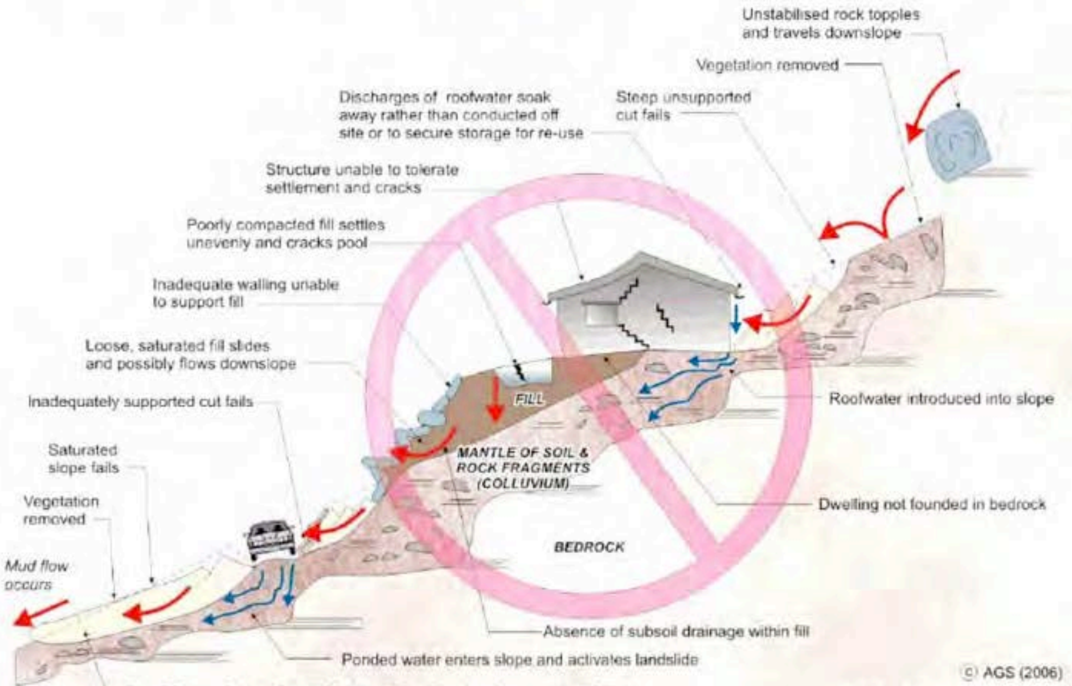
EXAMPLES OF **GOOD** HILLSIDE PRACTICE



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	A
10^{-2}		100 years	20 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-3}$	1000 years	200 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-4}$	10,000 years	2000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-5}$	100,000 years	20,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}	$5x10^{-6}$	1,000,000 years	200,000 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%		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%	100%	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%	40%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	10%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%	1%	Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

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

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

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

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.