Geotechnical Assessment

Project: Dual Occupancy Dwellings
52A Abbott Road, North Curl Curl NSW

Prepared for:
Lukas Paling

Ref: AG 25179
16 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

✉ admin@ascentgeo.com.au ☎ 9913 3179 🌐 ascentgeo.com.au

AG 25179
16 May 2025

Geotechnical Assessment

For **Dual Occupancy Dwellings** at

52A Abbott Road, North Curl Curl

Document Status		Approved for Issue	
Version	**Author**	**Reviewer**	**Date**
1	C.young Cameron Young BEnvSci Geol MAIG	Ben Morgan BScGeol MAIG RPGeo	16.05.2025

Document Distribution				
Version	**Copies**	**Format**	**To**	**Date**
1	1	PDF	Lukas Paling	16.05.2025
1	1	PDF	Action Plans	16.05.2025

Limitations

This report has been prepared for Lukas Paling in accordance with AscentGeo's fee proposal dated 22 April 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 52A Abbott Road, North Curl Curl (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 59 in DP 225371 being 52A Abbott Road, North Curl Curl.

Details of the proposed development are outlined in a series of architectural drawings prepared by Action Plans, drawing numbers DA00 – DA19, dated 10 April 2025.

The works comprise the following:

- Demolition of existing dwelling
- Construction of two storey dual occupancy dwelling with basement carpark level
- Construction of two in-ground swimming pools and associated works.
- Various 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 site conditions

Parameter	**Description**
Site visit	Cameron Young, Engineering Geologist – 24 April 2025
Site address	52A Abbott Road, North Curl Curl – Lot 59 in DP 225371
Site area m^2 (approx.)	612.92m^2 (by calc.)
Existing development	Single storey brick dwelling. Concrete driveway and parking area.
Slope Aspect	South
Average gradient	< 5 degrees
Vegetation	Lawn areas. Small shrubs.
Retaining structures	None.
Neighbouring environment	Residentially developed to the south, east and west. Abbott Road to the south. Curl Curl North Public School to the north.

Figure 1. Site location – 52A Abbott Road, North Curl Curl NSW (© SIX Maps NSW Gov)

2.2 Site Description

The subject site is situated in a residential area, is a battle axe shape and is accessed via a long concrete driveway off the northern side of Abbott Road. The site is bounded by residential properties to the south, east and west. Curl Curl North public School adjoins the northern site boundary. The site is on very gently sloping ground with a gradient of <5 degrees, with southerly aspect (falling to its frontage). The immediately adjoining areas are of a similar topography.

The existing building at the site is a single-storey brick house with a grassed front yard and smaller grassed backyard areas. Bedrock was not outcropping on the subject site or in the immediate adjoining areas. The specific history of the site is unknown, however the area between Harbord Road and North Curl Curl Beach, south of Abbott Road has been previously utilised as a council tip, as such, it is possible that portions of the subsurface of the subject site contain buried fill material.

A site plan is included in Appendix A. 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 Quaternary age Alluvial fan deposit sediments comprising fluvially deposited quartz lithic sand, silt gravel and clay and overlying Hawkesbury Sandstone (Rh).

The soil profile consists of shallow uncontrolled fill and sand topsoil (O & A Horizons), deep alluvial sand (B Horizon) and weathered bedrock (C Horizon). The depth to bedrock is unconfirmed as bedrock was not encountered in our testing to 4.5m depth.

Note: The local geology is comprised predominantly of deep alluvial sands overlying sandstone. The sandstone bedrock is not expected to be encountered within practical excavation depths for this project.

2.4 Fieldwork

A site visit and investigation were undertaken on 24 April 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

Three hand auger boreholes (BH01 – BH03) 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

Three (3) 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 @ 0.6m Bouncing on suspected hard fill.
DCP 2	End test at 4.5m. Grey sand on moist tip. Rods moist (not wet). Bedrock not encountered.
DCP 3	Practical refusal, no longer progressing in inferred dense sand. Rods moist (not wet). Bedrock not encountered.

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

Unit	Material	Comments
1	**Topsoil / Fill**	Sandy topsoil and fill material. Unit 1 is inferred to be uncontrolled and poorly compacted
2	**Sand**	Fine to medium grained sand of alluvial origin, to depths up to and greater than 4.5m. Loose at shallow depths and becoming medium dense at depth.
3	**Sandstone**	Not encountered within 4.5m depth. Depth to bedrock is unknown.

* 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

Due to the low bearing capacity of the underling sandy soils encountered on site, the Site is classified as **"P"** in accordance with AS 2870–2011.

Table 4. Site classification table for residential slabs and footings (AS 2870-2011)

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
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes.	>75mm

Site Classification	Soil description	Expected range of movement
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 to 4.5m depth.

Due to the site elevation and position of the site relative to the slope and the underlying geology, there is the potential that the regional permanent groundwater water table may be encountered within the depths of the piers recommended for excavation support.

Water NSW Borehole GW110933 is located on the northern side of Abbott Road, approximately 80m south-west of the subject site, notes a water bearing zone from 1.9m depth.

Dedicated groundwater monitoring was not within the scope of this assessment, as such we recommend preconstruction or construction stage groundwater monitoring prior to commencement of excavations or installation of shoring.

The project should allow for fluctuations of the water table. Due to the sandy soil, it is not possible to put a number on expected fluctuations, however fluctuations >1m are possible in sand.

The slab should be designed to resist hydrostatic pressures, similarly, the piles should be designed to resist lateral pressure from groundwater.

Intermittent groundwater to the basement level is possible. If a drained basement design is adopted the pump out system should anticipate this and be designed by qualified hydrologic engineer.

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.

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.
- 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: 52A Abbott Road, North Curl Curl NSW (© **NBC Maps**)

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, Public School and the road reserve.

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 proposed excavations.

Table 5. Risk analysis summary

HAZARDS	HAZARD ONE
TYPE	Failure of the proposed excavations
LIKELIHOOD	‘Possible’ (10^{-3})
CONSEQUENCES TO PROPERTY	‘Minor’ (5%)
RISK TO PROPERTY	‘Moderate’ (2×10^{-3})
RISK TO LIFE	4.5×10^{-4}/annum
COMMENTS	Following implementation of the recommendations outlined in Section 3.7, the above risk levels would reduce to ‘Acceptable’ levels within the site.

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, undertaken by others (typically by a structural engineer or licenced building inspector), be prepared for the immediately adjacent properties, road, footpath and any affected infrastructure before any demolition, installation of shoring systems or excavations commence on site. The aim of the dilapidation surveys is to establish a detailed condition report prior to commencement of works to allow an accurate assessment of claims of damage resulting from construction related activities.
Soil Excavation	All excavation recommendations as outlined below should be read in conjunction with Safe Work Australia's *Code of Practice: Excavation Work*, published October 2018. Soil excavation, expected to extend ~2.4m from current surface levels, will be required for the construction of the basement floor levels. Soil excavations will also be required for construction of the in-ground swimming pools. It is anticipated that these excavations will encounter shallow uncontrolled fill and sandy topsoil and sand, increasing in density with depth. The excavation of soil materials should be possible with the use of bucket excavators and rippers, or for piered footings, traditional auger attachments. There is the potential the buried fill materials may be encountered in the excavations. Temporary batter slopes may be considered where setbacks from existing structures and property boundaries permits. For shallow excavations (<1.0m), provided the residual soil is battered back to a minimum of 35 degrees, 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. All excavations >1.0m on site must be supported by engineer designed retaining walls to be in place prior to the commencement of any site excavation. No significant rock excavation is anticipated for the completion of the proposed works. All excavated material is to be removed from the site in accordance with current Office of Environment and Heritage (OEH) regulations.

Recommendation	Description
Vibrations	During the excavation it may be necessary to use appropriate methods and equipment to keep ground vibration within acceptable limits. The Australian Standard AS 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. If necessary, we would suggest that allowable vibration limits for machinery used for excavation or installation of shoring systems be set at 5mm/s PPV, and monitoring devices installed at the footing level of any adjacent structures. Manufactures of the adopted plant should be contacted for information regarding peak vibration output.
Excavation Support	Where vertical excavation is required to enable construction (or the recommended maximum temporary batter slopes cannot be maintained with suitable clearance to site boundaries), it will be necessary to provide permanent excavation support around the perimeter. This support may comprise internally braced contiguous/secant bored piles, sheet piles or equivalent to be designed by the structural engineer. All excavation retention systems are to be designed to comply with Councils minimum setbacks as advised in the relevant Development Control Plan. Embedment below excavation depth may be required to maintain acceptable Factors of Safety (FOS) against wall rotation. Typical embedment depth below excavation in uniform sand is close to twice the retained height and target FOS values for temporary retaining structures range from 1.25 to 2.0 depending on wall behaviour and analysis method. It is critical that the basement excavation support system be installed before excavation commences. The type of support system selected must not contain gaps that sand grains could pass through. If upon excavation there are gaps discovered, then these are to be sealed immediately before excavation progresses. When considering the design of the excavation support system, it will be necessary to include surcharge loading from structures on adjoining properties, any ground surface slope, and the effects of ground water. Where the structures in adjoining properties are within the zone of influence of the excavation, it will be necessary to adopt at rest Ko, earth pressure coefficients when designing the temporary support system and stiffness of the wall should attempt to minimise wall movement. Cantilever walls will experience deflection during excavation and should only be adopted if the impact of calculated wall deflection can be tolerated by adjacent assets.

<table>
<tr><th>Recommendation</th><th>Description</th></tr>
<tr><td></td><td>Internal bracing can be used to provide wall restraint, reducing potential wall deflection and shoring embedment depth. If anchors or similar supporting measures extend into an adjoining property, it will be necessary to obtain the permission of the property owners. It is not anticipated that any temporary or permanent anchors will be required under council road reserve or other council property. When props or anchors are used for support, a rectangular earth pressure distribution should be adopted on the active side of the support. Ko should also be used to design the permanent support.

Further investigation in the form of a mechanical auger/borehole will be required if confirmation of depth to bedrock is a required parameter for the design of shoring/excavation support.</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 using the following geotechnical parameters:

<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>2.50</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 adjacent structures and footings, and construction related activities such as compaction of fill, traffic of vehicles and construction plant.

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.</td></tr>
<tr><td>Footings</td><td>Deep sands with low bearing strength were encountered from current surface levels across the area of the proposed works. The loose sand could provide a maximum allowable bearing pressure of 50 kPa. To achieve higher bearing pressures (100–150 kPa), it may be necessary to over excavate and compact, reintroducing the desired footing depth is achieved. excavated material should be reintroduced and compacted in layers of no greater than 150mm at</td></tr>
</table>

Recommendation	Description
	a time. We would suggest a minimum of 600mm of compacted material would be appropriate to achieve tolerable allowable bearing capacities. The thickness of over excavation and replacement will depend on individual footing load and geometry. Footing width may be increased to reduce bearing capacity requirement and improve access for plate compactors, rollers or other plant required for compaction. Alternatively, the use of screw piles may provide a practical solution where piles can be installed to desired bearing strength/torque parameters as specified by the structural engineer. Other propriety concrete free footings may be suitable. **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 concrete booked.** **If screw piles are adopted, the structural engineer is to specify the helix size appropriate to the described soil conditions, give consideration to the presence of a water table and the specialist installer must provide certification of pile installation parameters in accordance with the structural plans. This certification should be forwarded to AscentGeo.**
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.

Recommendation	Description
Stormwater Disposal	The effective management of ground and surface water on site is an important factor in maintaining the long-term performance of built structures, and the stability of the block more generally. It is essential that gutters, downpipes, drains, pipes, and connections are appropriately sized, functioning effectively, and discharging appropriately via non-erosive discharge. 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 and the detailed stormwater management plan by others. Saturation of soils is one of the key triggers for many landslide events and a significant factor in destabilisation of structures over time. As such, the review and design of stormwater systems must consider climate change and the increased potential for periods of concentrated heavy rainfall.
Inspections	It is essential that 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.**
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 BEnvSci Geol MAIG
Engineering Geologist

BENJAMIN J. MORGAN
RPGeo No:
10269

Ben Morgan BScGeol MAIG RPGeo
Managing Director | Engineering Geologist

4 References

Australian Geomechanics Society Landslide Taskforce, Landslide Practice Note Working Group 2007, *Practice note guidelines for landslide risk management 2007*, *Australian Geomechanics Journal*, vol. 42, no. 1, pp. 63–114.

Colquhoun, GP, Hughes, KS, Deyssing, L, Ballard, JC, Phillips, G, Troedson, AL, Folkes, CB & Fitzherbert, JA 2024, *The Geological Survey of New South Wales (GSNSW) Seamless Geology Project, Version 2.4, May 2024*, State of New South Wales and Department of Regional NSW, accessed 23 April 2025, https://minview.geoscience.nsw.gov.au.

NSW Department of Finance, Services and Innovation n.d., *Spatial Information Viewer*, accessed 23 April 2025, https://maps.six.nsw.gov.au.

Northern Beaches Council n.d., *Online mapping: Warringah Landslip Risk Map (WLEP 2011)*, accessed 23 April 2025, https://www.northernbeaches.nsw.gov.au.

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

Safe Work Australia 2018, *Code of practice: Excavation work*, October, Safe Work Australia, Canberra.

Standards Australia 1997, *Methods of testing soils for engineering purposes – Soil strength and consolidation tests – Determination of permeability of a soil – Constant head method for a remoulded specimen*, AS 1289.6.3.2–1997, Standards Australia, Sydney.

Standards Australia 2001, *Evaluation of human exposure to whole-body vibration – Part 1: General requirements*, AS 2670.1–2001, Standards Australia, Sydney.

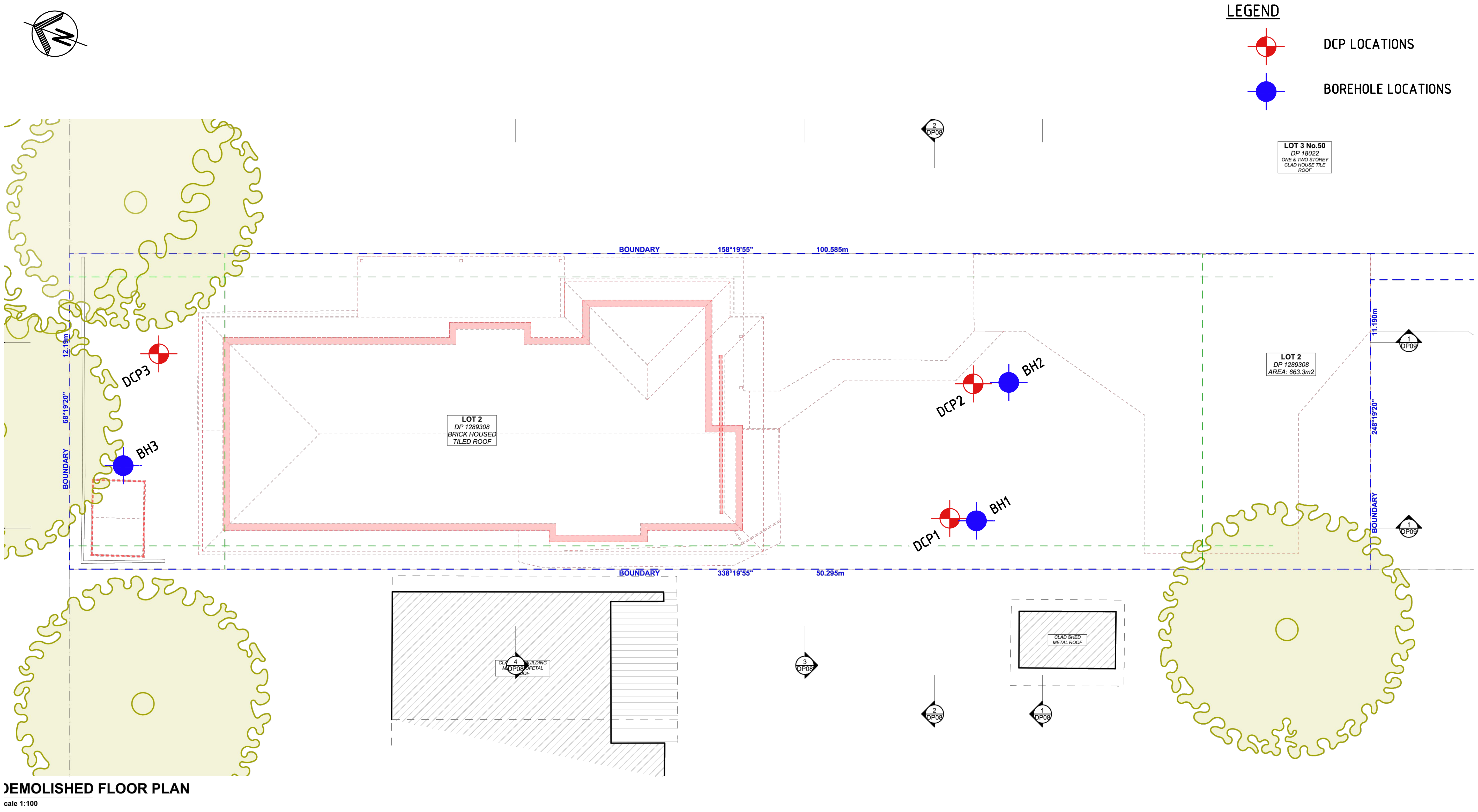
Standards Australia 2011a, *Residential slabs and footings*, AS 2870–2011, Standards Australia, Sydney.

Standards Australia 2011b, *Structural design actions – Part 2: Wind actions*, AS 1170.2–2011, Standards Australia, Sydney.

Standards Australia 2017, *Geotechnical site investigations*, AS 1726–2017, Standards Australia, Sydney.

Appendix A

Site plans



SITE PLAN/GROUND TEST LOCATIONS

SCALE NTS

REV	DATE	REVISION DESCRIPTION	REV BY	CHCKD
A	15.05.25	PRELIMINARY ISSUE	VT	BM

ASCENTGEO
GEOTECHNICAL CONSULTING

ABN: 71 621 428 402
www.ascentgeo.com.au

(02) 9913 3179
admin@ascentgeo.com.au

1457 Pittwater Road
North Narrabeen NSW 2101

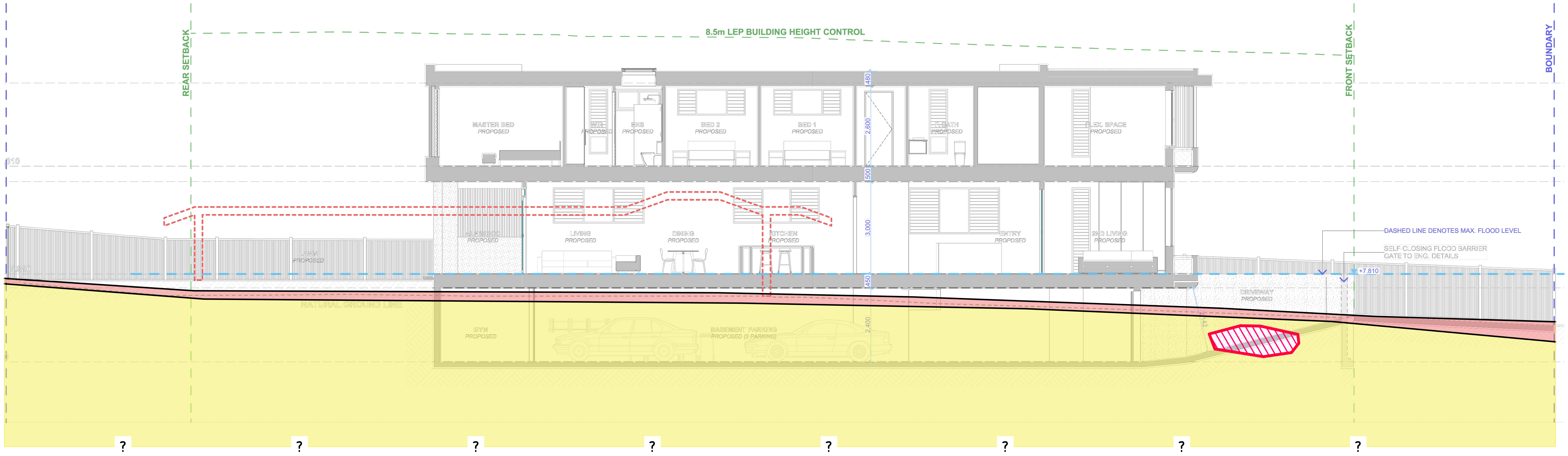
CLIENT:
LUKAS PALING

COPYRIGHT:
THE INFORMATION CONTAINED IN THIS DOCUMENT IS THE PROPERTY OF ASCENT GEOTECHNICAL CONSULTING. COPYING OF THIS MATERIAL IN WHOLE OR IN PART WITHOUT THE WRITTEN PERMISSION OF ASCENT GEOTECHNICAL CONSULTING CONSTITUTES AN INFRINGEMENT OF COPYRIGHT LAWS.

SITE PLAN/GROUND TEST LOCATIONS
AT 52A ABBOTT ROAD
CURL CURL NSW

DATE: 15/05/2025
SCALE: AS SHOWN @ A3
DRAWING TITLE: SITE PLAN
DRAWING NO: AG 25179- S1

INTERPRETED SUBSURFACE SECTION ONLY.
ACTUAL GROUND CONDITIONS MAY VARY.



LEGEND

🟥	SANDY TOPSOIL / UNCONTROLLED FILL
▨	POSSIBLE HARD FILL, EXTENT UNKNOWN
🟨	ALLUVIAL SAND
— ? —	DEPTH TO BEDROCK UNKNOWN

INFERRED GEOLOGICAL SECTION

SCALE NTS

REV	DATE	REVISION DESCRIPTION	REV BY	CHCKD
A	15.05.25	PRELIMINARY ISSUE	VT	BM

ASCENTGEO
GEOTECHNICAL CONSULTING

ABN: 71 621 428 402
www.ascentgeo.com.au

(02) 9913 3179
admin@ascentgeo.com.au

1457 Pittwater Road
North Narrabeen NSW 2101

CLIENT:
LUKAS PALING

COPYRIGHT:
THE INFORMATION CONTAINED IN THIS DOCUMENT IS THE PROPERTY OF ASCENT GEOTECHNICAL CONSULTING. COPYING OF THIS MATERIAL IN WHOLE OR IN PART WITHOUT THE WRITTEN PERMISSION OF ASCENT GEOTECHNICAL CONSULTING CONSTITUTES AN INFRINGEMENT OF COPYRIGHT LAWS.

INFERRED GEOLOGICAL SECTION
AT 52A ABBOTT ROAD
CURL CURL NSW

DATE: 15/05/2025
SCALE: AS SHOWN @ A3
DRAWING TITLE: SECTION
DRAWING NO: AG 25179- S2

Appendix B

Site photos

Photo 1: Looking north, residence frontage

Photo 2: Looking south, residence rear.

Photo 3: Looking south along western boundary

Photo 4: Looking south along eastern boundary

Appendix C

Bore Logs | DCP Test Results

Borehoe Log: BH01

PROJECT NUMBER AG 25179
PROJECT NAME Dual Occupancy Dwellings
CLIENT Lukas Paling

DRILLING DATE 24/04/2025
METHOD HAND AUGER

ADDRESS 52A Abott Road
Curl Curl 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
0.2 0.4	Dry		M	FILL: SAND. Dark grey. Fine to medium grained. Loose.	N/A	N/A	
0.6 0.8 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				Auger scraping and grinding on hard surface, possible buried hard fill			

Disclaimer Refer to report limitations

produced by ESlog.ESdat.net on 24 Apr 2025

ASCENTGEO
GEOTECHNICAL CONSULTING

Borehoe Log: BH02

PROJECT NUMBER AG 25179
PROJECT NAME Dual Occupancy Dwellings
CLIENT Lukas Paling

DRILLING DATE 24/04/2025
METHOD HAND AUGER

ADDRESS 52A Abott Road
Curl Curl 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
0.2	Dry		M	Topsoil / Fill: SAND. Dark grey. Fine to medium grained. Loose.	N/A	N/A	
0.4 0.6 0.8 1 1.2 1.4 1.6 1.8				SAND: Light grey to light brown to greyey brown. Medium grained. Loose and becoming medium dense with depth. Moisture increasing with depth.	SC	L - MD	
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				End test at 2.0m max depth of hand auger. Bedrock not encountered. Water table not encountered.			

Disclaimer Refer to report limitations

Borehoe Log: BH03

PROJECT NUMBER AG 25179
PROJECT NAME Dual Occupancy Dwellings
CLIENT Lukas Paling

DRILLING DATE 24/04/2025
METHOD HAND AUGER

ADDRESS 52A Abott Road
Curl Curl 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
0.2	Dry		M	Topsoil / Fill: SAND. Dark grey. Fine to medium grained. Loose. Grass Rootlets.	N/A	N/A	
0.4 0.6 0.8 1 1.2 1.4 1.6 1.8				SAND: Light grey to light brown. Medium grained. Loose and becoming medium dense with depth. Moisture increasing with depth.	SC	L - MD	
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				End test at 2.0m max depth of hand auger. Bedrock not encountered. Water table not encountered.			

Disclaimer Refer to report limitations

produced by ESlog.ESdat.net on 24 Apr 2025

ASCENTGEO
GEOTECHNICAL CONSULTING

1457 Pittwater Road, North Narrabeen NSW 2101
T: (02) 9913 3179 E: admin@ascentgeo.com.au

Dynamic Cone Penetration Test Report

Client:	Lukas Paling	**Job No:**	AG 25179
Project:	Dual Occupancy Dwellings	**Date:**	24/4/2025
Location:	52A Abbott Road, North Curl Curl	**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:		Test No:	
Test Location: Refer to Site Plan		Test Location: Refer to Site Plan		Test Location: Refer to Site Plan		Test Location:		Test Location:	
RL:		RL:		RL:		RL:		RL:	
Soil Classification: P		Soil Classification: P		Soil Classification: P		Soil Classification:		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	3	0.0 – 0.3	2				
0.3 – 0.6	1	0.3 – 0.6	3	0.3 – 0.6	3				
0.6 – 0.9	10 Rs	0.6 – 0.9	2	0.6 – 0.9	4				
0.9 – 1.2		0.9 – 1.2	12	0.9 – 1.2	4				
1.2 – 1.5		1.2 – 1.5	14	1.2 – 1.5	14				
1.5 – 1.8		1.5 – 1.8	13	1.5 – 1.8	15				
1.8 – 2.1		1.8 – 2.1	19	1.8 – 2.1	19				
2.1 – 2.4		2.1 – 2.4	15	2.1 – 2.4	22				
2.4 – 2.7		2.4 – 2.7	14	2.4 – 2.7	21				
2.7 – 3.0		2.7 – 3.0	18	2.7 – 3.0	27				
3.0 – 3.3		3.0 – 3.3	22	3.0 – 3.3	33				
3.3 – 3.6		3.3 – 3.6	23	3.3 – 3.6	39				
3.6 – 3.9		3.6 – 3.9	24	3.6 – 3.9	45 Pr				
3.9 – 4.2		3.9 – 4.2	34	3.9 – 4.2					
4.2 – 4.5		4.2 – 4.5	37 EOT	4.2 – 4.5					
4.5 – 4.8		4.5 – 4.8		4.5 – 4.8					
DCP 1: Refusal @ 0.6m Bouncing on possible hard fill.		DCP 2: End test at 4.5m. Grey sand on moist tip. Rods moist (not wet). Bedrock not encountered.		DCP 3: Practical refusal, no longer progressing in inferred dense sand. Rods moist (not wet). Bedrock not encountered.					

Remarks: No groundwater encountered.

Weight:	9	kg
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

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.

COPYRIGHT AND REPRODUCTION

The contents of this document are and remain the intellectual property of Ascent. This document should only be used for the purpose for which it was commissioned and should not be used for other projects, or by a third party without written permission from Ascent.

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 (%)

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

CORE RECOVERY (%)

$$= \frac{\text{core recovered}}{\text{core llft}} \text{ x } 100$$

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

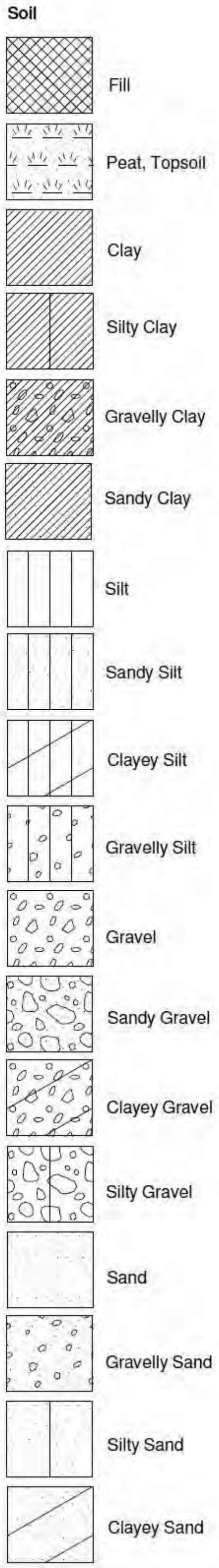
Shape	Description
Planar	Consistent orientation
Curved	Gradual change in orientation
Undulose	Wavy surface
Stepped	One or more well defined steps
Irregular	Many sharp changes in orientation

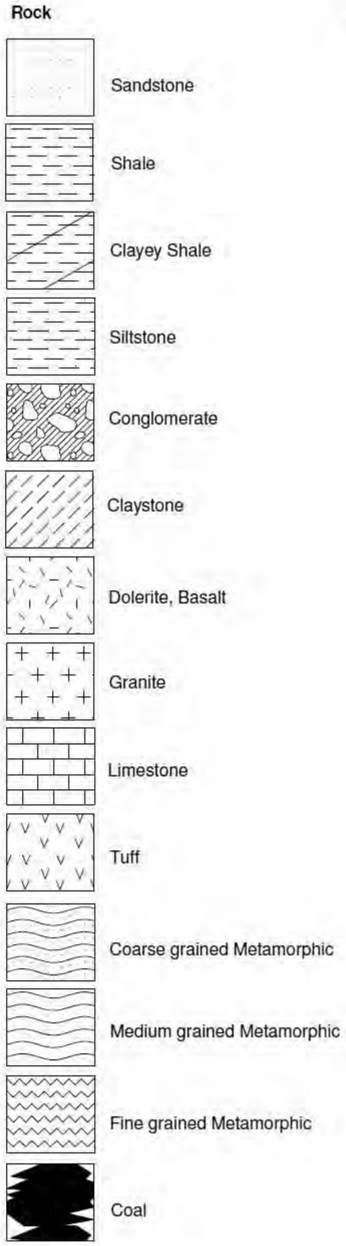
Infill or Coating	Description
Clean	No visible coating or discolouring
Stained	No visible coating but surfaces are discoloured
Veneer	A visible coating of soil or mineral, too thin to measure; may be patchy
Coating	Visible coating ≤ 1mm thick. Ticker soil material described as seam

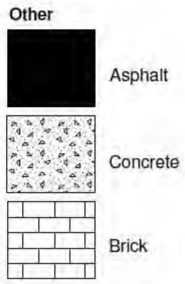
Roughness	Description
Polished	Shiny smooth surface
Slickensided	Grooved or striated surface, usually polished
Smooth	Smooth to touch. Few or no surface irregularities
Rough	Many small surface irregularities (amplitude generally < 1mm). Feels like fine to coarse sandpaper

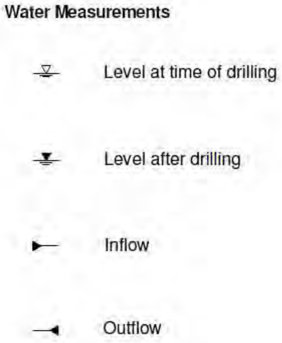
Note: soil and rock descriptions are generally in accordance with AS1726-1993 Geotechnical Site Investigations

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

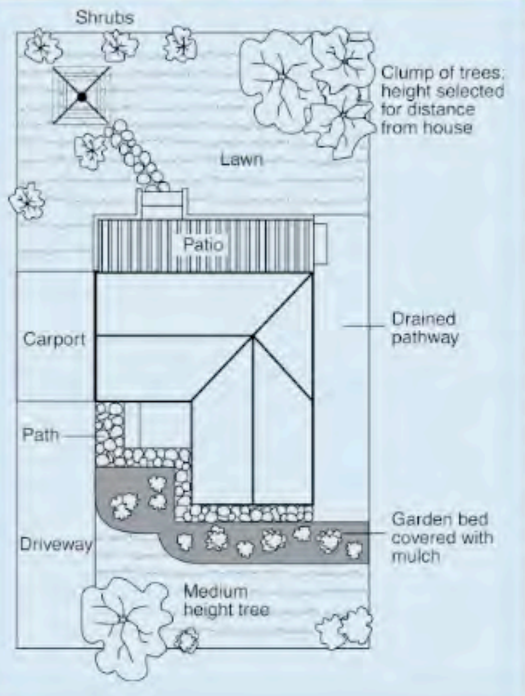
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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.

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

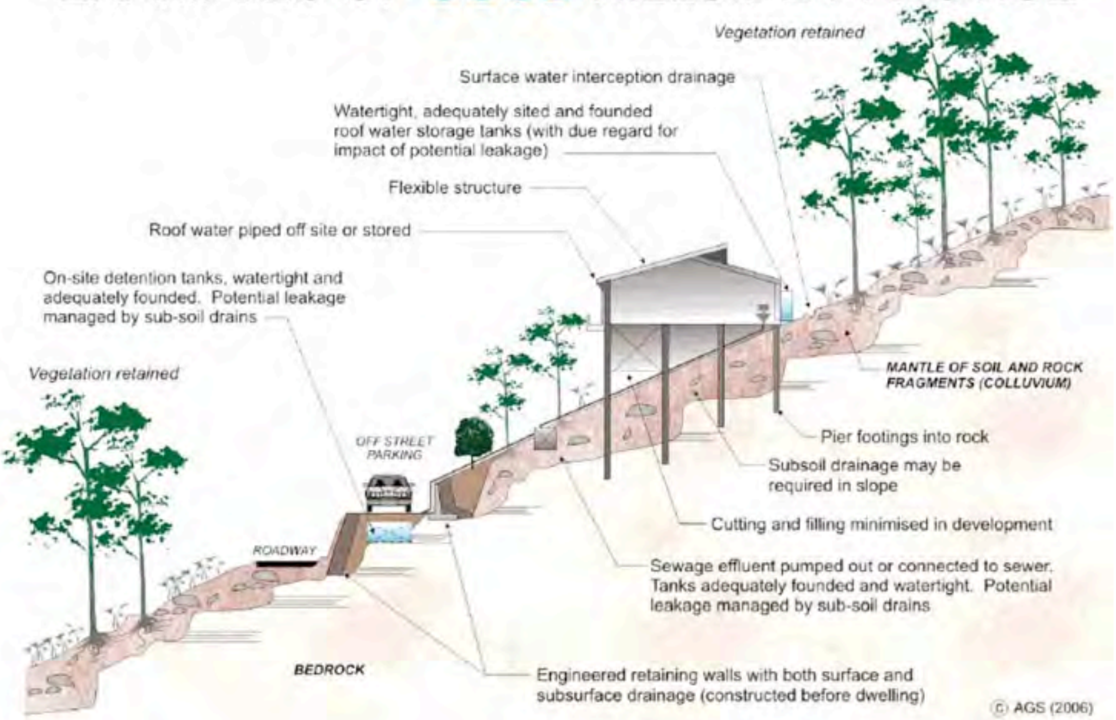
The information is advisory. It is provided in good faith and not claimed to be an exhaustive treatment of the relevant subject.

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

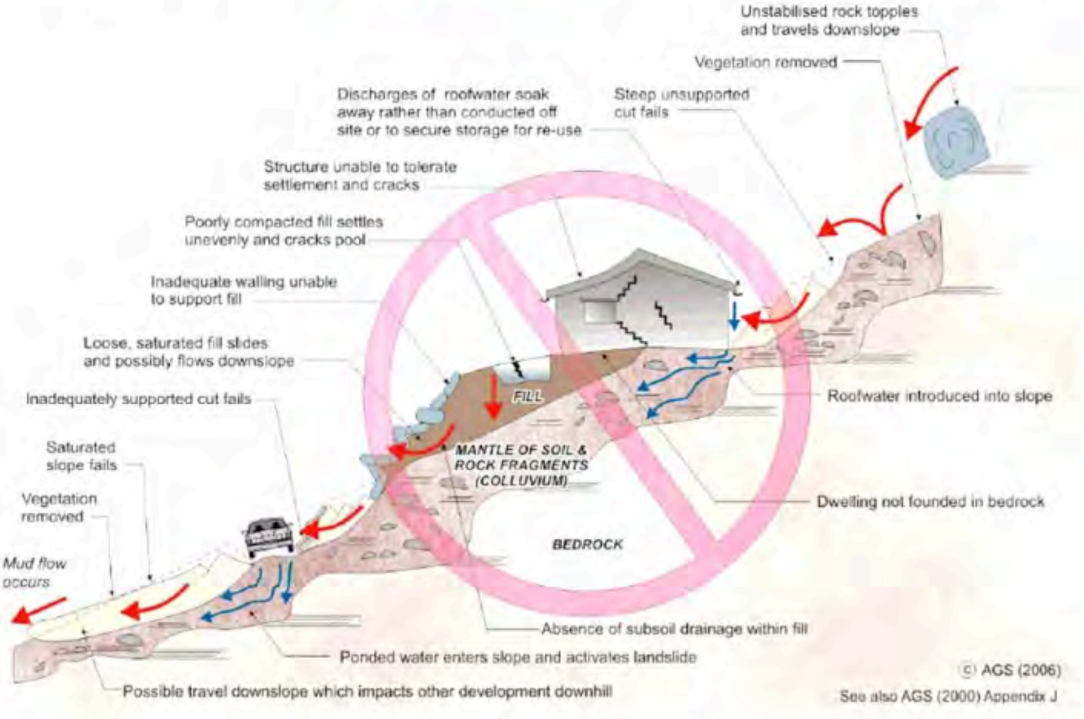
Distributed by
CSIRO PUBLISHING PO Box 1139, Collingwood 3066, Australia
Freecall 1800 645 051 Tel (03) 9662 7666 Fax (03) 9662 7555 www.publish.csiro.au
Email: publishing.sales@csiro.au

© CSIRO 2003. Unauthorised copying of this Building Technology file is prohibited

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	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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