GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for ______________________________	
Name of Applicant	
Address of site 25 – 27 Kevin Avenue, Avalon Beach, NSW	

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

I, __***Troy Crozier***_ *on behalf of* ***Crozier Geotechnical Consultants*** __on this the __04 October 2023__ certify that I am a engineering geologist as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above company to issue this document and to certify that the company has a current professional indemnity policy of at least $2million.

I:

☐ have prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

■ am willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

☐ have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with Section 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. I confirm that the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy for Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.

☐ have examined the site and the proposed development/alteration in detail and I am of the opinion that the Development Application only involves Minor Development/Alteration that does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.

☐ have examined the site and the proposed development/alteration is separate from and is not affected by a Geotechnical Hazard and does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.

☐ have provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: GEOTECHNICAL INVESTIGATION AND RISK ASSESSMENT FOR PROPOSED NEW RESIDENTIAL APARTMENT BUILDING AT 25-27 KEVIN AVENUE, AVALON BEACH, NSW	
Report Date: 04 October 2023	**Project No.:** 2023-156
Author: J. Lu / T. Crozier	
Author's Company/Organisation: Crozier Geotechnical Consultants	

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

Architectural:	Gartner Trovato Architects – Project Number: 2306, Drawing Nos: A01 to A15, Revision: P06,
	Dated 03 October 2023;
Survey:	Bee & Lethbridge, – Reference No: 21372,

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

Signature ....

Name ...**Troy Crozier**..

Chartered Professional Status...**RPGeo (AIG)** ....

Membership No. ...**10197**..

Company... **Crozier Geotechnical Consultants**

AUSTRALIAN INSTITUTE OF GEOSCIENTISTS
REGISTERED PROFESSIONAL GEOSCIENTIST
TROY CROZIER
10197

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER
FORM NO. 1(a) - Checklist of Requirements For Geotechnical Risk Management Report for Development Application

Development Application for ________________________________
Name of Applicant

Address of site _______25 – 27 Kevin Avenue, Avalon Beach, NSW

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Geotechnical Report. This checklist is to accompany the Geotechnical Report and its certification (Form No. 1).

Geotechnical Report Details:

Report Title: GEOTECHNICAL INVESTIGATION AND RISK ASSESSMENT FOR PROPOSED NEW RESIDENTIAL APARTMENT BUILDING AT 25-27 KEVIN AVENUE, AVALON BEACH, NSW
Report Date: 04 October 2023 **Project No.:** 2023-156
Author: J. Lu / T. Crozier
Author's Company/Organisation: Crozier Geotechnical Consultants

Please mark appropriate box

- ■ Comprehensive site mapping conducted ___07 August 2023________ (date)
- ■ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
- ■ Subsurface investigation required
  - ☐ No Justification ....
  - ■ Yes Date conducted ......07 August 2023......
- ■ Geotechnical model developed and reported as an inferred subsurface type-section
- ■ Geotechnical hazards identified
  - ☐ Above the site
  - ■ On the site
  - ☐ Below the site
  - ☐ Beside the site
- ■ Geotechnical hazards described and reported
- ■ Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
  - ■ Consequence analysis
  - ■ Frequency analysis
- ■ Risk calculation
- ■ Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ■ Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ■ Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
- ■ Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified conditions are achieved.
- ■ Design Life Adopted:
  - ■ 100 years
  - ☐ Other .... specify
- ■ Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
- ■ Additional action to remove risk where reasonable and practical have been identified and included in the report.
- ☐ Risk assessment within Bushfire Asset Protection Zone.

I am aware that Pittwater Council will rely on the Geotechnical Report, to which this checklist applies, as the basis for ensuring that the geotechnical risk management aspects of the proposal have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated, and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature ....

Name ...**Troy Crozier**...........................

Chartered Professional Status...**RPGeo (AIG)**..........

Membership No. ...**10197**........................

Company... **Crozier Geotechnical Consultants**

AUSTRALIAN GEOSCIENTISTS TROY CROZIER 10,197

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Crozier Geotechnical Consultants , a division of PJC Geo-Engineering Pty Ltd

REPORT ON GEOTECHNICAL INVESTIGATION AND RISK ASSESSMENT

for

PROPOSED NEW RESIDENTIAL APARTMENT BUILDING

at

25-27 KEVIN AVENUE, AVALON BEACH, NSW

Prepared For

Gregory Nattrass

Project No.: 2023-156

Document Revision Record

Issue No	Date	Details of Revisions
0	01 September 2023	DRAFT issue
1	04 October 2023	Original Issue

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Crozier Geotechnical Consultants is a division of PJC Geo-Engineering Pty Ltd

Date: 04 October 2023
No. Pages: 1 of 19
Project No.: 2023-156

REPORT ON GEOTECHNICAL INVESTIGATION AND RISK ASSESSMENT FOR PROPOSED NEW RESIDENTIAL APARTMENT BUILDING AT 25-27 KEVIN AVENUE, AVALON BEACH, NSW

1. INTRODUCTION:

This report details the results of a Geotechnical Investigation (GI) and Risk Assessment carried out to provide advice and recommendations for the Development Application (DA) submission for a proposed new senior living development building at 25-27 Kevin Avenue, Avalon Beach, NSW. The investigation was undertaken by Crozier Geotechnical Consultants (CGC) at the request of Gartner Trovato Architects, on behalf of the client, Gregory Nattrass.

2. PROPOSED DEVELOPMENT:

The following documents supplied by the client, were relied on in the preparation of the proposed investigation and this report:

- Architectural Design Drawings prepared by Gartner Trovato Architects – Project Number: 2306, Drawing Nos: A01 to A15, Revision: P06, Dated 03 October 2023;
- Site Survey plan prepared by Bee & Lethbridge, – Reference No: 21372. The datum in the survey plan is in Australian Height Datum (AHD), therefore, all the Reduced Levels (RL) mentioned in this report are henceforth in AHD.

It is understood that the proposed works involve demolition of existing structures and the construction of a new seniors living development which will contain 10 apartments across two living levels and a basement garage (Basement Upper and Basement Lower). The basement steps and rises through the site towards the rear with a lowest finished floor level at the driveway entry of RL 20.20m rising to RL23.10 at the rear (Basement Upper), which indicates that a bulk excavation will be required to a maximum of approximately 5.50m depth within central to rear portions of the block. Locally deeper excavations appear required for footings, lift pits and service trenches.

The excavation will extend to within 3.50 to 6.90m of the west side boundary, within 3.10 to 2.70m of the east side boundary and will be >10.0m of the rear southern boundary with the excavation reducing to the north and formed above road reserve levels at >20.0m separation distance.

The site is located within the H1 (highest category) landslip hazard zone as identified within Northern Beaches Councils precinct (Geotechnical Risk Management Policy for Pittwater – 2009). The depths of excavation also invoke the Councils risk management policy.

To meet the Councils Policy requirements for land classified as H1, it is required to provide a detailed Geotechnical Report which meets the requirements of Paragraph 6.5 of that policy. This report must include a landslide risk assessment to the methods of AGS 2007 for the site and proposed works, plans, geological sections and provide recommendations for construction and to ensure stability is maintained for a preferred design life of 100 years.

The Acid Sulfate Soils Map of Pittwater Local Environmental Plan 2014 shows that the site is located within a Class 5 Acid Sulfate Soils hazard zone.

3. OBJECTIVES AND SCOPE OF WORK:

This report is provided for submission as part of a Development Application (DA) to Northern Beaches Council and to provide at least preliminary information for use in the structural design. It includes details of investigation works undertaken, plans showing test locations, a geological section and provides assessment and recommendations for construction. The site investigation and reporting were undertaken as per the Fee Proposal P23-305, Dated 18 July 2023.

The investigation comprised:

a) Before You Dig (BYDA) plan request and onsite clearing of test locations by an accredited service location contractor.
b) Detailed geotechnical mapping of the entire site and adjacent land, with identification of geotechnical conditions and hazards related to the existing site and proposed work;
c) A photographic record of site conditions;
d) Auger drilling of five boreholes (BH1 to BH5) by restricted access drill rig using solid stem spiral flight augers equipped with a ‘Tungsten-Carbide’ (T-C) bit to about 5.0m depth or refusal on bedrock;
e) Hand auger drilling of one borehole (BH6) within grassy area within the rear site area of 25 Kevin Ave, where access for the rig was not possible;
f) Dynamic Cone Penetrometer tests carried out adjacent BH1 to BH6 across the whole site to refusal/target depths;
g) Soil sample collection and logging as per “AS1726: 2017 Geotechnical Site Investigation”;

All fieldwork was conducted under the full-time supervision of an experienced Geotechnical Engineer who logged and ensured the quality of all geotechnical data.

4. SITE FEATURES:

4.1. Description:

The site contains two rectangular blocks (Lots 10 and 11 DP 12435) located on the south side of Kevin Avenue within generally gently (0º to 10º) north-east dipping topography on the north-eastern side of a ridge.

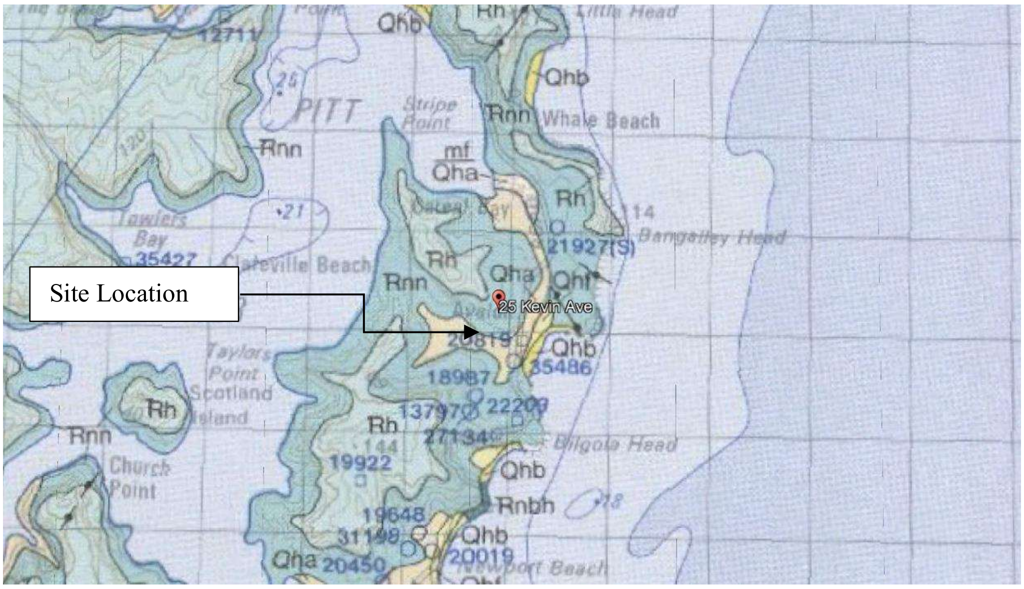
An aerial photograph of the site and its surrounds as Photograph 1, as sourced from NSW Government SIX Maps spatial data website.

Photograph-1: Aerial photo of site and surrounds (source: SIX Maps, access 16/8/2023)

4.2. Geology:

Reference to the Sydney 1: 100,000 Geological Series sheet (9130) indicates that the site is underlain by weathered bedrock of the Newport Formation (Upper Narrabeen Group) rock (Rnn) which is of middle Triassic Age. The Newport Formation typically comprises interbedded laminite, shale and quartz to lithic quartz sandstones and pink clay pellet sandstones and tends to weather to significant depth.

Narrabeen Group rocks are dominated by shales and thin siltstone/sandstone beds and often form rounded convex ridge tops with moderate angle (<20°) side slopes. These side slopes can be either concave or convex depending on geology, internally they comprise of interbedded shale and siltstone/sandstone beds with close spaced bedding partings that have either close spaced vertical joints or in extreme cases large space convex joints.



Extract of Sydney (9130 Geology Series Map): 1:100000 - Geology underlying the site

5. FIELD WORK:

5.1. Methods:

The field investigation comprised a walk over inspection/mapping of the site and adjacent properties on the 07 August 2023 by a Geotechnical Engineer. It included a photographic record of site conditions as well as geological/geomorphological mapping of the site and adjacent land with examination of existing structures and limited inspection of neighbouring properties. It also included the drilling of six boreholes (BH1 to BH6) using both a restricted access drill rig (BH1 to BH5) utilising solid stem auger drilling and a Tungsten Carbide bit and hand auger techniques (BH6) to investigate the sub-surface geology.

Soil sample collection and logging was undertaken by a Geotechnical Engineer by inspection of disturbed soil recovered from the augers. Logging was undertaken in accordance with "AS1726: 2017 Geotechnical Site Investigation".

Dynamic Cone Penetrometer (DCP) testing (DCP1 to DCP5) was carried out adjacent to the boreholes in accordance with AS1289.6.3.2 – 1997, "Determination of the penetration resistance of a soil – 9kg Dynamic Cone Penetrometer test" to estimate near surface soil conditions.

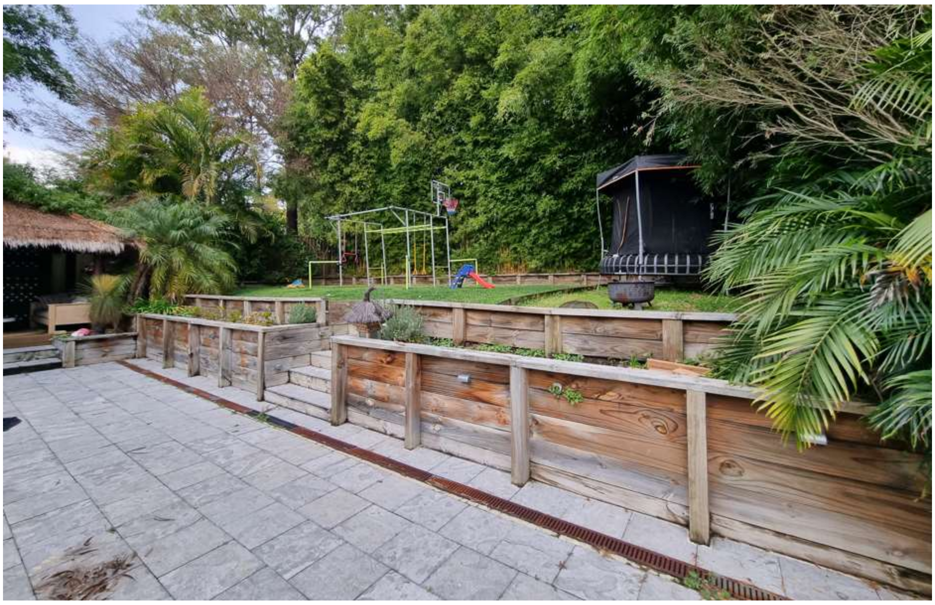
Explanatory notes are included in Appendix: 1. Mapping information and test locations are shown on Figure: 1, along with detailed bore log and DCP sheets in Appendix: 2. Two geological models/sections are provided as Figure: 2 and Figure: 3, Appendix: 2.

5.2. Field Observations:

The site is situated on the south- side of Kevin Avenue within a gently north-eastern dipping slope. General views of the site are shown in Photograph 2 to 5.

Photograph-2: View of front of 25 Kevin Avenue. View looking south-west from the roadway.

Photograph-3: View of front area of 27 Kevin Avenue. View looking south-west from the roadway.



Photograph-4: View of rear area of 25 Kevin Avenue. View looking south from the rear yard.

Photograph-5: View of rear area of 27 Kevin Avenue. View looking south-west from the rear yard.

At the time of investigation, the site containing two blocks was occupied by two separate brick residential dwellings with associated detached storage, granny flat, swimming pool, pavilions, and other structures:

- 25 Kevin Avenue: contains a two-storey brick building with two detached granny flats (within the front site area), a swimming pool and a pavilion. The buildings/structures appeared in fair to good condition. The remaining area of the block was occupied by timber decking, concrete driveway, footpath, timber retaining walls, trees and lawn.
- 27 Kevin Avenue: comprises a two-storey brick dwelling with attached garage and a detached storage area located within the rear area of the block. The main house and storage area appeared in fair to good condition. The remaining area is occupied by asphalt-paved driveway, footpath, trees and lawn.

No signs of significant cracking or geotechnical issues were observed within the site during the investigation.

The surrounding properties are as follows:

- North: Kevin Avenue, a two-lane, asphalt-paved road with concrete kerb, footpath, and lawn reserve located downslope of the site. The footpath abuts the north/front 'site' boundary. The roadway has an offset of about 2.0m from the boundary and has a similar elevation to the front boundary of the 'site'. The roadway was in good condition without any sign of significant cracking.
- East: Property at 23 Kevin Avenue, a two-storey residential dwelling with a granny flat at the front area of the block. The main house appeared in fair to good condition and has an offset of no more than 1.0m to the 'site' boundary. The remaining area was occupied by concrete driveway, trees and grassy area. The property has a similar elevation to the 'site' adjacent to the common boundary.
- South: Properties at 22-24 Park Ave, two separated brick residential dwellings with associated garage, concrete driveway, footpath, trees and grassy area. The main houses appearing in good condition have offsets of more than 15.0m to the 'site' boundary. These properties have a higher elevation to the 'site'.
- West: Property at 29 Kevin Avenue, a single-storey residential dwelling with driveway, footpath, trees and grassy area. The main house appeared in fair condition and has offset of about 1.0m to the 'site' boundary. This block ground has a similar elevation to the 'site' adjacent to the common boundary.

The neighbouring buildings and properties were only inspected from within the site or from the road reserve however the visible aspects did not show any significant signs of large-scale slope instability or other major geotechnical concerns which would impact the site.

5.3. Investigation Results:

For a description of the ground conditions encountered at the borehole/DCP test locations, the Borehole Log and DCP test result sheets should be consulted, however, a very broad summary of the subsurface conditions encountered is provide below:

- **TOPSOIL/FILL – (Silty) SAND** encountered in all test locations from the surface or underlying the pavement, to varying depths between 0.1m (BH2) and 0.4m (BH3). The (silty) sandy fill was classified as loose to medium dense, fine to medium grained, dark grey or brown, dry to moist, with trace of rootlets near surface.
- **NATURAL (Clayey) SAND** underlies the fill, encountered within BH1, BH2, BH4 and BH6 only, to the maximum depth of approximately 1.2m in BH6. It was classified as loose to very dense (BH1 only), fine to medium grained, grey-brown or brown, moist to wet (BH6 only).
- **NATURAL Sandy/Silty CLAY** underlies the fill (BH3 and BH5 only) or natural sand (BH1, BH2 and BH4) to the maximum investigation depth of about 5.5m (BH2). It was classified as firm increasing to hard with depth, then grading into extremely weathered materials (interpreted from DCP tests), low to high plasticity, grey, brown, red brown or pale grey, moist.
- **BEDROCK – SANDSTONE** encountered within BH3 (2.35m or RL 24.25m) and BH4 (3.00m or RL 24.7m) only. It was classified as fine to medium grained, highly to moderately weathered, and interpreted as low strength based on the TC-bit refusal.

Minor groundwater seepage was encountered at about 0.7m (RL 26.5m) within BH6 only during the investigation.

6. COMMENTS:

6.1. Geotechnical Assessment:

The site investigation identified the presence of interpreted sand fill to a maximum depth of 0.4m (BH3), underlain by natural sand/clay soil to the maximum investigated depth of 5.5m (RL 17.1m) below the existing surface level. Sandstone bedrock was encountered within BH3 (RL 24.25m) and BH4 (RL 24.7m) drilled across the rear south-west corner of the site only. Groundwater seepage was encountered at 0.7m depth (RL 26.5m) within BH6 only.

No signs of existing, previous, or potential natural instability or geotechnical issues were observed within the site or adjacent properties.

The proposed works involve demolition of existing structures and the construction of a new apartment building comprising two living levels and a basement/garage. The basement has a variable floor level rising from RL 20.20 at the north-west corner to RL23.10 across the rear southern side with a stepped form including a lower/front level. The ground surface levels and design indicate that a bulk excavation will be required to a maximum of approximately 5.50m depth within central to rear portions of the block.

The investigation completed was limited by existing structures on site, therefore further detailed investigation is required to below bulk excavation level prior to final design of engineering support and footing systems.

In view of the provided architectural plans, the proposed basement outline has a setback of about 2.80m to 6.90m from the west side boundary and 2.70m to 5.00m to the west side boundary with more than 10.0m from the rear boundary and 20.0m from the front site boundary, though the basement is above road reserve level. Based on the excavation depths and the investigation results, temporary safe batter slopes can be achieved for the front and rear boundary of this site only, however batters >3.0m in height are not recommended. Where batters are proposed, either staggered or <3.0m in height it must be ensured that no ponding occurs at the base of batters or surface flow on the face is allowed to impact stability. Preliminary design parameters for batters/excavation support are provided in **Section 6.3**.

Where space for temporary batters is not available, a suitable retention system will be required for the support of the entire depth of the excavation. This may be best achieved on this site using soldier pile walls or similar, with shotcrete infill panels with a separation distance/gap between piles of no greater than 1.50m recommended due to the soils encountered, although the structural design may dictate a smaller separation. Piles will need to be installed below the excavation level within bedrock, which is estimated at low strength. Preliminary design parameters are provided in **Section 6.3**. Additional geotechnical investigation in the form of cored boreholes is required to confirm the condition of bedrock below the existing investigation and proposed bulk excavation level.

For support post excavation, where temporary batter slopes can be used, the construction of steel reinforced concrete/concrete block wall designed in accordance with Australian Standard AS 4678-2002 Earth Retaining Structures is a viable option. The design parameters for both temporary and permanent retention systems are provided in **Section 6.3**.

Prior to any demolition work, we recommend that detailed dilapidation surveys be carried out on all structures and infrastructures surrounding the site that fall within the zone of influence of the excavation considered to be 10.0m horizontal from the perimeter to allow assessment of the adjacent condition and protect the client against spurious claims of damage.

Based on the investigation results, it is anticipated that the proposed bulk excavation may be through all the geological units listed above (sand fill, natural sand/clay soil and bedrock), with the bedrock potentially increasing to low and medium strength below auger refusal levels. For this site, soil profiles and extremely weathered very low strength bedrock can be excavated using conventional earthmoving equipment, however low and greater strength bedrock will require the use of the rock breaking equipment (e.g., ripper or rock hammers and rock saw).

The use of rock hammers can create ground vibrations which could damage the neighbouring and adjacent structures even during demolition works. Care will be required during the demolition, construction and excavation works to ensure the neighbouring properties, structures and services are not adversely impacted by ground vibrations. Medium scale equipment (i.e., rock hammer <500kg) along with rock saw and a good excavation methodology are recommended to be used to maintain low vibration levels and avoid the need for full time vibration monitoring, however onsite calibration will be required to confirm this.

Although groundwater seepage was encountered within BH6 during the investigation, the groundwater table is anticipated to be well below the proposed development based on investigation results, site elevations and local topography. Therefore, groundwater is unlikely to be a significant issue during excavation/construction, and it is expected that the seepage (if any) will be able to be controlled by a conventional gravity drainage and/or sump and pump system, with mass dewatering or detrimental impact to the water or local hydrogeological conditions not anticipated. However, this will require confirmation once access for detailed geotechnical investigation is available. Prevention of surface stormwater flow into the excavation is recommended.

Following the bulk excavation, the materials at the base of Basement Upper (RL 23.1m) and Basement Lower (RL20.40) are anticipated to be bedrock across the rear southern half grading to at least very stiff clay soil (low) to the north. However, it is expected that variations across the foundation levels will occur as a result of natural geological variability.

Preliminary allowable bearing pressures appropriate for the conditions encountered underlying the site are provided in **Section 6.3.1**. It is recommended that all footings for the proposed building be founded within the same material of similar strength to reduce the potential risk of differential settlement, which is expected to require a bedrock foundation of at least low strength. Geotechnical inspections of foundations are required to determine or confirm the required bearing capacity is achieved to meet the engineering design and to identify any potential variations between the boreholes.

Pile footings designed to be founded on weathered bedrock is a suitable option for this site if a higher bearing capacity is required. An additional geotechnical investigation post to demolition of 25 Kevin Street is required to confirm the depth and condition of bedrock.

The Acid Sulfate Soils Map of Pittwater Local Environmental Plan 2014 shows that the site is located within a Class 5 Acid Sulfate Soils zone. The investigation confirmed that the proposed work will not intersect acid sulfate soils and will not intersect or lower the water table. Therefore, the Preliminary Acid Sulfate Soil Assessment in line with the method of the Acid Sulfate Soil Manual (1998) indicates that an Acid Sulfate Soil Management Plan is not required.

The recommendations and conclusions in this report are based on an investigation utilizing only surface observations and a limited number of augered test boreholes. This test equipment provides limited data from small, isolated test points across the entire site, therefore some minor variation to the interpreted sub-surface conditions is possible, especially between test locations. Further detailed investigation is required across the site for engineering design; however, this only possible following demolition of the existing structures (25 Kevin Street).

The proposed works are considered suitable for the site and may be completed with negligible impact to existing nearby structures within the site or on neighbouring properties provided the recommendations of this report are implemented in the design and construction phases.

6.2. Site Specific Risk Assessment

Based on our site investigation we have identified the following geological/geotechnical landslip hazards which need to be considered in relation to the existing site and the proposed works. The main hazards are:

A. Landslip (earth slide <10.0m^3) from soils due to the proposed bulk excavation;

A qualitative assessment of risk to life and property related to these hazards is presented in **Table A and B**, Appendix: 3, and is based on methods outlined in Appendix: C of the Australian Geomechanics Society (AGS) Guidelines for Landslide Risk Management 2007. AGS terms and their descriptions are provided in Appendix: 4.

The Risk to Life from Hazard A was estimated to be up to **4.38 x 10^{-3}** for any person, while the Risk to Property was considered to be up to '**Very High**'.

The assessment determined risk levels which are above "Unacceptable" levels, however the assessments were based on excavations with no support implemented, with unsupported excavations over a design life of 100 years.

Provided the recommendations of this report are implemented including installation of support systems prior to bulk excavation (or similar) then the likelihood of any failure becomes 'Rare' and as such the consequences reduce with risk becoming **(<4.38 x 10^{-7} / Very Low),** which is within 'Acceptable' levels when assessed against the criteria of the Councils Risk Management Policy. As such the project is considered suitable for the site provided the recommendations of this report are implemented.

6.3. Design & Construction Recommendations:

The following recommendations should be considered to be preliminary and will need to be confirmed following further investigation.

6.3.1. New Footings:	
Site Classification as per AS2870 – 2011 for new footing design	Class 'P' due to the uncontrolled fill and presence of trees. Class 'A' at the base of excavation into bedrock.
Type of Footing	Strip/Pad or Slab at base of excavation or piles.
Founding material and Maximum Allowable Bearing Capacity for Shallow Footing Design	Very stiff clay or better: 300kPa Very Low Strength Bedrock: 700kPa Low strength bedrock: 1000kPa*
Site sub-soil classification as per *Structural design actions AS1170.4 – 2007, Part 4: Earthquake actions in Australia*	Class C_e – Shallow soil. The hazard factor (z) for Sydney is 0.08.
<u>Remark:</u> * requires confirmation by core drilling. All new footings must be inspected by an experienced geotechnical professional before concrete or steel are placed to verify the preliminary maximum bearing capacities provided above and the in-situ nature of the founding strata. This is mandatory to allow them to be 'certified' at the end of the project. Individual structures should not be founded on materials with varying bearing and settlement characteristics unless the potential for differential movement has been allowed for in structural design.	

6.3.2. Excavation Methodology and Monitoring:

Basement Excavation

Table 1: Basement excavation and structure separation distances

Boundary	Adjacent Property	Bulk Excavation Depth (m bgl)	Separation Distances (m)	
			Boundary* (m)	Structure* (m)
North	Roadway	Nil	>20.0	Footpath abuts the boundary; roadway is a further 2.0m
East	23 Kevin Ave	Up to 5.50	3.00	A further 2.0m to the main house
South	Houses at 22-24 Park Ave	Up to 5.50	10.0	A further >15.0m to the houses
West	29 Kevin Ave	Up to 5.50	2.80	A further 1.0m to the house.

* All the distances are approximate.

Type of Material to be Excavated.	Fill and natural soil;
	Weathered bedrock to LS and potential MS

Guidelines for un-surcharged batter slopes for this site are tabulated below:

Material	Safe Batter Slope (H: V)*	
	Short Term/Temporary	Long Term/Permanent
Fill or natural Loose sand	1.5:1.0	2.5:1.0
Medium dense sand or stiff Clay	1.0:1.0	2.0:1.0
Very low to low strength bedrock	0.25:1.0*	0.5:1.0*

* Dependent on defects and assessment by geotechnical engineers

Remarks:

Where safe batter slopes cannot be implemented due to the excavation's proximity to the boundaries, the stability of the excavation cannot be guaranteed until the installation of permanent support measures. This should also be considered with respect to safe working conditions.

As a general guide, any surcharge loads (e.g., load out points, adjacent building, or structure footings) should be at a distance greater than 2.5H (H being height of batter) away from the crest/top of any adjacent excavated batter within soils. If this separation distance cannot be maintained positive retention will be required.

Equipment for Excavation	Fill and natural soil	Excavator with bucket
	VLS bedrock	Excavator with bucket and ripper
	LS to HS bedrock	Rock hammer and saw

ELS – extremely low strength, VLS – very low, LS – low, MS – medium, HS – high strength

Remarks:

Based on previous testing of ground vibrations created by various rock excavation equipment within medium strength bedrock, to maintain a vibration level below 5mm/s PPV the below hammer weights and buffer distances are required:

Buffer Distance from Structure	Maximum Hammer Weight
2.0m	200kg
4.0m	500kg
5.0m	800kg
8.0m	1000kg

Onsite calibration will provide accurate vibration levels to the site-specific conditions and will generally allow for larger excavation machinery or smaller buffers to be used. Calibration of rock excavation machinery should be carried out prior to commencement of rock excavation works where ≥250kg rock hammers are proposed for use.

Rock sawing of the excavation perimeter is recommended as it has several advantages. It often reduces the need for rock bolting as the cut faces generally remain more stable and require a lower level of rock support than hammer cut excavations, ground vibrations from rock saws are minimal, the saw cuts will provide a slight increase in buffer distance for use of rock hammers whilst also reducing deflection of separated rock across boundaries.

The strength of bedrock below the maximum depth achieved during the investigation is unconfirmed and would require cored boreholes using specialist restricted access drilling equipment.

Excavation of soils to ELS will not create excessive vibrations provided it is undertaken with medium scale (<30 tonne excavator) excavation equipment in a sensible manner.

Recommended Vibration Limits (Maximum Peak Particle Velocity (PPV))	Adjacent residential structure = 5mm/s (Frequency ≥1.3 Hz) Road Reserve = 5mm/s (Frequency ≥1.3 Hz)
Full time vibration Monitoring Required	Not required unless large >500kg rock hammers proposed for use
Dilapidation Surveys Requirement	Required on the neighbouring structures/infrastructures or parts within 10m of the excavation perimeter. **Note:** CGC have the experience in performing Dilapidation Surveys.

6.3.3. Retaining Structures:	
Required	Pre-excavation or post excavation retention systems around perimeter of basement excavation is required as part of the works.
Types	Pre-excavation retention system such as bored solider pile wall, maybe cantilever where deflection criteria can be met. Or post-excavation concrete block/concrete wall. Designed in accordance with AS4678:2002 'Earth-Retaining Structures'

Parameters for calculating pressures acting on retaining walls for the materials likely to be retained:

Material	**Unit Weight (kN/m^3)**	**Friction angle (Long Term - Drained) ϕ'**	**Earth Pressure Coefficients**		**Passive Earth Pressure - Coefficient * (K_p)**
			Active (Ka)	**At Rest (K_0)**	
Fill and Sand (L)	18	28°	0.35	0.52	N/A
Sand/Silty Sand/Clayey Sand (L to VD)	20	33°	0.29	0.46	N/A
Silty/Sandy Clay to EW	20	30°	0.33	0.50	3.0
VLS to LS bedrock	23	38°	0.10	0.15	300 kPa

Remarks:

In suggesting these parameters, it is assumed that the retaining walls will be fully drained with suitable subsoil drains provided at the rear of the wall footings. If this is not done, then the walls should be designed to support full hydrostatic pressure in addition to pressures due to the soil backfill. It is suggested that the retaining walls should be backfilled with free-draining granular material (preferably not recycled concrete) which is only lightly compacted to minimize horizontal stresses.

Retaining structures near site boundaries or existing structures should be designed with the use of at rest (K_0) earth pressure coefficients to reduce the risk of movement in the excavation support and resulting surface movement in adjoining areas. Backfilled retaining walls within the site, away from site boundaries or existing structures, that may deflect can utilize active earth pressure coefficients (Ka).

Triangular pressure distribution is suitable for cantilever or braced systems at the depth of excavation proposed.

6.3.4. Drainage and Hydrogeology		
Groundwater Table or Seepage identified in Investigation		Presence of seepage within BH6 only
Excavation likely to intersect	Water Table	No
	Seepage	Likely within conduits in soil and at soil/bedrock interface or defects in bedrock. Minor (<0.5L/min/m) around excavation
Site Location and Topography		High elevation to Kevin Avenue within gently north-east dipping topography
Impact of development on local hydrogeology		Negligible
Remarks: An excavation trench should also be installed at the base of excavation cuts to below floor slab levels to reduce the risk of long-term dampness. Trenches, as well as all new building gutters, down pipes and stormwater intercept trenches should be connected to a stormwater system designed by a Hydraulic Engineer which discharges to the Council's stormwater system off site.		

6.4. Conditions Relating to Design and Construction Monitoring:

To allow certification as part of construction, building and post-construction activity for this project, it will be necessary for CGC to conduct:

- Complete further detailed investigation once access is available.
- Review structural design drawings for implementation of the recommendations of this report and future reporting,
- Inspect any pre-excavation support system installation to assess the base material and confirm the geotechnical conditions match those upon which design is based;
- Inspect any excavation where is unsupported, at maximum 1.50m depth intervals.
- At completion of the excavation to confirm the material at the base of the excavation;
- Inspect all new footings to confirm compliance to design assumptions with respect to allowable bearing pressure and stability prior to the placement of steel or concrete.
- Where ground conditions vary from those anticipated and outlined in this report are encountered.

The client and builder should make themselves familiar with the requirements spelled out in this report for inspections during the construction phase. Crozier Geotechnical Consultants cannot provide certification for the Occupation Certificate if it has not been called to the site to undertake the required inspections.

6.5. Design Life of Structure:

We have interpreted the design life requirements specified within Council's Risk Management Policy to refer to structural elements designed to support the existing structures, control stormwater and maintain the risk of instability within acceptable limits. Specific structures and features that may affect the maintenance and stability of the site in relation to the proposed and existing development are considered to comprise:

- stormwater and subsoil drainage systems,
- retaining walls and instability,
- maintenance of trees/vegetation on this and adjacent properties.

Man-made features should be designed and maintained for a design life consistent with surrounding structures (as per AS2870 – 2011 (100 years)). It will be necessary for the structural and geotechnical engineers to incorporate appropriate design and inspection procedures during the construction period. Additionally, the property owner should adopt and implement a maintenance and inspection program.

If this maintenance and inspection schedule are not maintained the design life of the property cannot be attained. A recommended program is given in Table: C in Appendix: 3 and should also include the following guidelines.

- The conditions on the block don't change from those present at the time this report was prepared, except for the changes due to this development.
- There is no change to the property due to an extraordinary event external to this site
- The property is maintained in good order and in accordance with the guidelines set out in;
  a) CSIRO sheet BTF 18
  b) Australian Geomechanics "Landslide Risk Management" Volume 42, March 2007.
  c) AS 2870 – 2011, Australian Standard for Residential Slabs and Footings

Where changes to site conditions are identified during the maintenance and inspection program, reference should be made to relevant professionals (e.g. structural engineer, geotechnical engineer or Council). Where the property owner has any lack of understanding or concerns about the implementation of any component of the maintenance and inspection program the relevant engineer should be contacted for advice or to complete the component. It is assumed that Council will control development on neighbouring properties, carry out regular inspections and maintenance of the road verge, stormwater systems and large trees on public land adjacent to the site so as to ensure that stability conditions do not deteriorate with potential increase in risk level to the site.

Also, individual Government Departments will maintain public utilities in the form of power lines, water, and sewer mains to ensure they don't leak and increase either the local groundwater level or landslide potential.

7. CONCLUSION:

The site investigation identified the presence of interpreted sand fill to a maximum depth of 0.4m (BH3), underlain by natural sand/clay soil to the maximum investigated depth of 5.5m (RL 17.1m) below the existing surface level. Bedrock interpreted as sandstone was encountered within BH3 (RL 24.25m) and BH4 (RL 24.7m) only at the rear of the site. Groundwater as seepage was encountered at 0.7m depth (RL 26.5m) within BH6 only.

It is anticipated that the proposed bulk excavation will extend through sand fill, natural sand/clay soil, and bedrock. Based on the excavation depths/setbacks and the investigation results, temporary safe batter slopes can be achieved for the front and rear boundary only. However, batters >3.0m height is not recommended therefore if implemented a staggered/separated batter slope would be required. Where space for temporary batters is not available (as for the side boundaries), a suitable pre-excavated retention system will be required for the support of the entire depth of the excavation. It is considered that this will be best achieved via a bored soldier pile wall with shotcrete infill panels implemented as the excavation progresses.

Following the bulk excavation, the materials at the base of Basement Upper and Basement Lower are anticipated to be bedrock to at least very stiff clay soil. However, it is expected that variations across the foundation levels will occur. It is recommended that all new footings be founded on the same material of similar bearing to avoid any differential settlement.

The proposed work will not intersect or lower the water table. Therefore, the Preliminary Acid Sulfate Soil Assessment indicates that an Acid Sulfate Soils Management Plan is not required.

The risks associated with the proposed development can be maintained within 'Acceptable Risk Management Criteria' of the Councils policy with negligible impact to neighbouring properties or site structures provided the recommendations of this report and any future geotechnical directive are implemented.

As such the site is considered suitable for the proposed construction works provided that the recommendations outlined in this report and any future geotechnical reporting or directive are followed.

Prepared By:

Jeff (Yingyi) Lu
Geotechnical Engineer

Reviewed By:

Troy Crozier
Principal
MIE Aust. MAIG,
RPGeo – Geotechnical and Engineering
PRE (NSW)

8. REFERENCES:

i. Australian Standard AS1726:2017, Geotechnical Site Investigations

ii. Australian Standard AS2159:2009, Piling – Design and Installation

iii. Australian Standard AS2870:2017, Residential Slabs and Footings;

iv. Australian Standard AS3600:2009, Concrete Structures;

v. Australian Standard AS3798:2007, Guidelines on Earthworks for Commercial and Residential Developments;

vi. Australian Standard AS 4678:2002, Earth-Retaining Structures;

vii. Sydney 1:100,000 Geological Series Sheet 9130 (Edition 1). Geological Survey of New South Wales, Department of Mineral Resources;

viii. Spatial Information Viewer, maps.six.nsw.gov.au, NSW Department of Finance and Service.

ix. Das. 2004, Principles of Foundation Engineering, 5th Edition, Brooks/Cole;

x. Acid Sulfate Soil Manual, 1998, Acid Sulfate Soil Management Advisory Committee, NSW.

CROZIER
GEOTECHNICAL CONSULTANTS

Appendix 1

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Crozier Geotechnical Consultants, a division of PJC Geo-Engineering Pty Ltd

NOTES RELATING TO THIS REPORT

Introduction

These notes have been provided to amplify the geotechnical report in regard to classification methods, specialist field procedures and certain matters relating to the Discussion and Comments section. Not all, of course, are necessarily relevant to all reports.

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

Description and classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, Geotechnical Site Investigation Code. In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. Sandy clay) on the following bases:

Soil Classification	Particle Size
Clay	less than 0.002 mm
Silt	0.002 to 0.06 mm
Sand	0.06 to 2.00 mm
Gravel	2.00 to 60.00mm

Cohesive soils are classified on the basis of strength either by laboratory testing or engineering examination. The strength terms are defined as follows:

Classification	Undrained Shear Strength kPa
Very soft	Less than 12
Soft	12 - 25
Firm	25 – 50
Stiff	50 – 100
Very stiff	100 - 200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration tests (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	SPT “N” Value (blows/300mm)	CPT Cone Value (Qc – MPa)
Very loose	less than 5	less than 2
Loose	5 – 10	2 – 5
Medium dense	10 – 30	5 -15
Dense	30 – 50	15 – 25
Very dense	greater than 50	greater than 25

Rock types are classified by their geological names. Where relevant, further information regarding rock classification is given on the following sheet.

Sampling

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling to allow information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Drilling Methods

The following is a brief summary of drilling methods currently adopted by the company and some comments on their use and application.

Test Pits – these are excavated with a backhoe or a tracked excavator, allowing close examination of the insitu soils if it is safe to descent into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) – the hole is advanced by a rotating plate or short spiral auger, generally 300mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling – the hole is advanced by pushing a 100mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling soils, since moisture content is unchanged and soil structure, strength, etc. is only marginally affected.

Continuous Spiral Flight Augers – the hole is advanced using 90 – 115mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPT's or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling - the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

Rotary Mud Drilling – similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. From SPT).

Continuous Core Drilling – a continuous core sample is obtained using a diamond-tipped core barrel, usually 50mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests (abbreviated as SPT) are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedures is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" – Test 6.3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube under the impact of a 63kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150mm of say 4, 6 and 7
  as 4, 6, 7 then N = 13
- In the case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm then as 15, 30/40mm.

The results of the test can be related empirically to the engineering properties of the soil. Occasionally, the test method is used to obtain samples in 50mm diameter thin wall sample tubes in clay. In such circumstances, the test results are shown on the borelogs in brackets.

Cone Penetrometer Testing and Interpretation

Cone penetrometer testing (sometimes referred to as Dutch Cone – abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in Australia Standard 1289, Test 6.4.1.

In tests, a 35mm diameter rod with a cone-tipped end is pushed continually into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separte 130mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected buy electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) their information is plotted on a computer screen and at the end of the test is stored on the computer for later plotting of the results.

The information provided on the plotted results comprises: -

- Cone resistance – the actual end bearing force divided by the cross-sectional area of the cone – expressed in MPa.
- Sleeve friction – the frictional force on the sleeve divided by the surface area – expressed in kPa.
- Friction ratio - the ratio of sleeve friction to cone resistance, expressed in percent.

There are two scales available for measurement of cone resistance. The lower scale (0 – 5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main scale (0 – 50 MPa) is less sensitive and is shown as a full line. The ratios of the sleeve friction to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios 1% - 2% are commonly encountered in sands and very soft clays rising to 4% - 10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range: -

Q_c (MPa) = (0.4 to 0.6) N blows (blows per 300mm)

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range: -

Q_c = (12 to 18) C_u

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculations of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes, etc. This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

Dynamic Penetrometers

Dynamic penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150mm increments of penetration. Normally, there is a depth limitation of 1.2m but this may be extended in certain conditions by the use of extension rods.

Two relatively similar tests are used.

- Perth sand penetrometer – a 16mm diameter flattened rod is driven with a 9kg hammer, dropping 600mm (AS1289, Test 6.3.3). The test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
- Cone penetrometer (sometimes known as Scala Penetrometer) – a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS 1289, Test 6.3.2). The test was developed initially for pavement sub-grade investigations, and published correlations of the test results with California bearing ratio have been published by various Road Authorities.

Laboratory Testing

Laboratory testing is generally carried out in accordance with Australian Standard 1289 “Methods of Testing Soil for Engineering Purposes”. Details of the test procedure used are given on the individual report forms.

Borehole Logs

The bore logs presented herein are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable, or possible to justify on economic grounds. In any case, the boreholes represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes, the frequency of sampling and the possibility of other than ‘straight line’ variations between the boreholes.

Details of the type and method of sampling are given in the report and the following sample codes are on the borehole logs where applicable:

D	Disturbed Sample	E	Environmental sample	DT	Diatube
B	Bulk Sample	PP	Pocket Penetrometer Test		
U50	50mm Undisturbed Tube Sample	SPT	Standard Penetration Test		
U63	63mm “ “ “ “ “	C	Core		

Ground Water

Where ground water levels are measured in boreholes there are several potential problems:

- In low permeability soils, ground water although present, may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report.
- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made. More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be interference from a perched water table.

Engineering Reports

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. A three-storey building), the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty-storey building). If this happens, the Company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface condition, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- unexpected variations in ground conditions – the potential for this will depend partly on bore spacing and sampling frequency,
- changes in policy or interpretation of policy by statutory authorities,
- the actions of contractors responding to commercial pressures,

If these occur, the Company will be pleased to assist with investigation or advice to resolve the matter.

Site Anomalies

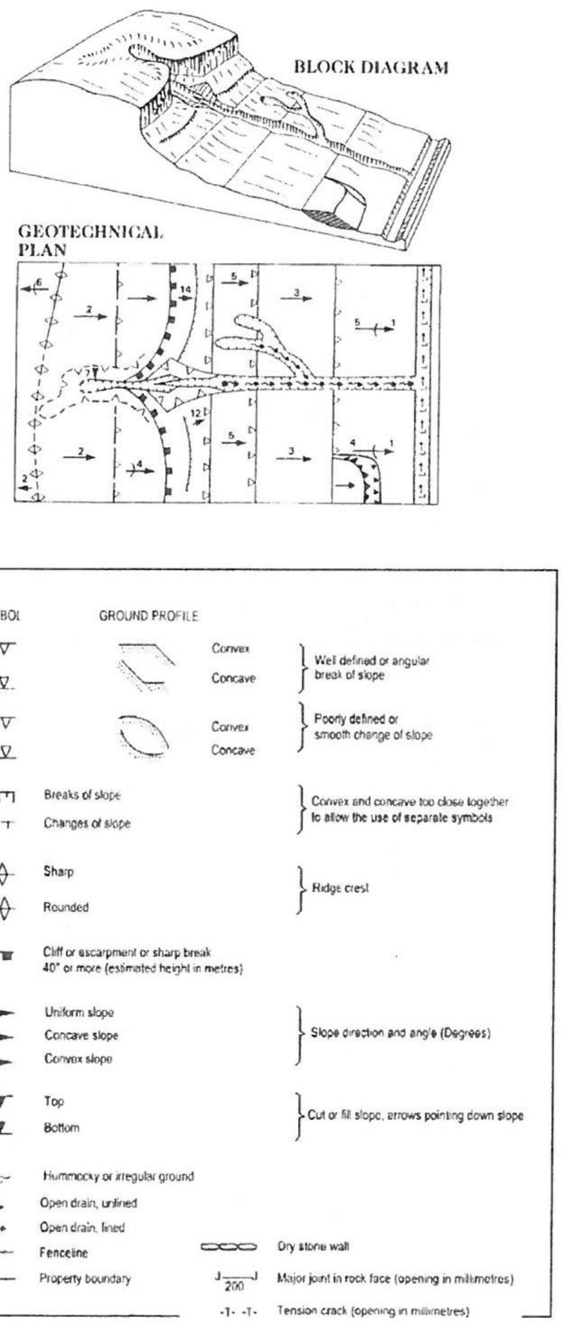
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some later stage, well after the event.

Reproduction of Information for Contractual Purposes

Attention is drawn to the document "Guidelines for the Provision of Geotechnical Information in Tender Documents", published by the Institution of Engineers Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a special ally edited document. The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

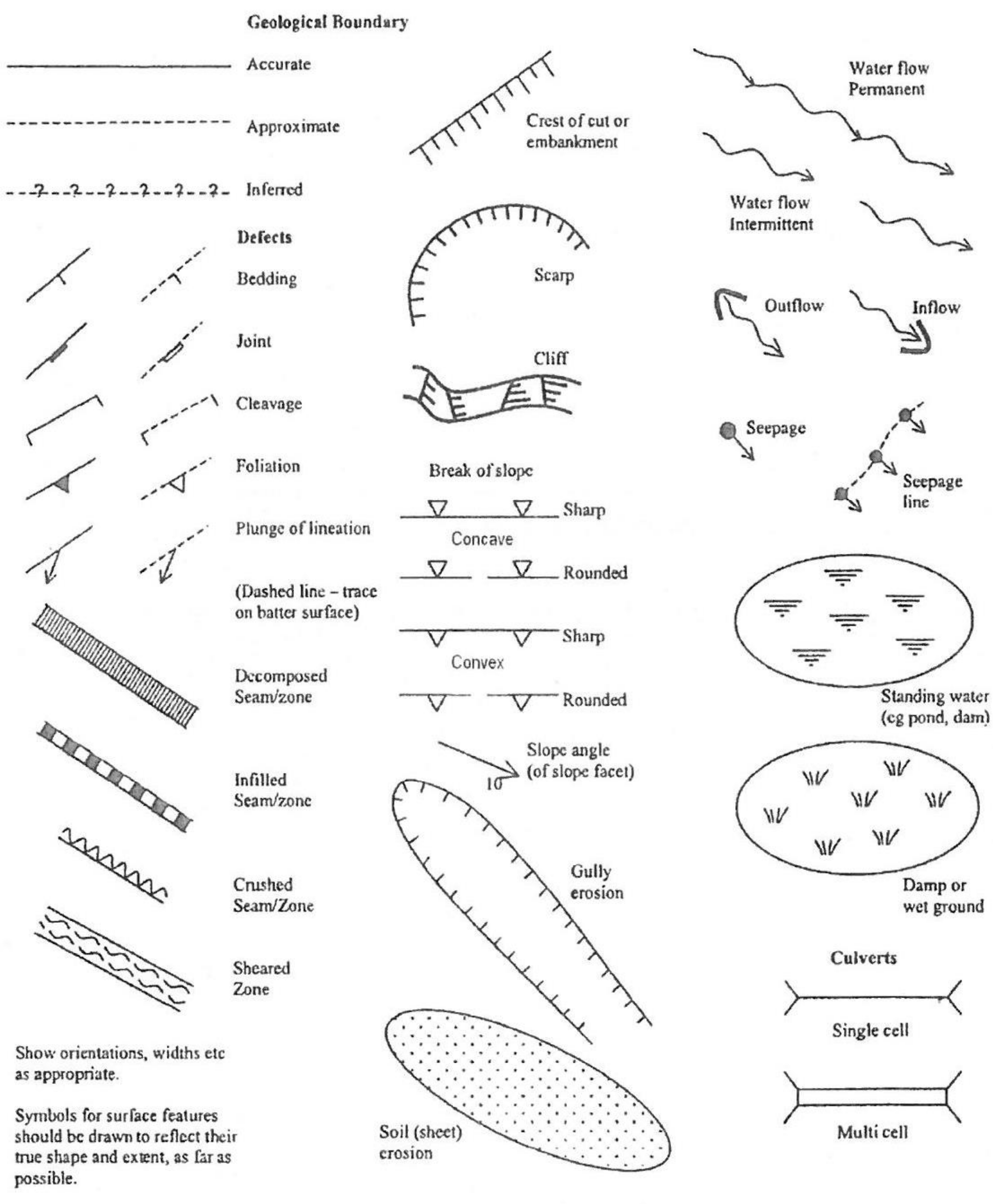
The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.



Example of Mapping Symbols

(after V Gardiner & R V Dackombe (1983).Geomorphological Field Manual. George Allen & Unwin).

APPENDIX E - GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING SYMBOLS AND TERMINOLOGY



Examples of Mapping Symbols (after Guide to Slope Risk Analysis Version 3.1 November 2001, Roads and Traffic Authority of New South Wales).

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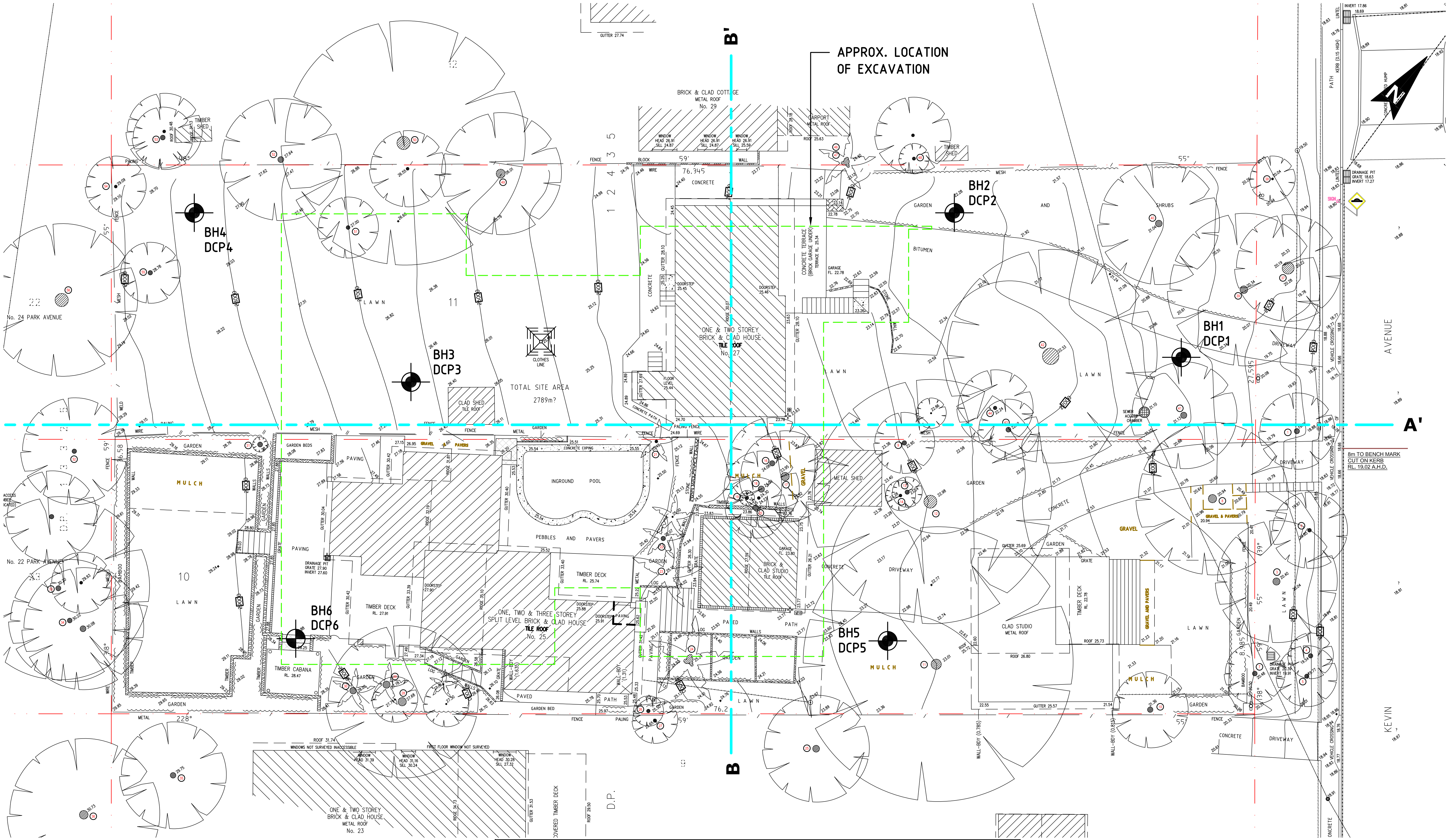
Appendix 2



0 2.5 5 7.5 10 12.5

5 4 3 2 1

SCALE 1:250

VL - Very Loose	VS - Very Soft	ELS - Extremely Low Strength	EW - Extremely Weathered	fg - Fine Grained
L - Loose	S - Soft	VLS - Very Low Strength	HW - Highly Weathered	mg - Medium Grained
MD - Medium Dense	F - Firm	LS - Low Strength	DW - Distinctly Weathered	cg - Coarse Grained
D - Dense	St - Stiff	MS - Medium Strength	MW - Moderately Weathered	MAS - Massive
VD - Very Dense	VSt - Very Stiff	HS - High Strength	SW - Slightly Weathered	BD - Bedded
	H - Hard	VHS - Very High Strength	FR - Fresh	OC - Outcrop

SITE PLAN AND TEST LOCATIONS FIGURE 1

CROZIER GEOTECHNICAL CONSULTANTS

Crozier Geotechnical
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Email: info@croziergeotech.com.au
Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

LEGEND

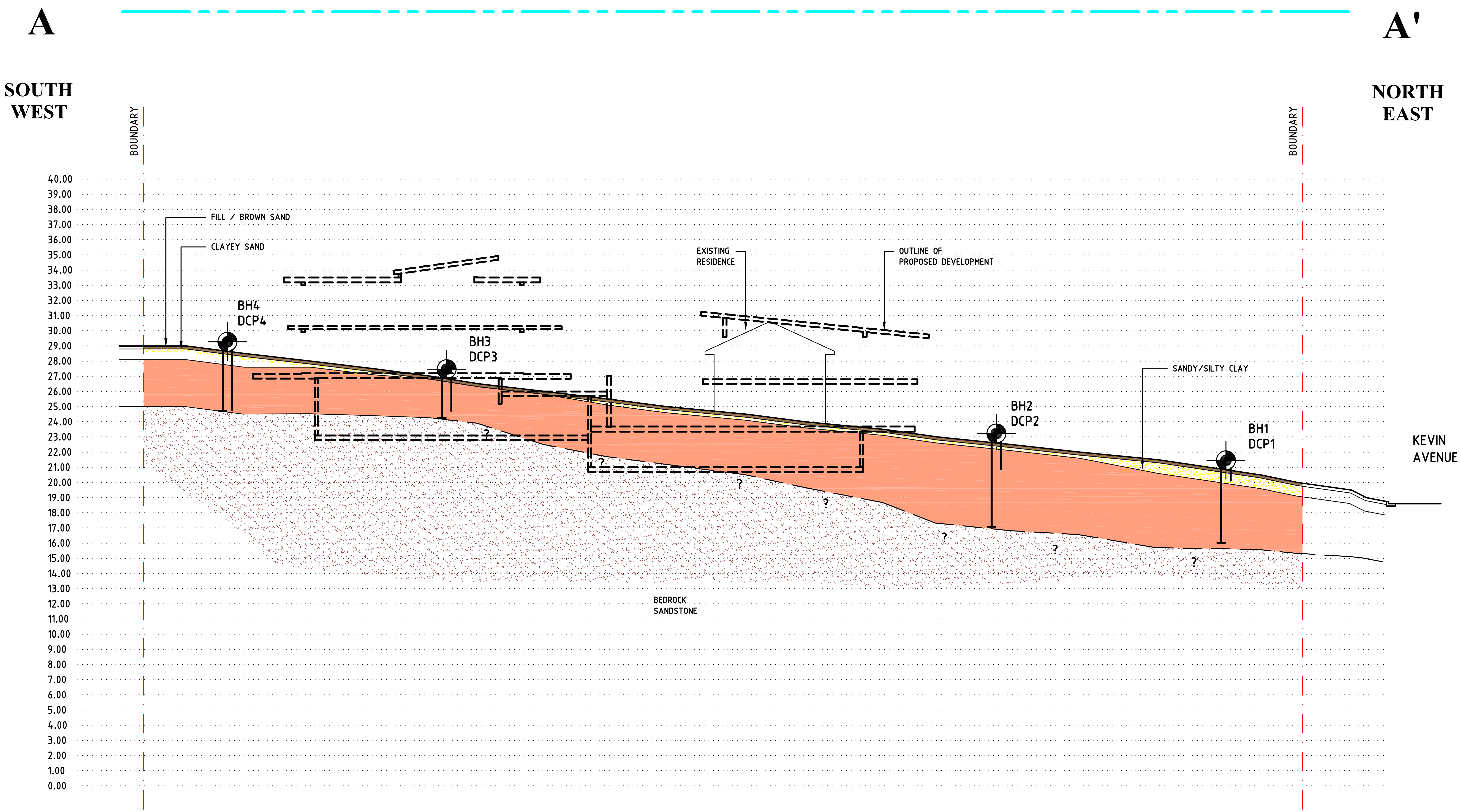
- BH- HAND AUGER LOCATION
- BH- DCP- AUGER / DYNAMIC PENETRATION TEST
- DCP- DYNAMIC PENETRATION TEST
- TP- TEST PIT LOCATION
- A—A' CROSS SECTION REFERENCE LINE
- BOUNDARY LINE

SCALE : 1:200
DRAWING : FIGURE 1
DATE : 21.08.23

APPROVED BY : J.L.
DRAWN BY : A.C.W.
PROJECT : 2023-156

PREPARED FOR :
GREGORY NATTRASS

ADDRESS :
25 - 27 KEVIN AVENUE
AVALON BEACH, N.S.W.



0 2.5 5 7.5 10 12.5

5 4 3 2 1

SCALE 1:250

GEOLOGICAL MODEL

FIGURE 2

CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical
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Phone: (02) 9939 1882
Email: info@croziergeotech.com.au
Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

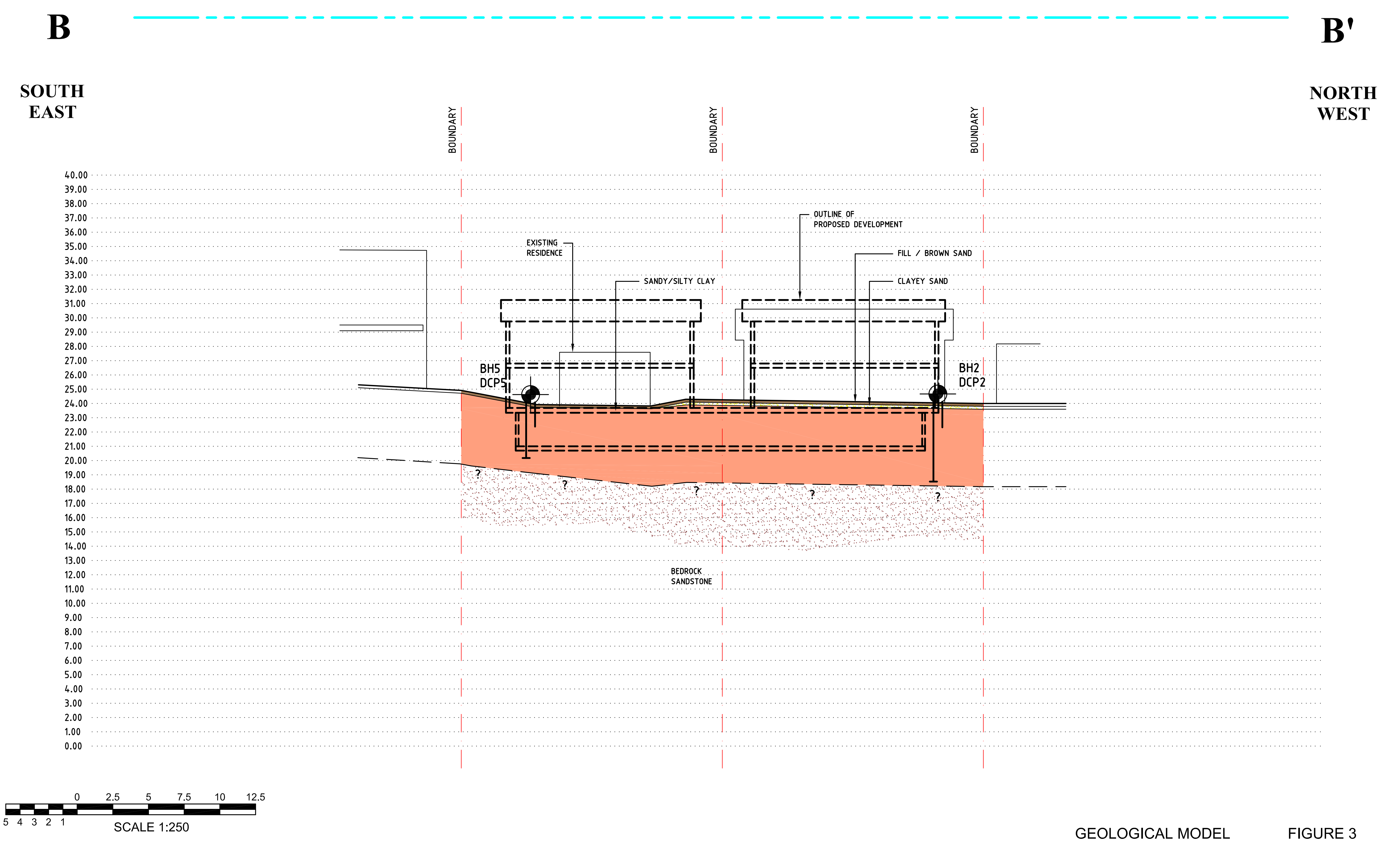
LEGEND

- HAND AUGER LOCATION
- AUGER / DYNAMIC PENETRATION TEST
- DCP- DYNAMIC PENETRATION TEST
- BOUNDARY LINE
- BROWN SANDY TOPSOIL
- CLAYEY SAND
- CLAYEY SAND
- BEDROCK SANDSTONE

SCALE :	1:200
DRAWING :	FIGURE 2
DATE :	21.08.23
APPROVED BY :	J.L.
DRAWN BY :	A.C.W.
PROJECT :	2023-156

PREPARED FOR :
GREGORY NATTRASS

ADDRESS :
25 - 27 KEVIN AVENUE
AVALON BEACH, N.S.W.



GEOLOGICAL MODEL

FIGURE 3

CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical
Unit 12, 42-46 Wattle Road
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LEGEND

- HAND AUGER LOCATION
- AUGER / DYNAMIC PENETRATION TEST
- DCP- DYNAMIC PENETRATION TEST
- BOUNDARY LINE
- BROWN SANDY TOPSOIL
- CLAYEY SAND
- CLAYEY SAND
- BEDROCK SANDSTONE

SCALE :	1:200
DRAWING :	FIGURE 3
DATE :	21.08.23
APPROVED BY :	J.L.
DRAWN BY :	A.C.W.
PROJECT :	2023-156

PREPARED FOR :
GREGORY NATTRASS

ADDRESS :
25 - 27 KEVIN AVENUE
AVALON BEACH, N.S.W.

BOREHOLE LOG

CLIENT: **Gregory Nattrass** **DATE:** 7/08/2023 **BORE No.:** 1

PROJECT: **Proposed New Apartment** **PROJECT No.:** 2023-156 **SHEET:** 1 of 1

LOCATION: **25-27 Kevin Ave, Avalon Beach, NSW** **SURFACE LEVEL:** 20.5m AHD

Depth (m)	Classification	Description of Strata **PRIMARY SOIL** - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00						
0.20	-	TOPSOIL: medium dense, brown, fine grained, moist, silty sand, trace rootlets.				
	SC	Clayey SAND: very dense, orange brown, fine grained, moist, clayey sand, trace silt.	D	0.30 0.40		
0.90						
1.00	CI	Sandy CLAY: hard, red brown, medium plasticity, moist,dry of plastic limit, sandy clay; sand is fine to medium grained, ironstained.				
1.20		From 1.2m, pale grey and red brown.	D	1.20 1.40		
2.00						
2.30		From 2.3m, pale grey, indurated.				
3.00						
3.80		From 3.8m, grading into extremely weathered materials.				
4.00						
4.80						
5.00		Terminated at 4.8m, TC-Bit refusal on iron-stained sandstone band.				

RIG: Dingo - Restrict Access Drill Rig DRILLER: AC

METHOD: Auger Drilling LOGGED: JL

GROUND WATER OBSERVATIONS: Groundwater not encountered

REMARKS: D=Disturbed CHECKED: TMC

BOREHOLE LOG

CLIENT: **Gregory Nattrass** **DATE:** 7/08/2023 **BORE No.:** 2

PROJECT: **Proposed New Apartment** **PROJECT No.:** 2023-156 **SHEET:** 1 of 2

LOCATION: **25-27 Kevin Ave, Avalon Beach, NSW** **SURFACE LEVEL:** 22.6m AHD

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
0.00			Type	Tests	Type	Results
0.10	-	TOPSOIL: dark grey, fine grained, moist silty sand, trace rootlets.		0.10		
	SP	SAND: loose, pale brown grey, fine to medium grained, moist, sand.	D	0.20		
0.40						
	CI	Sandy CLAY: firm, pale brown, low plasticity, moist, dry of plactic limit, sandy clay, with iron stainings.		0.50		
			D	0.60		
0.80						
	CI-CH	Silty CLAY: stiff, red brown and orange brown, medium to high plasticity, moist, dry of plastic limit, with iron stainings.		0.90		
1.00			D	1.00		
1.10		From 1.1m, very stiff.				
1.40		From 1.4m, hard.				
1.80		From 1.8 to 1.9m, soft sandy clay band.				
2.00		From 2.0m, pale grey and red brown, indurated.				
				2.30		
			D	2.40		
3.00						
3.20						
	CL-CI	Sandy CLAY: hard, pale grey and red brown, low to medium plasticity, moist, dry of plastic limits, sandy clay.		3.40		
			D	3.50		
4.00						
5.00						

RIG: Dingo - Restrict Access Drill Rig DRILLER: AC

METHOD: Auger Drilling LOGGED: JL

GROUND WATER OBSERVATIONS: Groundwater not encountered

REMARKS: D=Disturbed CHECKED: TMC

BOREHOLE LOG

CLIENT: **Gregory Nattrass** **DATE:** 7/08/2023 **BORE No.:** 2

PROJECT: **Proposed New Apartment** **PROJECT No.:** 2023-156 **SHEET:** 2 of 2

LOCATION: **25-27 Kevin Ave, Avalon Beach, NSW** **SURFACE LEVEL:**

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
5.00			Type	Tests	Type	Results
5.50	CL-CI	Sandy CLAY: hard, pale grey and red brown, low to medium plasticity, moist, dry of plastic limits, sandy clay.				
6.00		Terminated at 5.5m, target depth.				

RIG: Dingo - Restrict Access Drill Rig

DRILLER: AC

METHOD: Auger Drilling

LOGGED: JL

GROUND WATER OBSERVATIONS: Groundwater not encountered

REMARKS: D=Disturbed

CHECKED: TMC

BOREHOLE LOG

CLIENT: **Gregory Nattrass** | **DATE:** 7/08/2023 | **BORE No.:** 3

PROJECT: **Proposed New Apartment** | **PROJECT No.:** 2023-156 | **SHEET:** 1 of 1

LOCATION: **25-27 Kevin Ave, Avalon Beach, NSW** | **SURFACE LEVEL:** 26.6m AHD

Depth (m)	Classification	Description of Strata **PRIMARY SOIL** - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00	-	TOPSOIL/FILL: very loose to loose, dark grey, fine grained, moist, silty sand, trace rootlets.				
0.40	CL-CI	Sandy CLAY: firm, brown, low to medium plasticity, moist, dry of plastic limit, sandy clay.	D	0.50 0.60		
0.90 1.00		From 0.9m, stiff, pale grey.				
1.20		From 1.2m, hard.	D	1.50 1.60		
2.00						
2.35		Terminated at 2.35m, TC-Bit refusal on low strength sandstone bedrock.				

RIG: Dingo - Restrict Access Drill Rig | DRILLER: AC

METHOD: Auger Drilling | LOGGED: JL

GROUND WATER OBSERVATIONS: Groundwater not encountered

REMARKS: D=Disturbed | CHECKED: TMC

BOREHOLE LOG

CLIENT: Gregory Nattrass | **DATE:** 7/08/2023 | **BORE No.:** 4

PROJECT: Proposed New Apartment | **PROJECT No.:** 2023-156 | **SHEET:** 1 of 1

LOCATION: 25-27 Kevin Ave, Avalon Beach, NSW | **SURFACE LEVEL:** 27.7m AHD

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00	-	TOPSOIL: Loose, dark grey, fine grained, moist, silty sand, trace rootlets.				
0.20				0.20		
	SM	Silty Sand: loose to medium dense, grey brown, fine grained, moist, silty sand.	D	0.30		
0.60				0.60		
		From 0.6m, brown, trace clay.	D	0.70		
0.90				0.90		
1.00	CL-CI	Sandy CLAY: stiff, yellow brown, low to medium plasticity, moist, dry of plasticity, sandy clay.	D	1.00		
1.40						
	CI-CH	Silty CLAY: stiff, brown, medium to high plasticity, moist, dry of plastic limit, silty clay, trace sand.				
1.80		From 1.8m, very stiff.				
2.00		From 2.0m, pale grey, indurated.				
				2.20		
			D	2.30		
2.60				2.60		
		From 2.6m, green grey.	D	2.70		
2.80		From 2.8m, grading into extremely weathered materials.				
3.00						
		Terminated at 3.0m, TC-Bit refusal on low strength sandstone bedrock.				

RIG: Dingo - Restrict Access Drill Rig | DRILLER: AC

METHOD: Auger Drilling | LOGGED: JL

GROUND WATER OBSERVATIONS: Groundwater not encountered

REMARKS: D=Disturbed | CHECKED: TMC

BOREHOLE LOG

CLIENT: **Gregory Nattrass** | **DATE:** 7/08/2023 | **BORE No.:** 5

PROJECT: **Proposed New Apartment** | **PROJECT No.:** 2023-156 | **SHEET:** 1 of 1

LOCATION: **25-27 Kevin Ave, Avalon Beach, NSW** | **SURFACE LEVEL:** 23.0m AHD

Depth (m)	Classification	Description of Strata **PRIMARY SOIL** - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
0.00			Type	Tests	Type	Results
0.30	-	FILL: medium dense to dense, dark grey, fine grained, dry, silty sand.				
0.60	CI-CH	Sandy CLAY: very stiff, red orange brown, medium to high plasticity, moist, dry of plastic limit, sandy clay with iron stainings.		0.60		
		From 0.6m, hard.	D	0.70		
1.00						
1.80		From 1.8m, pale grey and red brown.				
2.00						
2.80		From 2.8m, red brown, grading into extremely weathered materials.		2.80		
3.00			D	3.00		
3.80						
		Terminated at 3.8m, TC-Bit refusal on iron-stained sandstone band.				

RIG: Dingo - Restrict Access Drill Rig | DRILLER: AC

METHOD: Auger Drilling | LOGGED: JL

GROUND WATER OBSERVATIONS: Groundwater not encountered

REMARKS: D=Disturbed | CHECKED: TMC

BOREHOLE LOG

CLIENT: Gregory Nattrass | **DATE:** 7/08/2023 | **BORE No.:** 6

PROJECT: Proposed New Apartment | **PROJECT No.:** 2023-156 | **SHEET:** 1 of 1

LOCATION: 25-27 Kevin Ave, Avalon Beach, NSW | **SURFACE LEVEL:** 27.2m AHD

Depth (m)	Classification	Description of Strata **PRIMARY SOIL** - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00	-	FILL: loose, dark grey, low plasticity, moist, dry of plastic limit, silty clay, trace sand and rootlets.				
0.50	SP	SAND: loose, grey brown, fine to medium grained, moist to wet, sand, trace clay and silt.		0.70		
			D	0.80		
1.00						
1.20						
		Terminated at 1.2m, hole collapsed.				

RIG: N/A | DRILLER: GG

METHOD: Hand Auger | LOGGED: JL

GROUND WATER OBSERVATIONS: Groundwater seepage encountered at 0.7m

REMARKS: D=Disturbed | CHECKED: TMC

DYNAMIC PENETROMETER TEST SHEET

CLIENT: Gregory Nattrass | **DATE:** 7/08/2023

PROJECT: Proposed New Apartment | **PROJECT No.:** 2023-156

LOCATION: 25-27 Kevin Ave, Avalon Beach, NSW | **SHEET:** 1 of 1

	Test Location									
Depth (m)	DCP1	DCP2	DCP3	DCP4	DCP5	DCP6				
0.00 - 0.10	3	2	-	1	4	-				
0.10 - 0.20	4	2	-	1	8	1				
0.20 - 0.30	16	2	0	1	10	1				
0.30 - 0.40	14	2	1	2	9	2				
0.40 - 0.50	16	2	1	2	10	1				
0.50 - 0.60	17	3	2	3	7	3				
0.60 - 0.70	17	2	2	3	11	2				
0.70 - 0.80	END	2	2	5	12	2				
0.80 - 0.90		3	3	5	11	2				
0.90 - 1.00		6	5	5	10	3				
1.00 - 1.10		6	5	4	11	4				
1.10 - 1.20		10	6	5	11	7				
1.20 - 1.30		9	9	4	13	10				
1.30 - 1.40		11	12	3	16	9				
1.40 - 1.50		16	15	4	16	7				
1.50 - 1.60		16	14	4	17	7				
1.60 - 1.70		17	15	6	END	12(B)				
1.70 - 1.80		END	17	6		at 1.75m				
1.80 - 1.90			16	8						
1.90 - 2.00			END	8						
2.00 - 2.10				6						
2.10 - 2.20				6						
2.20 - 2.30				6						
2.30 - 2.40				9						
2.40 - 2.50				8						
2.50 - 2.60				7						
2.60 - 2.70				7						
2.70 - 2.80				16						
2.80 - 2.90				2 (B)						
2.90 - 3.00				at 2.92m						
3.00 - 3.10										
3.10 - 3.20										
3.20 - 3.30										
3.30 - 3.40										
3.40 - 3.50										
3.50 - 3.60										
3.60 - 3.70										
3.70 - 3.80										
3.80 - 3.90										
3.90 - 4.00										

TEST METHOD: AS 1289. F3.2, CONE PENETROMETER

REMARKS:
(B) Test hammer bouncing upon refusal on solid object
-- No test undertaken at this level due to prior excavation of soils

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Appendix 3

TABLE : A

Landslide risk assessment for Risk to life

HAZARD	Description	Impacting	Likelihood of Slide	Spatial Impact of Slide		Occupancy	Evacuation	Vulnerability	Risk to Life
A	Landslip (earth slide 10m³) from soils due to the bulk excavation		Retaining height generally about 5.50m within soil or bedrock for the proposed basement.	a) Proposed basement/building within the excavaton, impact 10% b) Pavement/footpath adjacent to the excavation, impact 5% c) House has an offset of about 5.0m to the excavation, impact 10%; d) House has an offset of about 4.0m to the excavation, impact 5%		a) Person in basement 14hr/day avge. b) Person on the pavement/footpath 2.0hr/day avge. c) Person within the house, 20hr/day avge. d) Peron within the house, 20hr/day avge.	a) Likely certain to not evacuate b) Possible to evacuate c) Likely to not evacuate d) Likely to not evacuate	a) Person in open area, buried b) Person in open area, buried c) Person in house, minor damage only d) Person in house, minor damage only	
			Rare	**Prob. of Impact**	**Impacted**				
		a) Proposed basement/building	0.00001	1.00	0.10	0.583	0.75	1.00	**4.38E-07**
		b) Pavement/footpath around the proposed main building	0.00001	1.00	0.05	0.083	0.50	1.00	**2.08E-08**
		c) Main building of 23 Kevin Ave	0.00001	0.20	0.10	0.833	0.75	0.05	**6.25E-09**
		c) Main building of 29 Kevin Ave	0.00001	0.05	0.10	0.833	0.75	0.05	**1.56E-09**

* hazards considered in current condition and/or without remedial/stabilisation measures or poor support systems
* likelihood of occurrence for design life of 100 years
* Spatial Impact - Probability of Impact refers to slide impacting structure/area expressed as a % (i.e. 1.00 = 100% probability of slide impacting area if slide occurs).
  Impacted refers to expected % of area/structure damaged if slide impacts (i.e. small, slow earth slide will damage small portion of house structure such as 1 bedroom (5%), where as large boulder roll may damage/destroy >50%)
* neighbouring houses considered for impact of slide to bedroom unless specified, due to high occupancy and lower potential for evacuation.
* considered for person most at risk, where multiple people occupy area then increased risk levels
* for excavation induced landslip then considered for adjacent premises/buildings founded off shallow footings, unless indicated
* evacuation scale from Almost Certain to not evacuate (1.0), Likely (0.75), Possible (0.5), Unlikely (0.25), Rare to not evacuate (0.01). Based on likelihood of person knowing of landslide and completely evacuating area prior to landslide impact.
* vulnerability assessed using Appendix F - AGS Practice Note Guidelines for Landslide Risk Management 2007

TABLE : B

Landslide risk assessment for Risk to Property

HAZARD	Description	Impacting	Likelihood		Consequences		Risk to Property
A	Landslip (earth slide 10m³) from soils due to the bulk excavation	a) Proposed basement/building	Almost Certain	Event is expected to occur over design life.	Medium	Moderate damage to some of structure or significant part of site or MINOR damage to neighbouring property, requires large stabilising works .	Very High
		b) Pavement/footpath around the proposed main building	Almost Certain	Event is expected to occur over design life.	Medium	Moderate damage to some of structure or significant part of site or MINOR damage to neighbouring property, requires large stabilising works .	Very High
		c) Main building of 23 Kevin Ave	Unlikely	The event might occur under very adverse circumstances over the design life.	Medium	Moderate damage to some of structure or significant part of site or MINOR damage to neighbouring property, requires large stabilising works .	Low
		c) Main building of 29 Kevin Ave	Unlikely	The event might occur under very adverse circumstances over the design life.	Medium	Moderate damage to some of structure or significant part of site or MINOR damage to neighbouring property, requires large stabilising works .	Low

* hazards considered in current condition, without remedial/stabilisation measures and during construction works.
* qualitative expression of likelihood incorporates both frequency analysis estimate and spatial impact probability estimate as per AGS guidelines.
* qualitative measures of consequences to property assessed per Appendix C in AGS Guidelines for Landslide Risk Management.
* Indicative cost of damage expressed as cost of site development with respect to consequence values: Catastrophic : 200%, Major: 60%, Medium: 20%, Minor: 5%, Insignificant: 0.5%.
* Cost of site development estimated at $5,000,000

TABLE: 2

Recommended Maintenance and Inspection Program

Structure	Maintenance/ Inspection Item	Frequency
Stormwater drains.	Owner to inspect to ensure that the open drains, and pipes are free of debris & sediment build-up. Clear surface grates and litter. Owner to check and flush retaining wall drainage pipes/systems	Every year or following each major rainfall event. Every 10 years or where
Retaining Walls. or remedial measures	Owner to inspect walls for deveation from as constructed condition and repair/replace.	Every two years or following major rainfall event.
Large Trees on or adjacent to site	Arborist to check condition of trees and remove as required. Where tree within steep slopes (>18°) or adjacent to structures requires geotechincal inspection prior to removal	Every five years
Slope Stability	Geotechnical Engineering Consultant to check on site stability and maintenance	Five years after construction is completed.

N.B. Provided the above shedule is maintained the design life of the property should conform with Councils Risk Management Policy.

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Appendix 4

APPENDIX A

DEFINITION OF TERMS

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES WORKING GROUP ON LANDSLIDES, COMMITTEE ON RISK ASSESSMENT

Risk – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

Hazard – A condition with the potential for causing an undesirable consequence (*the landslide*). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.

Elements at Risk – Meaning the population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

Probability – The likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible outcome, and 1 indicating that an outcome is certain.

Frequency – A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.

Likelihood – used as a qualitative description of probability or frequency.

Temporal Probability – The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.

Vulnerability – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

Consequence – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

Risk Analysis – The use of available information to estimate the risk to individuals or populations, property, or the environment, from hazards. Risk analyses generally contain the following steps: scope definition, hazard identification, and risk estimation.

Risk Estimation – The process used to produce a measure of the level of health, property, or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis, and their integration.

Risk Evaluation – The stage at which values and judgements enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental, and economic consequences, in order to identify a range of alternatives for managing the risks.

Risk Assessment – The process of risk analysis and risk evaluation.

Risk Control or Risk Treatment – The process of decision making for managing risk, and the implementation, or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

Risk Management – The complete process of risk assessment and risk control (*or risk treatment*).

Individual Risk – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.

Societal Risk – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental, and other losses.

Acceptable Risk – A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

Tolerable Risk – A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible.

In some situations risk may be tolerated because the individuals at risk cannot afford to reduce risk even though they recognise it is not properly controlled.

Landslide Intensity – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.

Note: Reference should also be made to Figure 1 which shows the inter-relationship of many of these terms and the relevant portion of Landslide Risk Management.

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}		100 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.

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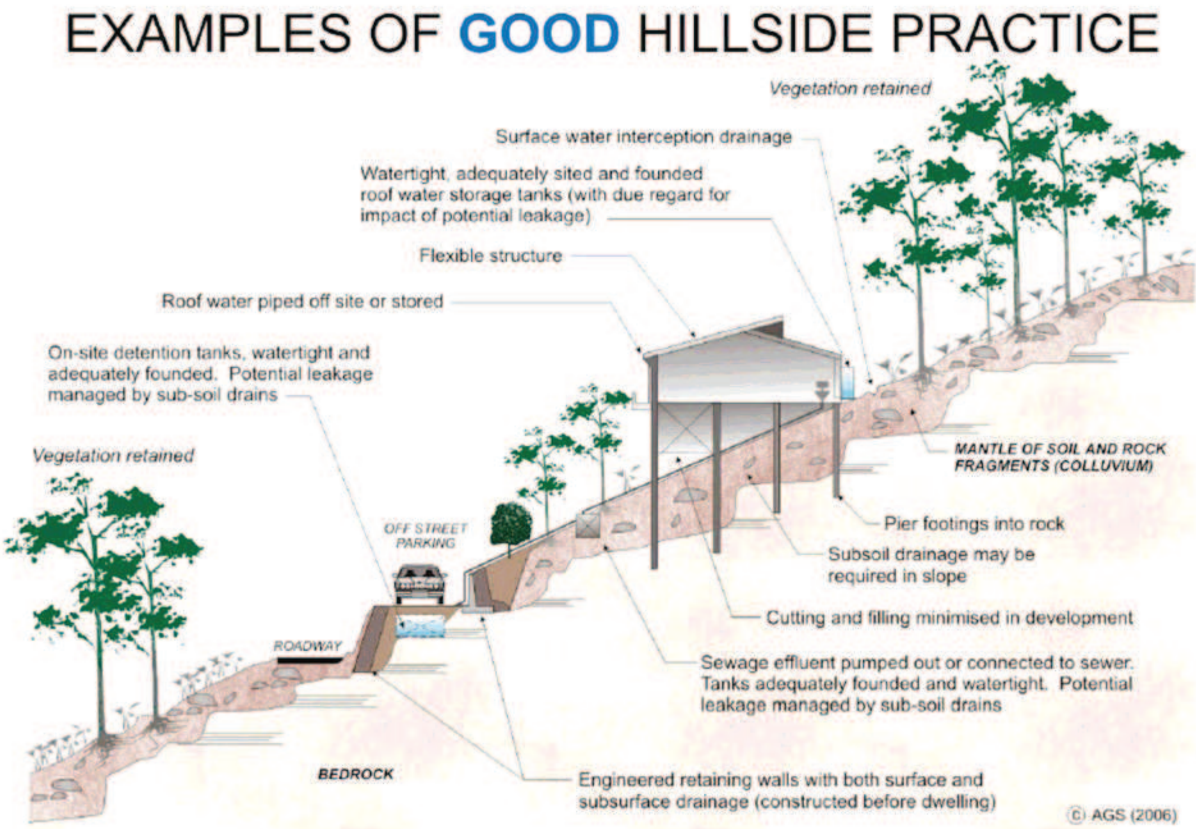
Appendix 5

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	


EXAMPLES OF GOOD HILLSIDE PRACTICE
Vegetation retained
Surface water interception drainage
Watertight, adequately sited and founded roof water storage tanks (with due regard for impact of potential leakage)
Flexible structure
Roof water piped off site or stored
On-site detention tanks, watertight and adequately founded. Potential leakage managed by sub-soil drains
Vegetation retained
OFF STREET PARKING
ROADWAY
MANTLE OF SOIL AND ROCK FRAGMENTS (COLLUVIUM)
Pier footings into rock
Subsoil drainage may be required in slope
Cutting and filling minimised in development
Sewage effluent pumped out or connected to sewer. Tanks adequately founded and watertight. Potential leakage managed by sub-soil drains
BEDROCK
Engineered retaining walls with both surface and subsurface drainage (constructed before dwelling)
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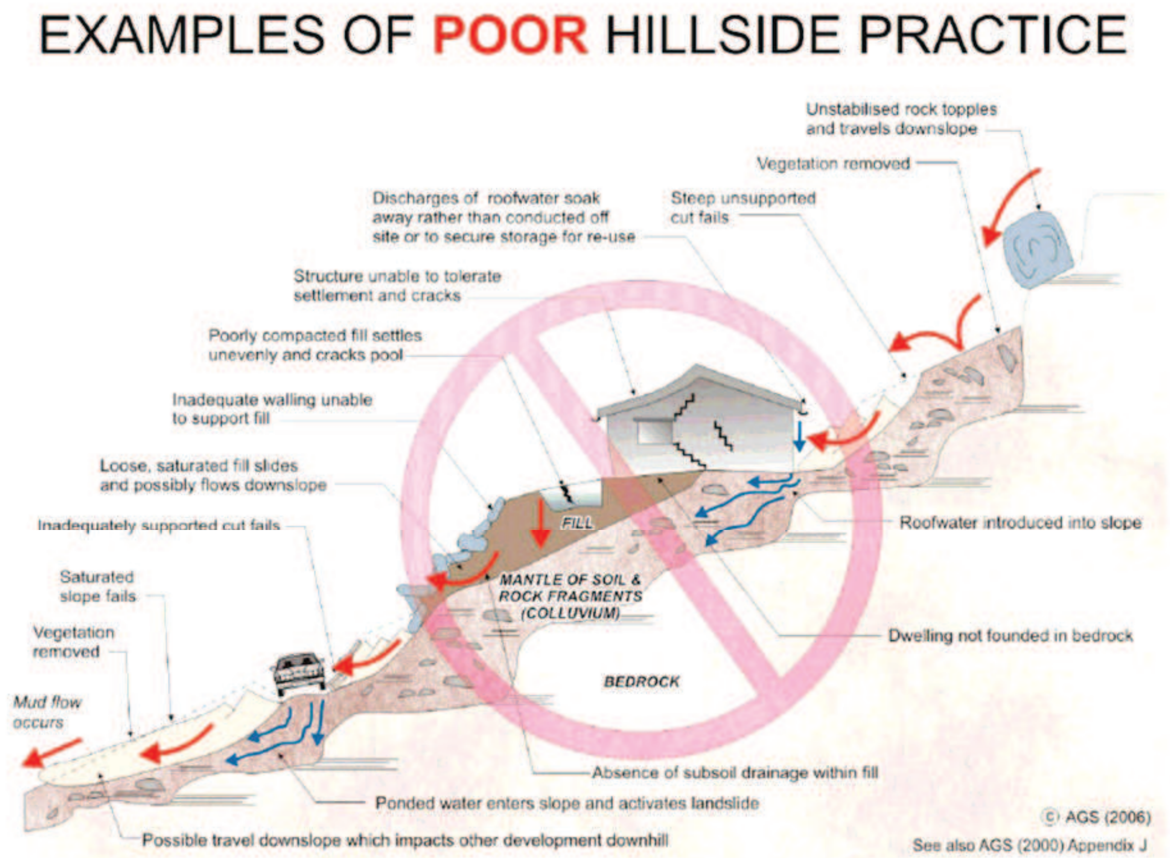
EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Loose, saturated fill slides and possibly flows downslope
Inadequately supported cut fails
FILL
Roofwater introduced into slope
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Saturated slope fails
Vegetation removed
Dwelling not founded in bedrock
BEDROCK
Mud flow occurs
Absence of subsoil drainage within fill
Ponded water enters slope and activates landslide
Possible travel downslope which impacts other development downhill
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See also AGS (2000) Appendix J