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REPORT ON GEOTECHNICAL SITE INVESTIGATION

for

PROPOSED ALTERATIONS AND ADDITIONS

at

552 PITTWATER ROAD, NORTH MANLY, NSW

Prepared For

Davy Constructions

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GEOTECHNICAL REPORT FOR PROPOSED NEW DWELLING
552 PITTWATER ROAD, NORTH MANLY, NSW

1. INTRODUCTION:

This report details the results of a geotechnical investigation carried out for proposed alterations and additions at No.552 Pittwater Road, North Manly, NSW. The investigations were undertaken by Crozier Geotechnical Consultants (CGC) at the request of the client Davy Constructions.

It is understood that the proposed works involve the demolition of the existing site structures and the construction of a new four storey residential dwelling with an inground swimming pool within the rear. The proposed residence will include a garage level, studio level and loft level excavated into the west dipping embankment. The main house level is to be formed at the approximate surface level of the existing dwelling and is not anticipated to require any bulk excavation. Bulk excavation is anticipated to a maximum depth of 11.0m within eastern portions of the proposed main excavation.

Northern Beaches Council's - Warringah 2011 LEP and DCP states that all building development applications must be accompanied by a geotechnical landslip assessment. That developments within Class 'A', 'B' and 'D' landslip risk zone may require a preliminary assessment only where excavation/fill is <2.0m depth, however Class 'C' and 'E' sites and where excavation/fill >2.0m depth is proposed in other sites then a full geotechnical report is required.

This site is located within landslip risk Class 'B' within the Landslip Risk Map _ Sheet 008. A review of the preliminary checklist and the proposed works identified that the Development Application (DA) involves works which exceed the preliminary assessment guidelines.

To meet the councils requirement, the report therefore outlines the site conditions and how the development may be achieved to ensure geotechnical stability and good engineering practice. This report includes a risk assessment of the site for both property and life as per the AGS March 2007 publication. It also includes a site mapping/plan, geological section and provide recommendations for construction.

The investigation and reporting were undertaken in general accordance with Proposal No.: P20-530, Dated: 11th November 2020.

The investigation comprised:

a) A detailed geotechnical inspection and mapping of the site and adjacent properties by a Geotechnical Engineer.
b) DBYD plan request and review.
c) Drilling of one borehole using hand tools along with seven Dynamic Cone Penetrometer (DCP) tests to investigate the sub-surface geology and identification of ground water conditions.

The following plans and drawings were supplied for the work:

- Architectural Plans by Nettletontribe, Drawing Number: 11802_ DA100 to DA103, DA111 to DA115, DA201, DA202, DA501, DA502, DA601 and DA604, Issue 1 dated 04.06.2021. Option 2.
- Survey Plan by Adam Clerke Surveyors Pty Ltd, Date: 22/02/19 and Ref. No.: 419.

2. PROPOSED WORKS:

The proposed works involve the demolition of the existing site structures and the construction of a four storey residence, which will include a garage level (RL6.45m), studio level (RL10.80m) and loft level (RL13.90m) towards the front of the site, with the main house level (RL17.20m) occupying the majority of the building envelope. A central elevator will connect the four levels of the proposed development.

Bulk excavation will be required for the construction of the lower three levels grading from approximately 2.60m depth at the front boundary to an anticipated maximum depth of 11.0m within eastern portions of the excavation at the centre of the site. The proposed house level is to be largely constructed at the surface level of the existing dwelling, requiring nil to minimal bulk excavation. A driveway ramp is to be constructed at the front of the site, providing vehicle access from Pittwater Road. The driveway ramp is anticipated to largely utilise the existing driveway/garage footprint and will not require any bulk excavation beyond the front boundary of the site. The swimming pool within the rear of the site will require bulk excavation to approximately 1.0m depth.

The proposed structure will have 0.9m northern and southern side boundary setbacks, a 6.5m rear boundary setback and a 1.2m front boundary setback, with concrete stairs to be formed to the west of the structure along the front boundary of the site. The swimming pool within the rear of the site is to have a 0.9m northern side boundary setback and a ≥2.0m rear boundary setback. A large tree is to be retained within the front of the site and will require the lower three levels of the proposed development to be formed around the tree.

3. SITE FEATURES:

3.1. Description:

The site is an irregular shaped block with a front west boundary of 17.0m, rear east boundary of 7.2m, side north boundary of 40.3m and side south boundary of 41.6m with a total area of 480.4m, as referenced from the provided survey plan.

An aerial photograph of the site and its surrounds is provided below in Photograph 1, as sourced from NSW Government Six Map spatial data system.

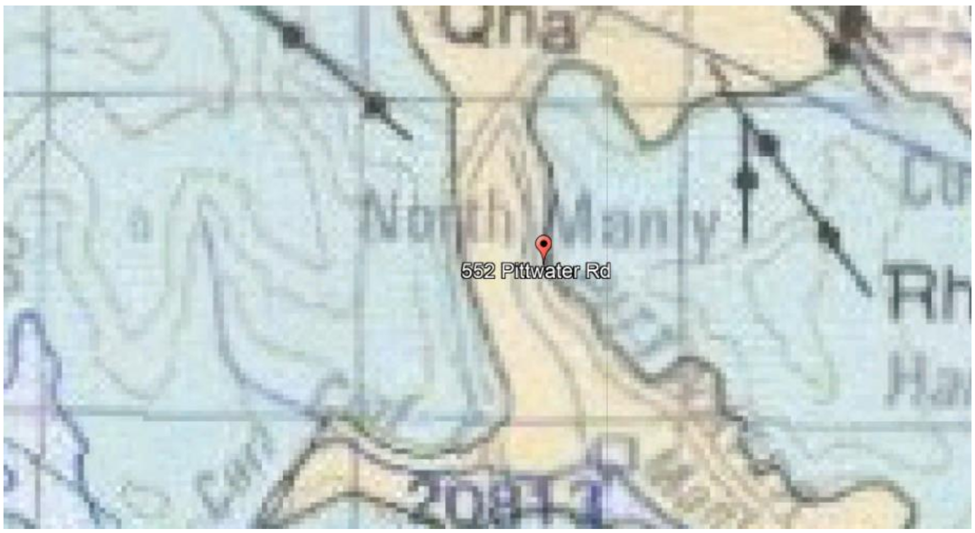
Photograph 1: Aerial photo of site and surrounds

The site is currently occupied by a single storey fibrous and rendered brick house located at the rear of the property with a garage at the front. The ground surface of the site falls from a high of approximately RL16.37 at the east rear of the block to a low of approximately RL6.00 at the front.

3.2. Geology:

Reference to the Sydney 1: 100,000 Geological Series sheet (9130) indicates that the site is located near the boundary between the Hawkesbury Sandstone (Rh) and overlying Quaternary Age silty to peaty quartz sand, silt, and clay (Qha). The Hawkesbury Sandstone typically comprises medium to coarse grained quartz sandstone with minor lenses of shale and laminite. This rock unit was identified in surface exposures within and adjacent to the site.

Morphological features often associated with the weathering of Hawkesbury Sandstone are the formation of near flat ridge tops with steep angular side slopes that consist of sandstone terraces and cliffs in part covered with sandy colluvium. The terraced areas often contain thin sandy clay to clayey sand residual soil profiles with intervening rock (ledge) outcrops. The outline of the cliff areas are often rectilinear in plan view, controlled by large bed thickness and wide spaced near vertical joint patterns. The dominant defect orientations being south-east and north-east. Many cliff areas are undercut by differential weathering along sub-horizontal to gently west dipping bedding defects or weaker sandstone/siltstone/shale horizons. Slopes are often steep (15º to 23°) and are randomly covered by sandstone boulders.



Extract of Sydney 1:100 000 Geological Series Sheet

4. FIELD WORK:

4.1. Methods:

The field investigation comprised a walk over inspection and mapping of the site and limited inspection of adjacent properties on the 25th November 2020 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 ground conditions. It also included the drilling of one borehole (BH1) using a hand auger to investigate sub-surface geology.

Dynamic Cone Penetrometer (DCP) testing was carried out adjacent to the borehole and at six separate locations 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 and confirm depths to bedrock.

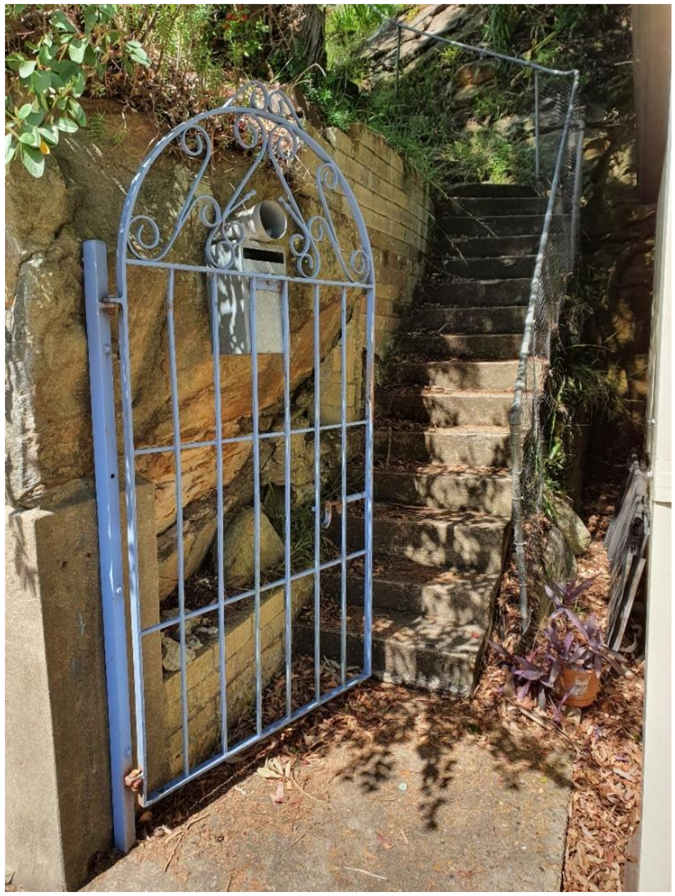
Explanatory notes are included in Appendix: 1. Mapping information and test locations are shown on Figure: 1, along with detailed log sheets in Appendix: 2. A geological model is provided as Figure: 2, Appendix: 1.

4.2. Field Observations:

The site is located on the high east side of Pittwater Road within moderate to steep west dipping topography. Pittwater Road is formed with a bitumen pavement with concrete gutter and kerb and is gently (-1°) south dipping where it passes the site. A concrete footpath and sandstone bedrock/outcrop lie between the road and site boundary. There were no signs of excessive cracking or deformation within the road pavement and footpath to suggest any movement or underlying geotechnical issues. The sandstone bedrock was excavated vertically on the western side to accommodate the footpath and also towards the east to accommodate the existing garage of the site and concrete steps accessing to the house. The sandstone bedrock comprises sandstone of medium to high strength with subhorizontal (-20°) north dipping bedding defect and very low strength to low strength siltstone band, see Photograph 2. The southern side of the rock face appears to be underpinned by brick walls due to weathering of the siltstone band, see Photograph 3.

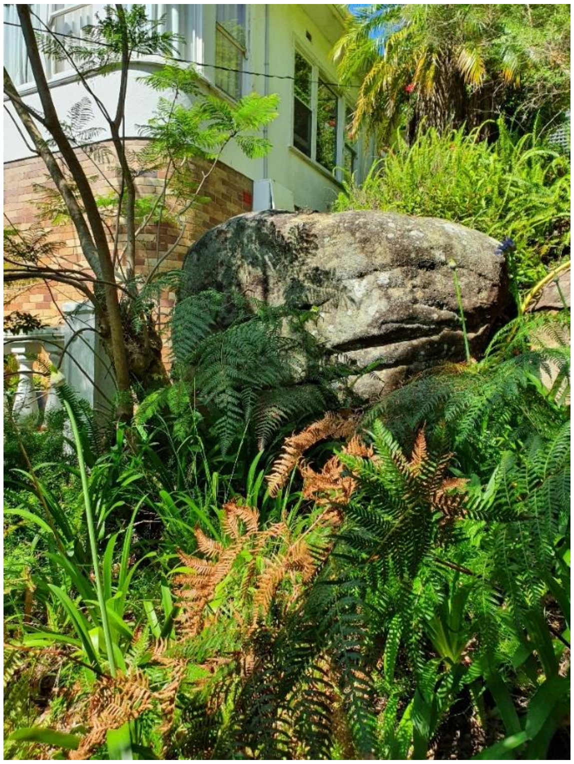
The concrete steps lead up to the site house through a steep (-20°) soil slope on both sides. Detached sections/boulders directly overlie the bedrock within the northern portion of the soil slope, which appear stable at present, see Photograph 4. The soil slope is covered by heavy vegetation and contains several large trees (up to 15m high).

Photograph 2. Rock face at the front of the site, facing east

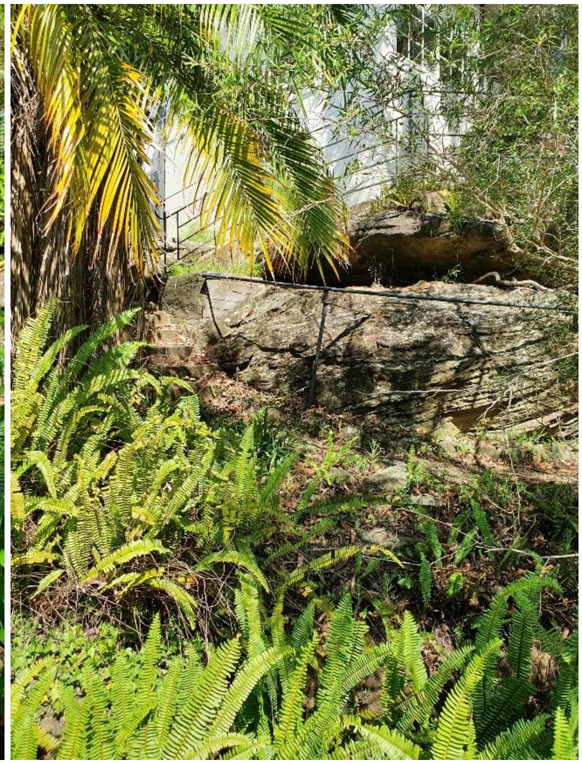


Photograph 3. Existing underpinning of bedrock at the front of the site, facing north

The front of the site house contains a north-south striking sandstone cliff up to 2.5m high. The cliff comprises sandstone of low to medium strength with subhorizontal (-10°) north dipping bedding defects and an upper massive unit of <0.5m thickness that is undercut approximately 1.0m laterally and 0.50m high by weathering of weak sandstone unit, see Photograph 5. The existing house is a single storey fibrous and rendered brick house situated on the top of the cliff within a terraced area. The structure appears in reasonable condition with no signs of significant cracking or deformation on its external walls.



Photograph 4. Boulder along north boundary buried in soil slope, facing east



Photograph 5. Sandstone cliff at the western front of the house with undercut

The rear of the site is accessed via a concrete path along the northern side of the house and contains a raised garden bed and a fibrous shed in the northeast corner. The raised garden is supported by a brick wall up to 0.30m high, which appears in a reasonable condition.

The neighbouring property to the north (No. 554) contains a one and two storey rendered house located broadly in the centre of the property with a garage at front and a backyard. The main structure appears approximately 40 years of age and in reasonable condition with no signs of excessive cracking or settlement on the external walls. The sandstone bedrock/outcrop underlying the site extends into the neighbouring property and dips towards the north, whilst the ground floor level of the neighbour's house is approximately 2.0m below the crest of the sandstone bedrock/outcrop. The house is located approximately 1.5m off the common boundary.

The neighbouring property to the south (No. 550) contains a single storey weatherboard house located at the centre of the property with weatherboard shed in the southeast corner. The building structure appears in good condition with no signs of excessive cracking or settlement on the external walls. The property is at a similar ground level as the site along the common boundary with the block having a similar topography to the site. The house is located within 2.40m of the common boundary.

The neighbouring property to the east (No. 2a Hope Ave) contains a single storey weatherboard house located at the south front of the property with a backyard. The building structure appears in good condition with no signs of excessive cracking or settlement on the external walls. The property is at a similar ground level as the site along the common boundary with the block. The house is located over 10.0m off 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.

4.3. Field Testing:

BH1 was drilled in the soil slope in the front of the site with auger refusal encountered on a sandstone boulder.

DCP tests were carried out across the front of the site with refusal encountered at varying depths between 0.20m (DCP7) and 1.65m (DCP4).

Based on the borehole logs and DCP test results, the sub-surface conditions at the project site can be classified as follows:

- **FILL –** this layer was encountered in BH1 to 0.60m depth. It is classified as pale brown, fine to medium grained silty sand with brick and gravel.
- **Silty SAND –** this layer was encountered in BH1 below the fill to auger refusal at 0.90m depth on boulder. It is classified as medium dense, brown, fine to medium grained, moist silty sand with gravel. It is considered as colluvium and is anticipated across the site overlying the bedrock and may include detached boulders.
- **SANDSTONE BEDROCK –** this layer was identified in surface exposure and outcropping within the site. Based on the DCP test results, sandstone bedrock of at least very low strength is interpreted at varying depths from 0.20m (DCP7) and 1.65m (DCP4) within the soil slope at the front of the site.

A freestanding ground water table or significant water seepage were not identified during the investigation.

5. COMMENTS:

5.1. Geotechnical Assessment:

The site investigation identified sandstone bedrock and boulders outcropping across the front of the site with a north-south striking cliff located at the front of the existing house. Between the front boundary and the cliff is a west dipping soil slope with granular fill/colluvium of 0.20m to 1.65m depth overlying bedrock. Several large boulders were identified within the northern side of the soil slope. No groundwater table or significant seepage was encountered during the investigation.

The proposed works will involve the demolition of all existing site structures with the construction of a four storey development with an inground swimming pool within the rear. Bulk excavation will be required to a maximum depth of approximately 11.0m within eastern portions of the main excavation for the garage, studio and loft levels. The house level will largely be formed at the existing ground level in the approximate footprint of the existing main structure. The swimming pool within the rear of the site will require bulk excavation to approximately 1.0m depth.

Sandstone bedrock of at least low strength is exposed at several locations across the site and is understood to underlay the natural surface level of the site at relatively shallow depths. As a result, the stability of the excavation and ground vibrations as a result of rock excavation equipment are considered to be the key geotechnical components of the proposed works.

The granular fill/colluvium near surface will not stand unsupported at steep batter slopes however in general soils will be of shallow thickness over the bedrock, allowing the implementation of safe batter slopes within the site without negative impact to adjacent structures. Where safe batter slopes cannot be achieved with respect to boundaries or adjacent structures then the installation of temporary support will be required.

Sandstone bedrock of at least low strength can be excavated at steep to vertical batter slopes provided it is unfractured by the excavation works and does not contain unfavorable defects. Where these are encountered then support systems (i.e. rock bolts/shotcrete) can be implemented as excavation works progress. There were limited stability hazards identified in the investigation, however, dense vegetation and soil cover reduced visibility of the bedrock. There is a potential for poorly oriented defects or localized zones of highly weathered bedrock (particularly near the upper surface) to result in localized rock slide/topple failure with potential impact to the site or adjacent properties. Therefore, core drilling of the bedrock adjacent to the front of the existing house to below BEL is required along with geotechnical inspection following initial clearing of the bedrock surface to confirm site conditions. Geotechnical inspection at regular depth intervals (i.e. 2.0m) during excavation should also occur. Through selection of suitable excavation equipment, geotechnical inspection and mapping during the excavation works along with the installation of support measures as determined necessary by the inspections, the risk from the proposed works can be maintained within 'Acceptable' levels for all situations.

The excavation of low up to high strength rock requires the use of rock excavation equipment which can produce ground vibrations of a level which can potentially cause damage to neighbouring structures. Therefore, selection of suitable equipment and a sensible methodology are critical. The need for full time vibration monitoring will be determined based upon the type of rock excavation equipment proposed for use. Crozier Geotechnical Consultants should be consulted for assessment of the proposed equipment prior to its use. It is recommended that a rock saw and small (≤300kg) rock hammers be proposed for use at this site to avoid the need for full time monitoring, however this is likely to result in slow excavation progress and large hammers are anticipated. CGC should be consulted prior to use of any rock hammers. An excavation methodology should be prepared by the excavation contractor for review by the geotechnical engineer prior to site works.

Deflection is expected in excavations as a result of removal of confining material. Whilst for this project it is anticipated to be only minor and principally within the deeper portions, it could result in dilation of bedrock defects, impacting existing footings adjacent to the excavation or facilitating instability.

Detached sections/boulders were identified directly overlying the bedrock within the northern portion of the soil slope and adjacent to the north boundary. They are considered stable at present. However, the proposed excavation will extend adjacent to and even into the boulders and could/will cause instability. Therefore, stabilizing measures or the removal of these boulders is recommended.

It is understood that several trees within the western portion of the block are to remain, including the significant tree to be retained along the southern boundary, towards the front of the site, which alters the building footprint of the lower three levels. It is expected that root systems of the trees are over the bedrock and extend along rock defects. The proposed excavation will make damage to the roots of these trees, therefore, it will require assessment by an Arborist. The rock excavation may also undermine the support to adjacent trees and result in localized rock slide/topple failure. Therefore, geotechnical inspections during excavations that are adjacent to retained trees will be required.

It is recommended to undertake additional cored boreholes to confirm rock strength and quality, including defects adjacent to the front of the existing house to below the main excavation base level (RL6.45m), to allow machinery selection and assessment of excavation stability.

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

The recommendations and conclusions in this report are based on an investigation utilising only surface observations and hand tools. 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. However provided the recommendations of this report are implemented in the design and construction phases the proposed development is considered suitable for the site.

5.2. Site Specific Risk Assessment:

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

A. Landslip (Rockslide/topple <$3m^3$) of bedrock around perimeter of excavation for garage due to poorly oriented defects and root system of remaining trees
B. Rockslide (<$3m^3$) of boulders around perimeter of excavation due to instability
C. Landslip (Rockslide/topple <$15m^3$) of bedrock around perimeter of excavation for garage due to major poorly oriented NE/SE striking defects

A qualitative assessment of risk to life and property related to the 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.

Hazard A and Hazard B were estimated to have a **Risk to Life** of up to **1.56×10^{-6}** for a single person, whilst the **Risk to Property** was considered to be up to **'Moderate'** in some situations.

The assessments were based on excavations with no support, planning or implementation of engineered retention. Provided the recommendations of this report are implemented including the installation of the recommended engineered support around the critical boundaries the likelihood of any failure becomes 'Rare' and as such the consequences reduce and risk becomes within 'Acceptable' levels when assessed against the criteria of the AGS. As such the project is considered suitable for the site provided the recommendations of this report are implemented.

5.3. Design & Construction Recommendations:

Design and the construction recommendations are tabulated below:

5.3.1. New Footings:	
Site Classification as per AS2870 – 2011 for new footing design	- Class 'A' for footings founded on bedrock
Type of Footing	Strip/Pad or Slab or Piers
Sub-grade material and Maximum Allowable Bearing Capacity	- Weathered, VLS Sandstone: 800kPa - Weathered LS Sandstone: 1000kPa - Weathered MS Sandstone: 2000kPa
Site sub-soil classification as per *Structural design actions AS1170.4 – 2007, Part 4: Earthquake actions in Australia*	B_e – rock site
Remarks: All footings should be founded off bedrock of similar strength to prevent differential settlement. All new footings must be inspected by an experienced geotechnical professional before concrete or steel are placed to verify their bearing capacity and the in-situ nature of the founding strata. This is mandatory to allow them to be 'certified' at the end of the project. Footings adjacent to excavations in Low strength bedrock or where defects exist in the bedrock below foundation level may require extension to the base of the excavation or alternative support methods.	

5.3.2. Excavation:	
Depth of Excavation	To 10.60m depth for new garage;

Property Separation:

Boundary	Adjacent Property	Bulk Excavation Depth	Separation Distances*	
			Boundary	Structure
North	No. 554	Up to 11.0m	0.90m	Balcony on boundary, house another 1.40m
South	No. 550	Up to 11.0m	0.90m	Yard on boundary, house another 2.40m
West	Pittwater Rd	From 2.60m	1.20m from garage structure, stairs on boundary	Road reserve concrete footpath further 4.80m

South	No. 2a Hope Ave	1.00m	2.0m	Yard on boundary

*All distances/depths should be confirmed as part of early site mark out.

Type of Material to be Excavated	Granular fill/colluvium up to 1.65m depth
	Sandstone bedrock from ground surface

Guidelines for batter slopes for general information are tabulated below:

Material	Safe Batter Slope (H:V)*	
	Short Term/ Temporary	Long Term/ Permanent
Fill and Colluvium	2.0:1	2.5:1
Very Low Strength (VLS) to Low strength (LS) bedrock	0.75:1	0.5:1*
Medium strength (MS), defect free bedrock	Vertical*	Vertical*

*Dependent on defects and assessment by geotechnical engineer.

Remarks:

Seepage at the bedrock surface or along defects in the soil/rock can also reduce the stability of batter slopes or rock cuts and invoke the need to implement additional support measures.

Where safe batter slopes cannot be implemented due to the excavation's proximity to the boundaries, the stability of the excavation and maintenance of density of soils below adjacent structures cannot be guaranteed. This should also be considered with respect to safe working conditions.

Equipment for Excavation	Fill/natural soils	Excavator with bucket
	VLS bedrock	Bucket and ripper
	LS-MS/HS bedrock	Rock hammer and rock saw

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

Remarks:

Rock sawing of the hard rock excavation perimeters 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 and the saw cuts will provide a slight increase in buffer distance for use of rock hammers. It also reduces deflection across boundary of detached sections of bedrock near surface.

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

Maximum Hammer Weight	Required Buffer Distance from Structure
300kg	2.00m
400kg	3.00m
600kg	6.00m
≥1 tonne	10.00m

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. Inspection of equipment and review of dilapidation surveys and excavation location is necessary to determine need for full time monitoring.	
Recommended Vibration Limits (Maximum Peak Particle Velocity (PPV))	5mm/s (component) PPV at residential structures unless determined as sensitive/heritage listed or suitable for higher limits 3mm/s for services
Vibration Calibration Tests Required	If larger scale (i.e. rock hammer >300kg) excavation equipment is proposed
Full time vibration Monitoring Required	Pending proposed excavation equipment and vibration calibration testing results, if required
Geotechnical Inspection Requirement	Yes, recommended that these inspections be undertaken as per below mentioned sequence: • Upon demolition and initial clearing of soils • Upon installation of excavation support if determined necessary • At 2.00m depth intervals of excavation • At completion of the excavation • Where ground conditions are exposed that differ to those than expected
Dilapidation Surveys Requirement	Recommended on neighbouring structures or parts thereof within 10m of the excavation perimeter prior to site work to allow assessment of the recommended vibration limit and protect the client against spurious claims of damage.

5.3.3. Retaining Structures:	
Required	New retaining structures will be required as part of the proposed development.
Types	Temporary support as part of pre-excavation support. Steel reinforced concrete/concrete block walls where excavation stability can be ensured during excavation and construction phases. Designed in accordance with Australian Standards AS4678-2002 Earth Retaining Structures.
Parameters for calculating pressures acting on retaining walls for the materials likely to be retained:	

Material	Unit Weight (kN/m3)	Long Term (Drained)	Earth Pressure Coefficients		Passive Earth Pressure Coefficient *
			Active (Ka)	At Rest (K_0)	
Fill/Sand	18	$\phi' = 28°$	0.35	0.52	N/A
VLS to LS bedrock	23	$\phi' = 38°$	0.10	0.15	300kPa
MS bedrock (defect free)	24	$\phi' = 40°$	0.00	0.01	600kPa

Remarks:

In suggesting these parameters, it is assumed that the retaining walls will be fully drained due to the sand site soil. It is suggested that post excavation retaining walls should be back filled with free-draining granular material (preferably not recycled concrete) which is only lightly compacted in order 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).

It is expected that the pool shell will provide permanent support to the pool excavation.

Rock Anchor	Where extend across boundary will require permission from neighbouring property owners and should be based on a temporary system with permanent support implemented by the proposed development.
Ultimate Bond Stress	Very Low Strength Rock = 200kPa Low Strength Rock = 350kPa Medium Strength Rock = 600kPa

5.3.4. Drainage and Hydrogeology		
Groundwater Table or Seepage identified in Investigation		No
Excavation likely to intersect	Water Table	No
	Seepage	Minor (≤0.50 L/min), on defects and at soil/rock interface
Site Location and Topography		High east side of the road, within moderate to steep west dipping topography
Impact of development on local hydrogeology		Appears negligible
Onsite Stormwater Disposal		No

Remarks:
As the excavation faces are expected to encounter some seepage, an excavation trench should be installed at the base of excavation cuts to below floor slab levels to reduce the risk of resulting dampness issues. 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.

5.4. Conditions Relating to Design and Construction Monitoring:

To allow certification at the completion of the project it will be necessary for Crozier Geotechnical Consultants to:

1. Undertake further investigation via cored boreholes adjacent to the site house and adjacent boundaries
2. Review and approve the structural drawings, including the retaining structure/batter slope design and construction methodology, and stormwater system plans for compliance with the recommendations of this report,
3. Review excavation methodology and equipment prior to hard rock excavation
4. Inspection of site and works as per Section 4.3 of this report
5. Inspect all new footings to confirm compliance to design assumptions with respect to allowable bearing pressure, basal cleanness and stability prior to the placement of steel or concrete,
6. Inspect completed works to ensure that all required stabilisation and drainage measures are in place.

Crozier Geotechnical Consultants cannot provide certification for the Occupation Certificate if it has not been called to site to undertake the required inspections.

6. CONCLUSION:

The site investigation identified sandstone bedrock and boulders outcropping across the front of the site with a north-south striking cliff located at the front of the existing house. Between the front boundary and the cliff is a west dipping soil slope with granular fill/colluvium of 0.20m to 1.65m depth overlying bedrock. Several large boulders were identified within the northern side of the soil slope. No groundwater table or significant seepage was encountered during the investigation.

The proposed works involve the demolition of the existing site structures and the construction of a four storey residence. The proposed development will require bulk excavation increasing from approximately 2.60m adjacent to the west boundary to a maximum of 11.00m depth within eastern portions of the main excavation.

Bulk excavation will extend to 0.90m from the north and south boundaries and to the west boundary, with the inground swimming pool within the rear extending to approximately 2.0m from the eastern boundary. It is also understood that several trees including a large Gum tree within the western portion of the block are to be retained, whilst the exposed rock section between the front boundary and public footpath will be kept.

It is expected that the proposed excavation will extend through sandy fill/colluvium and very low strength sandstone bedrock which is likely to grade quickly to medium to high strength sandstone and hard rock excavation equipment is likely to be required.

It is recommended to undertake additional cored boreholes to confirm rock strength and quality to allow machinery selection and assessment of excavation stability.

It is recommended that a preliminary vibration limit (Maximum Peak Particle Velocity, PPV) of 5mm/s PPV be set at the founding level for neighbouring structures for all excavation work on this site to maintain comfort levels and provide a very low probability of structural damage.

The bedrock has the potential for weathered seams and defects which will reduce bedrock/excavation stability and that the existing tree root systems may have grown into further impacting the stability of the excavation. Therefore, geotechnical inspection following initial clearing of the bedrock surface is required to confirm site conditions along with inspection at regular depth intervals during excavation.

The risks associated with the proposed development can be maintained within 'Acceptable' levels with negligible impact to the neighbouring properties or 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 are followed.

Updated by:

Josh Cotton
Engineer

Reviewed by:

Troy Crozier
Principal
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MAIG, RPGeo – Geotechnical and Engineering
Registration No.: 10197

7. REFERENCES:

1. Australian Geomechanics Society 2007, “Landslide Risk Assessment and Management”, Australian Geomechanics Journal Vol. 42, No 1, March 2007.
2. Geological Society Engineering Group Working Party 1972, “The preparation of maps and plans in terms of engineering geology” Quarterly Journal Engineering Geology, Volume 5, Pages 295 - 382.
3. C. W. Fetter 1995, “Applied Hydrology” by Prentice Hall. V. Gardiner & R. Dackombe 1983, “Geomorphological Field Manual” by George Allen & Unwin

Appendix 1

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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

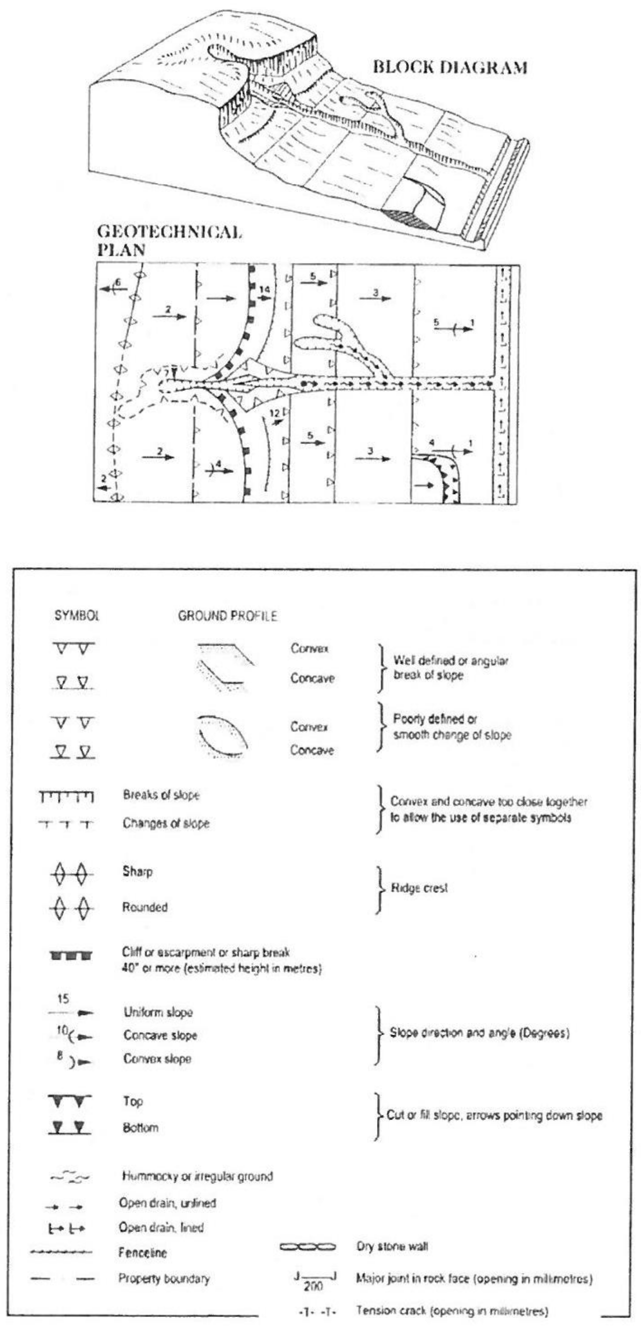
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some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

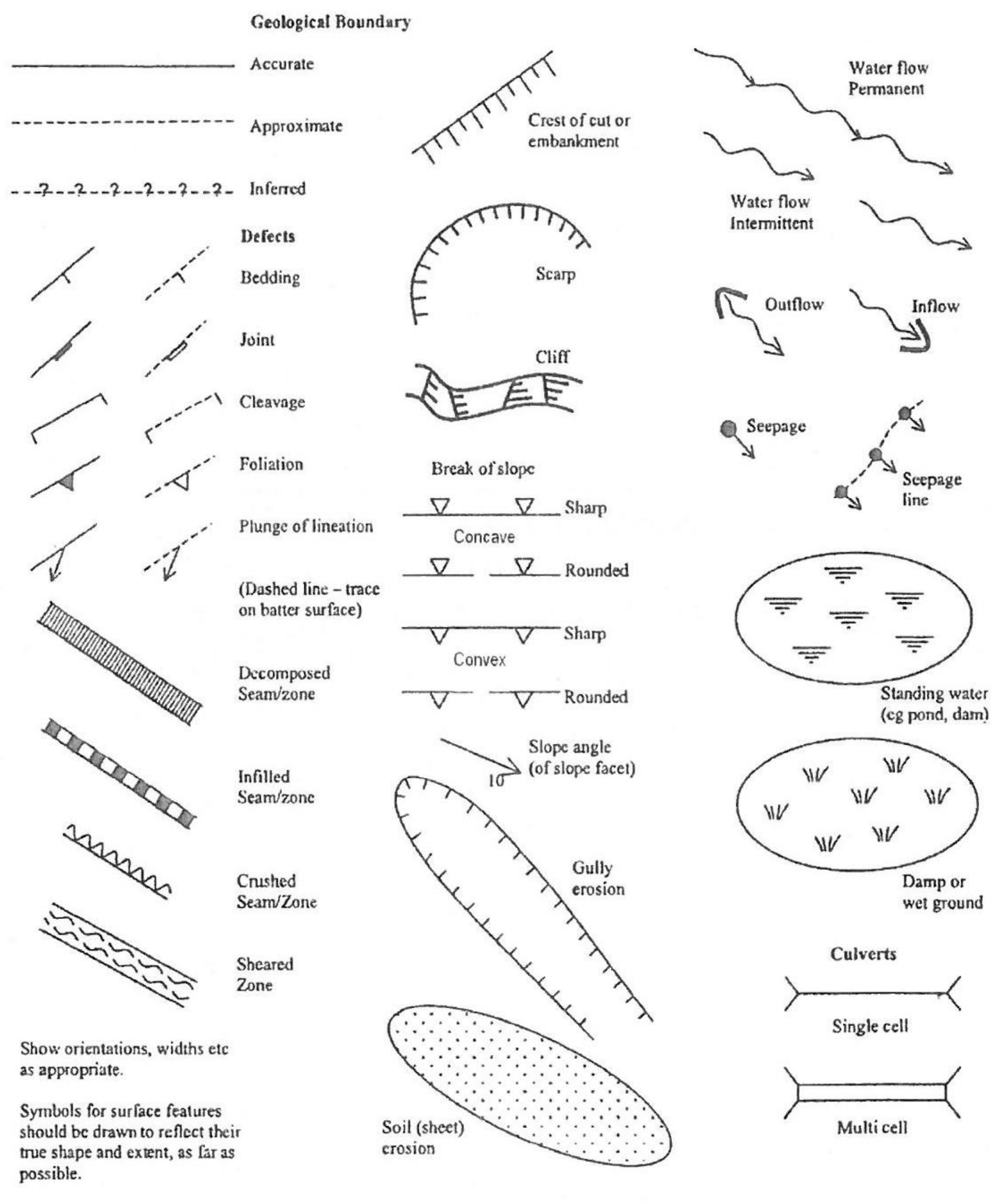
Site Inspection

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.



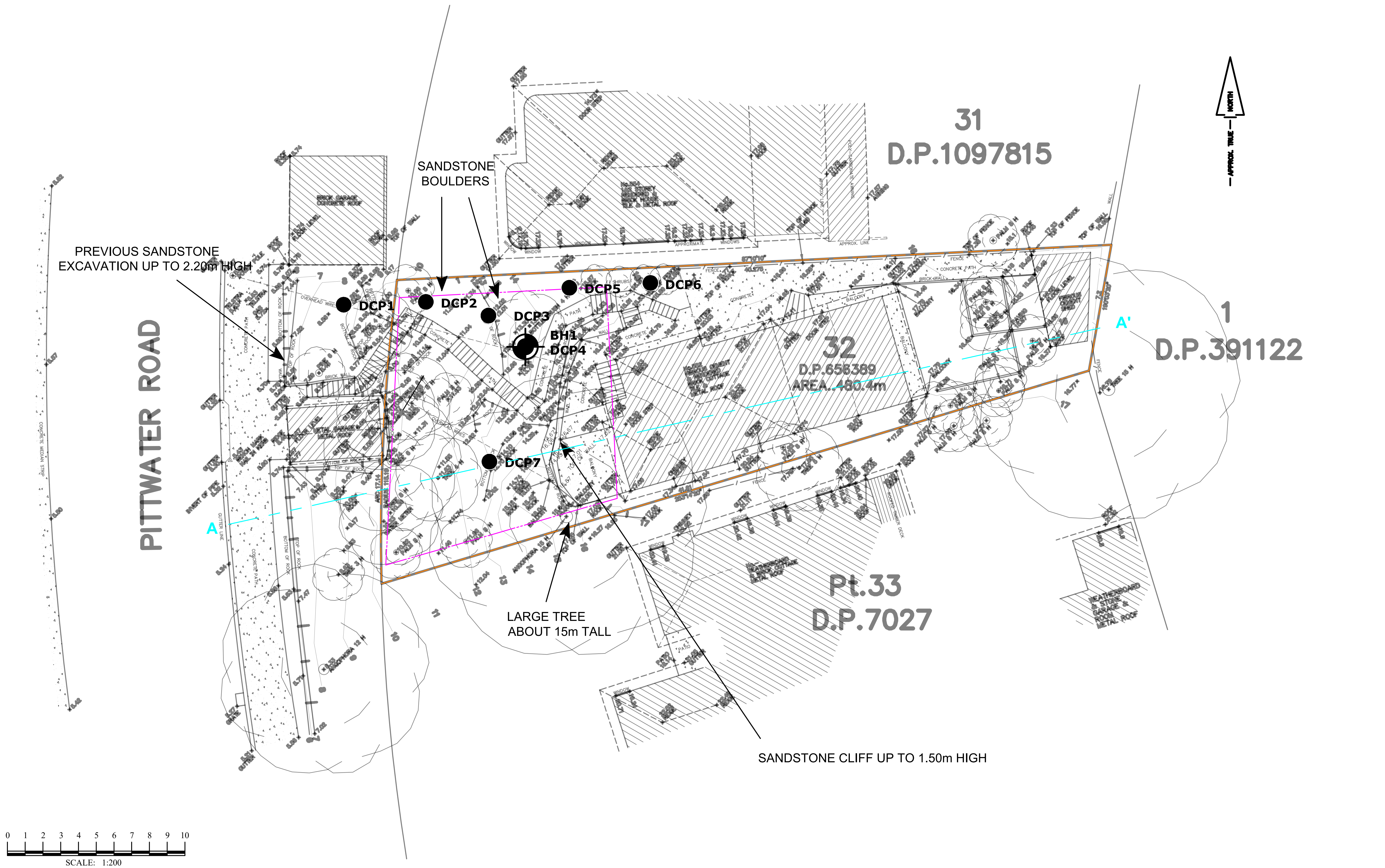
Example of Mapping Symbols
(after V Gardiner & R V Dackombe (1983).Geomorphological Field Manual. George Allen & Unwin).

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).

Appendix 2



SITE PLAN & TEST LOCATIONS FIGURE 1.

CROZIER
GEOTECHNICAL CONSULTANTS

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Unit 12, 42-46 Wattle Road
Brookvale NSW 2100

ABN: 96 113 453 624
Phone: (02) 9939 1882
Fax: (02) 9939 1883

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

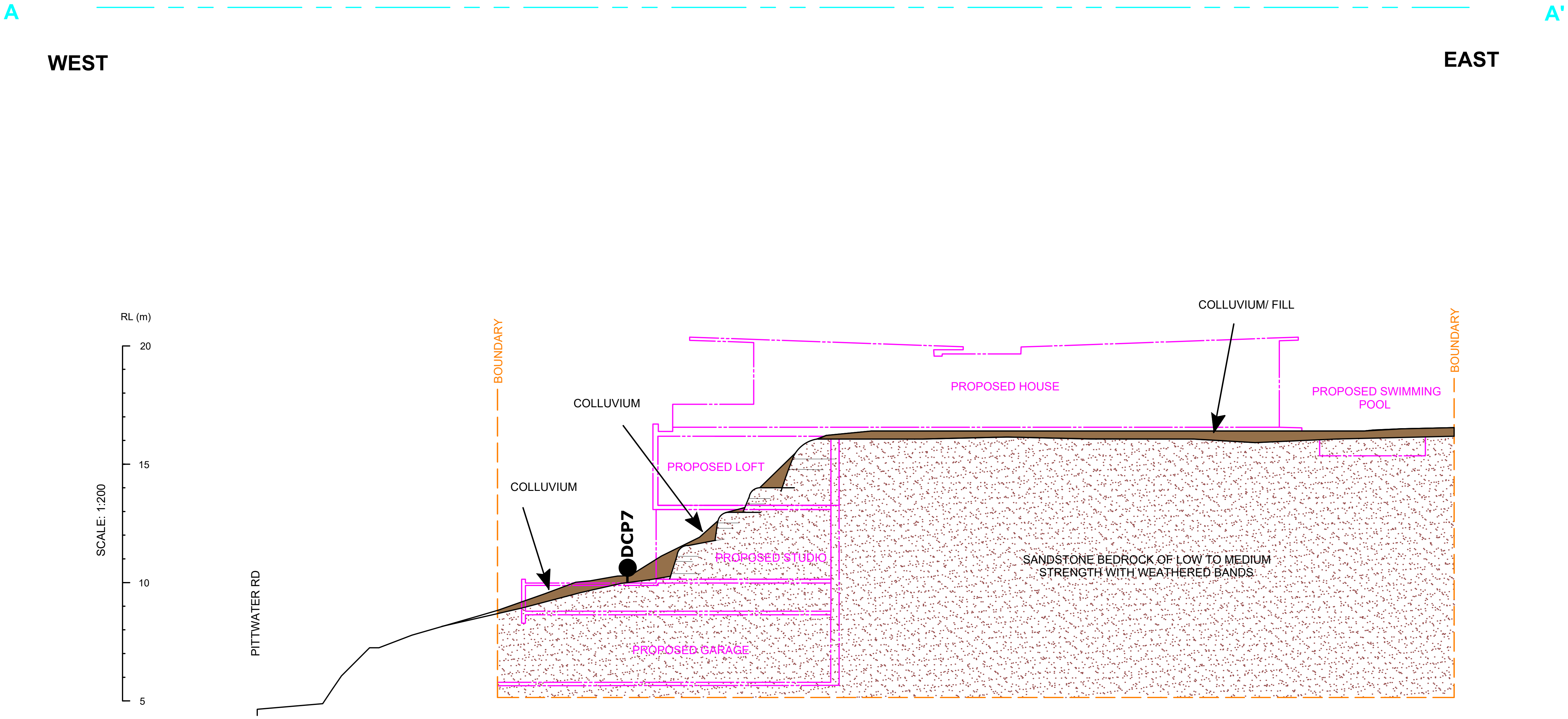
LEGEND

BH DCP	AUGER / DYNAMIC CONE PENETROMETER LOCATION
DCP	DYNAMIC CONE PENETROMETER
A —— A'	CROSS-SECTION REFERENCE LINE
(magenta line)	PROPOSED GARAGE EXCAVATION OUTLINE
(orange line)	PROPERTY BOUNDARY

SCALE:	1:200 @ A3
DRAWING:	FIGURE 1
DATE:	13/07/2021
APPROVED BY:	TMC
DRAWN BY:	JY & JC
PROJECT:	2020-236

PREPARED FOR:
DAVY CONSTRUCTION

ADDRESS:
552 PITTWATER ROAD,
NORTH MANLY



0 1 2 3 4 5 6 7 8 9 10

SCALE: 1:200

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

NB. FOR LOCATION OF SECTION A-A', PLEASE REFER TO FIGURE 1. SITE PLAN AND TEST LOCATIONS

GEOLOGICAL MODEL FIGURE 2.

CROZIER
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LEGEND

● DCP	DYNAMIC CONE PENETROMETER
A — A'	CROSS-SECTION REFERENCE LINE
(orange dashed line)	PROPERTY BOUNDARY
(magenta line)	PROPOSED STRUCTURES
(hatch)	COLLUVIUM/FILL
(hatch)	SANDSTONE BEDROCK

SCALE: 1:200 @ A3
DRAWING: FIGURE 2
DATE: 13/07/2021

APPROVED BY: TMC
DRAWN BY: JY & JC
PROJECT: 2020-236

PREPARED FOR:
DAVY CONSTRUCTION

ADDRESS:
552 PITTWATER ROAD,
NORTH MANLY

BOREHOLE LOG

CLIENT: Davy Constructions **DATE:** 25/11/2020 **BORE No.:** 1

PROJECT: Alterations and additions **PROJECT No.:** 2020-236 **SHEET:** 1 of 1

LOCATION: 552 Pittwater Road, North Manly **SURFACE LEVEL:** RL11.50

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: pale brown, fine grained silty sand with brick and gravel				
0.60	SM	Silty SAND: medium dense, brown, fine to medium grained, moist silty sand with gravel				
0.90		Auger refusal at 0.90m depth on boulder				
1.00						
2.00						

RIG: NA DRILLER: AC

METHOD: Hand auger LOGGED: JY

GROUND WATER OBSERVATIONS: no freestanding groundwater found

REMARKS: CHECKED:

DYNAMIC PENETROMETER TEST SHEET

CLIENT: Davy Constructions **DATE:** 25/11/2020

PROJECT: Alterations and additions **PROJECT No.:** 2020-236

LOCATION: 552 Pittwater Road, North Manly **SHEET:** 1 of 1

	Test Location							
Depth (m)	1	2	3	4	5	6	7	
0.00 - 0.15	3	0	0	0	1	1	3	
0.15 - 0.30	6	2	1	1	2 (B) ref at 0.22m	2	4 (B) ref at 0.20m	
0.30 - 0.45	20 (B) ref at 0.35m	7	10	2		2		
0.45 - 0.60		15 (B) ref at 0.52m	7	2		3		
0.60 - 0.75			11	3		14 (B) ref at 0.70m		
0.75 - 0.90			13 (B) ref at 0.90m	7				
0.90 - 1.05				7				
1.05 - 1.20				9				
1.20 - 1.35				26				
1.35 - 1.50				24				
1.50 - 1.65				38 (B) ref at 1.65m				
1.65 - 1.80								
1.80 - 1.95								
1.95 - 2.10								
2.10 - 2.25								
2.25 - 2.40								
2.40 - 2.55								
2.55 - 2.70								
2.70 - 2.85								
2.85 - 3.00								
3.00 - 3.15								
3.15 - 3.30								
3.30 - 3.45								
3.45 - 3.60								
3.60 - 3.75								
3.75 - 3.90								
3.90 - 4.05								

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

CROZIER
GEOTECHNICAL CONSULTANTS

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 (Rockslide/topple <3m³) of bedrock around perimeter of excavation for garage due to poorly oriented defects and root system of remaining trees		Excavation up to approxiamtely 10.60m depth, excavation along west boundary, within 0.90m of north and south boundaries and adjacent to front of the existing house. house. Some potential for adverse defects to intersect excavation.	a) excavation 0.90m off boundary, balcony along boundary, impact 10% b) excavation 0.90m off boundary, house another 1.50m, impact 5% c) excavation 0.90m off boundary, front yard along boundary, impact 1% d) excavation 0.90m off boundary, house another 2.40m, impact 1% e) excavation adjacent to the house, impact 20% f) excavation along boundary, footpath another 4.80m, impact 10%		a) Person in balcony 1hrs/day avge b) Person in house 20hrs/day avge c) Person in front yard 0.5hr/day avge d) Person in house 20hr/day avge e) Person in house 20hr/day avge f) Person in footpath 2hr/day avge	a) Likely to not evacuate b) Likely to not evacuate c) Likely to not evacuate d) Likely to not evacuate e) Likely to not evacuate f) Likely to not evacuate	a) Person in open space, buried b) Person in building, minor damage only c) Person in open space, buried d) Person in building, minor damage only e) Person in building, minor damage only f) Person in open space, crushed	
			Possible	**Prob. of Impact**	**Impacted**				
		a) No. 554 Balcony	0.001	0.20	0.10	0.0417	0.75	0.80	**5.00E-07**
		b) No. 554 House	0.001	0.10	0.05	0.8333	0.75	0.10	**3.13E-07**
		c) No. 550 Front yard	0.001	0.25	0.01	0.0208	0.75	0.80	**3.13E-08**
		d) No. 550 House	0.001	0.05	0.01	0.8333	0.75	0.10	**3.13E-08**
		e) Pittwater Road footpath	0.001	0.05	0.10	0.0833	0.75	1.00	**3.13E-07**
B	Rockslide (<3m³) of boulders around perimeter of excavation due to instability		Boulders adjacent to boundary and situated in soil slope directly overlying bedrock	a) boulders adjacent to boundary, balcony along boundary, impact 10% b) boulders adjacent to boundary, house another 1.50m, impact 1% of structure		a) Person in balcony 1hrs/day avge b) Person in house 20hr/day avge	a) Likely to not evacuate b) Likely to not evacuate	a) Person in open space, crushed b) Person in building, minor damage only	
			Possible	**Prob. of Impact**	**Impacted**				
		a) No. 554 Balcony	0.001	0.50	0.10	0.0417	0.75	1.00	**1.56E-06**
		b) No. 554 House	0.001	0.50	0.01	0.8333	0.75	0.10	**3.13E-07**
C	Landslip (Rockslide/topple <15m³) of bedrock around perimeter of excavation for garage due to major poorly oriented NE/SE striking defects		Excavation up to approxiamtely 10.60m depth, excavation along west boundary, within 0.90m of north and south boundaries and adjacent to front of the existing house. house. Some potential for adverse defects to intersect excavation.	a) excavation 0.90m off boundary, balcony along boundary, impact 20% b) excavation 0.90m off boundary, house another 1.50m, impact 10% c) excavation 0.90m off boundary, front yard along boundary, impact 5% d) excavation 0.90m off boundary, house another 2.40m, impact 5% e) excavation adjacent to the house, impact 40%		a) Person in balcony 1hrs/day avge b) Person in house 20hrs/day avge c) Person in front yard 0.5hr/day avge d) Person in house 20hr/day avge e) Person in house 20hr/day avge	a) Likely to not evacuate b) Likely to not evacuate c) Likely to not evacuate d) Likely to not evacuate e) Likely to not evacuate	a) Person in open space, buried b) Person in building, minor damage only c) Person in open space, buried d) Person in building, minor damage only e) Person in building, minor damage only	
			Unlikely	**Prob. of Impact**	**Impacted**				
		a) No. 554 Balcony	0.0001	0.25	0.20	0.0417	0.75	1.00	**1.56E-07**
		b) No. 554 House	0.0001	0.15	0.10	0.8333	0.75	0.20	**1.88E-07**
		c) No. 550 Front yard	0.0001	0.30	0.05	0.0208	0.75	1.00	**2.34E-08**
		d) No. 550 House	0.0001	0.10	0.05	0.8333	0.75	0.20	**6.25E-08**

* hazards considered in current condition and/or without remedial/stabilisation measures
* likelihood of occurrence for design life of 100 years
* Spatial Impact - Probaility of Impact referes to slide impacting structure/area expressed as a % (1.00 = 100% probability of slide impacting area if it occurs), Imapcted refers to % of area/strucure impacted if slide occurred
* neighbouring houses considered for bedroom impact unless specified
* considered for person most at risk
* considered for adjacent premises/buildings founded via 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 knwoing 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 (Rockslide/topple $<3m^3$) of bedrock around perimeter of excavation for garage due to poorly oriented defects and root system of remaining trees	a) No. 554 Balcony	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
		b) No. 554 House	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Moderate
		c) No. 550 Front yard	Possible	The event could occur under adverse conditions over the design life.	Insignificant	Little Damage, no significant stabilising required or no impact to neighbouring properties.	Very Low
		d) No. 550 House	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
		e) Pittwater Road footpath	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
B	Rockslide ($<3m^3$) of boulders around perimeter of excavation due to instability	a) No. 554 Balcony	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
		b) No. 554 House	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
C	Landslip (Rockslide/topple $<15m^3$) of bedrock around perimeter of excavaiton for garage due to major poorly oriented NE/SE striking defects	a) No. 554 Balcony	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
		b) No. 554 House	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, requires large stabilising works or MINOR damage to neighbouring property.	Low
		c) No. 550 Front yard	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
		d) No. 550 House	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, requires large stabilising works or MINOR damage to neighbouring property.	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%.

TABLE: 2

Recommended Maintenance and Inspection Program

Structure	Maintenance/ Inspection Item	Frequency
Stormwater drains.	Owner to inspect to ensure that the drains, and pipes are free of debris & sediment build-up. Clear surface grates and litter.	Every year or following each major rainfall event.
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	Arbourist to check condition of trees and remove as required. Where treee within steep slopes or adjacent to structures require geotechincal inspection prior to removal	Every five years
Slope Stability	Hydraulics (stormwater) & Geotechnical Consultants to check on site stability at same time and provide report.	One year 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.

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

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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

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.

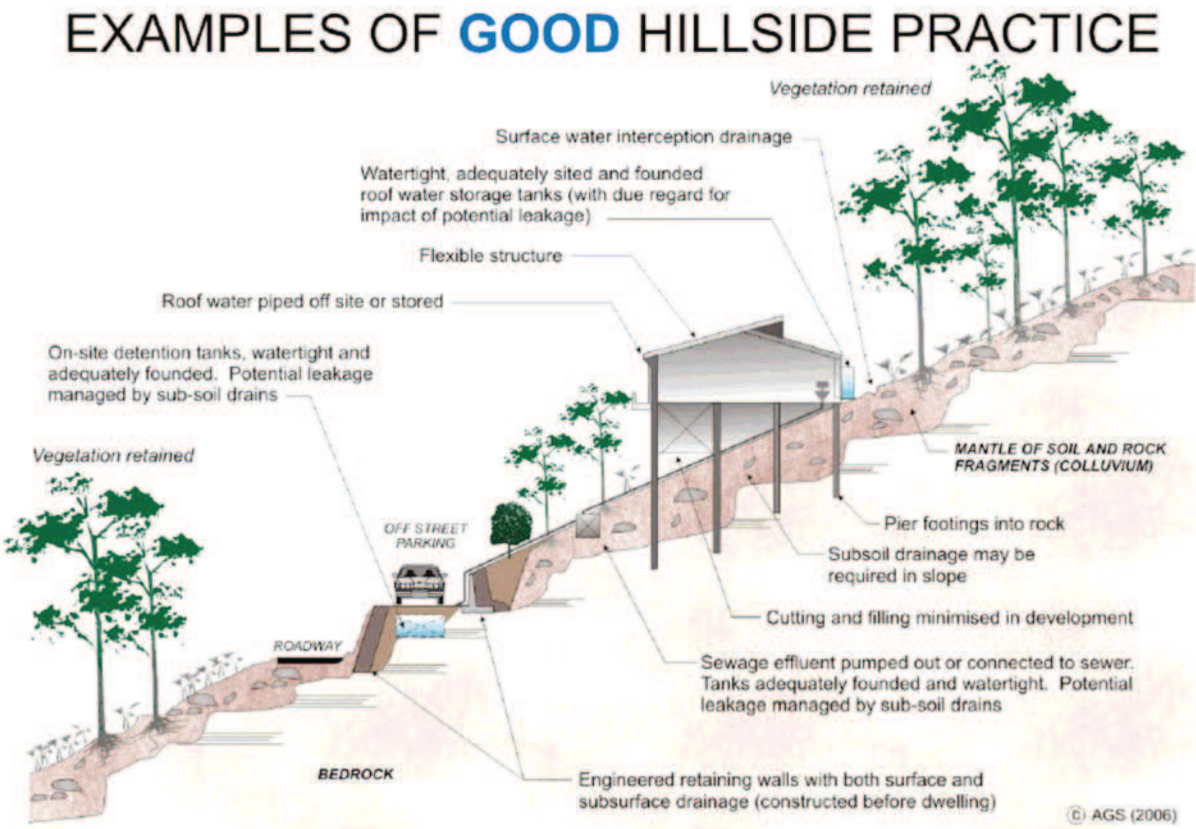
Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

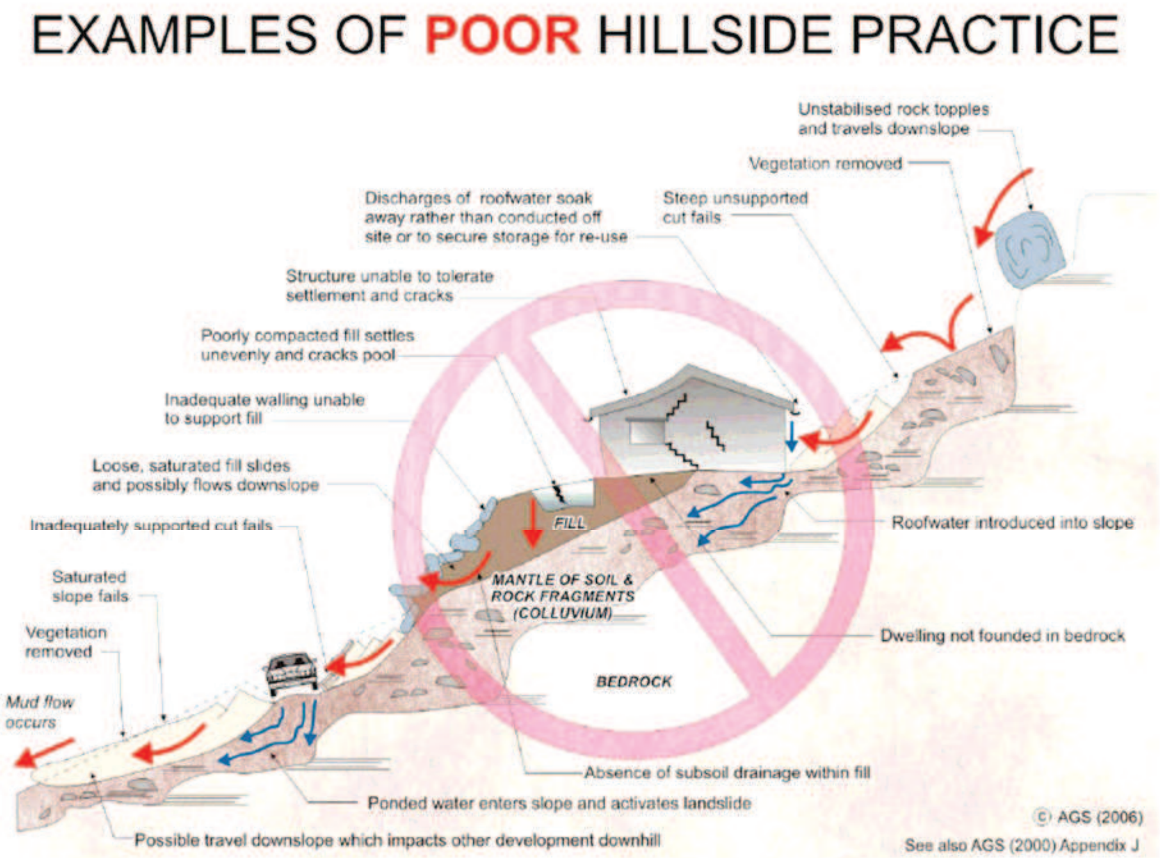
CROZIER
GEOTECHNICAL CONSULTANTS

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)
© AGS (2006)


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
Saturated slope fails
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Vegetation removed
Dwelling not founded in bedrock
Mud flow occurs
BEDROCK
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