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REPORT ON GEOTECHNICAL SITE INVESTIGATION

for

PROPOSED DEVELOPMENT

at

41 UPPER CLIFFORD,
FAIRLIGHT
NSW

Prepared For

Carl Oscar Peterson and
Heaton Family Investments Pty Ltd

Project No.: 2019-212.1
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GEOTECHNICAL REPORT FOR PROPOSED DEVELOPMENT
41 UPPER CLIFFORD AVENUE, FAIRLIGHT, NSW

1. INTRODUCTION:

This report details the results of a geotechnical investigation carried out for a proposed new development at 41 Upper Clifford Avenue, Fairlight, NSW. The investigation was undertaken by Crozier Geotechnical Consultants (CGC) at the request of Platform Architects on behalf of Carl Oscar Peterson and Heaton Family Investments Pty Ltd.

The site is situated on the low, southern side of Upper Clifford Avenue within steeply south dipping topography with Lauderdale Avenue passing the rear southern boundary. It is currently occupied by a one and two storey sandstone block and brick residence with numerous pathways and garden areas.

It is understood from the supplied architectural and survey drawings that the proposed works involve demolition of the existing structures and construction of a five storey apartment building, containing two units with a basement level garage accessed from Lauderdale Avenue (southern half) and a two storey unit with a garage at the north east corner of the site, accessed from Upper Clifford Street.

With reference to Northern Beaches (Manly) Councils ï Development Control Plan 2013 ï Schedule 1 Map C, the site is located within Landslip Risk Class ñG2ò which is classified as Flanking Slopes ï 15º to 25º. Due to the extent of excavation proposed a geotechnical report will be required in line with the Manly Council DCP requirements. This report must detail how the development may be achieved to ensure geotechnical stability and good engineering practice. The report must also include a risk assessment of the site for both property and life as per the AGS March 2007 publication.

The investigation and reporting were taken as per Tender No. P19-455, Dated: 19th November 2019.

The investigation comprised:

a) A detailed geotechnical inspection and mapping of the entire site and adjacent land, with identification of all geotechnical conditions including potential hazards related to the existing site and proposed structures, by a Principal Engineering Geologist and Geotechnical Engineer including a photographic record of site conditions,

b) Prior geotechnical inspection and mapping of the site and adjacent properties by a Geotechnical Engineer for previous owner.

c) Drilling of two boreholes using hand tools along with Dynamic Cone Penetrometer testing (DCP) to investigate the subsurface geology, depth to bedrock and identification of ground water.

The following plans and drawings were supplied for the work:

- Architectural Drawings ï platform Architects, Dated: February 2020, Revision: F, Project: UCS, Status: DA, Number: 00-24.
- Survey Drawings ï Bee & Lethbridge Quality Surveying & Development Solutions Pty Ltd, Date: 28/05/2019, Ref No.: 21317, Drawn: J.M., Rev No.: 00.

2. PROPOSED WORKS:

It is understood from provided plans that the apartment building (including basement) at the southern portion of the site will require a vertical excavation up to 12.0m depth, to achieve a lower basement carpark with a Finished Floor Level (FFL) of R.L. 35.450m. The bulk excavation is located approximately 1m from the west and east boundaries, 30m from the north boundary and it will extend south (beyond the south boundary) to the edge of bitumen pavement (Lauderdale Avenue), however it will be at ground level in this location. It is understood that the public footpath above the basement garage entry will be excavated and reinstated, though methodology is to be confirmed.

The two-storey unit at the northern portion of the site will require excavation up to 5.0m depth in the north east portion of the site, to achieve the construction of a lobby and lift with a Finished Floor Level (FFL) of R.L. 52.13m. The north west part of the unit will be formed/supported by piers above ground level and will require minor excavation only (Ò1.0m depth). The excavations will comprise mainly hard rock excavation, located approximately 5.0m from the west boundary, 1.0m from the east boundary, 6.0m from the north boundary and 35.0m from the south boundary.

Some filling/void is proposed below Unit 1 garage (northern portion) and in between the basement garage and Unit 3 Ground Floor (southern portion).

3. SITE FEATURES:

3.1. Description:

The site is a rectangular shaped block with front boundary to Upper Clifford Avenue of 15.240m, southern boundary to Lauderdale Avenue of 15.575m, eastern boundary of 52.15m and western boundary of 48.93m as determined from the provided survey plan.

It is situated within steeply south dipping topography which extends down from Upper Clifford Avenue as a series of cliffs with gardens, lawns and pathways/stairs to the house. The existing house is situated on the centre of the block and is principally accessed via Lauderdale Avenue. It is a one and two storey rendered brick and timber structure with sandstone block footings and walls forming a lower level below the southern end. The southern part of the block is formed with sandstone cliffs with gardens along with concrete stairs and pathways. A concrete footpath extends along the southern boundary, above the crest of a 4.0 to 5.0m high sandstone cliff and some retaining walls that rise up from the Lauderdale Avenue road edge.

An aerial photograph of the site and its surrounds is provided below, as sourced from NSW Government Six Map spatial data system, as Photograph 1. General view of the site at the time of investigation are provided in Photograph 2 and Photograph 3

Photograph: 1 – Aerial photo of site and surrounds.

3.2. Geology:

Reference to the Sydney 1: 100,000 Geological Series sheet (9130) indicates that the site is underlain by Hawkesbury Sandstone (Rh) which is of Triassic Age. The rock unit typically comprises medium to coarse grained quartz sandstone with minor lenses of shale and laminite. This rock unit was identified in surface exposures over the site and the Lauderdale Avenue road reserve.

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 sub-vertical 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 Services Sheet

4. FIELD WORK

4.1 Methods:

The field investigation comprised a walk over inspection and mapping of the site and adjacent properties on the 4th December 2019 by a Principal Engineering Geologist and Geotechnical Engineer. It included a photographic record of site conditions as well as basic geological/geomorphological mapping of the site and adjacent land with examination of soil slopes, vegetation, outcrops, existing site structures and neighbouring buildings. Previous investigation including inspection/mapping and the drilling of two auger boreholes (BH1 and BH2) on the 6th December 2017, using a hand auger to determine sub-surface geology in areas of soil cover.

Dynamic Cone Penetrometer (DCP) testing was carried out adjacent to the boreholes and at separate locations in accordance with AS1289.6.3.2 ï 1997, ñDetermination of the penetration resistance of a soil ï 9kg Dynamic Cone Penetrometer testò 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 bore log and DCP sheets in Appendix: 2.

4.2. Field Observations:

Upper Clifford Avenue is formed with a gently west dipping bitumen pavement with concrete kerb and gutter and then concrete footpath adjacent to the site. The road pavement appears slightly deteriorated however there were no indications of significant ground movement.

The front boundary of the site is formed with a steel fence. Below the fence is a sandstone block retaining wall of up to 1.0m in height that supports the road reserve above the level of the site. In the north-east corner of the site is a single car brick garage which is supported on its western and southern sides off a large outcrop of sandstone, considered to be bedrock. This outcrop extends to the south with a sub-vertical cliff marking its western edge within the site. The sandstone is characterised as being medium grained, massive, of at least medium strength and forms a 4.0 to 5.0m high sub-vertical cliff adjacent to the north-east corner of the existing site house.

Upper Clifford Avenue boundary, viewed to west.

Sandstone outcrop on east boundary, garage to left.

An additional outcrop forming a cliff is located to the west of the garage close to the front boundary with a set of concrete stairs extending down its surface to the east and then around its base to the west. This outcrop is obscured by dense vegetation however it appears to consist of several thin, medium strength sandstone units with some minor undercutting and is up to 3.00m in height.

At the base of the cliffs is dense garden and gently south dipping lawn with another garden and pathway along the western boundary. The lower southern end of the lawn is supported by <1.00m high masonry and timber log retaining walls above a concrete terrace with another low (<1.0m) brick retaining wall supporting the terrace above a concrete footpath that runs along the rear edge of the existing house at upper floor level. The lower retaining wall is in a deteriorated condition whilst the terrace and path show some signs of cracking/deformation, though this all appears age related.

The existing house is a one and two storey rendered masonry structure with timber floors supported above sandstone block and brick footing walls and columns. Based on the NSW Government Six Map spatial data system, the existing house was in existence pre-1943 and therefore is > 75 years of age. The lower level is formed below the southern end of the house only due to the sloping ground surface levels and is utilised as a storage area and workshop. The ground surface below the house is gently sloping and formed with soil and pavers. The house is in a deteriorated state due to its age however there were no indications of larger scale cracking/issues to suggest deep seated foundation movement.

The southern third of the site is formed with concrete pathways and steps that wind down and around dense gardens and sandstone cliff outcrops. The cliffs are up to 4.0m in height and strike across the block in a general east-west orientation. The sandstone bedrock is characterised by widely (1.0m) spaced bedding defects and appears of medium strength with some sub-vertical joint defects striking east forming the cliff faces. The southern boundary is formed with a masonry block retaining wall, which is hollow, that supports the site up to 1.0m above the Lauderdale Avenue footpath. There were no indications of instability in the cliffs, though they were mostly obscured by vegetation. The south boundary retaining wall is cracked and rotated though this is related to poor construction.

Lauderdale Avenue is formed with a gently east dipping bitumen pavement with concrete kerb and gutter on its northern side. Rising up from the kerb is a sandstone bedrock cliff outcrop of between 2.0m and 5.0m in height with a cemented sandstone rock retaining wall of up to 2.0m in height at its crest for the western part where the cliff is lower. This wall is formed near vertical to steeply south dipping and supports a concrete footpath that runs along the sites southern boundary. The sandstone bedrock is characterised as being moderately weathered, low to medium strength and with closely (<0.50m) spaced bedding defects. It shows increased weathering along defects with some iron stained/coated defects evident.

Southern boundary showing cliff and boundary wall. Lauderdale Avenue with site above.

To the east are two neighbouring properties, No. 39 Upper Clifford Avenue and No. 54 Lauderdale Avenue. Access to No. 54 is provided via a basement level garage formed at Lauderdale Avenue that is excavated into the slope through the road reserve with the footpath re-formed above the garage entry. A multi-level rendered masonry residential structure then steps up the slope above the garage towards the north within 1.50m of the common boundary with the site. The structure appears < 10 years of age and inspection of the garage excavation in relation to other works indicated Medium Strength sandstone excavation has been done to allow the complete construction of the basement level garage.

To the rear, within No. 39, are rendered masonry residential structures that step up and above the cliff outcrop detailed within the site to a set of garages formed at Upper Clifford Level. The structure appears <20 years of age and extends in part to the common boundary.

To the west is a single property (No. 43 Upper Clifford Avenue) which contains a three and four-storey residential development that steps down the slope towards Lauderdale Avenue. The structure within this property is accessed via a driveway from Upper Clifford Avenue. The second storey (Unit 3) has a FFL of approximately 49.46m (similar floor level as front of No.41 site house), it extends north and has a lower level than the northern portion of south dipping No.41 site. This indicates that prior excavation could have been done on No.43 to accommodate construction. The lower level is formed below the southern end of the house on natural slope ground surface.

No. 54 viewed from south showing garage entry

No. 43 viewed from Lauderdale Avenue

4.3. Field Testing:

The boreholes (BH1 ï BH2) were drilled within the lawn and garden areas at the front and rear of the site, with hand auger refusal encountered at 0.35m (BH1) in fill and at 0.70m (BH1) depth on interpreted sandstone bedrock.

Dynamic Cone Penetrometer (DCP) tests were carried out from ground surface adjacent to the boreholes and at separate locations with the tests refusing at between 0.45m depth and 2.50m depth on interpreted bedrock.

Based on the field borehole logs, DCP test results and our experience in the local area the subsurface conditions at the project site are expected to comprise:

- **Fill** ï this was identified at the hand auger locations to a maximum depth of 0.70m below the existing ground surface. It is classified as loose to medium dense, fine grained, moist sand to sandy clay with some organic matter and gravel.
- **Sandy clay/clayey sand –** this material was not identified in the boreholes however it appears to be intersected in DCP1b to 2.50m depth. It is expected to comprise medium dense to dense, medium grained sand with high plasticity clay and ironstone gravels grading towards extremely weathered, extremely low strength sandstone/shale with depth.
- **SANDSTONE BEDROCK** ï based on the geological mapping of the bedrock outcrops over the project site it is classified as slightly to moderately weathered, medium grained, medium strength sandstone. Based on the results of DCP testing in areas of soil cover, the depth to the sandstone bedrock of a minimum of very low strength was interpreted to vary from 0.45m to 2.50m depth.

A free-standing ground water table or significant water seepage were not identified within any of the boreholes. No signs of ground water were observed after the retrieval of the DCP rods.

5. COMMENTS:

5.1. Geotechnical Assessment:

The site investigation identified the presence of fill and residual soils up to 2.50m in depth overlying sandstone bedrock. However, the bedrock is also outcropping in numerous locations across the site and is generally expected at shallow depth through the majority of the property. There were no indications of slope instability or geotechnical issues across the site with the conditions exposed within the built structure related to age deterioration.

It is understood that the proposed development comprises demolition of existing structures and construction of a five-storey apartment building adjacent to Lauderdale Avenue and a two storey unit with a garage adjacent to Upper Clifford Street, they require excavation up to 12.0m and 5.0m depth, respectively. The southern excavation will be distanced approximately 1.0m from the west and east boundaries, 30.0m from the north boundary and it will extend south to the edge of bitumen pavement (Lauderdale Avenue) where it reduces to nil due to the existing slope. The works will include excavation and reinstallation of the footpath above the basement garage entry. The northern excavation will be distanced approximately 5.0m from the west boundary, 1.0m from the east boundary, 5.0m from the north boundary and 35.0m from the south boundary.

The sandstone bedrock exposed in the majority of locations is of at least medium strength and dominated by near horizontal bedding defects with only minor discontinues joint defects identified. Outside of localized areas of fill and residual soil the majority of any excavation will extend through sandstone bedrock of medium and potentially high strength with some potential areas of very low to low strength. As such the probability of instability is significantly reduced and will generally be dependent on defects encountered within the bedrock. As such it is considered that excavation support will not need to be implemented prior to bulk excavation except in isolated locations where soil/weak rock prevent safe batter slope formation. These can be confirmed at initial mark out by geotechnical inspection.

Where medium to high strength sandstone with no poorly oriented defects is encountered it will be free standing and can be excavated near vertically without the need for support measures. Where defects are encountered these may be supported during the works (i.e. rock bolts). However, should highly fractured rock mass be encountered then there may be a need for support prior to further excavation, though this is unlikely based on exposed conditions and experience within adjacent sites.

The medium to high strength sandstone bedrock will require the use of the rock breaking equipment for excavation. This equipment has the potential to create significant ground vibrations which could damage neighbouring houses therefore the selection of suitable excavation equipment is also an important factor. The type of equipment used and the requirement for stabilizing measures will be related to the condition and strength of the bedrock. Therefore, it is recommended that cored boreholes be drilled in the location of the deep excavations to confirm sub-surface conditions prior to final structural design. Where this is not undertaken then regular detail geotechnical inspection during excavation works will be required with potential stop/hold points to allow support installation prior to proceeding.

Whilst there were no stability hazards identified in the investigation, there is a potential for poorly oriented defects within the excavated bedrock to result in localized rock slide/topple failure with potential impact to the work site or the adjacent structures. However, through selection of suitable excavation equipment, a more detailed geotechnical investigation (cored boreholes) and 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 óAcceptableô levels.

The recommendations and conclusions in this report are based on an investigation utilising only surface observations and hand drilling tools due to access limitations. This test equipment provides limited data from small isolated test points across the entire site with limited penetration into rock, therefore some minor variation to the interpreted sub-surface conditions is possible, especially between test locations. However, the bedrock underlying the site is encountered across the majority of the eastern half of Sydney and is well suited to the proposed works with numerous excavations of similar and larger size achieved safely. A similar development has been completed with the adjacent property (No. 54) as such we see no geotechnical reason why the proposed development could not be undertaken.

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 (earth slide <1.5m^3) from soils due to excavation along the northern half of the site ï Unit 2 Ground floor and Upper basement level.
B. Landslip (rockslide/topple <3m^3) within rock excavation ï Upper basement and Car lift.

C. Landslip (earth slide <1m^3) from soils due to excavation along the southern half of the site ï First, second and third floor ï Unit 3 and four townhouses

D. Landslip (rockslide/topple <3 m^3) within rock excavation ï Ground level and Basement level.

A qualitative assessment of risk to life and property related to this hazard is presented in Table A, B, C and D 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 was estimated to have a **Risk to Life** of **5.86 x 10^{-9}** for a single person, while the **Risk to Property** was considered to be **'Moderate'**.

Hazard B was estimated to have a **Risk to Life** of up to **1.05 x 10^{-7}** for a single person, while the **Risk to Property** was considered to be **'Moderate'**.

Hazard C was estimated to have a **Risk to Life** of up to **1.17 x 10^{-9}** for a single person, while the **Risk to Property** was considered to be **'Moderate'**.

Hazard D was estimated to have a **Risk to Life** of up to **1.41 x 10^{-7}** for a single person, while the **Risk to Property** was considered to be **'Moderate'**.

Although the óModerateô Risk to Property for Hazard A and B is considered to be óUnacceptableô, the assessments were based on excavations with no support or planning. Provided the recommendations of this report are implemented including geotechnical inspection and installation of engineered support as required the likelihood of any failure becomes óRareô and as such the consequences reduce and risk reduces further and is within óAcceptableô 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:

5.3.1. New Footings:	
Site Classification as per AS2870 ï 2011 for new building footings design	Class óAô for footings founded off sandstone bedrock underlying the site.
Type of Footing	Strip/pad, slab or piers in areas of deeper soil.
Sub-grade material and Maximum Allowable Bearing Capacity	- 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 ï Rock site
Remarks: - All new footings should be founded within sandstone bedrock of similar strength unless designed to accommodate potential differential settlement. - All new footings must be inspected by an experienced geotechnical professional before concrete or steel are placed to verify the bearing capacity of the founding strata. This is mandatory to allow them to be ócertifiedô at the end of the project. - * Subject to geotechnical inspection during construction/excavation, higher bearing pressure possible through core drill investigation.	

5.3.2. Excavation:	
Depth of Excavation	Up to 12.00m for basement level within the southern half of the site and up to 5.00m for basement level within the northern half of the site.
Distance to Neighbouring Properties/buildings	<u>Southern half excavation</u> No. 43 Upper Clifford Avenue - <1.0m form western boundary, building another 2.5m. No. 54 Lauderdale Avenue - <1.0m from the eastern boundary, building another 1.5m. Road reserve (Upper Clifford Avenue) - <30.0m from northern boundary, edge of bitumen another 2.0m. Road reserve (Lauderdale Avenue) ï basement extends to edge of bitumen pavement for Lauderdale Avenue.

	<u>Northern half excavation</u> No. 43 Upper Clifford Avenue - <5.0m from western boundary, building another 2.5m. No. 39 Upper Clifford Avenue - <1.0m from the eastern boundary, building another 1.5m. Road reserve (Lauderdale Avenue) ï <35.0m from the southern boundary, edge of bitumen pavement another 3.0m. Road reserve (Upper Clifford Avenue) - <5.0m from the road reserve, edge of bitumen pavement another 2.0m.
Type of Material to be Excavated	Areas of soil ï generally <0.50m but up to 2.50m depth
	LS ï MS/HS sandstone

Guidelines for batter slopes for this site are tabulated below:

Material	Safe Batter Slope (H: V)	
	Short Term/ Temporary	Long Term/ Permanent
Fill soils	1:1	2:1
Very Low (VLS) to Low strength (LS) or fractured bedrock	0.75:1	1:1
Medium strength (MS), defect free bedrock	Vertical*	Vertical*

*Dependent on defects and assessment by engineering geologist.

Remarks:

Seepage at the bedrock surface or along defects in the 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 are not implemented 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 and protection of property boundaries.

Equipment for Excavation	Fill/Residual soil to ELS bedrock	Excavator with bucket
	LS ï MS/HS bedrock	Rock hammer and saw

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

Remarks:

Based on previous testing of ground vibrations created by various rock excavation equipment within medium strength sandstone bedrock, to achieve the generally recommended low level of vibration (5.0mm PPV) to protect neighbouring structures. the below tabulated hammer weights and buffer distances are required:

Buffer Distance from Structure	Maximum Hammer Weight
5.0m	800kg
8.0m	1000kg
15.0m	2000kg

Confirmation of bedrock strengths prior to excavation and onsite calibration of the actual equipment to be used will provide accurate vibration levels for the site-specific conditions and may allow for larger excavation machinery/smaller buffer distances to be used. Calibration of rock excavation machinery will need to be carried out prior to commencement of bulk rock excavation works and will determine the need for full time monitoring.

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 and it will reduce the potential for movement of detached sections of rock across the boundary below adjacent structures.

Recommended Vibrations Limits (Maximum Peak Particle Velocity (PPV)	Adjacent residential Developments = 5mm/s PPV pending actual conditions from dilapidation surveys
Vibration Calibration Tests Required	Yes
Full time vibration Monitoring Required	Pending proposed equipment and vibration calibration testing results
Geotechnical Inspection Excavation Requirement	Yes, recommended that these inspections be undertaken as per below mentioned sequence: • Following cleaning of soils from bedrock surface • At 1.50m depth interval of excavation where unsupported • At completion of the excavation
Dilapidation Surveys Requirement	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.

Remarks: Water ingress into exposed excavations can result in erosion and stability concerns in both soil and rock portions. Drainage measures will need to be in place during excavation works to divert any surface flow away from the excavation crest and any batter slope.

5.3.3. Retaining Structures:	
Required	MS-HS sandstone bedrock is self supporting and does not require retaining walls provided it is un-fractured by excavation works and contains no poorly orientated defects. If poor quality rock masses are encountered then retention may be required prior to excavation or post excavation.
Types	Concrete soldier piles or anchored shotcrete walls where poor quality rock masses or deep soils encountered, steel reinforced concrete walls post excavation if required. Designed as per Australian Standard AS 4678-2002 Earth Retaining Structures.

Material	Unit Weight (kN/m^3)	Long Term (Drained)	Earth Pressure Coefficients		Passive Earth Pressure Coefficient *
			Active (Ka)	At Rest (K_0)	
Fill/Soil	18	$\phi' = 28°$	0.35	0.52	N/A
LS bedrock (fractured)	23	$\phi' = 40°$	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 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 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).

5.3.4. Drainage and Hydrogeology		
Groundwater Table or Seepage identified in Investigation		No
Excavation likely to intersect	Water Table	No
	Seepage	Minor (Ò2.0L/min during or following intense rainfall) along surface or defects in bedrock
Site Location and Topography		On the low south side of the road within steeply south dipping topography.
Impact of development on local hydrogeology		Negligible
Onsite Stormwater Disposal		Not recommended or required
Remarks: Excavation faces should not remain open for long periods of time unless assessed to be stable by a geotechnical professional due to potential deterioration by groundwater. 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.		

6. CONCLUSION:

The site investigation identified the presence of fill and residual soils however extensive bedrock outcrops were identified and bedrock is generally expected at shallow depth (<0.50m). There were no obvious signs of instability or impending instability however large portions of the site are obscured by vegetation. The existing house is >75 years old and appears in reasonable condition with no indications of slope movement.

It is understood that the proposed development will involve demolition of all existing structures and construction of five storey apartment building, containing two units with a basement level (southern half) and a two storey unit with a front garage (northern half). The southern excavation will be up to 12.0m depth and will be approximately 1.0m from the west and east boundaries, 30.0m from the north boundary and it will extend to the edge of bitumen pavement (Lauderdale Avenue). The northern excavation will be up to 5.0m depth and will be approximately 5.0m from the west boundary, 1.0m from the east boundary, 6.0m from the north boundary and 35.0m from the south boundary.

Excavation is expected to generally extend through sandstone bedrock of medium strength. The medium strength bedrock should stand unsupported following excavation provided there are no unfavorably oriented defects or areas of deep weathering. Whilst these do not appear to exist, care will be required during excavation including regular geotechnical inspections to ensure the stability of the proposed excavation is maintained at all times.

Due to the bulk rock excavation, proximities to the boundaries and neighbouring structures, it is a critical step to assess proposed excavation equipment (e.g. rock hammers) prior to use. As this will directly influence the likelihood of damaging neighbouring properties (including road reserve) due to the significant ground vibrations generated by the equipment, when rock excavating.

The risks associated with the proposed development can be maintained within óAcceptableô levels with negligible impact to 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: Prepared by:

Marvin Lujan
Geotechnical Engineer

Troy Crozier
Principal

7. REFERENCES:

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5. V. Gardiner & R. Dackombe 1983, ñGeomorphological Field Manualò by George Allen & Unwin.
6. Australian Standard AS1170.4 ï 2007, Part 4: Earthquake actions in Australia

CROZIER
GEOTECHNICAL CONSULTANTS

Appendix 1

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Unit 12/ 42-46 Wattle Road Phone: (02) 9939 1882
Brookvale NSW 2100 Email: info@croziergeotech.com.au
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: -

Qc (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: -

Qc = (12 to 18) Cu

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

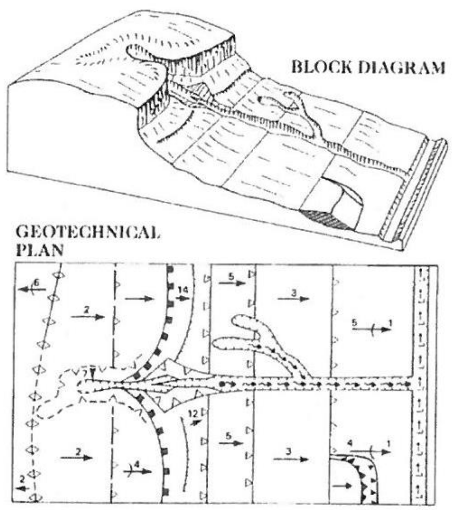
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some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

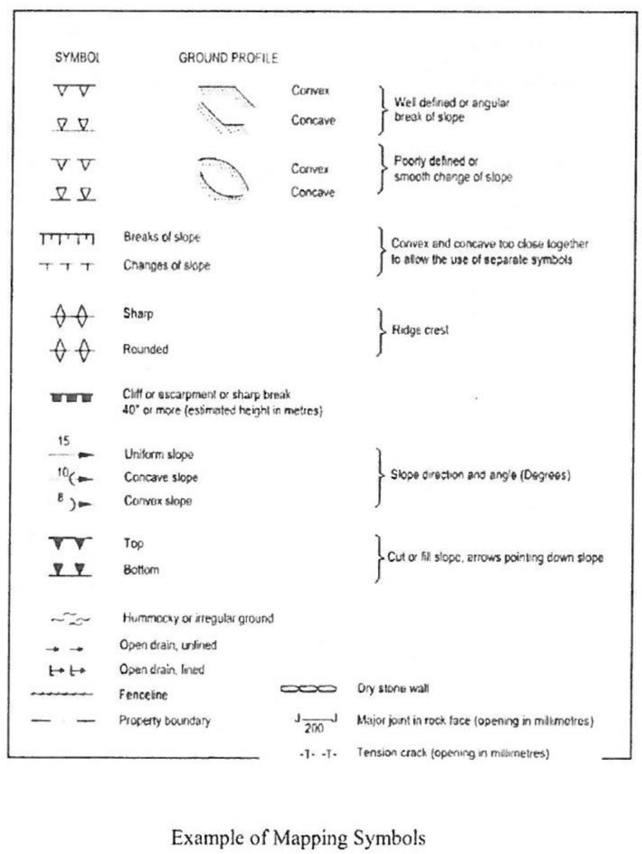
Reproduction of Information for Contractual Purposes

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

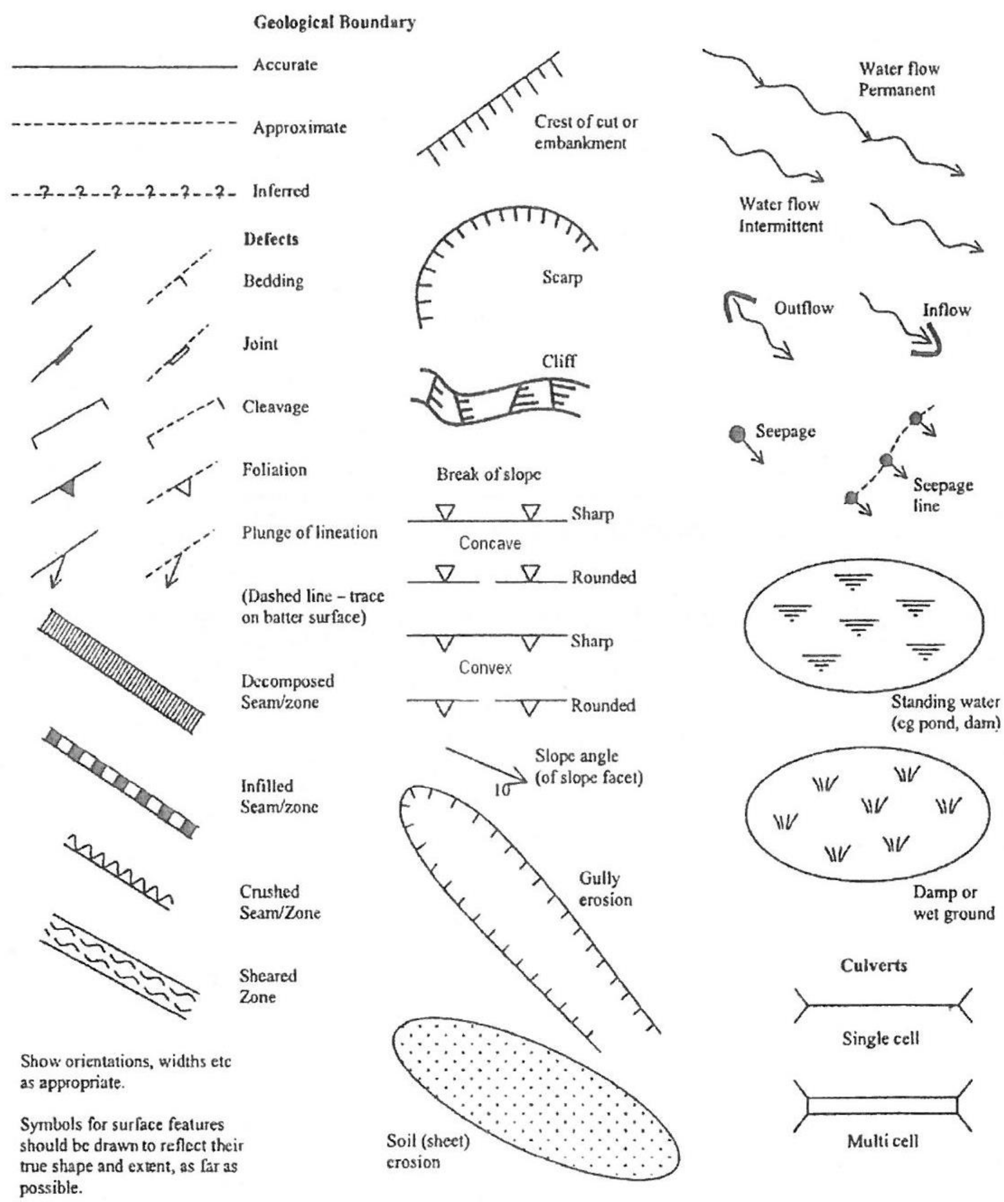
The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.





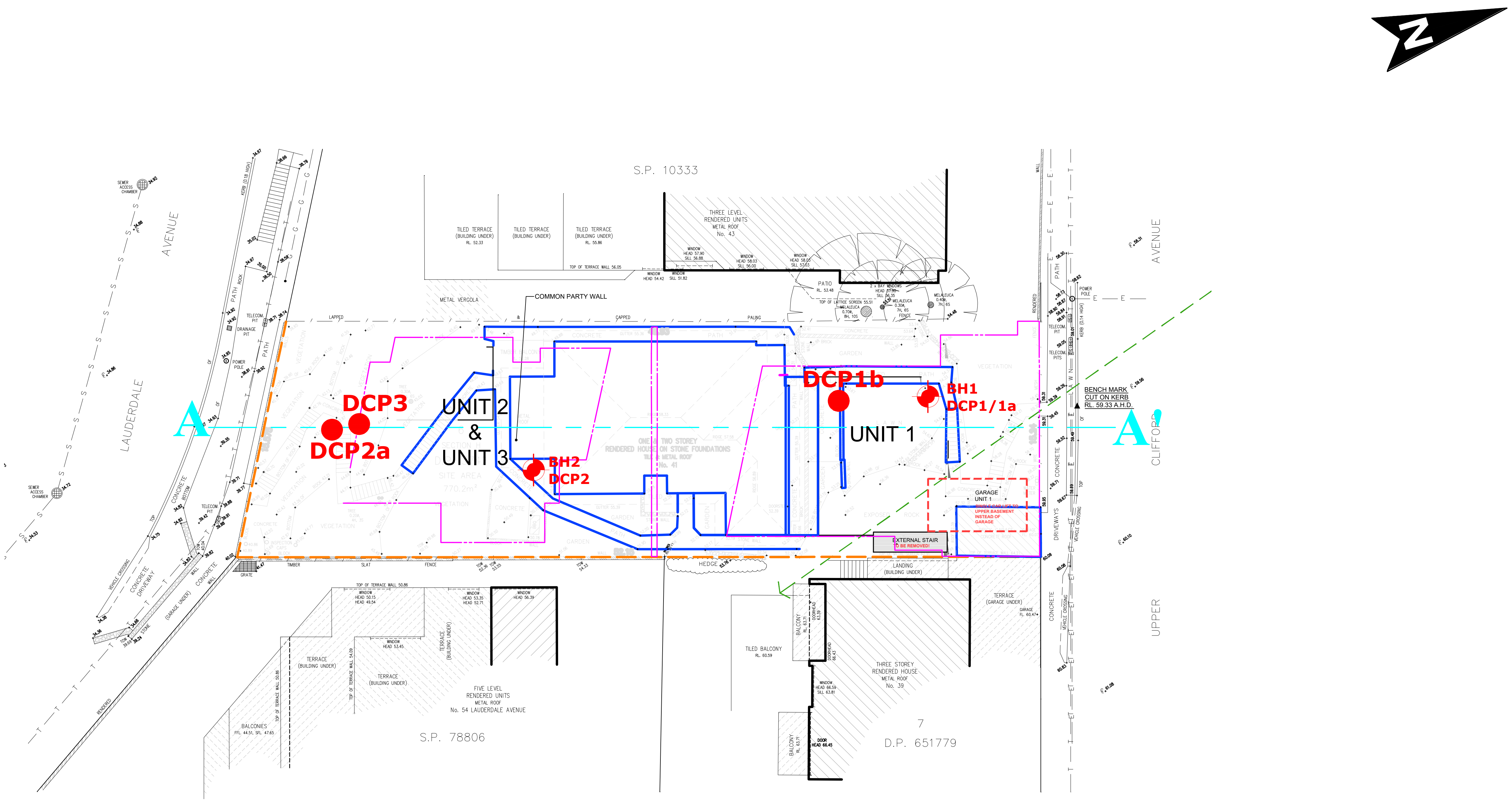
Example of Mapping Symbols
(after V Gardiner & R V Dackombe (1983).Geomorphological Field Manual. George Allen & Unwin).

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



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

0 1 2 3 4 5 6 7 8 9 10

SCALE: 1:300

SITE PLAN & TEST LOCATIONS FIGURE 1.

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

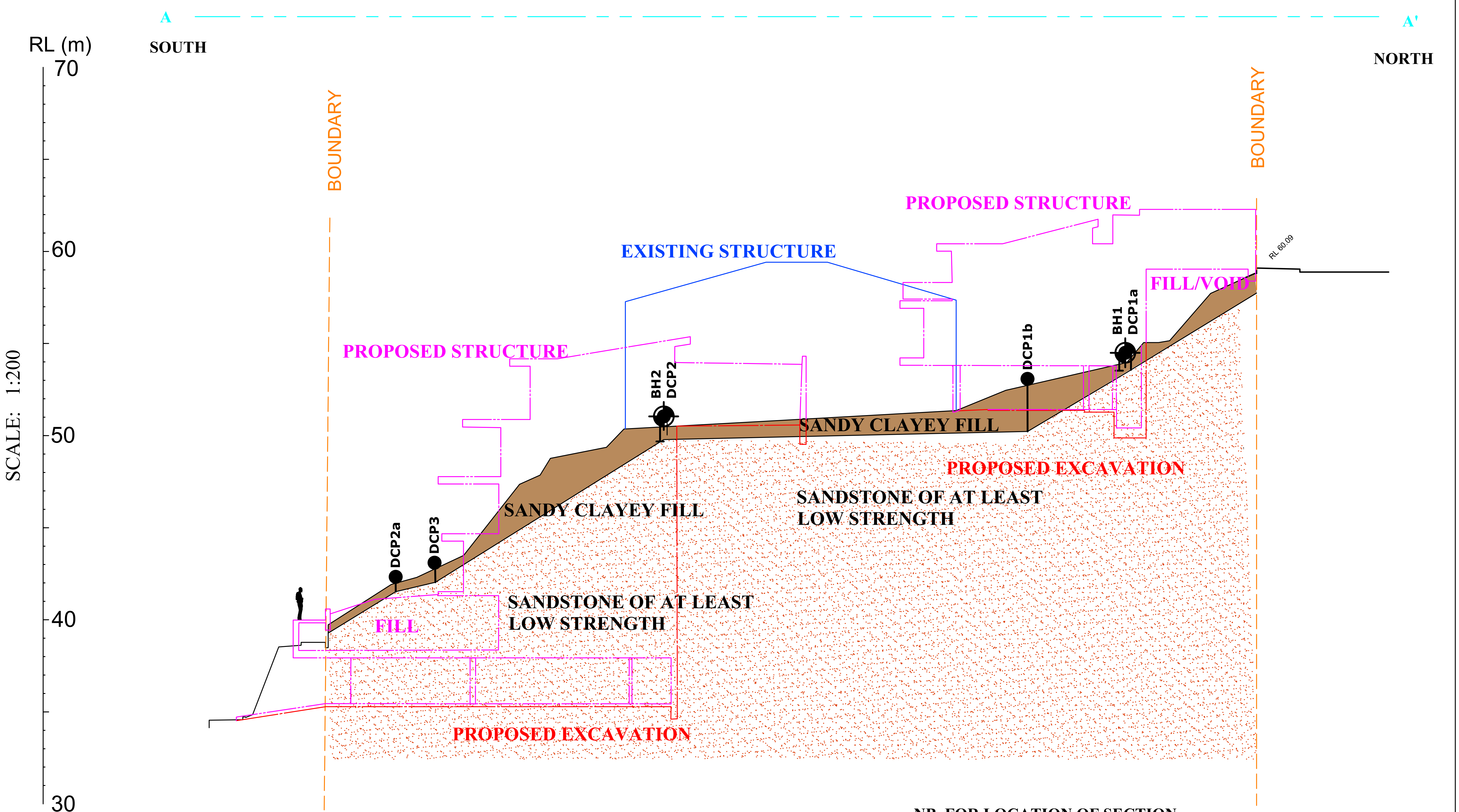
LEGEND

AUGER LOCATIONS · DYNAMIC PENETROMETER TEST · PROPERTY BOUNDARY · EXISTING STRUCTURE · PROPOSED STRUCTURE · A — A' CROSS-SECTION REFERENCE LINE

SCALE:	1:300@A3
DRAWING:	FIGURE 1
DATE:	20/02/2020
APPROVED BY:	TMC
DRAWN BY:	ML
PROJECT:	2019-212.1

PREPARED FOR:
CAR OSCAR PETERSON & HEATON FAMILY INVESTMENTS PTY LTD

ADDRESS:
41 UPPER CLIFFORD AVENUE
FAIRLIGHT



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

BH DCP — AUGER / DYNAMIC CONE PENETROMETER LOCATION

DYNAMIC CONE PENETROMETER TEST

A — A' CROSS-SECTION REFERENCE LINE

PROPOSED EXCAVATION

PROPERTY BOUNDARY

EXISTING STRUCTURE

PROPOSED STRUCTURE

SANDY CLAYEY FILL

INTERPRETED SANDSTONE

SCALE:	1:200@A3	PREPARED FOR:	CAR OSCAR PETERSON & HEATON FAMILY INVESTMENTS PTY LTD
DRAWING:	FIGURE 2		
DATE:	20/02/2020		
APPROVED BY:	TMC	ADDRESS:	41 UPPER CLIFFORD AVENUE FAIRLIGHT
DRAWN BY:	ML		
PROJECT:	2019-212.1		

TEST BORE REPORT

CLIENT: Carl Oscar Peterson &
Heaton Family Investments Pty Ltd

DATE: 6/12/2017

BORE No.: 1

PROJECT: New Residential Development

PROJECT No.: 2019-212

SHEET: 1 of 1

LOCATION: 41 Upper Clifford Avenue, Fairlight

SURFACE LEVEL: Ground surface

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing		
		Type	Depth (m)	Type	Results	
0.00						
	GRASS					
	FILL- very loose, brown, dry, fine grained, sandy fill with some organic matter					
0.20	*medium dense					
0.35						
	HAND AUGER DISCONTINUED at 0.35m depth in FILL					
1.00						
2.00						

RIG: None

DRILLER: KB

LOGGED: DA

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: No free standing ground water observed

REMARKS:

CHECKED: TMC

TEST BORE REPORT

CLIENT: Carl Oscar Peterson & Heaton Family Investments Pty Ltd
DATE: 6/12/2017
BORE No.: 2

PROJECT: New Residential Development
PROJECT No.: 2019-212
SHEET: 1 of 1

LOCATION: 41 Upper Clifford Avenue, Fairlight
SURFACE LEVEL: Ground surface

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	Results	
0.00	SANDY FILL- loose, brown, fine grained, dry, sandy fill					
0.25	CLAY FILL- very loose, red, moist, sandy-clay fill	D	0.30			
0.50	* with some ironstone gravels					
0.60	SANDY FILL- very loose,dark brown, coarse grained, wet, sandy fill					
0.70	HAND AUGER REFUSAL at 0.70m on at least very low strength sandstone bedrock					
1.00						
2.00						

RIG: None
DRILLER: KB
LOGGED: DA

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: No free standing ground water observed

REMARKS:
CHECKED: TMC

DYNAMIC PENETROMETER TEST SHEET

CLIENT: Carl Oscar Peterson & Heaton Family Investments Pty Ltd

DATE: 6/12/2017

PROJECT: New Development

PROJECT No.: 2019-212

LOCATION: 41 Upper Clifford Avenue, Fairlight

SHEET: 1 of 1

	Test Location							
Depth (m)	DCP1	DCP1a	DCP1b	DCP2	DCP2a	DCP3		
0.00 - 0.15	1	1	2	1	1	2		
0.15 - 0.30	5	3	4	2	6	1		
0.30 - 0.45	3(B)	4	3	4(B)	1 (B)	0		
0.45 - 0.60		6(B)	4			1		
0.60 - 0.75		Refusal at 0.57m	5			0(B)		
0.75 - 0.90			14			Refusal at 0.73m		
0.90 - 1.05			10					
1.05 - 1.20			8					
1.20 - 1.35			5					
1.35 - 1.50			9					
1.50 - 1.65			9					
1.65 - 1.80			9					
1.80 - 1.95			9					
1.95 - 2.10			10					
2.10 - 2.25			10					
2.25 - 2.40			13(B)					
2.40 - 2.55			Refusal at 2.50m					
2.55 - 2.70								
2.70 - 2.85								
2.85 - 3.00								

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 <1.0m³) from soils due to excavation along the northern half of the site - Unit 1 Ground Floor & First Floor		Excavation up to 1.5m depth of fill/soil	a) Building Ò7.0m from northern portion excavation b) Pathway and patio Ò5.0m from northern portion excavation c) House Ò5.5m from northern portion excavation; and no soil underlying the house d) Staircase Ò4.0m from northern portion excavation e) Road Reserve Ò6.0m from northern portion excavation		a) Person in house 10hrs/day avge. b) Person in pathway and patio 0.25hr/day avge. c) Person in house 10hrs/day avge. d) Person in staircase 0.25hr/day avge. e) Person on path 0.25hrs/day avge.	a) Almost certain to not evacuate b) Possible to not evacuate c) Almost certain to not evacuate d) Possible to not evacuate e) Possible to not evacuate	a) Person in building, minor damage only b) Person in open space, unlikely buried c) Person in building, minor damage only d) Person in open space, unlikely buried e) Person in open space, likely buried	
			Unlikely	**Prob. of Impact**	**Impacted**				
		a) Unit/structure No. 43 Upper Clifford	0.001	0.010	0.001	0.4167	1	0.01	**4.17E-11**
		b) Pathway & patio No.43 Upper Clifford	0.001	0.010	0.050	0.0104	0.5	0.15	**3.91E-10**
		c) House No.39 Upper Clifford	0.00001	0.001	0.001	0.4167	1	0.01	**4.17E-14**
		d) Staircase & pathway No.39 Upper Clifford	0.00001	0.001	0.050	0.0104	0.5	0.15	**3.91E-13**
		e) Road reserve pathway (Upper Clifford)	0.001	0.050	0.150	0.0104	0.5	0.15	**5.86E-09**
B	Landslip (rock slide/topple <3m³) within rock excavation - Unit 1 Ground Floor & First Floor		Rock excavations up to 5.0m depth expected, likely unfavourable defects in some portion	a) Building Ò7.0m from rock excavation b) Pathway and patio Ò5.0m from rock excavation c) House Ò8.0m from rock excavation d) Staircase Ò1.0m from rock excavation e) Road Reserve Ò6.0m from rock excavation		a) Person in house 10hrs/day avge. b) Person in pathway and garden 0.25hr/day avge. c) Person in house 10hrs/day avge. d) Person in staitcase & pathway 0.25hr/day avge. e) Person in road reserve 0.25hrs/day avge.	a) Almost certain to not evacuate b) Possible to not evacuate c) Almost certain to not evacuate d) Likely to not evacuate e) Possible to not evacuate	a) Person in building, minor damage only b) Person in open space, likely buried c) Person in building, minor damage only d) Person in open space, likely buried e) Person in open space, likely buried	
			Unlikely	**Prob. of Impact**	**Impacted**				
		a) Unit/structure No. 43 Upper Clifford	0.001	0.001	0.001	0.4167	1	0.01	**4.17E-12**
		b) Pathway & patio No.43 Upper Clifford	0.001	0.001	0.050	0.0104	0.5	0.9	**2.34E-10**
		c) House No.39 Upper Clifford	0.001	0.100	0.001	0.4167	1	0.01	**4.17E-10**
		d) Staircase & pathway No.39 Upper Clifford	0.001	0.150	0.100	0.0104	0.75	0.9	**1.05E-07**
		e) Road reserve pathway (Upper Clifford)	0.001	0.050	0.150	0.0104	0.5	0.9	**3.52E-08**
C	Landslip (earth slide <1m³) from soils due to excavation along the southern half of the site - First, second and third floor - Unit 3 & 4 townhouses		Excavation up to 0.73m depth of fill/soil	a) House Ò3.5m from the <0.73m soil excavation b) Pathway and garden Ò1m the Ò0.73m deep soil excavation c) Building Ò1.0m from soil excavation d) Road reserve pathway (Lauderdale Avenue) is on the south boundary of <0.73m deep excavation.		a) Person in house 10hrs/day avge. b) Person in pathway and garden 0.25hr/day avge. c) Person in apartment 10hrs/day avge. d) Person in driveway 0.25hr/day avge.	a) Almost certain to not evacuate b) Possible to not evacuate c) Almost certain to not evacuate d) Possible to not evacuate	a) Person in building, minor damage only b) Person in open space, unlikely buried c) Person in building, minor damage only d) Person in open space, unlikely buried	
			Unlikely	**Prob. of Impact**	**Impacted**				
		a) Unit/structure No. 43 Upper Clifford	0.001	0.001	0.010	0.4167	1	0.01	**4.17E-11**
		b) Pathway & patio & front gardens No.43 Upper Clifford	0.001	0.05	0.050	0.0104	0.5	0.01	**1.30E-10**
		c) Building No.54 Lauderdale Avenue	0.00001	0.001	0.001	0.4167	1	0.01	**4.17E-14**
		d) Road reserve pathway (Lauderdale Avenue)	0.001	0.15	0.150	0.0104	0.5	0.01	**1.17E-09**
D	Landslip (rock slide/topple <3m³) within rock excavation - Ground Level & Basement Level		Rock excavations up to 12.0m depth expected, likely unfavourable defects in some portion	a) House Ò3.5m from western side of Ò12m deep rock excavation b) Pathway and garden Ò1m from western side of Ò12m deep rock excavation c) House Ò1.0m from eastern side of Ò12m deep rock excavation d) Road reserve pathway (Lauderdale Avenue) is on the south boundary of rock excavation		a) Person in house 10hrs/day avge. b) Person in pathway and garden 0.25hr/day avge. c) Person in house 10hrs/day avge. d) Person in road reserve pathway 0.25hr/day avge.	a) Almost certain to not evacuate b) Possible to not evacuate c) Almost certain to not evacuate d) Possible to not evacuate	a) Person in building, minor damage only b) Person in open space, likely buried c) Person in building, minor damage only d) Person in open space, likely buried	
			Unlikely	**Prob. of Impact**	**Impacted**				
		a) Unit/structure No. 43 Upper Clifford	0.001	0.10	0.001	0.4167	0.9	0.01	**3.75E-10**
		b) Pathway & patio & front gardens No.43 Upper Clifford	0.001	0.15	0.050	0.0104	0.5	0.9	**3.52E-08**
		c) Building No.54 Lauderdale Avenue	0.00001	0.001	0.001	0.4167	0.9	0.01	**3.75E-14**
		d) Road reserve pathway (Lauderdale Avenue)	0.001	0.20	0.150	0.0104	0.5	0.9	**1.41E-07**

* 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 <u>not</u> 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 $<1.0m^3$) from soils due to excavation along the northern half of the site - Unit 1 Ground Floor & First Floor	a) Unit/structure No. 43 Upper Clifford	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) Pathway & patio No.43 Upper Clifford	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) House No.39 Upper Clifford	Rare	The event is conceivable but only under exceptional circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Very Low
		d) Staircase & pathway No.39 Upper Clifford	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) Road reserve pathway (Upper Clifford)	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	Landslip (rock slide/topple $<3m^3$) within rock excavation - Unit 1 Ground Floor & First Floor	a) Unit/structure No. 43 Upper Clifford	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
		b) Pathway & patio No.43 Upper Clifford	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) House No.39 Upper Clifford	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
		d) Staircase & pathway No.39 Upper Clifford	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
		e) Road reserve pathway (Upper Clifford)	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 (earth slide $<1m^3$) from soils due to excavation along the southern half of the site - First, second and third floor - Unit 3 & 4	a) Unit/structure No. 43 Upper Clifford	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) Pathway & patio & front gardens No.43 Upper Clifford	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) Building No.54 Lauderdale Avenue	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) Road reserve pathway (Lauderdale Avenue)	Likely	Event will probably occur under adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
D	Landslip (rock slide/topple $<3m^3$) within rock excavation - Ground Level & Basement Level	a) Unit/structure No. 43 Upper Clifford	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) Pathway & patio & front gardens No.43 Upper Clifford	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) Building No.54 Lauderdale Avenue	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) Road reserve pathway (Lauderdale Avenue)	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

* 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%.

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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}	$5x10^{-3}$	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.