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REPORT ON GEOTECHNICAL SITE INVESTIGATION

for

PROPOSED DEVELOPMENT

at

30 FAIRLIGHT STREET, FAIRLIGHT NSW

Prepared For

Castle 240 Pty Ltd

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TABLE OF CONTENTS

APPENDICES

CROZIER
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GEOTECHNICAL REPORT FOR PROPOSED FOUR STOREY RESIDENTIAL DEVELOPMENT 30 FAIRLIGHT STREET, FAIRLIGHT, NSW

1. INTRODUCTION:

This report details the results of a geotechnical assessment carried out for the construction of a new four storey residential apartment complex with a basement carpark at 30 Fairlight Street, Fairlight, NSW. The investigation was undertaken by Crozier Geotechnical Consultants (CGC) at the request of the client Castle 240 Pty Ltd.

With reference to Northern Beaches (Manly) Councils – Development Control Plan 2013 – Schedule 1 Map C, the site is located within Landslip Risk Class "G4" which is classified as Ridge crests, major spur slopes and dissected plateau areas, with slopes angles < 15°.

A review of the preliminary slope stability assessment checklist and the proposed works indicated that the Development Application would require a full site stability (geotechnical) report. Therefore, this report is prepared to meet Councils requirements. It includes a description of site and sub-surface conditions, a geotechnical assessment and landslip risk assessment for both property and life as per the AGS 2007, site mapping/plan, geological section and provides recommendations for future construction.

The site assessment and reporting were undertaken as per the Tender P19-393, Dated: 10th October 2019.

The investigation comprised:

a) A detailed geotechnical inspection and mapping of the entire site and limited inspection of adjacent land, with identification of geotechnical conditions including potential hazards related to the existing site and proposed structures, by a Geotechnical Engineer including a photographic record of site conditions,
b) DBYD plan request and onsite clearing of test locations by an accredited service location contractor.
c) Drilling of four hand auger boreholes along with Dynamic Cone Penetrometer (DCP) testing to investigate the subsurface geology, depth to bedrock and identification of ground water

d) All fieldwork was conducted under the full-time supervision of an experienced Geotechnical Professional who completed logging of soils and ensured the quality of all geotechnical data.

The following plans and drawings were supplied for the work:

- Preliminary Drawings – by Bianchino Associates, Drawing No: 2019-01-DA02 to 2019-01-DA15, Date: Nov-2019, Checked: JB, Drawn by: FZ, Issue: P8.
- Survey Drawing – As supplied by Bianchino Associates, Drawing No: 2019-01-DA01, Dated: Nov-2019, Issue P8.

2. PROPOSED DEVELOPMENT:

It is understood from the supplied drawings that the proposed works involve demolition of the existing structures and construction of a new four storey residential apartment complex. The works include a total of seven apartments as well as a basement level for car parking.

The basement floor plan will have a Finished Floor Level (FFL) of RL. 40.97m and an excavation up to approximately 6.6m depth will be required at the northern portion of the site, gradually decreasing to 1.5m depth at the southern portion of the site. The bulk excavation will be located approximately 1.0m from the west boundary, 5.8m from the north boundary and it will extend to the east and south boundaries. Between the north boundary and northern side of basement excavation, it is understood that a deep soil zone will be created and will require excavation of up to 4.0m depth within 1.0m of the north boundary, 2.0m of the west boundary and extending to the east boundary.

3. SITE FEATURES:

3.1. Description:

The site is a rectangular shaped block located on the high north side of Fairlight Street. It has front south and rear north boundaries of 16.01m and 15.68m with west and east boundaries of 54.65m and 54.19m, respectively with a total area of 862.28m² as reference from the supplied preliminary drawings.

The site is within gently south dipping topography and has a high of approximately R.L. 51.15m at the north end of the site and a low of R.L. 42.23m at the south end of the site.

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 views of the site at the time of investigation are provided in Photograph 2 and Photograph 3

Photograph: 1 – Aerial photo of site and surrounds.

Photograph-2: Front view of the site from Fairlight Street, facing north

Photograph-3: Rear view of the site from rear lawn, facing south.

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.

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 are 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 (15° to 23°) and are randomly covered by sandstone boulders.

4. FIELD WORK:

4.1. Methods:

The field investigation comprised a walk over inspection and mapping of the site and adjacent properties on the 19th November 2019 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 neighbouring properties.

It also included the drilling of four boreholes (BH1 to BH4) to investigate sub-surface geology. A hand auger was used as access to required test locations within the site for a conventional drilling rig was unavailable.

DCP testing was carried out from ground surface adjacent to and within the boreholes in accordance with AS1289.6.3.2 – 1997, "Determination of the penetration resistance of a soil – 9kg dynamic cone penetrometer" to estimate near surface soil conditions and depth 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. A Geological models/section is provided as Figure: 2, Appendix: 2.

4.2. Field Observations:

The site is situated on the high north side of Fairlight Street within gently south dipping topography. Fairlight Street is formed with a gently east dipping bitumen pavement, with low concrete gutters and kerbs adjacent to the bitumen pavement. Adjacent to the site's south boundary, the road reserve contains a gently dipping lawn and a concrete footpath along the boundary. There were no signs of excessive cracking or deformation within the road pavement or pathway to suggest any movement or underlying geotechnical issues.

Access to the site is gained from the south east corner of the site. The entrance contains a series of stairs (Photograph-4) which leads to the entrance door of the dwelling (to the west) and a pathway (to the east) between the eastern side of the house and the eastern boundary. To the front of the entrance door is a patio (which is positioned right above the garage). The patio contains a tiled floor and it is surrounded by relatively small gardens along the edges. The patio appears to be in good condition with no significant cracks or undulations present within the patio floor. However, the external walls supporting the gardens contain vertical cracks of approximately 15mm width (Photographs 5&6). It appears that these cracks are due to lateral pressures exerted by the soil or poor lateral reinforcement of the wall structure.

Photograph-4: Staircase at entrance. View looking north.

Photograph-5: Garden crack, view looking south.

Photograph-6: Front garden crack. View from patio to road reserve

The site house is a one storey rendered brick structure located in the centre of the block with a separate basement garage located at the front boundary. A lawn is located at the rear north west of the site and an inground pool at the rear north east of the site. The house appears to be over 75 years of age and in reasonable condition with no signs of settlement or of excess cracking on the external walls. According to available NSW Government information, the site has been in its current configuration since at least 1943.

The site is within south dipping topography, therefore, the southern portion of the house is formed/supported by sandstone blocks and columns (Photographs 7&8) of approximately <1.8m in height, which extend to unknown footings. There were no signs of underlying geotechnical issues within the supporting sandstone block and columns, internally or externally.

Photograph-7: Sandstone block wall. View looking south.

Photograph-8: Sandstone column. View looking west.

Access to the rear of the site is gained via a narrow (approximately 1.5m wide) paved pathway which leads to a paved rear patio (Photograph-9). The rear patio comprises of an alfresco area at the south west corner with a tree adjacent to the eastern boundary. The paved pathway and patio floor appear to be in good condition, with no cracks. However, a minor undulation (Photograph-10) was observed to the base of the tree, it is likely that this is due to the presence of a tree root.

Photograph-9: Rear patio. View looking North.

Photograph-10: Minor floor undulation. To the base of of the tree

To the north of the rear patio is the rear end portion of the site, which is accessed via a gate, followed by a timber staircase. The rear end portion of the site contains a lawn at the western portion, an inground pool at the eastern portion and a raised garden (along the north boundary) which is retained by a concrete tiled retaining wall of approximately 1.5m height. To the base of the retaining wall and a tree is a minor rock outcrop comprising low to medium strength sandstone at approximately R.L.47.54m (Photograph 12&13). To the east of the sandstone outcrop (adjacent to the inground pool) is another rock outcrop (Photograph 14&15) comprising of similar composition at approximately R.L.47.41m.

Photograph-11: Lawn and inground pool. View looking north

Photograph-12: Concrete tiled retaining wall. View Looking north.

Photograph-13: Rock outcrop. To the base of the tree.

Photograph-14: *Second rock outcrop. View looking east*

Photograph-15: Close up to rock outcrop. View looking east.

The neighbouring property to the east of the site, No. 28, contains a driveway and a four-storey brick apartment building. The concrete driveway extends north along the site's eastern boundary to a raised lawn (approximately 3m height) adjacent to the site's (Photograph 16 &17) north-east corner. The boundary contains a brick retaining wall which appears to be in good condition with no significant cracks or rotation. The building is located approximately 4.2m off the boundary, appears formed at above ground surface levels and appears in good condition with no sign of cracking or settlement on the external walls.

Photograph-16: No.28 driveway. View looking north

Photograph-17: Raised lawn. View looking north

The neighbouring property to the west of the site, No.32, contains a one storey house with front and rear lawns. The property was observed to have a similar ground level to as the site (No.30 Fairlight Street). The building is located approximately 1.20m off the boundary, appears formed above ground surface levels and appears to be in good condition with no sign of cracking or settlement on the external walls.

The neighbouring property to the north (No.1 Berry Avenue) was not visible due to a relatively high boundary timber fence. However, based on information obtained from online sources, it appears that the site contains a three-storey brick apartment building, a south dipping concrete driveway along the eastern boundary with a courtyard and gardens to the rear south end of the block. The building is located 9m off the common boundary with the site and minor rock outcrop can be observed (from google maps images) at the north east corner of the property, adjacent to the driveway.

A review of the DBYD service plans indicated a Sydney Water asset runs west/east below the centre of the site. This asset appears significant (6570x6570), however there are no visible aspects and it is expected to be located at significant depth.

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 or the proposed development.

4.3. Field Testing:

The boreholes (BH1 to BH4) were drilled using a hand auger at the front and rear of the site with refusal encountered at varying depths between 0.70m (BH1) and 0.20m (BH3&BH4).

Dynamic Cone Penetrometer (DCP) tests were carried out from the ground surface adjacent to the boreholes with refusal at depths varying from 0.15m(DCP4a) to 1.35m(DCP4) depth.

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

- **TOPSOIL/FILL** – this layer was encountered at all boreholes to a maximum of 0.60m depth below the ground surface. It was classified as loose, dark brown, fine to medium grained, moist, silty sand with some plant roots, wood chips and fine gravel within BH1 and BH2 and with coarse gravel/cobbles within BH3 and BH4.
- **SILTY SAND** – this layer was encountered in BH1from 0.60m to 0.70m (BH1). It was classified as loose, yellow, fine to medium grained, moist, silty sand.

- **SANDSTONE BEDROCK –** Interpreted very low to low strength sandstone was encountered between varying depths of 0.30m(DCP2) to 1.35m (DCP4).

There were no indications of significant seepage or a groundwater table in any of the boreholes during drilling.

5. COMMENTS:

5.1. Geotechnical Assessment:

The site investigation identified topsoil/fill (≤1.35m) (DCP4) underlain by a thin layer of silty sand (BH1), overlying sandstone bedrock. Fill soil depth will vary across the site and increase to the rear of retaining walls and to the west of the inground pool. The surface of the bedrock was identified as dipping towards the south from a high of approximately R.L.= 46.16m (DCP4) to R.L.= 43.62m(DCP1). Some outcrop was observed in the north east corner of the site and the bedrock surface is expected to undulate with minor weathered/weak bedrock over low to medium strength bedrock expected. No groundwater table or significant seepage was encountered during the investigation. However, minor seepage is expected at the soil rock interface. Seepage is also likely along defects in the bedrock.

It is understood that excavation will be required to accommodate the construction of a basement carpark with R.L. 40.97m. To achieve this, excavation up to 6.6m depth will be required at the north portion of the site, gradually decreasing to a 1.5m depth at the southern portion.

Based on the investigation results, the excavation is anticipated to encounter sandstone bedrock of at least very low strength from 1.35m depth (in the northern portion of the site) and from 0.78m depth (in the southern portion of the site) down to the base of the excavation. The bedrock is expected to grade quickly to low and medium to potentially high strength and may contain thin/discontinuous shale/siltstone bands.

Considering the proposed depth of excavation and distance to the boundaries, the recommended safe temporary batter slopes provided in Section 5.3 do not appear achievable for the north, east and west boundary of the site and appear to require support prior to excavation to maintain boundary stability. This only appears related to soil portions provided the bedrock is of good quality, including strength and defects. Due to the depth of excavation, especially adjacent to the eastern boundary, it is recommended that further investigation via cored boreholes be completed prior to final design. The excavation adjacent to the south boundary is mostly required to achieve the proposed ramp and staircases down to the Basement Level. However, a store room extends to the south boundary where excavation to 1.5m below footpath level is required for a ≤1.5m length of the boundary. This zone may require installation of temporary support and should be assessed during initial site works.

There appears to be a significant Sydney Water asset passing below the site (west-east). DBYD plans indicates the asset is of dimensions 6570mm x 6570mm. Information obtained from Sydney Water-Northside Storage Tunnel, indicates the tunnel starts 40m below sea level west of Lane Cove River and runs 16km east to end 100m below sea level at North Head. This information indicates that the proposed works are well distanced from the asset below. However, Sydney Water should be contacted to confirm their requirements in regard to design and construction to prevent delays in approvals.

Significant rock excavation will be required to achieve the proposed development. The magnitude of the vibrations generated when rock excavation is depended on the strength of the rock, method and type of equipment use to excavate rock. If these vibrations are not well controlled, they can create damage to the neighbouring properties and to services including within the road reserve. It is therefore recommended to follow the recommendations in Section 5.3 and include them as part of an excavation plan.

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

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, the results of the investigation provide a reasonable basis for the Development Application analysis and subsequent preliminary design of the proposed works.

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 $<3m^3$) from soils due to excavation along the northern portion of the site.
B. Landslip (rockslide/topple $<15m^3$) within rock excavation for Ground and Basement Level.

A qualitative assessment of risk to life and property related to this hazard 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 was estimated to have a **Risk to Life** of **1.30 x 10^{-7}** 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 **3.26 x 10^{-5}** for a single person, while the **Risk to Property** was considered to be **'Moderate'**.

Although the 'Moderate' Risk to Property for Hazard A and B is considered to be 'Unacceptable', 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 'Rare' and as such the consequences reduce and risk reduces further and is 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 on bedrock
Type of Footing	Strip/Pad or Slab at base of excavation, piers external to the excavation if required to achieve uniform bearing
Sub-grade material and Maximum Allowable Bearing Capacity for Footing Design	- Very Low Strength Sandstone: 800kPa - Low Strength Sandstone: 1000kPa - Medium Strength 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: * Higher bearing pressures available through core drilling of bedrock All new footings must be inspected by an experienced geotechnical professional before concrete or steel are placed to verify the preliminary maximum bearing capacities provided above and the in-situ nature of the founding strata. This is mandatory to allow them to be 'certified' at the end of the project.	

Individual structures should not be founded on materials with varying bearing and settlement characteristics unless the potential for differential movement has been allowed for in structural design.

5.3.2. Excavation:	
Depth of Excavation	Up to approximately 6.6m excavation within the northern portion of the site, decreasing to 1.5m excavation within the southern portion of the site.
Distance of excavation to Neighbouring Properties and Structures.	- No. 32 Fairlight Street – approximately 1.0m from west boundary, building another 1.20m - No. 28 Fairlight Street – On eastern boundary, building another 4.2m. - No. 1 Berry Avenue – approximately 5.8m from north boundary, building another 9m. - Road Reserve (Fairlight St.): ✓ 40° stairs excavation approximately 1.3m from road reserve, edge of bitumen another 4m. ✓ 1.5m deep excavation on south boundary for proposed store room, edge of bitumen another 4m.
Type of Material to be Excavated	Topsoil/fill ≤1.35m
	Silty Sand ≤0.70m
	Sandstone Bedrock VLS to MS from ≤1.35m
VLS = Very low strength, MS = Medium strength	
Guidelines for batter slopes for this site are tabulated below:	

Material	Safe Batter Slope (H:V)	
	Short Term/ Temporary	Long Term/ Permanent
Fill & Silty Sand natural granular soils	1.5:1	2:1
Very Low strength bedrock or fractured bedrock	0.75:1*	1.25:1*
Low to Medium strength, 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 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.

Equipment for Excavation	Fill/Sand	Excavator with bucket
	VLS bedrock	Excavator with bucket and ripper
	LS-MS bedrock	Rock hammer and saw

Remarks:

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

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

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

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

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

An excavator with bucket will not create excessive vibrations provided it is undertaken with medium scale (<20 tonne excavator) excavation equipment in a sensible manner.

Recommended Vibration Limits (Maximum Peak Particle Velocity (PPV))	No. 32 Fairlight Street = 5mm/s No.28 Fairlight Street = 5mm/s No.1 Berry Avenue = 5mm/s Road reserve = 5mm/s
Vibration Calibration Tests Required	Yes, recommended for any rock hammer >250kg weight

Full time vibration Monitoring Required	Pending proposed equipment and vibration calibration testing results
Geotechnical Inspection Requirement	Yes, recommended that these inspections be undertaken as per below mentioned sequence: • Following removal of site soils and exposure of bedrock • During installation of boundary supporting systems • At 1.50m depth intervals within bedrock excavation • At completion of the excavation.
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.
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, whilst any groundwater seepage must be controlled within the excavation and prevented from ponding or saturating slopes/batters.	

5.3.3. Retaining Structures:	
Required	New retaining structures are required at boundaries, as part of the proposed development.
Types	Steel reinforced concrete/concrete block wall post excavation where safe temporary batters can be formed. Contiguous piles where batters can not be achieved or something similar to maintain support.
Parameters for calculating un-surcharged pressures on retaining walls for the materials likely to be retained:	

Material	Unit Weight (kN/m^3)	Long Term (Drained)	Earth Pressure Coefficients		Passive Earth Pressure Coefficient *
			Active (Ka)	At Rest (K_0)	
Sandy Fill/Loose Sand	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 utilise active earth pressure coefficients (Ka).

5.3.4. Drainage and Hydrogeology

Groundwater Table or Seepage identified in Investigation		Yes
Excavation likely to intersect	Water Table	No
	Seepage	Minor (<1L/min), on defects and at soil/rock interface
Site Location and Topography		High north side of Fairlight Street within gently south dipping topography.
Impact of development on local hydrogeology		Negligible
Onsite Stormwater Disposal		Not required or recommended.

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. Conduct additional borehole investigation to assess bedrock condition adjacent to boundaries.
2. Review and approve the structural design drawings, including the retaining structure design and construction methodology, for compliance with the recommendations of this report prior to construction,
3. Inspect any medium strength bedrock and the proposed excavation equipment prior to its excavation
4. 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,
5. Inspect completed works to ensure no new landslip hazards have been created by site works and 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 indicated the presence of fill (<1.35m) underlain by a thin layer of silty sand within the southern portion, overlying gently south dipping sandstone bedrock. Based on the investigation, the depth of at least very low strength bedrock is interpreted to be ranging between 0.15m(DCP4a) to 1.35m(DCP4) below the existing ground surface. The bedrock is expected to grade to medium strength at shallow depth.

The proposed works will require an excavation up to 6.6m depth within the northern portion of the site down to 1.5m excavation within the southern portion of the site. The excavation is expected to intersect fill material (including coarse gravel to cobbles) below the existing ground surface, then a thin layer of silty sand within the southern portion of the site then a variably weathered sandstone of interpreted very low to low strength, grading quickly to medium strength.

Based on the existing site levels and the proposed excavation depths, it appears that the recommended safe temporary batter slopes are not achievable within all boundaries. South boundary batter slopes are not achievable for a small section only (proposed store room). Support prior to excavation will be required to protect these boundaries and neighbouring structures. The design for this support should be based on further geotechnical investigation into the bedrock to below excavation level.

The proposed excavation is also expected to extend below the bedrock surface level. As such, it will be necessary to assess proposed excavation equipment (e.g. rock hammers) prior to use to determine whether vibration monitoring will be required during excavation.

The risks associated with the proposed development can be maintained within 'Acceptable' levels with negligible impact to 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.

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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

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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: -

$Q_c = (12 \text{ to } 18) C_u$

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

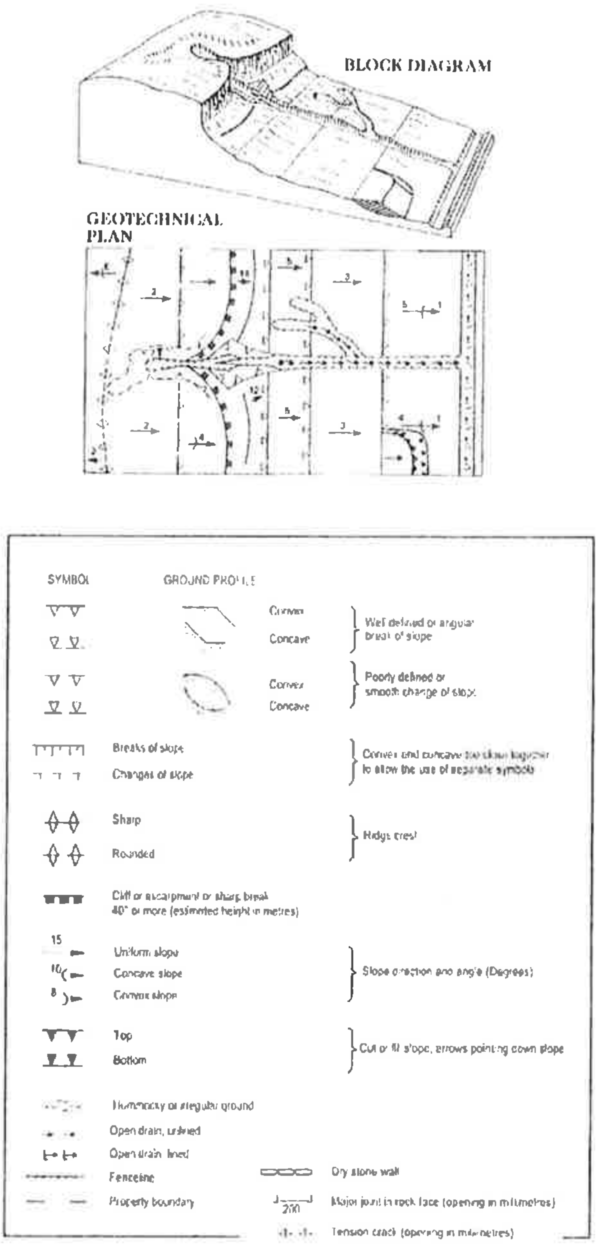
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some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

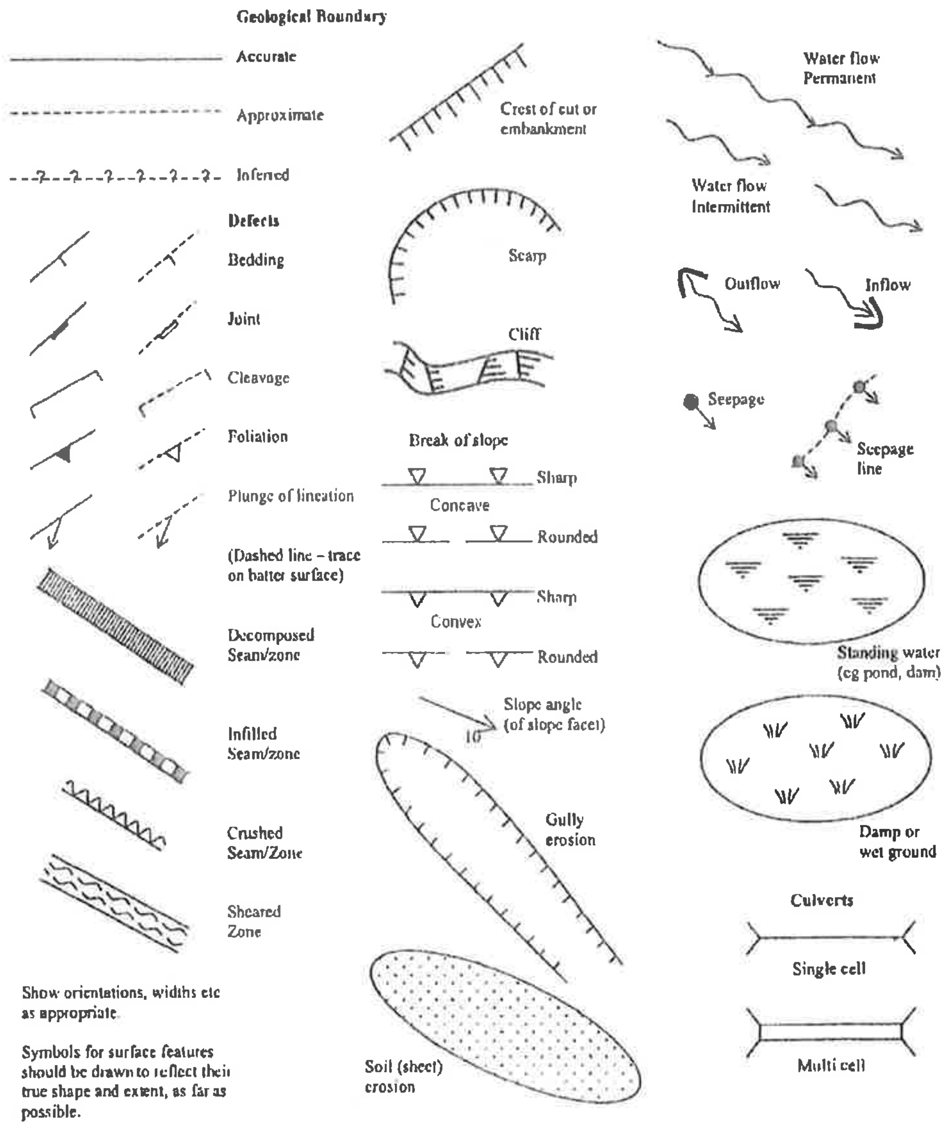
Site Inspection

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.



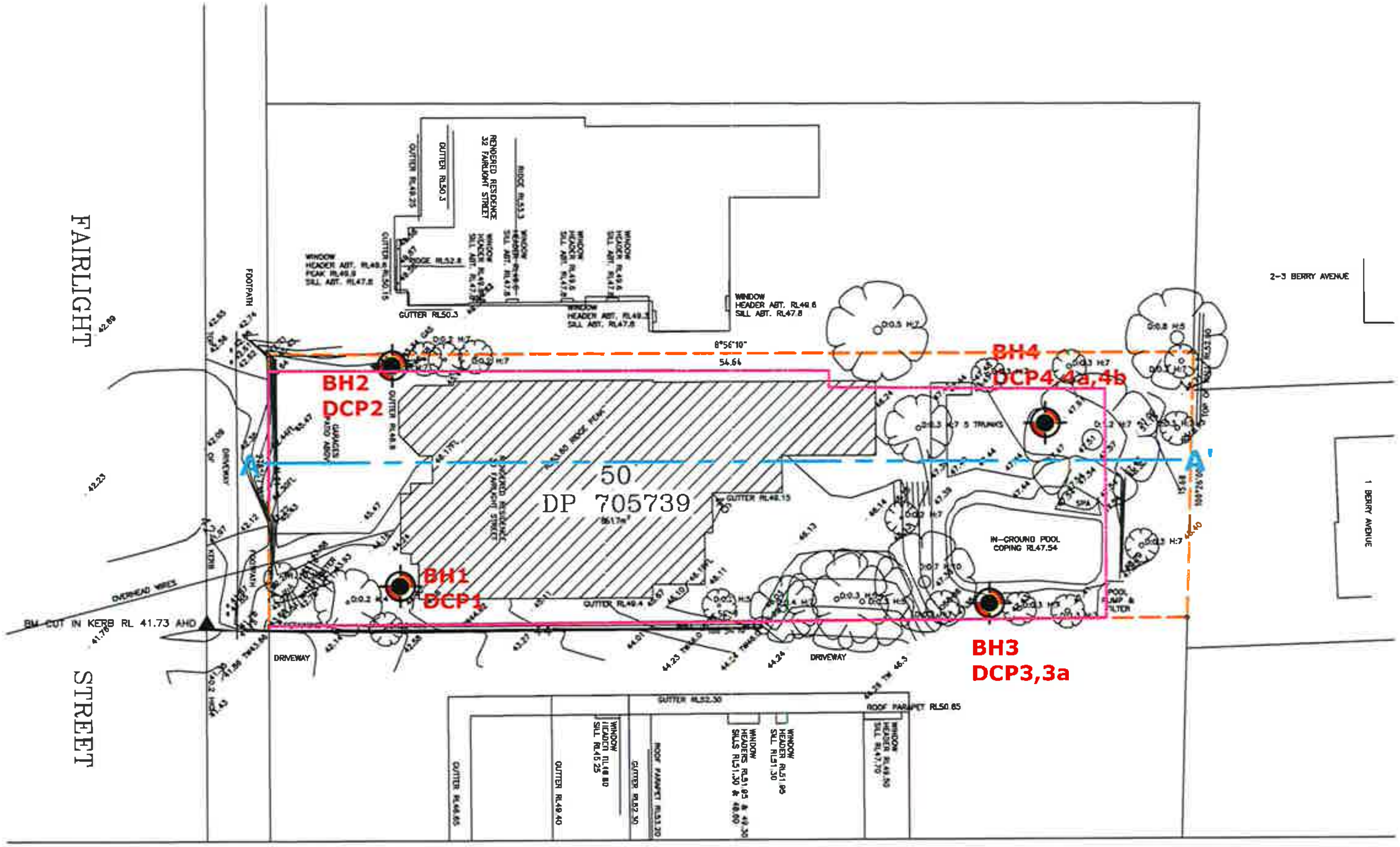
Example of Mapping Symbols
(after V Gardiner & R V Dackombe (1983).Geomorphological Field Manual. George Allen & Unwin).

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



SCALE 1:300

SITE PLAN & TEST LOCATIONS FIGURE 1.

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

LEGEND

A — A' CROSS-SECTION REFERENCE LINE

PROPERTY BOUNDARY

PROPOSED STRUCTURE

DCP DYNAMIC CONE PENETROMETER LOCATION

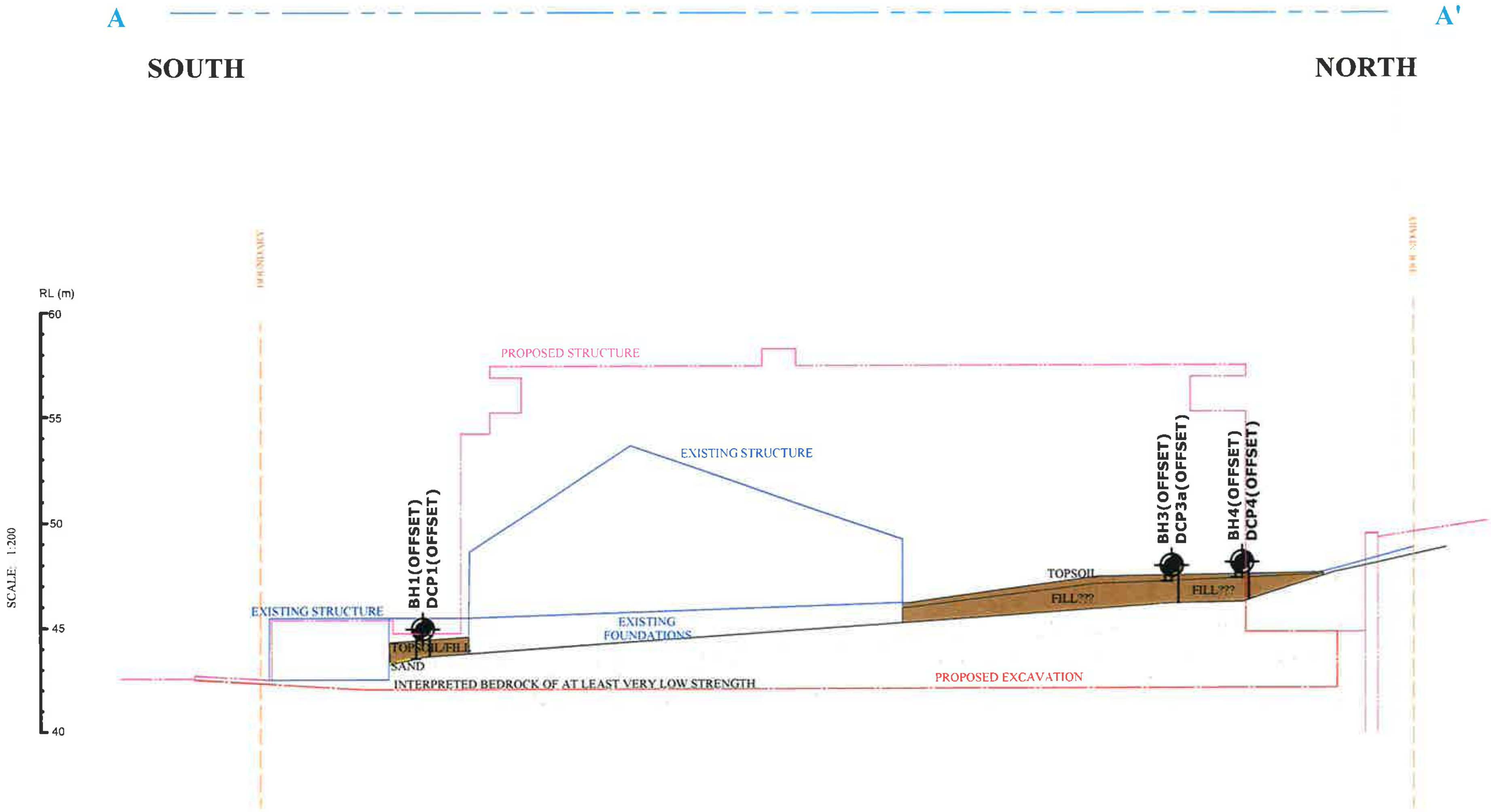
BH DCP AUGER / DYNAMIC CONE PENETROMETER LOCATION

SCALE:	1:300 @ A3
DRAWING:	Figure 1
DATE:	19/11/2019
APPROVED BY:	TMC
DRAWN BY:	ML
PROJECT:	2019 - 200

PREPARED FOR:
CASTLE 888 PTY LTD

ADDRESS:
30 FAIRLIGHT STREET
FAIRLIGHT

CROZIER GEOTECHNICAL CONSULTANTS
Crozier Geotechnical
Unit 12, 42-46 Wattle Road
Brookvale NSW 2100
ABN: 96 113 453 624
Phone: (02) 9939 1882
Fax: (02) 9939 1883



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 GEOTECHNICAL CONSULTANTS

Crozier Geotechnical
Unit 12, 42-46 Wattle Road
Brookvale NSW 2100
Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

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

LEGEND

A — A' CROSS-SECTION REFERENCE LINE
BH DCP AUGER / DYNAMIC CONE PENETROMETER LOCATION
PROPERTY BOUNDARY
PROPOSED EXCAVATION
EXISTING STRUCTURE
PROPOSED STRUCTURE
SANDSTONE
SAND/CLAYEY SAND
TOP SOIL/FILL

SCALE: 1:200 @ A3
DRAWING: Figure 2
DATE: 19/11/2019

APPROVED BY: TMC
DRAWN BY: ML
PROJECT: 2019 - 200

PREPARED FOR:
CASTLE 888 PTY LTD

ADDRESS:
30 FAIRLIGHT STREET
FAIRLIGHT

BOREHOLE LOG

CLIENT: Castle 888 Pty Ltd

DATE: 19/11/2019

BORE No.: 1

PROJECT: Demolition of existing property & construction of new four storey residential apartment complex

PROJECT No.: 2019-200

SHEET: 1 of 1

LOCATION: 30 Fairlight Street Fairlight

SURFACE LEVEL: R.L.= 44.40m

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling Type	Sampling Tests	In Situ Testing Type	In Situ Testing Results
0.00		FILL/TOPSOIL: Loose, dark brown, fine to medium grained, moist, silty sand with some plant roots, wood chips and fine to medium gravel.				
0.60	SM	SILTY SAND: Loose, yellow, fine to medium grained, moist, silty sand	D	0.60		
0.70		HAND AUGER REFUSAL @ 0.70m depth on interpreted bedrock.		0.70		
1.00						
2.00						

RIG: None

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: None

REMARKS:

DRILLER: ML

LOGGED: JY

CHECKED: TMC

BOREHOLE LOG

CLIENT: Castle 888 Pty Ltd **DATE:** 19/11/2019 **BORE No.:** 2

PROJECT: Demolition of existing property & construction of new four storey residential apartment complex **PROJECT No.:** 2019-200 **SHEET:** 1 of 1

LOCATION: 30 Fairlight Street Fairlight **SURFACE LEVEL:** R.L.= 45.44m

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/TOPSOIL: Loose, dark grey, fine to medium grained, moist, silty sand with some plant roots.				
0.50		HAND AUGER REFUSAL at 0.5m depth on interpreted bedrock.				
1.00						
2.00						

RIG: None DRILLER: ML

METHOD: Hand Auger LOGGED: JY

GROUND WATER OBSERVATIONS: None

REMARKS: CHECKED: TMC

BOREHOLE LOG

CLIENT: Castle 888 Pty Ltd
DATE: 19/11/2019
BORE No.: 3

PROJECT: Demolition of existing property & construction of new four storey residential apartment complex
PROJECT No.: 2019-200
SHEET: 1 of 1

LOCATION: 30 Fairlight Street Fairlight
SURFACE LEVEL: R.L. = 47.35m

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
			Type	Tests	Type	Results
0.00						
0.10		Pavers				
		FILL: Loose, dark grey, fine to medium grained, moist, silty sand with some plant roots and coarse gravel.				
0.20						
		HAND AUGER REFUSAL at 0.2m depth on coarse gravel and cobbles				
1.00						
2.00						

RIG: None
DRILLER: ML

METHOD: Hand Auger
LOGGED: JY

GROUND WATER OBSERVATIONS: None

REMARKS:
CHECKED: TMC

BOREHOLE LOG

CLIENT: Castle 888 Pty Ltd **DATE:** 19/11/2019 **BORE No.:** 4

PROJECT: Demolition of existing property & construction of new four storey residential apartment complex **PROJECT No.:** 2019-200 **SHEET:** 1 of 1

LOCATION: 30 Fairlight Street Fairlight **SURFACE LEVEL:** R.L. = 47.51m

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/TOPSOL: Loose, dark grey, fine to medium grained, moist, silty sand with some plant roots and coarse gravel to cobbles.				
0.20		HAND AUGER REFUSAL @ 0.20m depth on interpreted coarse gravel and cobbles.				
1.00						
2.00						

RIG: None DRILLER: ML

METHOD: Hand Auger LOGGED: JY

GROUND WATER OBSERVATIONS: None

REMARKS: CHECKED: TMC

DYNAMIC PENETROMETER TEST SHEET

CLIENT: Castle 888 Pty Ltd

DATE: 19/11/2019

PROJECT: Demolition of existing property & construction of new four storey residential apartment complex

PROJECT No.: 2019-200

LOCATION: 30 Fairlight Street
Fairlight

SHEET: 1 of 1

	Test Location							
Depth (m)	DCP1	DCP2	DCP3	DCP3a	DCP4	DCP4a	DCP4b	
0.00 - 0.15	-	1	-	2	1	3	3	
0.15 - 0.30	-	3 (B)	8	10	3	10 (B)	13 (B)	
0.30 - 0.45	-	Refusal @0.30m	20 (B)	15	5	Refusal @0.15m	Refusal @0.20m	
0.45 - 0.60	-		Refusal @0.45m	14	3			
0.60 - 0.75	-			8	5			
0.75 - 0.90	5 (B)			14	15			
0.90 - 1.05	Refusal @ 0.78m			14	8			
1.05 - 1.20				13	7			
1.20 - 1.35				10 (B)	17 (B)			
1.35 - 1.50				Refusal @1.25m	Refusal @1.35m			
1.50 - 1.65								
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								

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

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 <3m³) from soils due to excavation along the northern portion of the site - Ground Level excavation		Excavation up to 1.35m depth of fill/soil	a) House >3.2m from western side of <1.35m deep soil excavation b) Pathway and garden >1m from western side of <1.35m deep soil excavation c) Appartment building is >4.2m from eastern side of <1.35m deep soil excavation d) Driveway No.28 is on eastern side of the <1.35m deep soil excavation e) Lawn is on the eastern side of the <1.35m deep soil excavation f) House >14m from northen side of <1.35m deep soil excavation g) Courtyard >5.8m from northern side of <1.35m deep soil 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. e) Person in lawn 0.25hrs/day avge. f) Person in house 10hrs/day avge. g) Person in courtyard 0.25hrs/day avge.	a) Almost certain to not evacuate b) Unlikely to not evacuate c) Almost certain to not evacuate d) Unlikely to not evacuate e) Unlikely to not evacuate f) Almost certain to not evacuate g) Unlikely 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, unlikely buried f) Person in building, minor damage only g) Person in open space, unlikely buried	
			Possible	Prob. of Impact	Impacted				
		a) House No. 32 Fairlight Street	0.1	0.010	0.005	0.4167	0.9	0.01	1.88E-08
		b) Pathway and garden No. 32 Fairlight St	0.1	0.100	0.010	0.0104	0.25	0.1	2.60E-08
		c) Apartment building No.28 Fairligth St	0.1	0.010	0.005	0.4167	0.9	0.01	1.88E-08
		d) Driveway No.28 Fairlight St	0.1	0.500	0.010	0.0104	0.25	0.1	1.30E-07
		e) Lawn No.28 Fairlight St	0.1	0.500	0.010	0.0104	0.25	0.1	
		f) House No.1 Berry Avenue	0.1	0.005	0.005	0.4167	0.9	0.01	9.38E-09
		g) Courtyard No.1 Berry Avenue	0.1	0.005	0.010	0.0104	0.25	0.1	1.30E-09
B	Landslip (rock slide/topple <15m³) within rock excavation - Ground Level & Basement Level		Rock excavations up to 5.5m depth expected, likely unfavourable defects in some portion	a) House >3.2m from western side of <5.5m deep basement excavation b) Pathway and garden >1m from western side of <5.5m deep basement excavation c) Appartment building is >4.2m from eastern side of <5.5m deep basement excavation d) Driveway No.28 is on eastern side of the <5.5m deep basement excavation e) Lawn is on the eastern side of the <5.5m deep basement excavation f) House >14m from northen side of <5.5m deep basement excavation g) Courtyard >5.8m from northern side of <5.5m deep basement 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. e) Person in lawn 0.25hrs/day avge. f) Person in house 10hrs/day avge. g) Person in courtyard 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 f) Almost certain to not evacuate g) Unlikely 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 f) Person in building, minor damage only g) Person in open space, likely buried	
			Possible	Prob. of Impact	Impacted				
		a) House No. 32 Fairlight Street	0.1	0.05	0.050	0.4167	0.9	0.01	9.38E-07
		b) Pathway and garden No. 32 Fairlight St	0.1	0.25	0.050	0.0104	0.5	1	6.51E-06
		c) Apartment building No.28 Fairligth St	0.1	0.05	0.010	0.4167	0.9	0.01	1.88E-07
		d) Driveway No.28 Fairlight St	0.1	0.25	0.250	0.0104	0.5	1	3.26E-05
		e) Lawn No.28 Fairlight St	0.1	0.25	0.050	0.0104	0.5	1	6.51E-06
		f) House No.1 Berry Avenue	0.1	0.01	0.001	0.4167	0.9	0.01	
		g) Courtyard No.1 Berry Avenue	0.1	0.01	0.010	0.0104	0.25	0.1	2.60E-09

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

TABLE : B

Landslide risk assessment for Risk to Property

HAZARD	Description	Impacting	Likelihood		Consequences		Risk to Property
A	Landslip (earth slide <3m³) from soils due to excavation along the northern portion of the site - Ground Level excavation	a) House No. 32 Fairlight Street	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 and garden No. 32 Fairlight St	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) Apartment building No.28 Fairligth St	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) Driveway No.28 Fairlight St	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) Lawn No.28 Fairlight St	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
		f) House No.1 Berry Avenue	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
		g) Courtyard No.1 Berry 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
B	Landslip (rock slide/topple <15m³) within rock excavation - Ground Level & Basement Level	a) House No. 32 Fairlight Street	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 and garden No. 32 Fairlight St	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) Apartment building No.28 Fairligth St	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) Driveway No.28 Fairlight St	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) Lawn No.28 Fairlight St	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
		f) House No.1 Berry Avenue	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
		g) Courtyard No.1 Berry 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

Landslip (rock slide/topple <20m³) within rock excavation - Ground Level & Basement Level

* 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.

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	Notional Boundary					
10^{-1}	5×10^{-2}	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	5×10^{-3}	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	5×10^{-4}	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	5×10^{-5}	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	5×10^{-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.