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REPORT ON GEOTECHNICAL SITE INVESTIGATION

for

PROPOSED RESIDENTIAL DEVELOPMENT

at

45 LANTANA AVENUE, WHEELER HEIGHTS

Prepared For

Rob Mason

Project No.: 2020-242

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GEOTECHNICAL REPORT FOR PROPOSED NEW RESIDENTIAL DEVELOPMENT 45 LANTANA AVENUE, WHEELER HEIGHTS, NSW

1. INTRODUCTION:

This report details the results of a geotechnical investigation carried out for a proposed residential development at 45 Lantana Avenue, Wheeler Heights, NSW. The investigation was undertaken by Crozier Geotechnical Consultants (CGC) at the request of Gartner Trovato Architects on behalf of the client Rob Mason.

It is understood that the development will be undertaken under a State Environmental Planning Policy and will involve the demolition of all the existing site structures and the construction of two separate residential blocks with a shared basement under requiring excavation to approximately 4.0m depth.

A review of Warringah Council's LEP/DCP identified that located predominately within 'Class A' landslip hazard zone (LSR_009). The proposed works involve excavation >2.00m depth and therefore a 'full' geotechnical report will be required as part of the Development Application (DA).

This report includes a description of site and sub-surface conditions, a geotechnical assessment of the development, site mapping/plan, a geological section, site risk assessment in accordance with AGS March 2007 publication and provides recommendations for design, construction and stormwater disposal.

The investigation and reporting were undertaken as per the Proposal P20-544.1, Dated: 13th November 2020. The investigation and reporting were prepared to assist in the Development Application only and are not intended for detail design and construction costing.

The investigation comprised:

a) Service clearance by an accredited service location contractor
b) A geotechnical inspection of the site and adjacent properties by a Senior Engineering Geologist.
c) Drilling of three boreholes using a restricted access drill rig along with Dynamic Cone Penetrometer testing (DCP)

The following plans and drawings were supplied for the work:

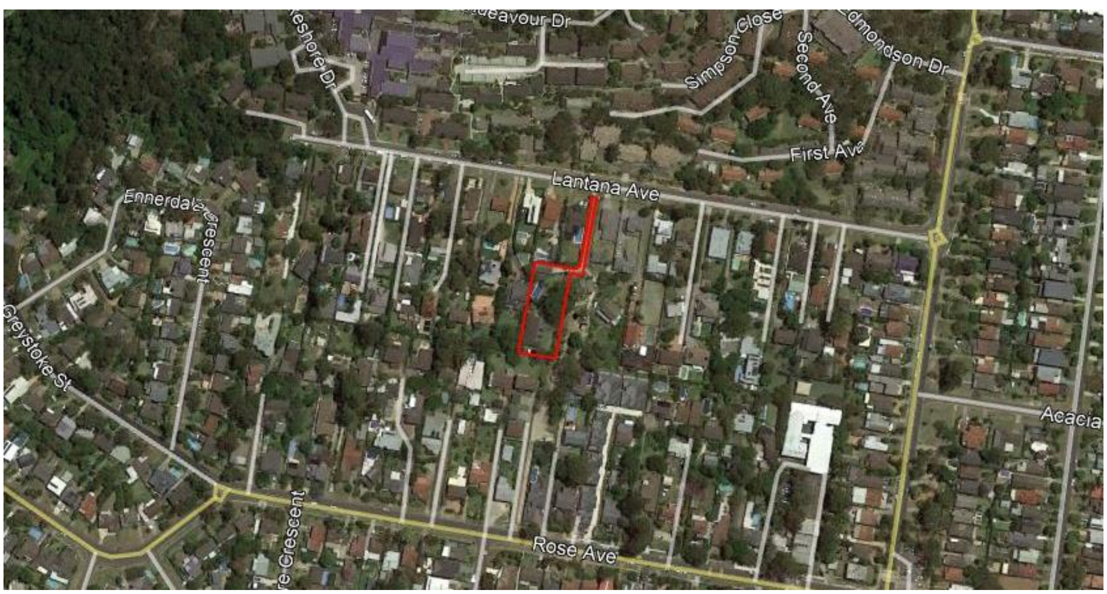
- Architectural Drawings – Gartner Trovato Architects, Project No.: 1930, Drawing No.: A.00 - A.07, Revision A, Dated: 4/12/2020
- Survey Drawing – Bee & Lethbridge Pty Ltd, Reference No.: 21816, Sheet No.: 1 – 2, Dated: 07/09/2020

2. SITE FEATURES:

2.1. Site Description:

The site is a battle axe shaped block covering an area of approximately 2029m^2 in plan as referenced from the provided survey drawing. It is located on the high south side of Lantana Avenue within gently north dipping topography and ground surface elevations vary between a high of approximately RL65.0m adjacent to the south east corner of the site and a low of approximately RL61.1m near the site entrance off Lantana Avenue to the north.

The main portion of the site is accessed via a narrow access driveway which extends from Lantana Avenue, approximately 55m to the north and forms the 'handle'' of the battle axe block. The main section of the site has north, east, south and west boundaries of approximately 29.8m, 63.0m, 25.1m and 69.1m as referenced from the provided survey plan. Aerial view of the site and immediate surrounds is provided in Photograph 1 obtained from Google Earth.



Photograph 1: Aerial view of the site (outlined red) and surrounding area.

The existing site residence comprises a single storey brick structure located towards the south end of the block. A clad garage/car port is present near the northern boundary of the main portion of the site and is accessed via a concrete driveway near the end of the shared driveway. A partially inground pool lies broadly mid-way between the site residence and garage.

The remainder of the site generally comprises a grass lawn at similar elevation to the site residence and partially supported by low (<1.5m), dry stone retaining walls to the south and east of the site residence and near the western boundary. General views of the site are provided in Photographs 2 to 4.

Photograph 2: Panoramic view of the site looking south to west from near BH1.

Photograph 3: View of the site looking broadly north from near the south west corner.

Photograph 4: View of the site looking broadly north from near BH1.

The site contains one large (see Photograph 2 and 3) mature tree and the roots of this tree were observed breaking through the lawn surface.

The site is surrounded by No's 47/No.49, No.43, No.'s 44/46a and No.53 Lantana Avenue to the north, east, south and west respectively.

No.'s 47/49 contain residential dwellings comprising one and two storey brick structures which are approximately 20.0m from the shared boundary and the ground surface is slightly (≤0.5m) lower than site immediately adjacent to the boundary. No.49 Contains a pool approximately 2.0m from the shared boundary.

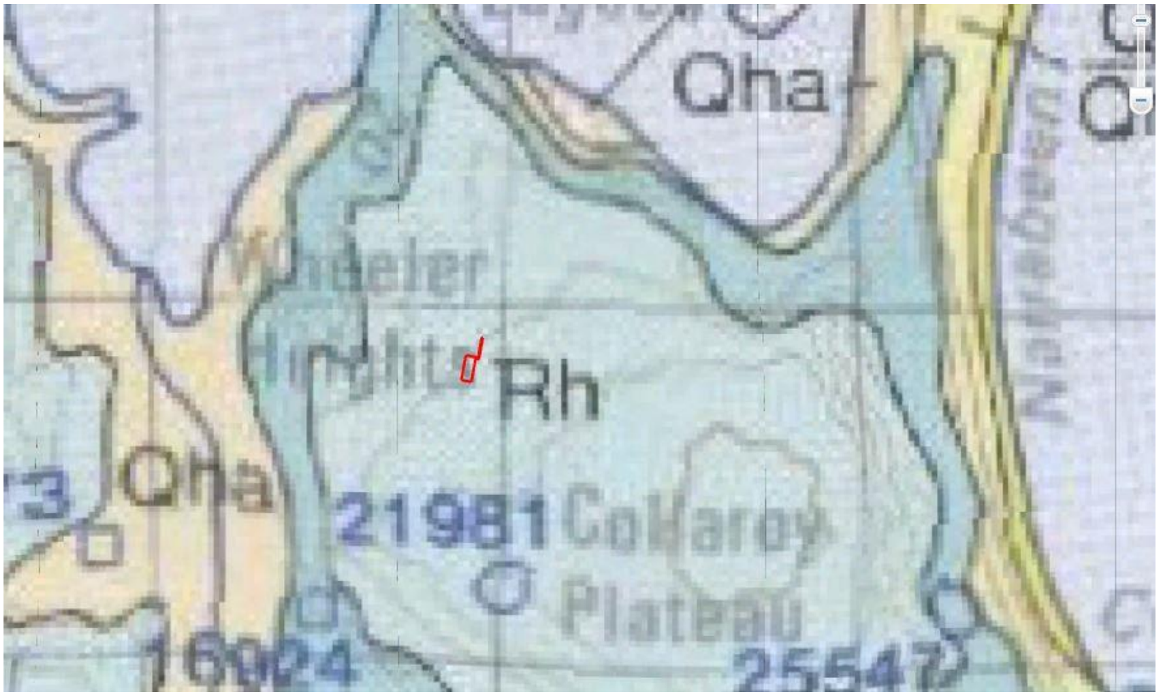
No.43 currently contains an unsealed gravel parking area but the construction of additional Seniors Living units is understood to be proposed which will comprise a two-storey unit block with a basement within 1.0m of the shared boundary. The ground surface is similar to the site immediately adjacent to the boundary.

No.'s 44/46a contain either an existing two storey dwelling (within No.46a) which is greater than approximately 20.0m from the boundary or an existing construction site (within No.44) which will comprise a Seniors Living unit development of one and two storey brick structures proposed greater than 10.0m from the shared boundary. The ground surface is similar to site immediately adjacent to the shared boundary.

No.53 contains a two-storey brick dwelling approximately 1.0m from the shared boundary and it is understood a Seniors Living development is proposed to the rear of this structure. The ground surface in the block is approximately 0.5m below site immediately adjacent to the boundary.

2.2. 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 of medium to coarse grained quartz sandstone with minor lenses of shale and laminite. An extract of the Sydney Series sheet is provided as Extract 1.



Extract 1: Sydney Series Geology sheet extract.

Morphological features often associated with the weathering of Hawkesbury Sandstone are the formation of near flat ridge tops with steep angular side slopes. These slopes often consist of sandstone terraces and cliffs with steep colluvial slopes below. The terraced areas above these cliffs often contain thin sandy (low plasticity) 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 pattern, many cliff areas are undercut by differential weathering. Slopes below these cliffs are often steep 15° to 23° with a moderately thick sandy colluvial soil profile that are randomly covered by sandstone boulders.

3. FIELD WORK:

3.1. Methods:

The field investigation comprised a walk over inspection and subsurface investigation of the site and adjacent properties on the 25th November 2020 which were supervised/undertaken by a Senior Engineering Geologist.

The walk over inspection comprised geological/geomorphological field mapping and observation of structures/conditions within and adjacent to the site to assess topography, slopes and structures as well as bedrock outcrops where applicable. The inspection was restricted to observations made from the ground surface of the site/adjacent, accessible land. Photographs of relevant observations were taken for inclusion in the report and to allow the creation of a photographic record to be made prior to commencement of construction works within the site.

The subsurface investigation comprised the drilling of three boreholes (BH1 to BH3) along with three DCP tests (DCP1 to DCP3) adjacent to the borehole locations. The boreholes were undertaken using a restricted access drill rig operating solid stem spiral flight augers in conjunction with a tungsten carbide bit. Soil samples were recovered from the augers for geotechnical logging purposes which was undertaken in accordance with AS1726:2017 'Geotechnical Site Investigations'. On completion the boreholes were backfilled with arisings and surface compacted.

DCP testing was carried out from ground surface adjacent to 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 ground conditions.

Explanatory notes are included in Appendix: 1. Mapping information and test locations are shown on Figure: 1, along with detailed Borehole Log sheets and Dynamic Penetrometer Test Sheet in Appendix: 2. Geological sections are provided as Figure: 2 and Figure 3, Appendix: 2.

3.2. Walk Over Inspection:

The majority of the site is gently north sloping and limited bedrock exposures were observed within the site with the possible exception of a small exposure within the access driveway comprising low to medium strength sandstone.

Inspection of the existing site structures did not indicate any signs movement such as cracking in the external brickwork or within the concrete driveway surfacing. The low dry-stone walls retaining the lawn were locally displaying minor instability/slumping (see Photograph 5) however it is considered that this is the result of general degradation which would be expected with this type of wall.


Photograph 5 and Photograph 6: View of degrading retaining wall to the south of the pool.

Inspection of the structures within the neighbouring properties was limited due to access conditions however no cracking or indications of movement where observed in the external brickwork walls of the adjacent property structures.

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

3.3. Ground Conditions:

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

- **SAND (FILL/TOPSOIL) –** this layer was encountered from surface at all test locations to a maximum depth of 1.35m (BH2) below the existing ground surface. Fragments of tile, plastic and brick were noted in the fill soils. Within BH1 between 0.9m - 1.0m depth, possible relict topsoil was encountered.
- **SAND –** Natural soils were only encountered within BH3 between 0.65m – 1.1m depth and comprised medium dense becoming dense, coarse grained, moist sand.
- **SANDSTONE BEDROCK** – Interpreted low strength sandstone bedrock (or better) was encountered within all boreholes below the fill in BH1 and BH2 and below the natural sand soils within BH3 at depths of between 0.9m and 1.35m. Within BH1 and BH2 the bedrock appeared pale grey/white and a limited zone of residual/extremely weathered bedrock was encountered overlying the competent bedrock.

Groundwater was not encountered during drilling or observed on the DCP rods on retrieval following testing.

4. COMMENTS:

4.1. Geotechnical Assessment:

The site investigation identified the presence of sandy topsoil/fill of shallow thickness (≤1.35m) across the site, underlain by residual sandy soils to a depth of 1.1m in BH3 only. The depth to sandstone bedrock of a minimum of low strength is inferred to be varying from 0.9m to 1.35m. This very low strength bedrock is at least low strength strength bedrock though actual bedrock strengths are unconfirmed. Groundwater was not encountered however previous investigations undertaken in the vicinity indicate groundwater may be encountered in excavation.

Excavation up to approximately 4.0m are envisaged for the proposed basement. The excavations will generally be located at least 3.0m from the shared property boundaries with the exception of a section of an access ramp within the north.

It is expected that the excavation will extend through sandstone bedrock of low and potentially medium to high strength along with intersecting sandy fill/residual soils to around 1.35m depth. The excavation of medium to high strength bedrock will require the use of rock excavation equipment which has the potential to create significant ground vibrations, but the probability of vibration damage to the neighbouring houses is reduced due to the nature of the geology and the separation distances. However, care will need to be taken to ensure that the excavation works do not create a vibration hazard for the neighbouring properties.

Considering the depth of the proposed excavations, geology of the site and separation distances from shared boundaries, safe batter slopes as detailed in Section 4.3 appear to be achievable for most parts of the project site subject to the presence of defects within the bedrock encountered during excavation. Groundwater may be encountered during excavation (e.g. and inflow rate would higher immediately following a rainfall event) which will destabilise any batter slope therefore it is recommended that groundwater monitoring wells are installed to determine the presence of groundwater seepages and additional investigation is undertaken to allow detail design and costing.

Where batter slopes are not feasible, support prior to excavation will be required. A bored pile wall or similar would be suitable which would likely need to be contiguous due to the sandy nature of the soil/fill.
The strength of the bedrock with depth is unconfirmed therefore there is a potential for the bedrock to be more deeply weathered and of lesser strength than interpreted. For confirmation of bedrock strength to below proposed excavation levels, an investigation utilizing cored boreholes would be required.

4.2. Site Specific Risk Assessment:

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

A. Landslip of surficial soils from excavation works.
B. Toppling/sliding of unstable block of rock formed by intersecting defects.

The hazards have been assessed in accordance with the methods of the Australian Geomechanics Society (Landslide Risk Management, AGS Subcommittee, May 2002 and March 2007), see Tables: A and B, Appendix: 3 The Australian Geomechanics Society Qualitative Risk Analysis Matrix is enclosed in

Appendix: 4 along with relevant AGS notes and figures. The frequency of failure was interpreted from existing site conditions and previous experience in these geological units.

The Risk to Life from both Hazards was estimated to vary from **1.07×10^{-5} to 2.08×10^{-6} for persons working within the excavation, whilst the Risk to Property was considered to be 'Low to Very Low'**. The hazard was therefore considered to be 'Acceptable' when assessed against the criteria of the AGS 2007.

4.3. Design & Construction Recommendations:

Design and the construction recommendations are tabulated below:

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

4.3.2. Excavation:	
Depth of Excavation	Up to 4.0m
Type of Material to be Excavated	Loose to medium dense sandy fill/topsoil to 1.35m depth
	LS bedrock (Below 1.35m)
	>1.35m LS – MS/HS bedrock
Guidelines for batter slopes for this site are tabulated below:	

Material	Safe Batter Slope (H:V) Short Term/ Temporary	Safe Batter Slope (H:V) Long Term/ Permanent
Fill and natural soils	1:1	2:1
Extremely Low to Low strength fractured bedrock	1:1	1.25:1
Low strength defect free bedrock	Vertical*	0.25:1.0
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 soil/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	Topsoil and residual soils	Excavator with bucket
	ELS bedrock	Excavator with bucket
	VLS bedrock/ironstone	Excavator with bucket and ripper
	LS – HS bedrock	Rock hammer and saw

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

Remarks: It is recommended that the hard rock excavation perimeter be saw cut prior to rock hammering, this will generally reduce the amount of rock support required, reduce deflection of rock across boundary and under neighbouring structures and will provide a slight buffer distance to ground vibrations for the use of rock hammers.

Based on previous testing of ground vibrations created by various rock excavation equipment within medium strength sandstone bedrock, to achieve the specified low level of vibration the below tabulated 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 for the site specific conditions and will generally allow for larger excavation machinery or 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.

Recommended Vibration Limits	Residential structures = 5mm/s

(Maximum Peak Particle Velocity (PPV))	
Vibration Calibration Tests Required	Recommended
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: • During installation of support measures • Following clearing of bedrock surface • Every 1.50m depth interval of the main excavation where unsupported • Where low to medium strength bedrock is exposed • 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.	

4.3.3. Retaining Structures:	
Required	Surficial soils above and near excavation crests be retained prior to bulk excavation to minimise the risk of a soil slide into the excavation. This can be achieved by either clearing the soils away from the excavation crests (batters), horizontal benches or by construction of a temporary and/or permanent retaining structure founded off the bedrock surface.
Types	Soldier piles/piers or steel reinforced concrete/concrete block wall designed in accordance with Australian Standard AS 4678-2002 Earth Retaining Structures.
Parameters for calculating pressures acting on retaining walls for the materials likely to be retained:	

Material	Unit Weight (kN/m^3)	Long Term (Drained)	Earth Pressure Coefficients		Passive Earth Pressure Coefficient *
			Active (Ka)	At Rest (K_0)	
Fill (sandy) (loose)	18	$\phi' = 29°$	0.35	0.52	N/A
ELS bedrock	22	$\phi' = 38°$	0.15	0.20	400 kPa
LS bedrock	23	$\phi' = 40°$	0.10	0.15	700kPa

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).

Grout/rock adhesion for temporary anchors	350kPa for LS rock

Remarks: Anchors should be installed at a minimum distance of 0.20m from excavation crest

4.3.4. Drainage and Hydrogeology		
Groundwater Table or Seepage identified in Investigation		No, however significant water seepage encountered in investigation of adjacent site and groundwater conditions will need to be confirmed.
Excavation likely to intersect	Water Table	No
	Seepage	Possibly
Site Location and Topography		On ridge in gentle topography, high north side of the road
Impact of development on local hydrogeology		Negligible
Onsite Stormwater Disposal		Not recommended

Remarks: Exposed excavation faces should be expected to receive seepage from surface and subsurface water flow. This can result in relaxation of excavation faces causing instability. Therefore excavation faces should not remain open for long periods of time unless assessed to be stable by a geotechnical professional. A stormwater diversion drain should be installed upslope of excavation crests to intercept stormwater runoff and prevent erosion and softening of the excavation faces. An excavation trench should also be installed at the base of excavation cuts to below floor slab levels to reduce the risk of long term dampness. Trenches, as well as all new building gutters, down pipes and stormwater intercept trenches should be connected to a stormwater system designed by a Hydraulic Engineer which discharges to the Council's stormwater system off site.

4.4. 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. Additional investigation for detailed design and construction information.
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. Supervise installation of support measures,
4. Inspect any exposed low to medium strength bedrock and the proposed excavation equipment prior to its use
5. Inspect excavation at 1.50m depth intervals
6. Inspect all new footings and earthworks to confirm compliance to design assumptions with respect to allowable bearing pressure, basal cleanness and stability prior to the placement of steel or concrete,
7. 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.

5. CONCLUSION:

- Sand fill/soils were encountered to a maximum depth of 1.35m underlain by low strength (or stronger) sandstone bedrock.

- It appears batter slopes may be feasible to support the excavation sides however support may be required where seepages are encountered.

- Vibration calibration testing is recommended where hammers heavier than 300kg are proposed.

- Existing landslip hazards were not identified however the excavation will create potential stability hazards though these are not expected to impact adjacent properties but will need to be considered during construction. .

The proposed works are considered suitable for the site and may be completed with negligible impact to existing nearby structures within the site or 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 a limited scope of investigation. This investigation 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 results of the investigation provide a reasonable basis for the analysis and subsequent design of the proposed works.

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6. REFERENCES:

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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: -

$$Q_c \text{ (MPa)} = (0.4 \text{ to } 0.6) \text{ N blows (blows per 300mm)}$$

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

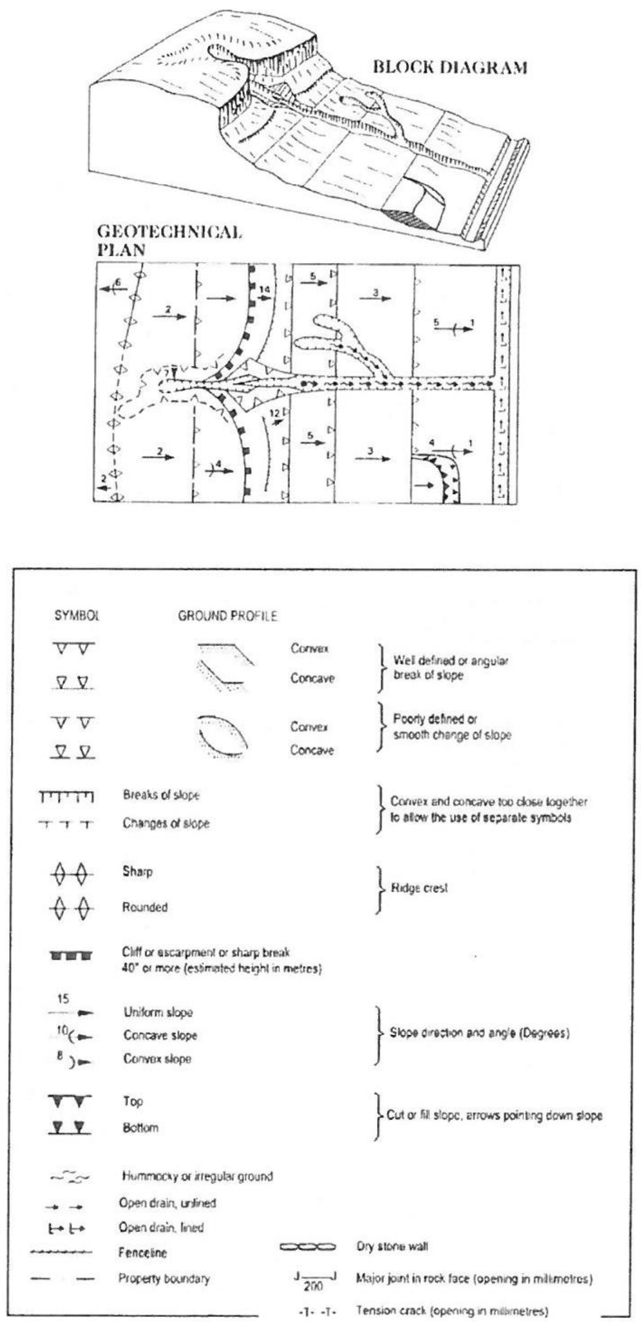
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some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

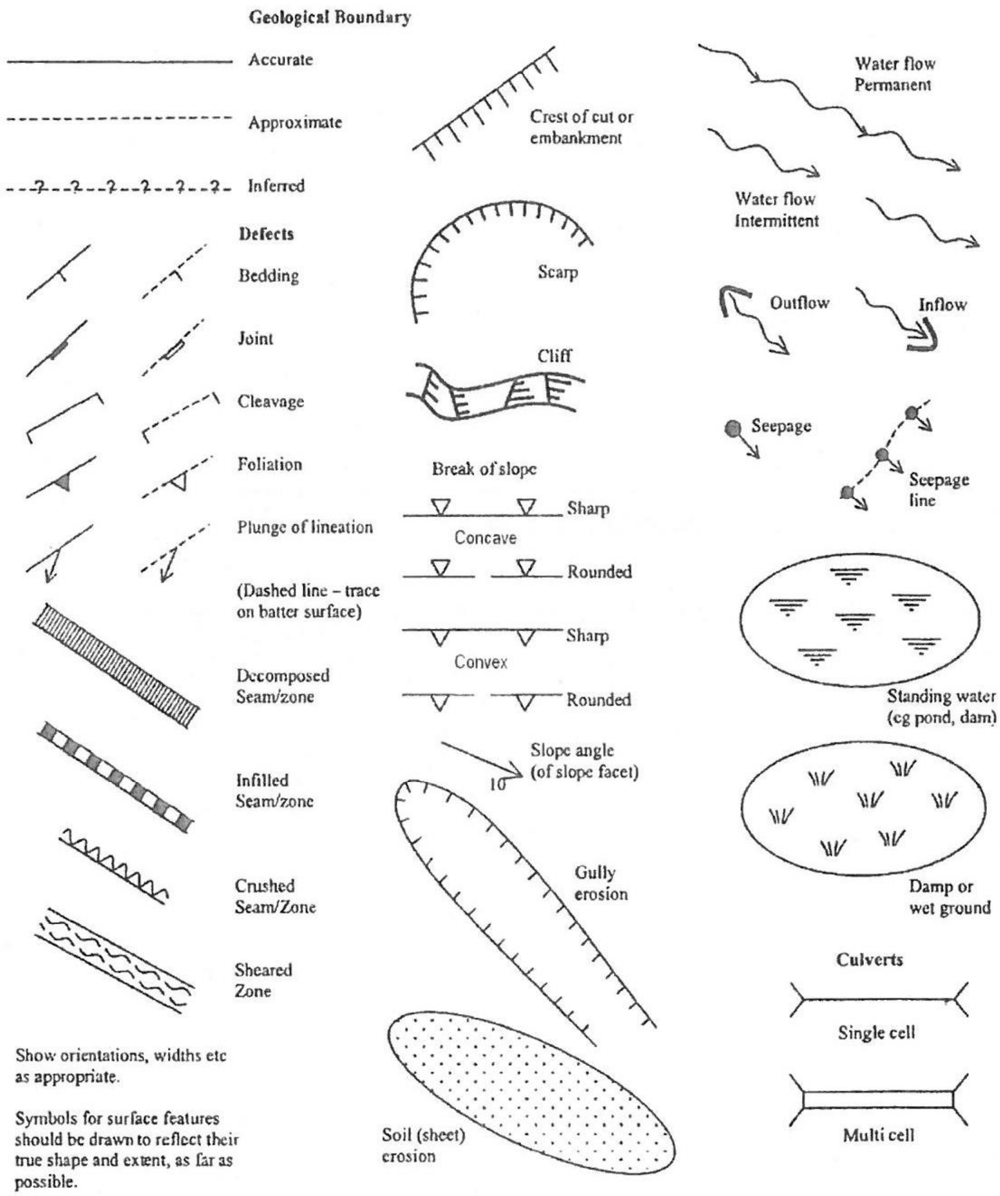
Site Inspection

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.



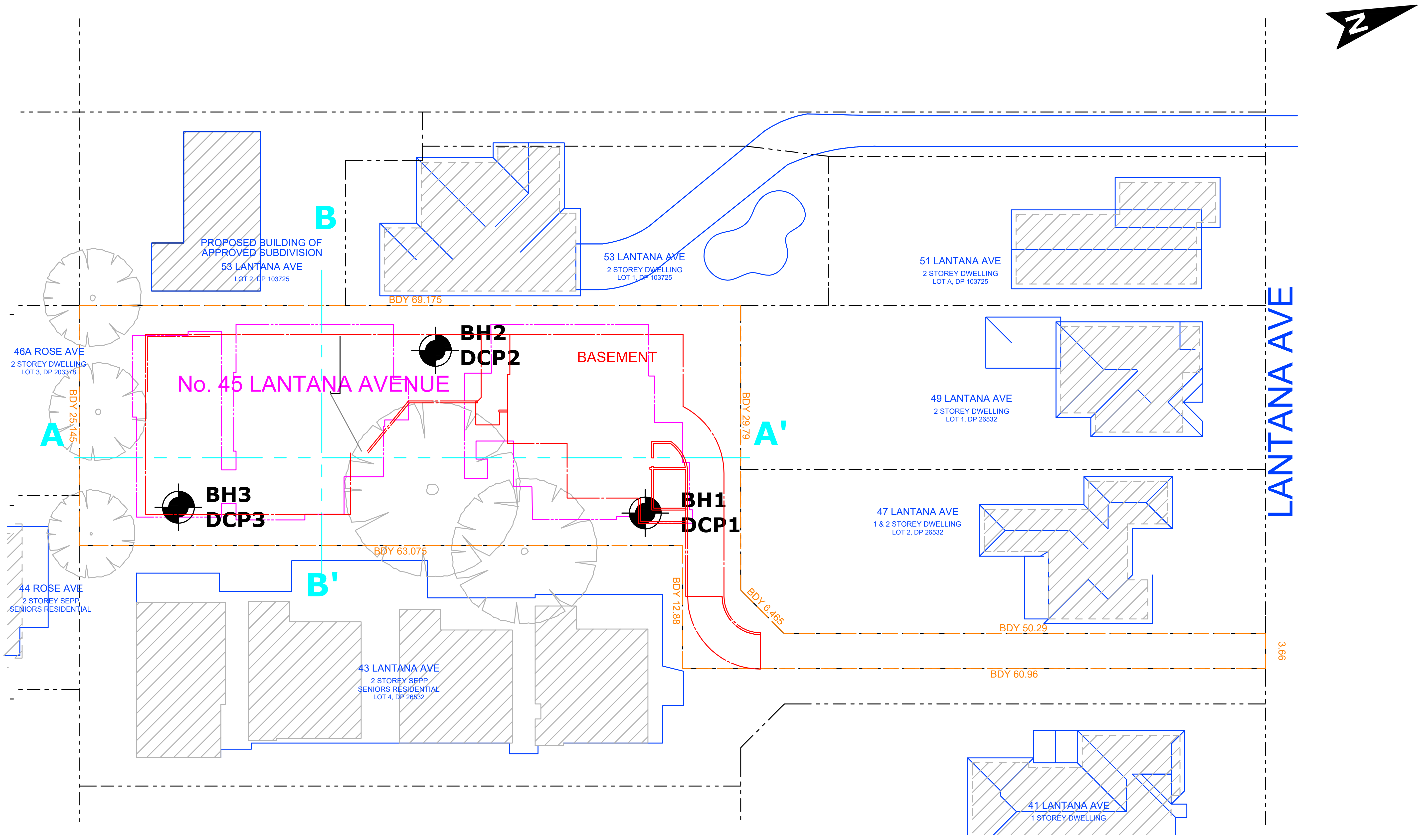
Example of Mapping Symbols
(after V Gardiner & R V Dackombe (1983).Geomorphological Field Manual. George Allen & Unwin).

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



0 10 20
SCALE: 1:400

SITE PLAN & TEST LOCATIONS

FIGURE 1.

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

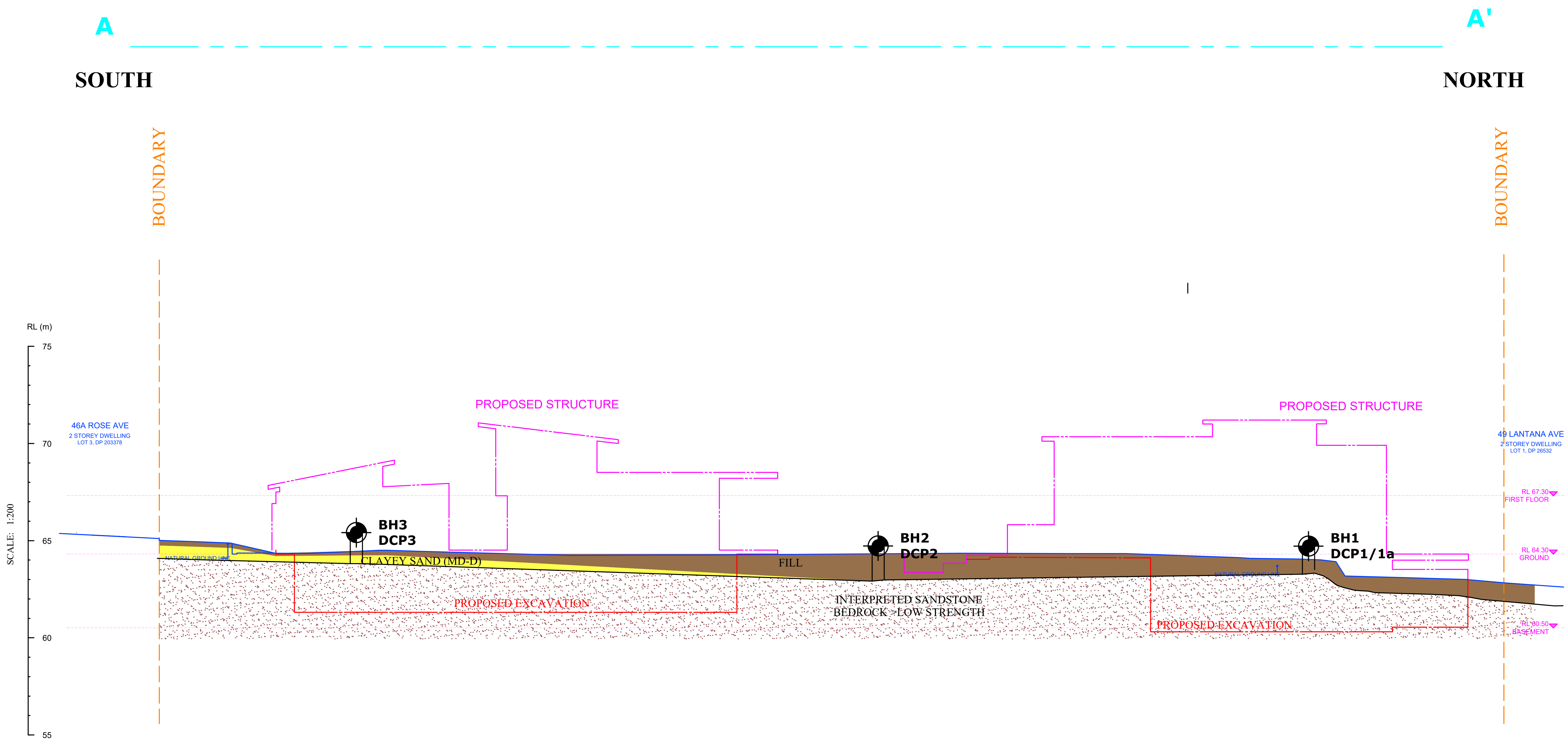
LEGEND

A —— A'	CROSS-SECTION REFERENCE LINE
BH DCP	AUGER / DYNAMIC CONE PENETROMETER LOCATION
	PROPERTY BOUNDARY
	EXISTING STRUCTURES
	PROPOSED STRUCTURE

SCALE:	1:200 @ A3
DRAWING:	FIGURE 1
DATE:	2/12/2020
APPROVED BY:	TMC
DRAWN BY:	ML
PROJECT:	2020-242

PREPARED FOR:
Rob Mason

ADDRESS:
45 LANTANA ROAD,
WHEELER HEIGHTS



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: 1:200

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

GEOLOGICAL MODEL FIGURE 2.

LEGEND

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

CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical
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Phone: (02) 9939 1882
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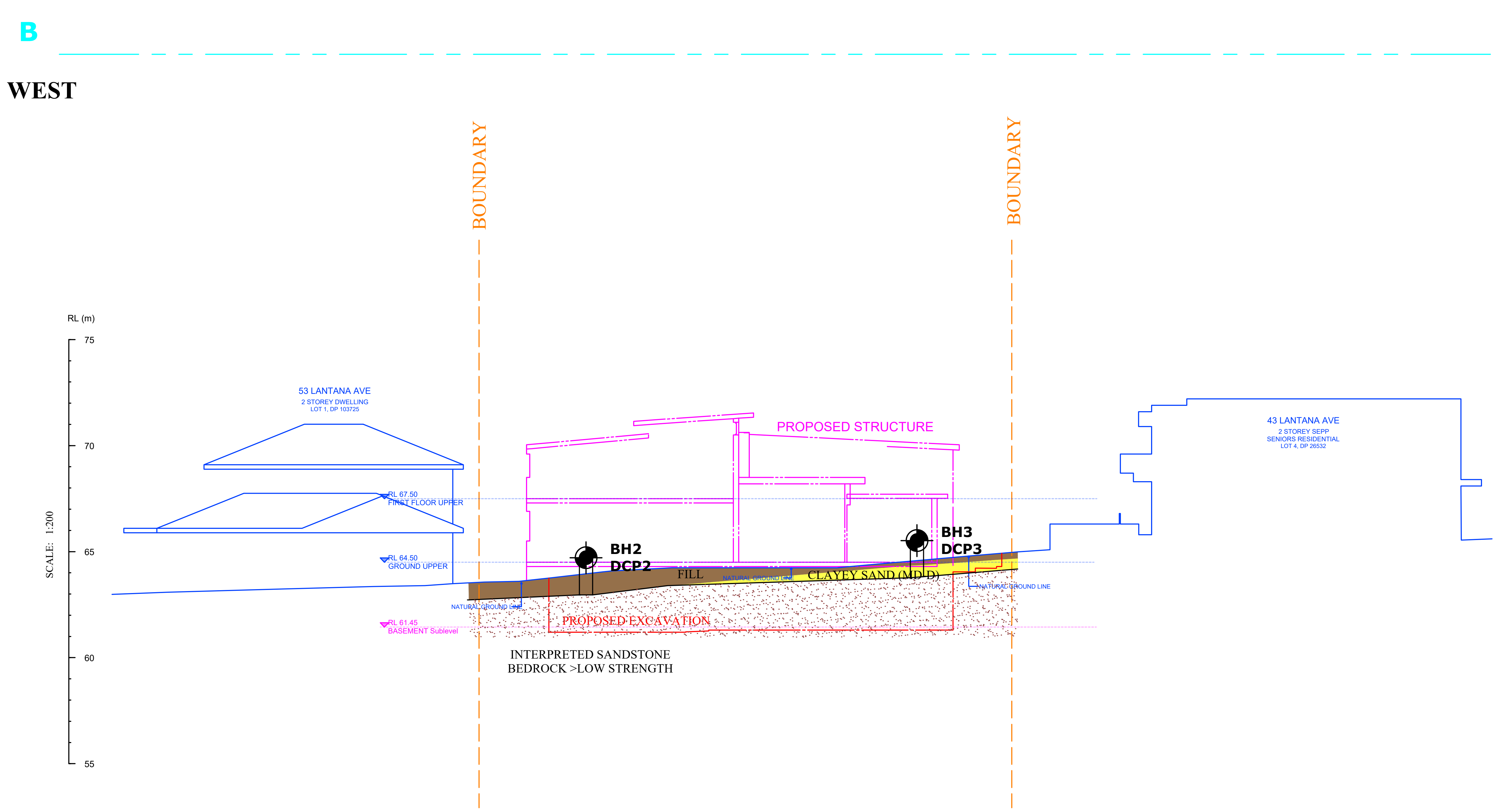
Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

SCALE:	1:200 @ A3
DRAWING:	FIGURE 2
DATE:	2/12/2020
APPROVED BY:	TMC
DRAWN BY:	ML
PROJECT:	2020-242

PREPARED FOR:
Rob Mason

ADDRESS:
45 LANTANA ROAD,
WHEELER HEIGHTS



0 1 2 3 4 5 6 7 8 9 10

SCALE: 1:200

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

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

GEOLOGICAL MODEL FIGURE 3.

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

LEGEND

- BH DCP — AUGER / DYNAMIC CONE PENETROMETER LOCATION
- PROPERTY BOUNDARY
- PROPOSED STRUCTURES
- PROPOSED EXCAVATION
- EXISTING GROUND
- SANDSTONE BEDROCK
- SOIL/FILL
- A — A' CROSS-SECTION REFERENCE LINE

SCALE:	1:200 @ A3
DRAWING:	FIGURE 3
DATE:	2/12/2020
APPROVED BY:	TMC
DRAWN BY:	ML
PROJECT:	2020-242

PREPARED FOR:
Rob Mason

ADDRESS:
45 LANTANA ROAD,
WHEELER HEIGHTS

BOREHOLE LOG

CLIENT: Rob Mason **DATE:** 2/12/2020 **BORE No.:** 1

PROJECT: Seniors Living Development **PROJECT No.:** 2020-242 **SHEET:** 1 of 1

LOCATION: No. 45 Lantana Avenue, Wheeler Heights **SURFACE LEVEL:** R.L.= 64.2m

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: Brown, medium grained, silty sand, trace sandstone gravel (Topsoil to 0.2m depth)				
0.20		é fill, plastic and tile				
0.40		é trace clay				
0.80		é dark grey, silty sand (possible relict topsoil)				
0.90		AUGER REFUSAL @ 0.90m depth on interpreted sandstone bedrock of at least low strength				
1.00						
2.00						

RIG: Dingo DRILLER: AC

METHOD: Spiral flight solid stem auger with tungsten carbide bit LOGGED: KN

GROUND WATER OBSERVATIONS: none encountred during auger drilling

REMARKS: CHECKED: TMC

BOREHOLE LOG

CLIENT: Rob Mason **DATE:** 2/12/2020 **BORE No.:** 2

PROJECT: Seniors Living Development **PROJECT No.:** 2020-242 **SHEET:** 1 of 1

LOCATION: No. 45 Lantana Avenue, Wheeler Heights **SURFACE LEVEL:** R.L.= 64.2m

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: Brown, medium grained, silty sand, trace sandstone gravel (Topsoil to 0.25m depth)				
0.30		é brown grey, fine to medium grained, charcoal, pipe				
1.00			D	1.00 1.20		
1.35		AUGER REFUSAL @ 1.35m depth on interpreted sandstone bedrock of at least low strength				
2.00						

RIG: Dingo DRILLER: AC

METHOD: Spiral flight solid stem auger with tungsten carbide bit LOGGED: KN

GROUND WATER OBSERVATIONS: none encountred during auger drilling

REMARKS: CHECKED: TMC

BOREHOLE LOG

CLIENT: Rob Mason **DATE:** 2/12/2020 **BORE No.:** 3

PROJECT: Seniors Living Development **PROJECT No.:** 2020-242 **SHEET:** 1 of 1

LOCATION: No. 45 Lantana Avenue, Wheeler Heights **SURFACE LEVEL:** R.L.= 64.9m

Depth (m)	Classification	Description of Strata PRIMARY SOIL - consistency / density, colour, grainsize or plasticity, moisture condition, soil type and secondary constituents, other remarks	Sampling		In Situ Testing	
0.00			Type	Tests	Type	Results
		FILL: Pale brown sand (Topsoil to 0.2m)				
0.30		..yellow brown				
0.65	SC	CLAYEY SAND: Medium dense pale orange and grey, coarse grained.				
1.00						
		Refusal at 1.1m depth-Interpreted sandstone bedrock of at last low strength				
2.00						

RIG: Dingo DRILLER: AC

METHOD: Spiral flight solid stem auger with tungsten carbide bit LOGGED: KN

GROUND WATER OBSERVATIONS: Not encountred during auger drilling

REMARKS: CHECKED: TMC

DYNAMIC PENETROMETER TEST SHEET

CLIENT: Rob Mason **DATE:** 2/12/2020

PROJECT: Seniors Living Development **PROJECT No.:** 2020-242

LOCATION: No. 45 Lantana Avenue, Wheeler Heights **SHEET:** 1 of 1

	Test Location							
Depth (m)	DCP1	DCP1a	DCP2	DCP3				
0.00 - 0.15	3	10	2	2				
0.15 - 0.30	14	23	4	12				
0.30 - 0.45	18	14*B @0.45m	4	10				
0.45 - 0.60	12		3	12				
0.60 - 0.75	23*B @ 0.70m		4	8				
0.75 - 0.90			3	10				
0.90 - 1.05			2	12				
1.05 - 1.20			8	25*B @1.08m				
1.20 - 1.35			12*B @1.30m					
1.35 - 1.50								
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								
3.00 - 3.15								
3.15 - 3.30								
3.30 - 3.45								
3.45 - 3.60								
3.60 - 3.75								
3.75 - 3.90								
3.90 - 4.05								

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

REMARKS: **(B)** Test hammer bouncing upon refusal on solid object

-- No test undertaken at this level due to prior excavation of soils

CROZIER GEOTECHNICAL CONSULTANTS

Appendix 3

TABLE : A

Landslide risk assessment for Risk to life

HAZARD	Description	Impacting	Likelihood	Spatial Impact	Occupancy	Evacuation	Vulnerability	Risk to Life
A	Landslip (earth slide <$3m^3$) of surficial soils from excavation works	Excavation area	3.80m deep excavation, loose to medium dense fill and residual sandy soils to 1.55m depth overlying sandstone bedrock Possible 0.001	Excavation at the west side boundary, approximately 30m long section of new driveway/ramp of the southern development 0.10	Person working in excavtion 8hrs/day 0.33	Unlikely to not evacuate 0.25	Person in open space, unlikely buried 0.25	**2.08E-06**
B	Toppling/sliding of unstable block of rock formed by intersecting defects, from unsupported cliff face	Excavation area	Ground vibrations created by using a larger rock hammer (>250kg) may cause toppling/sliding of unstable block of rock from cut face Possible 0.001	Individual block may hit small portion of excavtion 0.10	Workers within the excavation approx. 8hrs/day, Mon - Sat 0.29	Likely to not evacuate 0.75	Person possible to be crushed 0.50	**1.07E-05**

* hazards considered in current condition and/or without suitable remedial/stabilisation measures
* likelihood of occurrence for design life of house (considered 100years)
* considered for person most at risk
* considered for adjacent premises/buildings founded via shallow footings unless indicated
* evacuation scale from Almost Certain to not evacuate (1.0), Likely (0.75), Possible (0.5), Unlikely (0.25), Rare to not evacuate (0.01)
* 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) of surficial soils from excavation works	Excavation area	Unlikely	The event might occur under very adverse circumstances over the design life.	Insignificant	Little Damage, no significant stabilising required or no impact to neighbouring properties.	Very Low
B	Toppling/sliding of unstable block of rock formed by intersecting defects, from unsupported cliff face	Excavation area	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

* 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%.

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.