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REPORT ON PRELIMINARY GEOTECHNICAL SITE INVESTIGATION

for

PROPOSED NEW DEVELOPMENT

at

21 WHISTLER STREET, MANLY

Prepared For

Pavilion Residences No.3 Pty Ltd

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PRELIMINARY GEOTECHNICAL REPORT FOR CONSTRUCTION OF A RESIDENTIAL DEVELOPMENT AT 21 WHISTLER STREET, MANLY, NSW

1. INTRODUCTION:

This report details the results of a preliminary geotechnical investigation carried out for the proposed construction of a residential development at 21 Whistler Street, Manly, NSW. The investigation was undertaken by Crozier Geotechnical Consultants (CGC) at the request of Wolski Coppin Architecture on behalf of Pavilion Residences No.3 Pty Ltd.

It is understood that the proposed works involve the demolition of the existing building and the construction of a new five storey mixed use development (retail and residential) with a basement carpark and car stacker. It is understood that Finished Floor Level (FFL) for the proposed basement level is to be approximately RL2.20m with additional excavation to approximately RL0.00 to allow construction of a single level car stacker on the eastern side. The excavations are therefore up to approximately 5.50m depth below existing ground surface levels and will extend to all side boundaries.

The site is located within Landslip Risk Class óG3ô as identified within Northern Beaches (Manly) Councilôs Development Control Plan 2013 ï Schedule 1 Map C. It is also within Acid Sulfate Soils zone óClass 4ô (Sheet CL1_003).

A geotechnical report for Development Application purposes must therefore include a site specific stability assessment in accordance with the Australian Geomechanics Society 2007 Guidelines to ensure site stability can be maintained during excavation works. The site is situated within a Class 4 Acid Sulfate Soil hazard zone therefore investigation into potential acid sulfate soils is also required.

This report therefore includes a description of site and sub-surface conditions, a geotechnical assessment of the development, site mapping/plan, a geological section an acid sulfate soils assessment and recommendations for preliminary design and construction.

The investigation and reporting were undertaken as per the Tender: P18-076, Dated: 13th March 2018.

The investigation comprised:

a) A detailed geotechnical inspection and mapping of the site and adjacent properties by a Geotechnical Engineer.
b) Drilling of two boreholes using hand tools along with two Dynamic Cone Penetrometer (DCP) Tests to investigate the subsurface geology, collect samples for Acid Sulfate soil assessment and identification of ground water conditions.

The following plans and drawings were supplied for the work:

- Architect Plans by Wolski Coppin Architecture, Project No:21806, Rev: CI01, Dated: 16th August 2018, Drawing No: DA01-15, C01-03.
- Survey Plans by Norton Survey Partners, Ref:53011, 13th March 2018.
- Preliminary Study by Wolski Coppin Architecture, Dated 16th Feburary 2018.
- Controls Analysis by Wolski Coppin Architecture.

2. SITE FEATURES:

2.1. Description:

The site is a near-square shaped block located on the west side of Whistler Street within near level topography. As referenced from the provided survey plan, the site has north, south and west boundaries of approximately 15.9m, 15.8 and 17.5m respectively, with an east boundary of approximately 17.8m providing access to the property.

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

Photograph 1: Aerial photo of site and surrounds

The site dwelling comprises a one and two storey commercial/residential building with a courtyard and garden located at the rear. A general street view of the site is shown in Photograph 2.

Photograph 2: Street view of the site, looking west.

2.2. Geology:

Reference to the Sydney 1: 100,000 Geological Series sheet (9130) indicates that the site is underlain by Quaternary sands (Qhf). This foredune soil is described as medium to fine grained ómarineô sand (Qhf) and quartz sand consisting of minor shell content, interdune silt and fine sand (Qhbr). Previous experience in the local area indicates the depth to bedrock below the sands can vary significantly however it is generally >30m.

3. FIELD WORK:

3.1. Methods:

The field investigation comprised a walk over inspection and mapping of the site and adjacent properties on the 31st August 2018 by a Geotechnical Engineer. It included a photographic record of site conditions as well as inspection of adjacent land with examination of existing structures. It also included the drilling of two boreholes (BH1 & BH2) to depths of 5.0m and 4.0m using a hand auger to investigate sub-surface geology. A hand auger was used as access to the site for a conventional drilling rig was unavailable.

DCP testing was carried out from ground surface and adjacent to, and throughout the boreholes in accordance with AS1289.6.3.3 ï 1997, ñDetermination of the penetration resistance of a soil ï 9kg Perth Sand Penetrometerò to estimate near surface soil conditions. DCP2 was was started 1.5m depth below ground level to ensure buried services were not damaged due to identified potential services in that location.

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. A geological model/section is provided as Figure: 2, Appendix: 2.

3.2. Field Observations:

The site is situated on the west side of Whistler Street, Manly, within near-level topography. It is currently occupied by a one and two storey residential/commercial building. The street does not display any significant signs of cracking or settling.

The front of the existing dwelling is positioned directly adjacent to the Whistler Street footpath. Some cracking/distress was observed in the front wall of the dwelling, as seen in Photograph 3 below.

Photograph 3: Observed cracking within the front wall of the dwelling, looking west.

A courtyard and gardens occupy the centre and rear of the site and are accessed through the existing residential dwelling. The internal walls of the dwelling did not display any obvious signs of cracking or distress.

The courtyard area is separated into two sections by a small garden, with the section adjacent to the rear of the property raised approximately 0.40m above the section adjacent to the dwelling. The raised courtyard comprises a concrete/pebble surface whilst the lower courtyard is tiled. The raised concrete/pebble surface courtyard displayed some cracking and possible settling, whilst the lower tiled section did not. Photograph 4 displays some cracking present in the raised courtyard section.

Photograph 4: Cracking in raised courtyard, looking west.

Surrounding the courtyard area, there are a number of small gardens, some retained by concrete block walls <1.00m in height, which appeared in satisfactory condition.

The neighbouring property to the north of the site, No. 40 Belgrave Street, comprises a one storey rendered shop directly adjacent to the common boundary. It does not display any obvious signs of cracking or distress, however due to the orientation of the building, observations were made from the street only. The ground surface level within this property is anticipated to be similar to the site at the boundary with the remainder of the block having a similar topography to the site.

The neighbouring property to the west of the site, No. 35 - 39 Belgrave Street, comprises a two storey brick residential/commercial building positioned approximately 1.5m from the common boundary to the south and directly adjacent to the common boundary to the north. It did not display any obvious signs of cracking or distress. The ground surface level within this property appears approximately 1.00m-1.50m lower than the site at the boundary with the remainder of the block having a similar topography to the site.

The neighbouring property to the south of the site, No. 33 Belgrave Street, comprises a three storey rendered commercial and unit building approximately 1.0m from the common boundary. The north-east corner of the building displayed some signs of cracking, as seen in Photograph 5 below. The ground surface level within this property appears similar to the site at the boundary with the remainder of the block having a similar topography to the site.

Photograph 5: *Cracking observed in adjacent property (No. 33 Belgrave Street), looking west.*

The neighbouring properties and structures were inspected from the site or road reserves, however visible aspects showed no indications of geotechnical hazard that may impact the site. All neighbouring properties appear formed at ground surface level and without basement excavations.

3.3. Ground Conditions:

The results of individual boreholes and DCP tests are provided Appendix:2.

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

- **FILL –** this layer was encountered at both test locations to a maximum depth 1.20m (BH2) below the existing ground surface. It comprised fine to medium grained sand with gravels.

- **SAND** ï this layer was encountered at both test locations and extends to below the maximum depth of investigation of 5.00m. It comprised very loose to dense, fine to medium grained, moist sand.

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

3.4. Laboratory Testing

Eight selected samples were analysed for Acid Sulfate Soil (ASS) conditions using the pH, oxidized pH (fox) and sPOCAS methods. Samples were kept on ice and transported to a NATA accredited laboratory (Envirolab) for analysis under standard chain of custody protocol. A summary of the test results is given in Table 1. Envirolab Certificate of Analysis is included in Appendix: 2.

Table: 1 ï sPOCAS Test Results

Borehole	Depth (m)	Description	pH (KCL)	pH (OX)	TPA moles H^+ / t	Spos (% S)	Liming Rate kg CaCO3 / t
1	1.0-1.1	Sand	8.1	5.0	-	-	-
1	2.4-2.5	Sand	7.9	6.0	-	-	-
1	4.0-4.1	Sand	8.3	7.8	-	-	-
1	4.9-5.0	Sand	9.5	7.3	<5	<0.005	<0.75
2	0.9-10	Sand	8.6	4.8	-	-	-
2	2.5-2.6	Sand	8.4	6.7	-	-	-
2	3.0-3.1	Sand	6.7	6.1	<5	<0.005	<0.75
2	3.9-4.1	Sand	8.6	7.7	-	-	-

* Results in **Bold** exceed the Acid Sulfate Soils Advisory committee (ASSMAC) Action Criteria for disturbance of <1000 tonnes of soil (refer Section 4.2)

4. COMMENTS:

4.1. Geotechnical Assessment:

The site investigation identified the presence of granular (sand) fill of shallow thickness (Ò1.20m) overlying natural dune sand of variable density from loose to medium dense to at least 4.0m ï 5.0m depth. The investigation did not identify bedrock to the limit of the test equipment (5.0m) and the boreholes remained dry during drilling.

The proposed works involve demolition of all existing site structures and construction of a new five storey mixed use development with a basement and additional car stacker requiring excavation to at least 5.50m depth below existing ground surface levels. The basement excavation will extend up to all site boundaries and the car stacker will require excavation up to the north, east and south boundaries.

It is expected that the entire excavation for the basement and car stacker will extend through loose to dense sand. Whilst this will be easy to achieve, the excavation will not stand unsupported and support measures will be required prior to bulk excavation.

Based on the investigation results it is considered that there is a low likelihood of intersecting Acid Sulfate Soils below the site, whilst the proposed works do not appear to impact the water table. The excavation for the car stacker will be slightly deeper than the investigation was able to extend, however it is considered that conditions have a low likelihood of changing within the subsequent 0.50m depth below the investigaton base, though further investigation is recommended.

Adjacent neighbouring structures and the road reserve structures and services are expected to be founded at very shallow depth and therefore would be impacted be excavation movement/deflection or failure. As such excavation support design and construction are critical components.

Driven concrete, steel (ie sheet piles) or timber piles are not recommended on this site due to significant vibrations generated during installation of these structures. Bored concrete piles could be utilized in the excavation support and/or for new footings. These structures will need to be installed as a contiguous structure for boundary support and with a method that ensures the integrity of the foundation is maintained for footings and that over excavation of adjacent soils does not occur. It will be necessary to undertake additional geotechnical investigation to determine soil conditions to well below the proposed excavation base via both boreholes and CPT methods (following demolition of the existing buildings on site), to allow accurate and economic design.

It should be noted that the sandy soils are unlikely to remain stable in open bored pile excavation. It will therefore be necessary to adopt contiguous flight auger (CFA) piles especially if the water table is intersected to ensure stability prior to the placement of concrete.

The investigation did not identify a water table to 5.0m depth and soil samples above this level are not Acid Sulfate. Further investigation is required however based on the site works and requirements for geotechnical stability it is unlikely that Acid Sulfate Soils or the water table will be impacted by the works external to the site boundaries provided the recommendations of this report are implemented.

Table 2: Action Criteria Based on ASS Analysis for Three Broad Texture Categories

Type of Material		Action Criteria (1 – 1000 tonnes disturbed)		Action Criteria (> 1000 tonnes disturbed)	
Texture Range	**Approximate Clay Content (%)**	**Sulfur trail %S oxidisable**	**Acid Trail Mol H^+/tonne**	**Sulfur trail %S oxidisable**	**Acid Trail Mol H^+/tonne**
Coarse Texture Sands to loamy sands	<5	0.03	18	0.03	18
Medium Texture Sandy loams to light clays	5-40	0.06	36	0.03	18
Fine Texture Medium to heavy clays, silty clays	>40	0.1	62	0.03	18

It is anticipated that the volume of natural soil to be disturbed during site development works will exceed 1,000 tonnes, thus the *>1,000 tonnes disturbed Action Criteria* for the relevant soil types from Table 2 has been used as the basis for assessment of the presence of ASS requiring treatment. Based on these results treatment is not required.

The proposed works are therefore 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 hand drilling tools due to access limitations. 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. The results of the investigation provide a reasonable basis for the analysis and subsequent preliminary design of the proposed works however it is recommended that additional investigation be undertaken to confirm ground conditions at ódepthô.

4.2. Site Specific Risk Assessment:

Based on our site investigation we have identified the following geological/geotechnical landslip hazard which needs to be considered in relation to the existing site and the proposed works. This hazard is:

A. Landslip (soil slide <$50m^3$) of soils in basement excavation.

A preliminary 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 assessed as having a potential impact neighbouring properties and Whistler Street. The hazard achieves a Risk to Life of up to $2.50x10^{-4}$ for a single person and a óVery Highô risk to Property. These risk levels are considered to be óUnacceptableô when assessed against the criteria of the AGS 2007. However, implementation of permanent support measures detailed in this report the likelihood of instability becomes óRareô and the probability of excavation increases reducing risk levels to $<5.21x10^{-6}$ for a single person and óVery Lowô to property. As such it is considered that the development can be achieved within óAcceptableô risk levels.

4.3. Design & Construction Recommendations:

Design and the construction recommendations are tabulated below:

4.3.1. New Footings:	
Site Classification as per AS2870 ï 2011 for new footing design	Class óAô due to unreactive nature of sandy soils.
Type of Footing	Piles to below excavation base.
	Bored Piles (reinforced concrete) ï CFA methods required. For deep bored piles using the CFA method, geotechnical inspection of the footing/foundation base is not possible. Therefore detailed geotechnical investigation of site conditions is required prior to design and construction.
Site sub-soil classification as per *Structural design actions AS1170.4 – 2007, Part 4: Earthquake actions in Australia*	D_e ï Deep Soil Site (Subject to additional investigation)
Remarks: - Steel screw piles are not recommended due to the site conditions and issues with the design and construction of this style of footing. Crozier Geotechnical will not certify this style of footing. - Additional geotechnical investigation is required to confirm ground conditions and any water table to enable pile design. - Should a bored pile foundation solution be adopted it is considered that the sandy soils underlying the site will require the use of CFA methods which should be allowed for in project costings/timing.	

4.3.2. Excavation:		
Depth of Excavation	Up to 5.50m for the car stacker, decreasing to 4.50m for the basement.	
Distance to Neighbouring Properties	The basement excavation will be taken to all site boundaries with brick commercial/residential developments at the boundaries.	
Material to be excavated Ó 5.0m/ will require additional boreholes to confirm	0.00 to 1.00m	Topsoil/fill
	Between 1.0m and 5.0m	Loose to dense sand

Guidelines for <u>unsurcharged</u> batter slopes remote to site boundaries are tabulated below:

Material	Safe Batter Slope (H:V)*	
	Short Term/Temporary	Long Term/Permanent
Fill and natural sandy	1.5:1	2:1

- These batters are not achievable on this site for the bulk excavation.

- Permanent support measures via bored concrete pile contiguous wall using the cantilever, braced or anchored method are required. Extreme care is required for any driven construction method to ensure ground vibrations do not impact neighbouring structures. As all neighbouring structures are likely to be founded at shallow depth and very close proximity to the excavation, driven support or footing systems should not be used on this site. Based on proximity to neighbouring structures and their likely founding at shallow depth in sandy soils, sheet piling is not recommended.

Equipment for Excavation	Topsoil/Fill	Excavator with bucket
	Sand	Excavator with bucket

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))	All surrounding structures 5mm/s
Vibration Calibration Tests Required	No, unless variation to the recommendations of this report is proposed.
Full time vibration Monitoring Required	No
Geotechnical Inspection Requirement	Yes, recommended that these inspections be undertaken as per below mentioned sequence: • During installation of excavation support measures • At completion of the excavation.
Dilapidation Surveys Requirement	Recommended on all surrounding buildings within 10m of excavation perimeter.

Remarks: Water ingress into exposed excavations can result in erosion and stability concerns in soil. 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	New retaining structures will be required as part of the proposed development with permanent support installed prior to the bulk excavation
Types	Bored contiguous concrete piles prior to excavation designed in accordance with Australian Standard AS 4678-2002 Earth Retaining Structures.

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

Material	Unit Weight (kN/m3)	Long Term (Drained)	Earth Pressure Coefficients		Passive Earth Pressure Coefficient *
			Active (Ka)	At Rest (K_0)	
Sand Fill/Loose Sand	18	$\phi' = 28°$	0.35	0.52	N/A
Sand-Medium dense	18	$\phi' = 30°$	0.30	0.45	3.00
Sand-Dense	20	$\phi' = 35°$	0.27	0.43	3.69

Remarks: These parameters do not include surcharge loading from structures, pavements or the affect of the water table where it is identified at or likely to rise above the excavation base over the developments deisgn life.

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).

4.3.4. Drainage and Hydrogeology		
Groundwater Table or Seepage identified in Investigation		None ï will require additional boreholes within the site to below 5.0m.
Excavation likely to intersect	Water Table	Unknown - possible
Site Location and Topography		Low lying in dune deposits
Impact of development on local hydrogeology		Negligible
Onsite Stormwater Disposal		Possible at base of excavation

Remarks: Groundwater was not encountered to the depths investigated however groundwater conditions will require confirmation prior to bulk excavation and final design.

5. CONCLUSION:

The site investigation identified the presence of sandy soils to at least 5.0m depth. The investigation did not identify bedrock or a water table to the limit of the test equipment.

The proposed works involve demolition of all existing structures and construction of a new five storey residential block of apartments with a basement level car park and car stacker. The works will require an excavation of between 4.50m and 5.50m depth. The excavation will extend to all site boundaries. As such the bulk excavation will require installation of support measures prior to excavation. It is considered that a bored contiguous pile supported wall to be the most suitable to prevent impact to adjacent properties. It is recommended that further investigation via a rig augered borehole and CPT methods be undertaken to confirm site conditions below 5.0m depth following demolition of existing buildings currently occupying the site.

The site investigation results indicate there is a low probability of intersecting Acid Sulfate Soils below the site within the depth of the proposed works, whilst the proposed works should have no impact on the water table external to the site provided the recommendations of this report are implemeneted.

The risks associated with the proposed development can achieve ñUnacceptableò levels where unsupported/ poor excavation, design and construction are implemented. However, the risk can be maintained within óAcceptableô levels when assessed against AGS 2007 criteria 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 including for further investigation are followed.

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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 ï 50
Stiff	50 ï 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 ï 10	2 ï 5
Medium dense	10 ï 30	5 -15
Dense	30 ï 50	15 ï 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 ï 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) ï 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 ï 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 ï 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 SPTôs 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 óeelôand rate of penetration.

Rotary Mud Drilling ï 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 ï 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, ñMethods of Testing Soils for Engineering Purposesòï 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 óNôvalue 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.

ð 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

ð 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 ï 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: -

ð Cone resistance ï the actual end bearing force divided by the cross-sectional area of the cone ï expressed in MPa.
ð Sleeve friction ï the frictional force on the sleeve divided by the surface area ï expressed in kPa.
ð 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 ï 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 ï 50 MPa) is less sensitive and is shown as a full line. The ratios of the sleeve friction to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios 1% - 2% are commonly encountered in sands and very soft clays rising to 4% - 10% in stiff clays.

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

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

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

Qc = (12 to 18) Cu

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

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

Dynamic Penetrometers

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

Two relatively similar tests are used.

- ŏ Perth sand penetrometer ï a 16mm diameter flattened rod is driven with a 9kg hammer, dropping 600mm (AS1289, Test 6.3.2). The test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
- ŏ Cone penetrometer (sometimes known as Scala Penetrometer) ï 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 ñMethods of Testing Soil for Engineering Purposesò. 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 óstraight lineô 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
B	Bulk Sample	PP	Pocket Penetrometer Test
U50	50mm Undisturbed Tube Sample	SPT	Standard Penetration Test
U63	63mm ñ ñ ñ ñ î		

Ground Water

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

- ŏ 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.
- ŏ A localised perched water table may lead to an erroneous indication of the true water table.
- ŏ 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.
- ŏ 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:

- ŏ unexpected variations in ground conditions ï the potential for this will depend partly on bore spacing and sampling frequency,
- ŏ changes in policy or interpretation of policy by statutory authorities,
- ŏ 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.

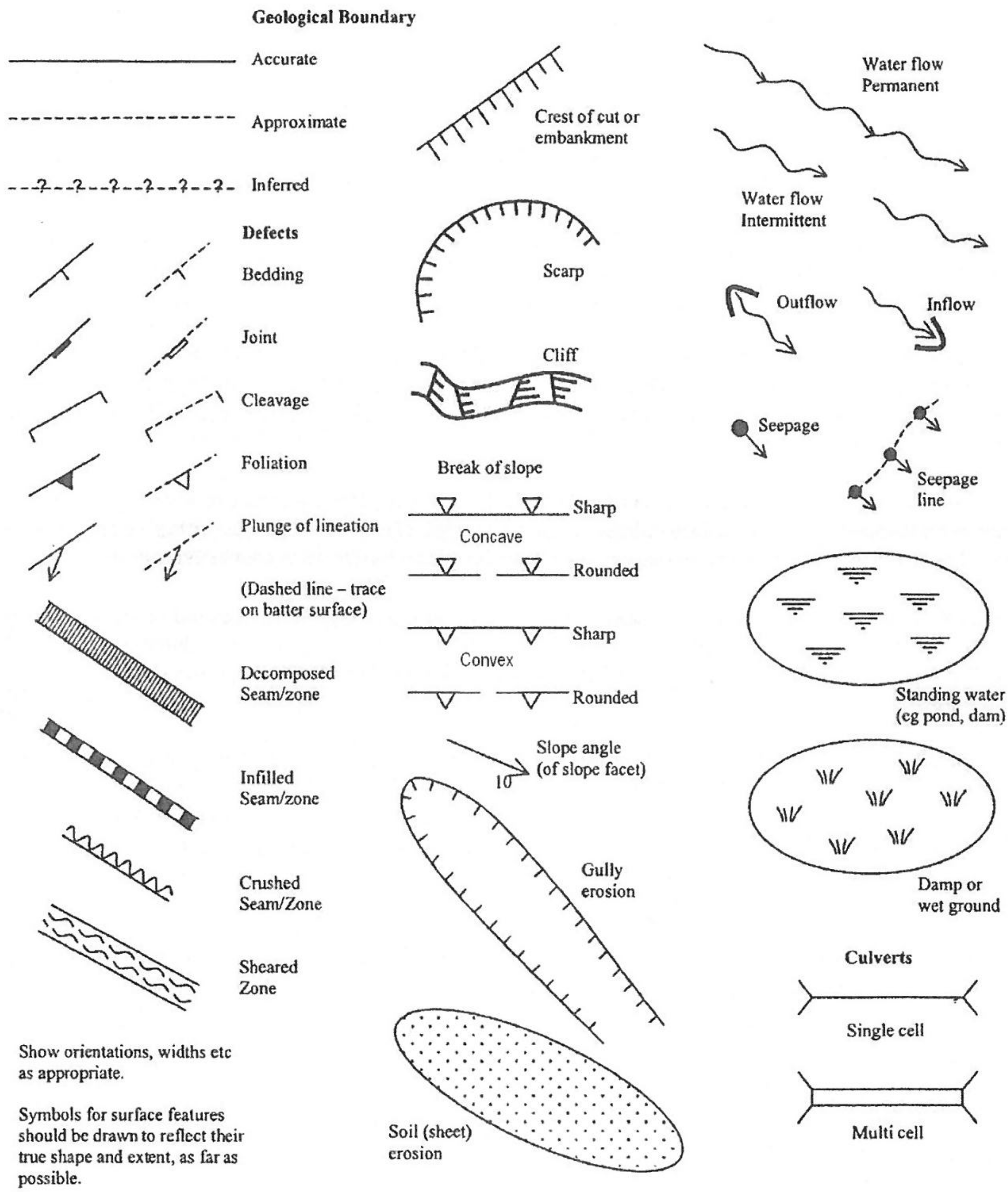
Reproduction of Information for Contractual Purposes

Attention is drawn to the document ñGuidelines for the Provision of Geotechnical Information in Tender Documentsò, 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.

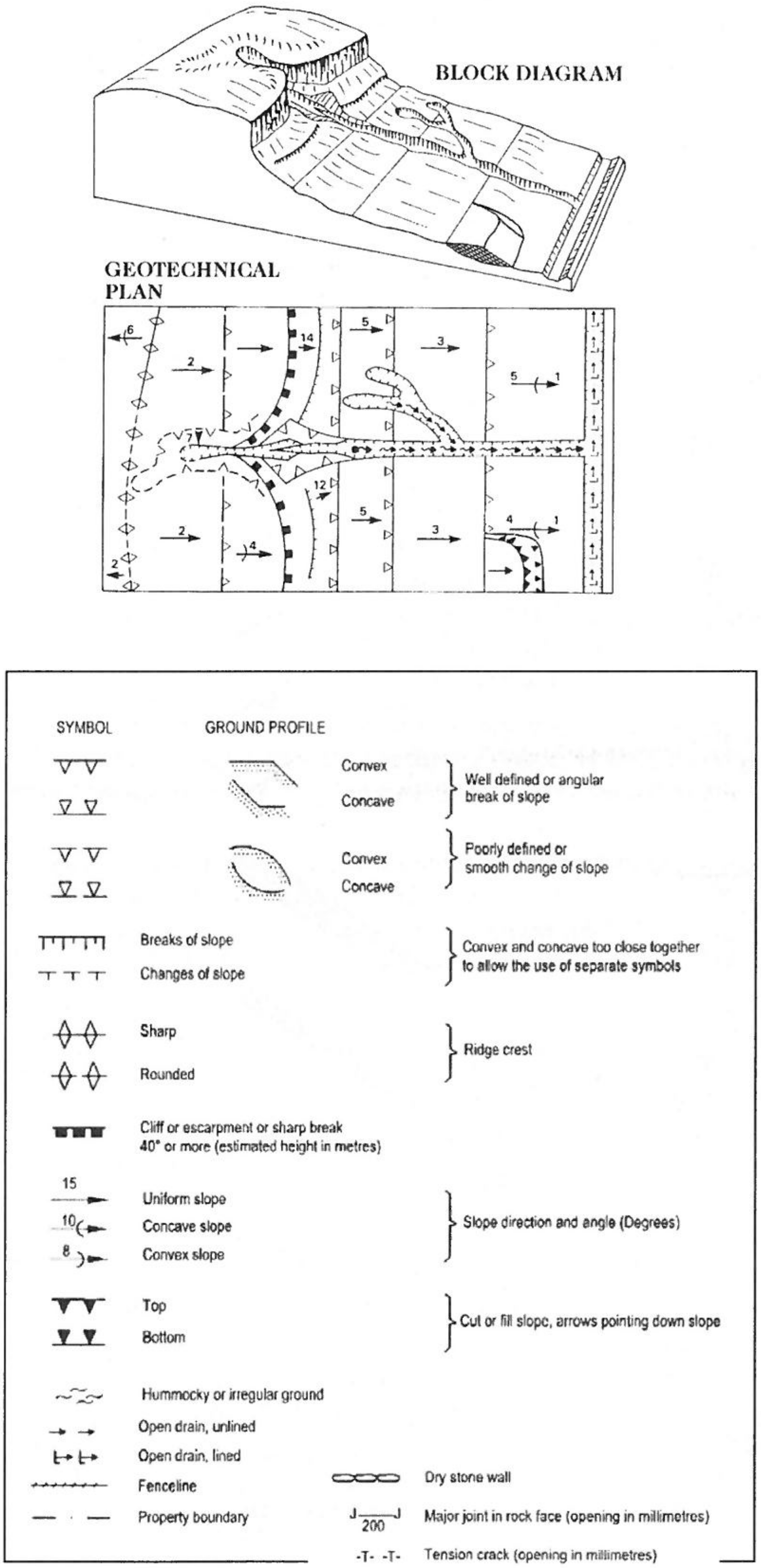
Site Inspection

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.

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).



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

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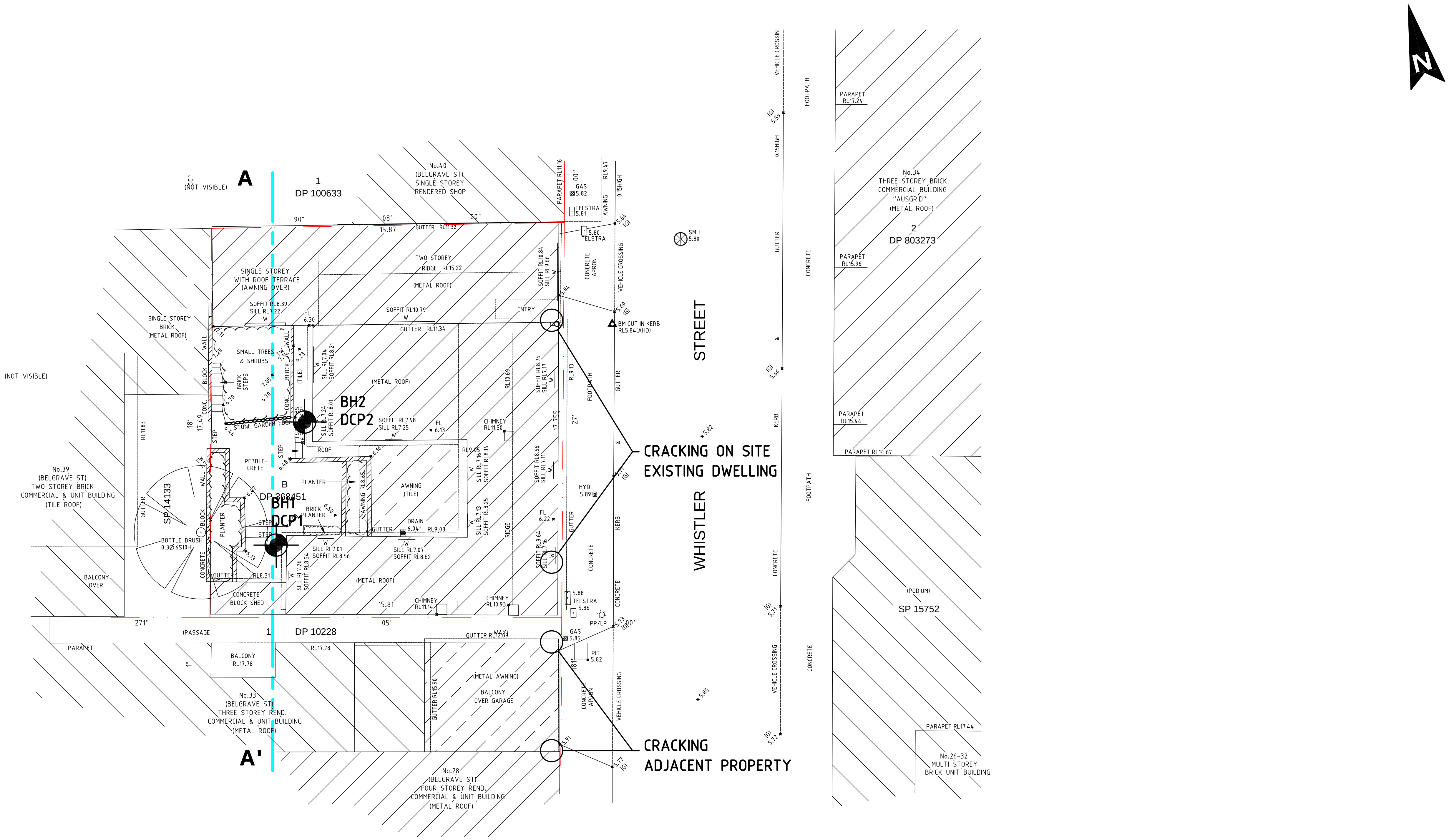
Appendix 2



0 2 4 6 8 10m

4 3 2 1

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

SITE PLAN AND 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
Email: info@croziergeotech.com.au

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

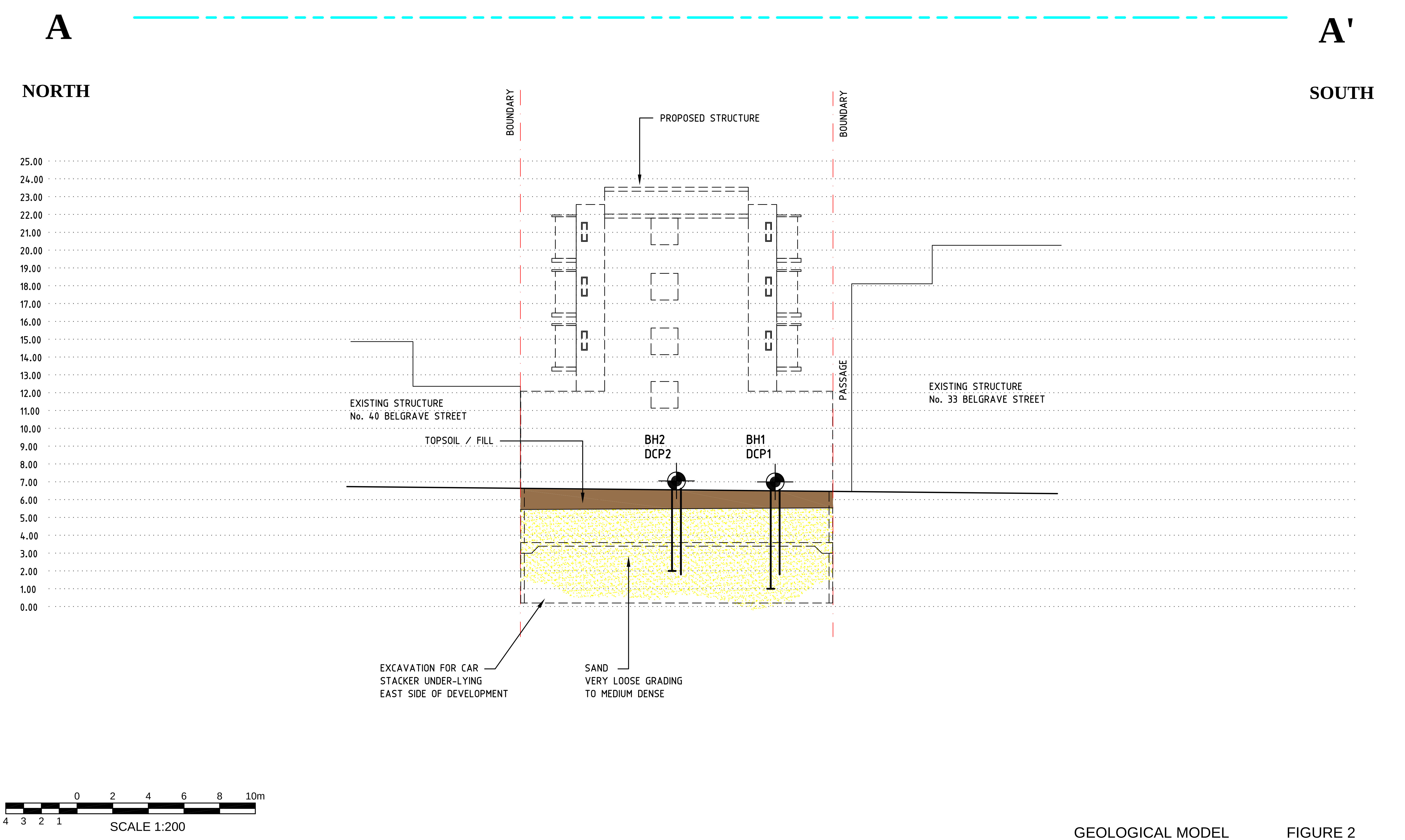
LEGEND

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

SCALE :	1:200
DRAWING :	FIGURE 1
DATE :	01.10.18
APPROVED BY :	C.L.
DRAWN BY :	A.C.W.
PROJECT :	2018-141

PREPARED FOR :
PAVILION RESIDENCES
No.3 Pty Ltd

ADDRESS :
21 WHISTLER STREET
MANLY, N.S.W.



GEOLOGICAL MODEL FIGURE 2

CROZIER
GEOTECHNICAL CONSULTANTS
Crozier Geotechnical
Unit 12, 42-46 Wattle Road
Brookvale NSW 2100
ABN: 96 113 453 624
Phone: (02) 9939 1882
Email: info@croziergeotech.com.au
Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

LEGEND

- AUGER LOCATION
- AUGER / DYNAMIC PENETRATION TEST
- DCP- DYNAMIC PENETRATION TEST
- BOUNDARY LINE
- TOPSOIL / FILL
- SAND

SCALE :	1:200
DRAWING :	FIGURE 2
DATE :	01.10.18
APPROVED BY :	C.L.
DRAWN BY :	A.C.W.
PROJECT :	2018-141

PREPARED FOR :
PAVILION RESIDENCES
No.3 Pty Ltd

ADDRESS :
21 WHISTLER STREET
MANLY, N.S.W.

BOREHOLE LOG

CLIENT: Pavilion Residences No.3 Pty Ltd **DATE:** 31/08/2018 **BORE No.:** 1

PROJECT: 5 Storey Residential Development **PROJECT No.:** 2018-141 **SHEET:** 1 of 2

LOCATION: 21 Whistler St, Manly **SURFACE LEVEL:** RL å 6.0m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	Results	
0.00						
0.10	TILE					
	FILL - Grey, fine to medium grained sand with gravels					
0.80						
	SAND - Loose to dense, pale brown, fine to medium grained, moist, sand.					
1.00			1,00			
		D	1.10			
		D	1.20			
1.50	...became Orange					
2.00			2.00			
		D	2.10			
			2.40			
		D	2.5			

RIG: N/A DRILLER: CL LOGGED: JY

METHOD: hand Auger

GROUND WATER OBSERVATIONS: No free ground water encountered.

REMARKS: CHECKED:

BOREHOLE LOG

CLIENT: Pavilion Residences No.3 Pty Ltd **DATE:** 31/08/2018 **BORE No.:** 1

PROJECT: 5 Storey Residential Development **PROJECT No.:** 2018-141 **SHEET:** 2 of 2

LOCATION: 21 Whistler St, Manly **SURFACE LEVEL:** RL å 6.0m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	In Situ Testing Results
2.50					
2.60	...became Yellow				
		D	3.00 3.10		
3.50					
		D	4.00 4.10		
4.50					
5.00		D	4.90 5.00		
	Hand Auger discontinued at 5.00m depth				

RIG: N/A DRILLER: CL LOGGED: JY

METHOD: hand Auger

GROUND WATER OBSERVATIONS: No free ground water encountered.

REMARKS: CHECKED:

BOREHOLE LOG

CLIENT: Pavilion Residences No.3 Pty Ltd **DATE:** 31/08/2018 **BORE No.:** 2

PROJECT: 5 Storey Residential Development **PROJECT No.:** 2018-141 **SHEET:** 1 of 2

LOCATION: 21 Whistler St, Manly **SURFACE LEVEL:** RL å 6.0m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	Results	
0.00						
	TILE/CONCRETE					
0.30	FILL - Grey, fine to medium grained sand with gravels.					
			0.90			
1.00		D	1.00			
		D	1.10			
1.20	SAND - Very loose to medium dense, pale brown, fine to medium grained, moist sand.					
1.80	...became Orange					
2.00			2.00			
		D	2.10			

RIG: N/A DRILLER: CL LOGGED: JY

METHOD: hand Auger

GROUND WATER OBSERVATIONS: No free ground water encountered.

REMARKS: CHECKED:

BOREHOLE LOG

CLIENT: Pavilion Residences No.3 Pty Ltd **DATE:** 31/08/2018 **BORE No.:** 2

PROJECT: 5 Storey Residential Development **PROJECT No.:** 2018-141 **SHEET:** 2 of 2

LOCATION: 21 Whistler St, Manly **SURFACE LEVEL:** RL å 6.0m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing		
		Type	Depth (m)	Type	Results	
2.50			2.5			
		D	2.60			
3.00	...became Yellow		3.00			
		D	3.10			
3.50						
			3.90			
4.00			4.00			
	Hand Auger discontinued at 4.00m depth.					
4.50						

RIG: N/A DRILLER: CL LOGGED: JY

METHOD: hand Auger

GROUND WATER OBSERVATIONS: No free ground water encountered.

REMARKS: CHECKED:

DYNAMIC PENETROMETER TEST SHEET

CLIENT: Pavilion Residences No.3 Pty L
DATE: 31/08/2018
PROJECT: 5 Storey Residential Developme
PROJECT No.: 2018-141
LOCATION: 21 Whistler St, Manly
SHEET: 1 of 1

	Test Location							
Depth (m)	DCP 1	DCP 1A	DCP 2	DCP 2A				
0.00 - 0.15	--	--	--	--				
0.15 - 0.30	--	1	--	--				
0.30 - 0.45	--	1	--	--				
0.45 - 0.60	--	5	--	--				
0.60 - 0.75	--	2	--	--				
0.75 - 0.90	--	2	--	--				
0.90 - 1.05	--	2	--	--				
1.05 - 1.20	--	2	--	--				
1.20 - 1.35	--	2	--	--				
1.35 - 1.50	--	2	--	--				
1.50 - 1.65	--	2	1	--				
1.65 - 1.80	--	2	2	--				
1.80 - 1.95	--	2	3	--				
1.95 - 2.10	--	4	3	--				
2.10 - 2.25	--	3	2	--				
2.25 - 2.40	--	3	3	--				
2.40 - 2.55	--	5		2				
2.55 - 2.70	--	4		2				
2.70 - 2.85	--	3		1				
2.85 - 3.00	--	4		0				
3.00 - 3.15	3			2				
3.15 - 3.30	3			2				
3.30 - 3.45	5			4				
3.45 - 3.60	4			3				
3.60 - 3.75	5			4				
3.75 - 3.90	4			5				
3.90 - 4.05	13			5				
4.05 - 4.20	14			9				

TEST METHOD: AS 1289. F3.2, CONE PENETROMETER
AS 1289. F3.3, PERTH SAND PENETROMETER

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

CROZIER
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Appendix 3

TABLE : A

Landslide risk assessment for Risk to life

HAZARD	Description	Impacting	Likelihood of Slide	Spatial Impact of Slide		Occupancy	Evacuation	Vulnerability	Risk to Life
A	Landslip (earth slide 50m³) from unsuported sandy soils due to excavation for basement		Excavation to 5.50m depth and to all side boundaries in sand	a) commercial development adjacent to boundary b) commercial and residential development adjacent to boundary c) commercial and residential development adjacent boundary d) footpath and road adjacent to boundary		a) Person in commercial portion of property 10hrs/day avge. b) Person in residential portion of development 20hr/day avge. c) Person in residential portion of development 20hr/day avge. d) Vehicle along road, 500/day, 40km/hr	a) Likely to not evacuate b) Likely to not evacuate c) Likely to not evacuate d) Likely to not evacuate	a) Person in building or open space, buried	
				Prob. of Impact	**Impacted**				
			Almost Certain						
		a) No. 40 Belgrave St (rear half)	0.1	1.00	0.75	0.4167	0.75	1.0	**2.34E-02**
		b) No. 35 - 39 Belgrave St	0.1	1.00	0.40	0.8333	0.75	1.0	**2.50E-02**
		c) No. 33 Belgrave St	0.1	1.00	0.10	0.8333	0.75	1.0	**6.25E-03**
		d) Whistler St	0.1	1.00	0.75	0.0026	0.75	1.0	**1.46E-04**
		With suitable engineered support system	Rare						
		a) No. 40 Belgrave St (rear half)	0.0001	1.00	0.50	0.4167	0.25	1.0	**5.21E-06**
		b) No. 35 - 39 Belgrave St	0.00001	1.00	0.40	0.8333	0.25	1.0	**8.33E-07**
		c) No. 33 Belgrave St	0.0001	1.00	0.10	0.8333	0.25	1.0	**2.08E-06**
		d) Whistler St	0.00001	1.00	0.75	0.0026	0.25	1.0	**4.88E-09**

* hazard considered for excavation without suitable support systems and then with engineered support system (reducing likelihhod to 'Rare' and 'Unlikely' to not evacuate
* likelihood of occurrence for design life of 100 years
* Spatial Impact - Probaility of Impact referes to slide impacting structure/area expressed as a % (1.00 = 100% probability of slide impacting area if it occurs), Imapcted refers to % of area/strucure impacted if slide occurred
* neighbouring structures considered for bedroom impact unless specified
* considered for single person most at risk
* considered for adjacent premises/buildings founded via shallow footings unless indicated
* evacuation scale from Almost Certain to<u>not</u> evacuate (1.0), Likely (0.75), Possible (0.5), Unlikely (0.25), Rare to not evacuate (0.01). Based on likelihood of person knowing of landslide and completely evacuating area prior to landslide impact.
* vulnerability assessed using Appendix F - AGS Practice Note Guidelines for Landslide Risk Management 2007

TABLE : B

Landslide risk assessment for Risk to Property

HAZARD	Description	Impacting	Likelihood		Consequences		Risk to Property
A	Landslip (earth slide 50m³) from unsuported sandy soils due to excavation for basement	a) No. 40 Belgrave St (rear half)	Almost Certain	Event is expected to occur over design life.	Major	Extensive damage to most of site/structures with significant stabilising to support site or MEDIUM damage to neighbouring properties.	Very High
		b) No. 35 - 39 Belgrave St	Almost Certain	Event is expected to occur over design life.	Major	Extensive damage to most of site/structures with significant stabilising to support site or MEDIUM damage to neighbouring properties.	Very High
		c) No. 33 Belgrave St	Almost Certain	Event is expected to occur over design life.	Major	Extensive damage to most of site/structures with significant stabilising to support site or MEDIUM damage to neighbouring properties.	Very High
		d) Whistler St	Almost Certain	Event is expected to occur over design life.	Major	Extensive damage to most of site/structures with significant stabilising to support site or MEDIUM damage to neighbouring properties.	Very High
		a) No. 40 Belgrave St (rear half)	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
		b) No. 35 - 39 Belgrave 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
		c) No. 33 Belgrave 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) Whistler 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

* hazard considered for excavation without suitable support systems and then with engineered support system (reducing likelihhod to 'Rare' and 'Unlikely' to not evacuate
* 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

Envirolab Services Pty Ltd
ABN 37 112 535 645
12 Ashley St Chatswood NSW 2067
ph 02 9910 6200 fax 02 9910 6201
customerservice@envirolab.com.au
www.envirolab.com.au

CERTIFICATE OF ANALYSIS 199986

Client Details

Client	Crozier Geotechnical Consultants
Attention	Troy Crozier
Address	Unit 12/42-46 Wattle Rd, Brookvale, NSW, 2100

Sample Details

Your Reference	**21 Whistler St Manly 2018-141**
Number of Samples	8 SOIL
Date samples received	04/09/2018
Date completed instructions received	04/09/2018

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Report Details

Date results requested by	11/09/2018
Date of Issue	11/09/2018

NATA Accreditation Number 2901. This document shall not be reproduced except in full.

Accredited for compliance with ISO/IEC 17025 - Testing. **Tests not covered by NATA are denoted with ***

Results Approved By
Nick Sarlamis, Inorganics Supervisor

Authorised By

Jacinta Hurst, Laboratory Manager

sPOCAS field test						
Our Reference		199986-1	199986-2	199986-3	199986-5	199986-6
Your Reference	UNITS	BH1	BH1	BH1	BH2	BH2
Depth		1.0-1.1	2.4-2.5	4.0-4.1	0.9-1.0	2.5-2.6
Date Sampled		31/08/2018	31/08/2018	31/08/2018	31/08/2018	31/08/2018
Type of sample		SOIL	SOIL	SOIL	SOIL	SOIL
Date prepared	-	06/09/2018	06/09/2018	06/09/2018	06/09/2018	06/09/2018
Date analysed	-	06/09/2018	06/09/2018	06/09/2018	06/09/2018	06/09/2018
pH_F (field pH test)*	pH Units	8.1	7.9	8.3	8.6	8.4
pH_{FOX} (field peroxide test)*	pH Units	5.0	6.0	7.8	4.8	6.7
Reaction Rate*	-	Slight	Slight	Moderate	Slight	Slight

sPOCAS field test		
Our Reference		199986-8
Your Reference	UNITS	BH2
Depth		3.9-4.1
Date Sampled		31/08/2018
Type of sample		SOIL
Date prepared	-	06/09/2018
Date analysed	-	06/09/2018
pH_F (field pH test)*	pH Units	8.6
pH_{FOX} (field peroxide test)*	pH Units	7.7
Reaction Rate*	-	Slight

sPOCAS + %S w/w			
Our Reference		199986-4	199986-7
Your Reference	UNITS	BH1	BH2
Depth		4.9-5.0	3.0-3.1
Date Sampled		31/08/2018	31/08/2018
Type of sample		SOIL	SOIL
Date prepared	-	06/09/2018	06/09/2018
Date analysed	-	06/09/2018	06/09/2018
pH_{kcl}	pH units	9.5	6.7
TAA pH 6.5	moles H^+ /t	<5	<5
s-TAA pH 6.5	%w/w S	<0.01	<0.01
pH_{Ox}	pH units	7.3	6.1
TPA pH 6.5	moles H^+ /t	<5	<5
s-TPA pH 6.5	%w/w S	<0.01	<0.01
TSA pH 6.5	moles H^+ /t	<5	<5
s-TSA pH 6.5	%w/w S	<0.01	<0.01
ANC_E	% $CaCO_3$	0.19	<0.05
a-ANC_E	moles H^+ /t	38	<5
s-ANC_E	%w/w S	0.06	<0.05
S_{KCl}	%w/w S	<0.005	<0.005
S_P	%w/w	<0.005	<0.005
S_{POS}	%w/w	<0.005	<0.005
a-S_{POS}	moles H^+ /t	<5	<5
Ca_{KCl}	%w/w	0.05	0.02
Ca_P	%w/w	0.07	0.01
Ca_A	%w/w	0.018	<0.005
Mg_{KCl}	%w/w	<0.005	<0.005
Mg_P	%w/w	<0.005	<0.005
Mg_A	%w/w	<0.005	<0.005
S_{HCl}	%w/w S	<0.005	<0.005
S_{NAS}	%w/w S	<0.005	<0.005
a-S_{NAS}	moles H^+ /t	<5	<5
s-S_{NAS}	%w/w S	<0.01	<0.01
Fineness Factor	-	1.5	1.5
a-Net Acidity	moles H^+ /t	<5	<5
s-Net Acidity	%w/w S	<0.01	<0.01
Liming rate	kg $CaCO_3$ /t	<0.75	<0.75
s-Net Acidity without -ANCE	%w/w S	<0.01	<0.01
a-Net Acidity without ANCE	moles H^+ /t	<5	<5
Liming rate without ANCE	kg $CaCO_3$ /t	<0.75	<0.75

Method ID	Methodology Summary
Inorg-063	pH- measured using pH meter and electrode. Soil is oxidised with Hydrogen Peroxide or extracted with water. Based on section H, Acid Sulfate Soils Laboratory Methods Guidelines, Version 2.1 - June 2004. To ensure accurate results these tests are recommended to be done in the field as pH may change with time thus these results may not be representative of true field conditions.
Inorg-064	sPOCAS determined using titrimetric and ICP-AES techniques. Based on Acid Sulfate Soils Laboratory Methods Guidelines, Version 2.1 - June 2004.

QUALITY CONTROL: sPOCAS + %S w/w					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
Date prepared	-			06/09/2018	4	06/09/2018	06/09/2018		06/09/2018	[NT]
Date analysed	-			06/09/2018	4	06/09/2018	06/09/2018		06/09/2018	[NT]
pH $_{kcl}$	pH units		Inorg-064	[NT]	4	9.5	9.3	2	90	[NT]
TAA pH 6.5	moles H^+/t	5	Inorg-064	<5	4	<5	<5	0	95	[NT]
s-TAA pH 6.5	%w/w S	0.01	Inorg-064	<0.01	4	<0.01	<0.01	0	[NT]	[NT]
pH $_{Ox}$	pH units		Inorg-064	[NT]	4	7.3	7.2	1	105	[NT]
TPA pH 6.5	moles H^+/t	5	Inorg-064	<5	4	<5	<5	0	96	[NT]
s-TPA pH 6.5	%w/w S	0.01	Inorg-064	<0.01	4	<0.01	<0.01	0	[NT]	[NT]
TSA pH 6.5	moles H^+/t	5	Inorg-064	<5	4	<5	<5	0	[NT]	[NT]
s-TSA pH 6.5	%w/w S	0.01	Inorg-064	<0.01	4	<0.01	<0.01	0	[NT]	[NT]
ANC_E	% $CaCO_3$	0.05	Inorg-064	<0.05	4	0.19	0.19	0	[NT]	[NT]
a-ANC_E	moles H^+/t	5	Inorg-064	<5	4	38	38	0	[NT]	[NT]
s-ANC_E	%w/w S	0.05	Inorg-064	<0.05	4	0.06	0.06	0	[NT]	[NT]
S_{KCl}	%w/w S	0.005	Inorg-064	<0.005	4	<0.005	<0.005	0	[NT]	[NT]
S_P	%w/w	0.005	Inorg-064	<0.005	4	<0.005	<0.005	0	[NT]	[NT]
S_{POS}	%w/w	0.005	Inorg-064	<0.005	4	<0.005	<0.005	0	[NT]	[NT]
a-S_{POS}	moles H^+/t	5	Inorg-064	<5	4	<5	<5	0	[NT]	[NT]
Ca_{KCl}	%w/w	0.005	Inorg-064	<0.005	4	0.05	0.06	18	[NT]	[NT]
Ca_P	%w/w	0.005	Inorg-064	<0.005	4	0.07	0.07	0	[NT]	[NT]
Ca_A	%w/w	0.005	Inorg-064	<0.005	4	0.018	0.009	67	[NT]	[NT]
Mg_{KCl}	%w/w	0.005	Inorg-064	<0.005	4	<0.005	<0.005	0	[NT]	[NT]
Mg_P	%w/w	0.005	Inorg-064	<0.005	4	<0.005	<0.005	0	[NT]	[NT]
Mg_A	%w/w	0.005	Inorg-064	<0.005	4	<0.005	<0.005	0	[NT]	[NT]
S_{HCl}	%w/w S	0.005	Inorg-064	<0.005	4	<0.005	<0.005	0	[NT]	[NT]
S_{NAS}	%w/w S	0.005	Inorg-064	<0.005	4	<0.005	<0.005	0	[NT]	[NT]
a-S_{NAS}	moles H^+/t	5	Inorg-064	<5	4	<5	<5	0	[NT]	[NT]
s-S_{NAS}	%w/w S	0.01	Inorg-064	<0.01	4	<0.01	<0.01	0	[NT]	[NT]
Fineness Factor	-	1.5	Inorg-064	<1.5	4	1.5	1.5	0	[NT]	[NT]
a-Net Acidity	moles H^+/t	5	Inorg-064	<5	4	<5	<5	0	[NT]	[NT]
s-Net Acidity	%w/w S	0.01	Inorg-064	<0.01	4	<0.01	<0.01	0	[NT]	[NT]
Liming rate	kg $CaCO_3$/t	0.75	Inorg-064	<0.75	4	<0.75	<0.75	0	[NT]	[NT]
s-Net Acidity without -ANCE	%w/w S	0.01	Inorg-064	<0.01	4	<0.01	<0.01	0	[NT]	[NT]
a-Net Acidity without ANCE	moles H^+/t	5	Inorg-064	<5	4	<5	<5	0	[NT]	[NT]

QUALITY CONTROL: sPOCAS + %S w/w					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
Liming rate without ANCE	kg $CaCO_3$/t	0.75	Inorg-064	<0.75	4	<0.75	<0.75	0	[NT]	[NT]

Result Definitions

NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

CROZIER
GEOTECHNICAL CONSULTANTS

Appendix 5

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.