GEOTECHNICAL ASSESSMENT REPORT

No. 8 Battle Boulevard
Seaforth, NSW

Prepared for

Mr Dylan Fan

Reference No. ESWN-PR-2019-423

15th August 2019

Geotechnical Engineering Services

- Geotechnical investigation
- Lot classification
- Geotechnical design
- Footing inspections
- Excavation methodology and monitoring plans
- Slope stability analysis
- Landslide risk assessment
- Permeability test

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4. Australian Standard – AS 3798-2007 Guidelines on Earthworks for Commercial and Residential Developments.
5. Australian Standard – AS 1170.4-2007 Structural Design Actions – Part 4: Earthquake actions in Australia.
6. Australian Standard – AS 4678-2002 Earth-retaining Structures.
7. Austroads – "Pavement Design – A Guide to the Structural Design of Road Pavements", 2004.
8. "NSW WorkCover: Code of Practice – Excavation" July 2015.
9. Pells, P.J.N, Mostyn, G. & Walker B.F., "Foundations on Sandstone and Shale in the Sydney Region", Australian Geomechanics Journal, 1998.
10. Australian Geomechanics Society, Landslide Risk Management Sub-Committee Guidelines: *Landslip Risk Management Concepts and Guidelines,* March 2007.
11. CSIRO, BTF 18 - "Foundation Maintenance and Footing Performance: A Homeowner's Guide".
12. Acid Sulfate Soils Map – Sheet CL1_002, Manly Local Environmental Plan 2013.
13. Clause 6.1- Acid Sulfate Soils, Manly Local Environmental Plan 2013.

1. INTRODUCTION

ESWNMAN Pty Ltd (ESWNMAN) was commissioned by Mr Dylan Fan to undertake a geotechnical investigation at No. 8 Battle Boulevard, Seaforth, NSW 2092 in a Professional Services Agreement referenced ESWN-PP-2019-507 and dated 2nd August 2019. The fieldwork was completed on 6th August 2019.

The purpose of geotechnical investigation was to assess the feasibility of the site in geotechnical prospective for proposed alterations and additions.

This report presents results of geotechnical investigation, geological mapping of rock outcrops exposed on site, interpretation and assessment (including landslide risk assessment), and provides comments on geotechnical related issues and recommendations.

1.1 Proposed Development

Based on design information provided, we understood that the proposed development will comprise the alterations and additions to an existing single storey rendered brick house, including the following:

- Addition of 1st & 2nd floor levels onto existing ground floor level;
- Construction of a new garage in the front of existing dwelling;
- Extension to front and rear of the existing dwelling.

A site walkover indicates the above proposed works are on or near steep sloping ground, and with close proximity to sandstone cliff and boulders, therefore, a landslip risk assessment in accordance with "Landslide Risk Management Concepts and Guidelines" of AGS 2007 (Reference 10) was undertaken and included in this report.

1.2 Scope of Work

The geotechnical investigation was carried out by ESWNMAN staff supervised by an experienced Geotechnical Engineer, including the following:

- Desktop study on local geology and Acid Sulfate Soil Map;
- Collection and on-site review of Dial-Before-You-Dig (DBYD) plans;
- A site walkover to assess the surface conditions, identify relevant site features and nominate borehole and testing locations;
- Augering of four(4) boreholes identified as BH1 and BH4 inclusive;

- Undertaking Dynamic Cone Penetrometer (DCP) Tests at four(4) locations next to boreholes;
- Geological mapping of rock outcrops encountered within the site;
- Identifying and assessing potential landslide hazard, mechanism of instability and likely counter-measures;
- Reinstatement of site with soil cuttings from boreholes;
- Interpretation of investigation data obtained; and
- Preparation of a geotechnical assessment report.

The approximate locations of boreholes and DCP tests completed during site investigation are shown on a site location plan as included in Appendix A of this report.

2. SITE DESCRIPTION

The site is located within Northern Beaches Council area, approximately 8.9km to the north of Sydney CBD and 210m to the north of The Spit Bridge & Middle Harbour.

The site is a semi trapezoidal-shaped land, identified as Lot 319 in Deposited Plan(DP)4889, with an approximate area of 809.4m^2, and is bounded by the following properties and infrastructure:

- North: Carriageway and road reserve of Edgecliffe Esplanade, including a sandstone cliff;
- East: A multistorey brick house at No. 6 Battle Boulevard;
- South: Carriageway and road reserve of Battle Boulevard; and
- West: A multistorey rendered house at No. 10 Battle Boulevard.

Based on a site walkover and the survey plan provided, the site is characterised by a steep sloping ground retained by several short sandstone block walls within front and rear gardens. Sandstone boulders and cliffs or near vertical cuts were present at several locations within the site.

At time of investigation, the site is inaccessible by a drilling machine. Selected site photographs recorded during site investigation are provided in Appendix B.

3. LOCAL GEOLOGY

Reference to the Sydney 1:100,000 Geological Series Sheet 9130 (Edition 1), dated 1983, by the Geological Survey of New South Wales, Department of Mineral Resources,

indicates the site is located within an area underlain by Hawkesbury Sandstone (Rh). The Hawkesbury Sandstone is described as "Medium to coarse-grained quartz sandstone, very minor shale and laminite lenses".

Results of the investigation as provided in Section 5.2, including geological mapping of rock outcrops exposed within the site, confirmed the published geology.

4. METHODOLOGY OF INVESTIGATION

4.1 Desktop Study

A desktop study on local geology and groundwater conditions was undertaken by ESWNMAN prior to the fieldwork. The information gathered from public domain and reviewed includes Acid Sulfate Soils Map – Sheet CL1_002 & Clause 6.1 – "Manly Local Environmental Plan 2013" (References 10 & 11).

4.2 Pre-fieldwork

Prior to the commencement of fieldwork, a site Safety Work Method Statement (SWMS) was prepared, which identifies potential hazards associated with the fieldwork on steep sloping ground and various control measures implemented to mitigate the hazards.

A 'Dial Before You Dig' (DBYD) services search, which forms a part of the SWMS, was also conducted and reviewed on site prior to the commencement of fieldwork.

4.3 Borehole Drilling

Four(4) boreholes were completed at selected locations where it was accessible by a portable equipment. The boreholes were extended to an approximate depth between 0.9m and 1.8m below existing ground level (BGL). A test pit aimed to expose existing footings was completed at south-western corner of existing building or approximate location of BH1/DCP1, as indicated on Photo 9 in Appendix B. The boreholes were terminated to the refusal by hand augering due to presence of boulders or sandstone bedrock. The location of boreholes is shown on the site location plan attached in Appendix A.

Engineering logs of boreholes processed using Bentley gINT software along with an explanatory note are presented in Appendix C.

4.4 Dynamic Cone Penetrometer (DCP) Test

A total of four(4) DCP tests, identified as DCPs 1 & 4 inclusive and located next to boreholes, were also completed during site investigation. The DCP tests reached refusal depth and bounce of hammer occurred at approximately 1.4m, 1.9m, 0.9m and 1.8m BGL at DCPs 1 to 4 respectively.

The location of DCP tests is shown on the site location plan attached in Appendix A. The record of DCP test results is presented in Appendix D.

4.5 Geological Mapping

Geological mapping and detailed examination of sandstone outcrops or cuts exposed within the site by an experienced Geotechnical Engineer or Engineering Geologist is proven to be most effective way of investigation.

Geological mapping on sandstone cliff/cuts and rock outcrops exposed within the site was also undertaken during the site investigation. The approximate location and extent of rock outcrops, grain size and colour, weathering degree, and estimated strength were recorded and assessed on-site by an experienced Geotechnical Engineer from ESWNMAN. The approximate locations of sandstone outcrops mapped are shown on Figure 1 – Site Location Plan as included in Appendix A, and also indicated on photos attached in Appendix B (2 sheets) of this report.

All fieldwork was supervised on a full time basis by an experienced Geotechnical Engineer who was responsible for nominating locations of boreholes and DCP tests, preparing field engineering logs of the subsurface strata encountered in accordance with AS 1726 for Geotechnical Site Investigation(Reference 1), undertaking geological mapping of rock outcrops and assessment of potential landslide risks, taking site photographs and conducting SWMS procedures.

5. INVESTIGATION RESULTS

5.1 Surface Conditions

Apart from existing rendered brick house, concrete path and steps from street entry to the building, several short sandstone block walls and a sandstone cliff near rear boundary, the

reminder of relatively flat terrain within front and rear gardens are covered with grass and lawns.

5.2 Subsurface Conditions

Based on our observations, borehole information, results of DCP test and geological mapping, a generalised ground profile obtained for the site consisted of the following:

- **Fill** (Unit 1): SAND/Gravelly SAND, medium grained, brown, moist, trace clay, some sandstone boulders with variable sizes on or near surface; overlying
- **Residual Soils** (Unit 2): Clayey SAND, medium grained, brown, moist, medium dense, extending to top of rock; overlying
- **Sandstone** (Unit 3): Class IV-III SANDSTONE, medium to coarse grained, brown, moderately to slightly weathered, medium to high strength, with some iron staining and seepage on surface of rock at some locations, based on visual examination on rock outcrops within the site. During fieldwork, sandstone outcrops encountered during investigation were mapped and measured as indicated on Figure 1 – Site Location Plan in Appendix A. The rock outcrops are also shown on photos included in Appendix B (2 sheets).

The classification of rock was carried out in accordance with Pells et al (Reference 9). A generalised ground profile is provided in Table 1 below.

Table 1 – Generalised Ground Profile*

Geotechnical Unit and Description		Inferred Depth to Top of Unit (m, BGL)			
		BH1/ DCP1	**BH2/ DCP2**	**BH3/ DCP3**	**BH4/ DCP4**
Fill (Unit 1)	SAND/Gravelly SAND, trace clay, some boulders on or near surface	0	0	0	0
Residual Soils (Unit 2)	Clayey SAND, medium, medium dense	1.1	1.4	-	1.2
Sandstone (Unit 3)	Class IV-III SANDTONE, moderately to slightly weathered, medium and high strength	1.4	1.9	0.9	1.8

Note: * - Ground profile is approximate and may vary with locations.

5.3 Groundwater

No groundwater or seepage was encountered during drilling of boreholes or conducting of DCP tests, or observed on faces of steep slope and rock cuts/cliff in a site walkover.

It is inferred that natural groundwater level may be much deeper than depth of investigation at this site. During construction excavation, it is possible to encounter

localised minor seepage/inflow through natural defects, such as bedding, joints/fractures within underlying sandstone, when an intense and prolonged rainfall occurs.

Based on local topography, the groundwater (if any) may drain/flow southerly towards Middle Harbour.

5.4 Acid Sulfate Soils (ASS) and Land Class

The site can be classified as "Class 5" in accordance with Acid Sulfate Soils Map – Sheet CL1_002, Manly Local Environmental Plan 2013 (Reference 12).

"Class 5" ASS land is defined in Clause 6.1 of Rockdale Local Environmental Plan 2013 (Reference 13) as "Works within 500 metres of adjacent Class 1, 2, 3 or 4 land that is below 5 metres Australian Height Datum and by which the watertable is likely to be lowered below metre Australian Height Datum on adjacent Class 1, 2, 3 or 4 land."

6. GEOTECHNICAL ASSESSMENT

The main geotechnical aspects associated with the proposed development are assessed to include the following:

- Site classifications;
- Excavation conditions;
- Stability of excavation and support/shoring measures;
- Earth retaining structures;
- Foundations;
- Ground vibration control measures;
- Water seepage/inflow management;
- Preliminary assessment on acid sulphate soils (ASS);
- Earthworks and material reuse; and
- Landslide risk assessment and mitigations.

The assessment of the geotechnical aspects as listed on the above and recommendations for the proposed development are presented in the following sections.

6.1 Site Classifications

(a) Site reactive classification

Based on ground profile of the site and the criteria specified in AS 2870 (Reference 2), the site is assessed as Class "P" due to presence of thick fill, steep and very steep ground/cliff and boulders with variables sizes, with potential landslip risk.

The above classification and footing recommendations are provided on the basis that the performance expectations set out in Appendix B of AS2870 are accepted.

Design, construction and maintenance of plumbing, ground drainage, protection of building perimeter, the garden, etc. should be carried out in accordance with CSIRO BTF18 (Reference 11) to avoid any water related problems or significant changes of moisture in building foundations, which may contribute to surface movement.

(b) Site earthquake classification

The results of the site investigation indicate the presence of fill underlain by Class IV Sandstone or better rock. In accordance with AS 1170.4 (Reference 5), the site may be classified as a "Rock site" (Class B_e) for design of foundations and retaining walls embedded in the underlying sandstone. The Hazard Factor (Z) for Seaforth in accordance with AS 1170.4 is considered to be 0.08.

6.2 Appraisal of Existing Footing

Based on our observations of rock outcrops exposed on surface, we assessed that the existing building structures are likely supported by shallow type footings and founded on sandstone bedrock. The existing building structures are generally in good conditions.

A test pit was excavated at south-western corner of existing building, where thick fill and/or deep rock within founding area was expected based on our site walkover and observations. The test pit dug shown on Photo 9 in Appendix B, information in borehole BH1 and results of DCP1 confirmed our prediction.

We recommend the existing building footings in vicinity of south-western corner along western and southern(front) external walls should be further checked for underpinning requirement.

6.3 Excavation Conditions

Based on design information on proposed alterations and additions, the majority of construction excavation is likely to involve the excavation of proposed garage and structural footing areas (pad/strip) for proposed extension, underpinning and retaining walls.

The observations and results of investigation indicate the presence of fill with sandstone boulders of variable sizes, residual soils underlain by sandstone during excavation.

Any fill and deleterious materials, including old footings/buried structures, plant/tree roots, redundant services, timber/brick material, and sandstone boulders, are expected to be stripped and removed from development area to spoils.

Excavation of the soils and low strength Class V Sandstone (may encounter locally) should be feasible using conventional earthmoving equipment. Heavy ripping and rock breaking equipment or vibratory rock breaking equipment is typically required for excavation in medium strength Class IV Sandstone or stronger rock. However, due to steep slope topography and site access constraints, the excavation is likely to be carried out by hand operated equipment for this site. **To minimise ground vibration induced by excavation within medium and high strength sandstone bedrock or boulders, vibration control measures in Section 6.7 should be adopted.**

6.4 Excavation Support / Stability of Excavation

(a) ***Shallow Excavation*** (i.e. <1.5 m in Depth)

The excavations should be carried out in accordance with the 'NSW WorkCover: Code of Practice – Excavation' July 2015 (Reference 8).

Temporary excavations through the underlying fill to a maximum depth of 1.5m, may be excavated near vertical provided that:

- They are barricaded when not in use;
- They are not left open for more than 24 hours;
- No surcharge loading is applied within 1.5m of the edge of the excavation;
- No groundwater flows are encountered; and
- They are not used for access by a worker.

Where access is required for workers, the temporary excavation batters should be re-graded to no steeper than 2 Horizontal (H) to 1 Vertical (V) for the fill above the natural groundwater level, or supported by a suitable temporary shoring measure.

Any permanent excavation (or filling) greater than 0.6m in height should be retained by a permanent retaining wall to be designed based on the recommendation provided in Section 6.5 of this report.

(b) *Deep Excavations* (i.e. >1.5 m in Depth)

If required, any excavation batters in soils greater than 1.5 m in depth, the safe batters for excavated slopes in Table 2 below can be adopted under dry conditions:

Table 2 - Recommended Safe Excavation Batters[1]

Geotechnical Unit	Maximum Batter Angle	
	Temporary	Permanent
Fill (Unit 1) and Residual Soils (Unit 2)	2.0H:1V	2.5H:1V or retained
Class IV Sandstone (Unit 3a)	1H:2.5V to Sub-vertical with shotcrete[2]	1H:2.5V to Sub-vertical[2] with rock bolts combined with reinforced shotcrete
Class III Sandstone (Unit 3b)	Sub-vertical	Sub-vertical with shotcrete[2]

Notes:
[1] - Typical temporary batters of excavated slopes (Hoerner, 1990). Assume no surcharge on top of new or existing cuts and no major adjoining structures. Excavation using benching technique can be adopted.
[2] – Reinforced shotcrete and/or rock bolts may be required for vertical or sub-vertical cut slope in this unit subject to assessment by an experienced Geotechnical Engineer during excavation.

Inspections of the excavation faces/shoring measures by a Geotechnical Engineer during construction will be required.

Earth retention structures should be designed in accordance with AS4678 (Reference 6) using the recommended parameters provided in Section 6.5.

With the recommended safe excavation batter, excavation shoring/support, inspection and geotechnical parameters, construction of the proposed works in the short and long terms is expected to have no impacts on the existing site structures, adjoining buildings, roads and infrastructure.

6.5 Earth Retaining Structures

The earth retaining structure should be designed to withstand the applied lateral pressures of the subsurface layers, the existing surcharges in their zone of influence, including

existing structures, construction machines, traffic and construction related activities. The design of retaining structures should also take into consideration hydrostatic pressures and lateral earthquake loads as appropriate.

The recommended preliminary parameters for design of retaining structures are presented in Tables 3 and 4 below. The coefficients provided are based on drained conditions.

Table 3 - Preliminary Geotechnical Design Parameters for Retaining Wall

Geotechnical Unit	Unit Weight (kN/m^3)	Effective Cohesion c′ (kPa)	Angle of Effective Internal Friction ϕ'(°)	Modulus of Elasticity E_{sh} (MPa)	Poisson Ratio ν
Fill (Unit 1)	17	0	30	8	0.35
Residual Soils (Unit 2)	18	0	33	15	0.35
Class IV-III Sandstone[1] (Unit 3)	24	150	35	100	0.20

[1] - Classification of the rock in accordance with Pells et al (Reference 9).

Table 4 - Preliminary Coefficients of Lateral Earth Pressure

Geotechnical Unit	Coefficient of Active Lateral Earth Pressure (Ka)	Coefficient of Active Lateral Earth Pressure at Rest (Ko)	Coefficient of Passive Lateral Earth Pressure (Kp)
Fill (Unit 1)	0.33	0.50	3.0
Residual Soils (Unit 2)	0.29	0.46	3.4
Class IV–III Sandstone[1] (Unit 3)	0.27	0.43	3.7

[1] - Classification of the rock in accordance with Pells et al (Reference 9).

The coefficients of lateral earth pressure should be verified by the project Structural Engineer for design of retaining walls. Simplified calculations of lateral active (or at rest) and passive earth pressures can be carried out using Rankine's equation shown below:

$Pa = K\,\gamma\,H - 2c\sqrt{K}$ For calculation of Lateral Active or At Rest Earth Pressure

$Pp = K_p\,\gamma\,H + 2c\sqrt{K_p}$ For calculation of Passive Earth Pressure

Where:

P_a = Active (or at rest) Earth Pressure (kN/m^2)
P_p = Passive Earth Pressure (kN/m^2)
γ = Bulk density (kN/m^3)
K = Coefficient of Earth Pressure (K_a or K_o)
Kp = Coefficient of Passive Earth Pressure
H = Retained height (m)
c = Effective Cohesion (kN/m^2)

For design of rock bolts/soils nails or anchors, an allowable bond stress of 100kPa and 200kPa can be adopted for Class IV Sandstone(Unit 3a) and Class III Sandstone(Unit 3b), respectively. The following is recommended for the anchor design:

- Anchor bond length of at least 3m behind the "active" zone of the excavation;
- Overall stability of anchor system and interaction is satisfactory; and
- The anchors are proof loaded to at least 1.3 times the design working load before locking off at working load.

6.6 Foundations

Based on the information provided on the proposed works and ground profile, we assessed that a foundation system consisting of cast-in-situ reinforced concrete shallow foundations, such as pad or strip footings, would be applicable for the proposed new structures, including garage, extension and retaining walls. The footings should be founded within Class IV Sandstone or better rock, with a minimum embedment of 0.3m into sandstone bedrock (instead of a boulder or floater).

Piers/piled foundation can also be adopted in localised areas, such as, an area in vicinity of south-western corner of building, if deep soil occurs during construction excavation.

The preliminary geotechnical parameters recommended for design of shallow and piled foundations are provided in Table 5 below.

Table 5 - Preliminary Geotechnical Foundation Design Parameters

Geotechnical Unit	Allowable Bearing Capacity (kPa[1])	Allowable Shaft Adhesion (kPa)	Modulus of Elasticity Es,v (MPa)
Fill (Unit 1)	N/A[2]	N/A[2]	10
Residual Soils (Unit 2)	N/A[2]	N/A[2]	20
Class IV Sandstone (Unit 3)	1000 (shallow footings) 1500 (piles)	80	200

[1] With a minimum embedment depth of 0.3m for shallow foundations and 0.5m for piled foundation.
[2] N/A, Not Applicable, not recommended for this development at this site.

Design of shallow and piled foundations should be carried out in accordance with Australian Standards AS2870(Reference 2) and AS2159(Reference 3).

To minimise the potential effects of differential settlement under the buildings loads, it is recommended all foundations of the proposed building should be founded on consistent materials of similar properties or rock of similar class.

Any water, debris, loose and wet materials should be removed from excavated footing areas prior to pouring of concrete.

An experienced Geotechnical Engineer should be engaged to inspect footing excavations to ensure foundation bases have suitable materials with adequate bearing capacity, and to check the adequacy of footing embedment depth. Verification of embedment depth, founding material and bearing capacity of foundation material by inspections would be required and inspections should constitute as "Hold Points".

6.7 Vibration Control Measures

Induced vibrations in structures adjacent to the excavation should not exceed a Peak Particle Velocity (PPV) of 10mm/sec for brick or unreinforced structures in good condition, 5mm/sec for residential and low rise buildings or 2mm/sec for historical or structures in sensitive conditions.

For excavation in rock and/or boulders, the plant/equipment selection will depend on the proximity of neighbouring structures and their susceptibility to damage caused by vibration induced by excavation plant. In order to control vibrations to an acceptable limit, we recommend that small to medium rock hammers would be feasible in consideration of rock strength at this site and proximity to the adjoining buildings and infrastructure.

The propagation of vibrations at a site will depend on the plant used and the ground conditions, construction activities, and type of foundations of the structure receiving the vibrations. The ground conditions, including type of soils and rocks, unit thickness, rock strength and defects, and groundwater condition, are unique for each site.

It should be noted that buffer distances for rock hammer may be reduced appreciably by application of prior saw cutting along excavation near site boundaries.

To ensure vibration levels remain within acceptable levels and minimise the potential effects of vibration, **excavation into Class IV Sandstone to Class III Sandstone should be carried out in a controlled & careful manner, and complemented with saw cutting or other appropriate methods prior to excavation.** Hammering is not recommended and should be avoided. However, if necessary, hammering should be carried out horizontally along bedding planes of (pre-cut) broken rock blocks or boulders where possible with noise levels restricted to acceptable to comfortable limits to adjacent residents.

6.8 Water Seepage/inflow Management

The observations summarised in Section 5.3 indicate minor seepage or inflow may be encountered during construction excavation when an intense and prolonged rainfall event occurs. The potential to occur large amount of inflow/seepage through interface of soils and rocks, and through joints within sandstone during construction is minor.

Nevertheless, it would be prudent at this stage of the design to allow for precautionary drainage measures in the design and construction of retaining walls and structures below or partially below ground surface. Such measures would include the following:

- Strip drains or drainage materials should be installed behind the retaining walls/shotcrete wall (if any).
- Subsoil drain, collection trenches or pipes and pits connected to the building stormwater system.
- Adequate surface drain should be provided in vicinity of footing areas of proposed new structures and existing building.
- Seepage/inflow should be diverted to stormwater system and flowing to any structural footing areas should be avoided.

6.9 Preliminary Assessment on Acid Sulfate Soils (ASS)

Based on groundwater conditions provided in Section 5.3, it is unlikely to encounter groundwater during excavation of proposed works. The proposed works and excavation will not lower the water table or cause drawdown in local groundwater table.

Based on information provided in Section 5.4 and Subclause 6(b) in Clause 6.1 of Manly Local Environmental Plan 2013 (Reference 13), the proposed works are unlikely to lower the water table within Class 5 ASS Land and we assessed that the proposed works are unlikely to have any issues associated with Acid Sulfate Soils (ASS).

6.10 Comments on Earthworks and Material Reuse

The excavated materials from footing excavation are assessed to be generally suitable for landscaping provided they are free of any contaminants. The suitability of the excavated materials for reuse should be subject to satisfying the following criteria:

- The materials should be clean (i.e. free of contaminants, deleterious or organic material), free of inclusions of >75mm in size, high plasticity material be removed

and suitably conditioned to meet the design assumptions where fill material is proposed to be used.

- The materials should satisfy the Australian Standard AS 3798 Guidelines on Earthworks for Commercial and Residential Developments (Reference 4).

As a guidance for fill construction, the following compaction targets can be adopted:

- Moisture content of ±2% of OMC (Optimal Moisture Content);
- Minimum density ratio of 100% of the maximum dry density (MDD) for filling within building/structural foundation areas;
- Minimum density ratio of 98% of MDD for backfilling surrounding pipes within trenches;
- The loose thickness of layer should not exceed 150mm for cohesive soils and 200mm for cohesionless materials; and
- For the driveway/footpath/pavement areas, minimum density ratio of 95% of MDD for general fill and 98% for the subgrade to 0.5m depth.

Design and construction of earthworks should be carried out in accordance with Australian Standard AS 3798-2007 (Reference 4).

6.11 Landslide Risk Assessment and Mitigations

6.11.1 General

Due to presence of steep sloping ground and sandstone cliff or near vertical cuts, and sandstone boulders of variable sizes within the site, slope stability and a landslide risk assessment in accordance with Guidelines by the Australian Geomechanics Society(AGS) (Reference 10) was also completed and included in this report.

During the site investigation, there were no obvious signs of previous, current or incipient instability or landslide within the areas upslope or downslope. The existing slope batters, retaining walls, rock cliff and sandstone boulders are generally in stable conditions without any signs of distressing or past movement.

Some sandstone boulders with variable sizes/diameters were present within the front and rear gardens as indicated on photos attached to Appendix B.

There are no obvious features to indicate if the existing site has potential risk of instability or landslide. Nevertheless, geotechnical investigation and assessment in accordance with

guidelines published by AGS (Reference 10) were carried out for this site in order to demonstrate the proposed development is justified in terms of geotechnical stability.

The AGS recommends the landslide risk of a site be assessed on the basis of the likelihood of a landslide event and the consequences of that event. The guidelines on qualitative measures for the likelihood and consequence of landslides and assumed level of risk are provided in Reference 10.

The stability of the site before, during and after construction of proposed works was preliminarily assessed based on AGS guidelines as provided in the following Sections.

6.11.2 Predevelopment

The stability of a site is generally governed by site factors such as slope angles, properties and depth of soils, strength of sub-surface material, groundwater and surface runoff conditions, drainage, vegetation, potential sliding planes such as interface of rock/soil and large scale defects such as faults within rock formation.

Based on an examination of existing slope and guidelines for landslide risk assessment as set out in the Australian Geomechanics Vol 42 No 1 March 2007, the majority of site in vicinity of the proposed works can be classified as being or close to steep to very steep ground. Stability of existing slopes/cliff/boulders within the site was also assessed. The following potential landslip hazards have been identified for the site:

- Soil creep;
- Instability of existing sandstone block walls;
- Rockfall from cliff and sandstone boulders on surface;
- Earth slump and earth slide; and
- Deep seated and shallow landslide.

The assessed risk levels of the hazards under existing conditions are summarised in Table 6 below. In the assessment, consideration was given to the potential effects of instability on the adjoining properties, in particular those at downhill side, including effects on the land, setback of structures, buildings and occupiers within the adjoining properties and public roads and road users.

Table 6 - Assessed Risk to Property - Predevelopment

Potential Hazard	Qualitative Measures of Likelihood	Qualitative Measures of Consequences to Property	Qualitative Risk Analysis – Level of Risk to Property
Soil creep	D – Unlikely (10^{-4})	3: Medium 20%	Low
Instability of existing block walls	D – Unlikely (10^{-4})	3: Minor 5%	Low
Rockfall from cliff and sandstone boulders on ground surface	C – Possible (10^{-3})	3: Medium 20%	Moderate
Earth slump and earth slide	D – Unlikely (10^{-4})	3: Medium 20%	Low
Deep seated and shallow landslide	E – Rare (10^{-5})	2: Major 60%	Low

The overall slope instability risk of the site under existing conditions is assessed to be **"Low to moderate"** resulting from downslope soil creep, instability of uphill fill, rockfall, earth slump and earth slide, potential deep seated or shallow landslide. According to AGS 2007c, "Low Risk Level" is usually acceptable to regulators where treatment is required to reduce risk to this level, with ongoing maintenance if any.

The annual probability of risk to life for the person most at risk pre-development due to the above listed hazards is assessed to be in the order of 5×10^{-5} to $1x10^{-4}$/annum. The AGS guidelines (Reference 10) recommend tolerable loss of life risk for the person most at risk for the "existing slopes" is 1×10^{-4}/annum.

6.11.3 During and Post-Development

The stability of existing sandstone cuts and sandstone boulders, and construction activities that are anticipated to be carried out for the proposed works on sloping ground or near the sandstone cliff/boulders indicate the potential for "Moderate Risk" impact on the site structures or adjoining properties **if footings of proposed works** (including building structures and retaining walls) **are not adequately embedded into sandstone bedrock** (instead of a boulder or a floater) **and vibration control measures in Section 6.7 not adopted.** Therefore, appropriate measures are required to mitigate against landslide risks should be incorporated into the design and construction.

The mitigation and control measures recommended for the proposed development are summarised in Section 6.11.4 of this report. Provided that the recommendations and design parameters provided in this report, in particular, control measures and recommendations in Section 6.11.4, should be taken into consideration during design, construction and post

construction, the assessed risks related to stability of the site during and after construction of structures associated with the proposed development are summarised in Table 7 below.

Table 7 - Assessed Risk to Property– During & Post-Development[1]

Potential Hazard	Qualitative Measures of Likelihood	Qualitative Measures of Consequences to Property	Qualitative Risk Analysis – Level of Risk to Property
Soil creep	E – Barely credible (10^{-6})	3: Medium 20%	Very low
Rockfall from cliff and sandstone boulders on ground surface	F - Rare (10^{-5})	3: Medium 20%	Low
Earth slump and earth slide	D – Unlikely (10^{-4})	3: Medium 20%	Low
Deep seated and shallow landslide	E – Rare (10^{-5})	2: Major 60%	Low
Instability of footing/retaining walls	D – Unlikely (10^{-4})	3: Medium 20%	Low
Instability of cut/fill and excavation	E – Rare (10^{-5})	3: Minor 5%	Very Low

Note: [1] Probability of failure was assessed based on the adoption of the control measures and recommendations made in Section 6.10.4.

The overall slope instability risk associated with the site post construction of the currently proposed development is assessed to be **"Low"** to **"Very Low"** resulting from activities within the site based on design and construction of the development to be in accordance with our recommendations**.**

The risk to life for the person most at risk post-development due to the above listed hazards is assessed to be in the order of 3×10^{-6}/annum. The AGS guidelines recommend tolerable loss of life risk for the person most at risk for the "new constructed slope/new development" is 1×10^{-5}/annum.

6.11.4 Landslip Mitigation and Control Measures

To reduce the level of risk of instability within this site, the proposed development at this site should be constructed according to the recommendations presented in this report alongside with following provisions:

- The design and construction of the proposed development should be carried out taking into consideration the recommendations, comments and parameters provided in this report.
- Footings for the proposed extension, garage, underpinning work and retaining walls, should be keyed into sandstone (instead of floaters or boulders) adequately designed to reduce the risk of instability. A minimum embedment depth of 0.3m for shallow footings and 0.5m for piled foundation is recommended. Suitable founding

material should be Class IV Sandstone or better bedrock (instead of floaters or boulders) and the verification by an experienced Geotechnical Engineer is required during footing excavation.

- The unstable rock and boulders on ground surface should be either stabilised or removed after an assessment by Project Geotechnical Engineer.
- All cut/fill during construction should be shored or retained in accordance with our recommendations provided in Sections 6.4 and 6.5.
- An experienced Geotechnical Engineer should be engaged to inspect foundation excavations to ensure shoring measures are appropriate and foundation bases have suitable materials with adequate bearing capacity and embedment depth. Verification of the founding material, embedment depth and bearing capacity of shallow or pile foundations by inspections would be required.
- No surcharge is allowed to impose inside a buffer zone of minimum 3.0m on top of the existing retaining walls or new cut slopes during construction or otherwise to be assessed by an experienced Geotechnical Engineer on site;
- Inspection and maintenance of retaining walls, batter slopes and drainage system should be carried out periodically.
- The design and construction works should be carried out in accordance with AGS guidelines for hillside construction as included in Appendix E.
- Construction activities should be carefully planned and be observed by an experienced Geotechnical Engineer familiar with content of this report for further assessment of the necessary mitigation and control measures.
- Implementation of the above measures should constitute as “Hold Points”.

Provided that the above provisions and recommendations in this report are taken into consideration during design and construction, the level of risk of the overall site instability due to proposed development can be considered to be low and reduced to normally acceptable levels.

7. CONCLUSIONS AND RECOMMENDATIONS

- The results of geotechnical investigation and assessment indicate the ground conditions at this site are suitable for the proposed alterations and additions.
- The site is assessed to be Class “P” in accordance with AS2870 due to presence of thick fill, steep ground, sandstone cliff/boulders with potential landslip risk.
- The assessment on existing footings is provided in Section 6.2. It is necessary to carry out further check existing footing conditions at more locations in vicinity of south-western corner(in particular along western and southern external walls) to

confirm our conclusion when the excavation equipment and other resources become available on site at early stage of construction.

- The potential landslide risk can be reduced to acceptable levels if our recommendations in Section 6.11.4 and guidelines for hillside construction as per AGS 2007 are adopted.
- A footing system consisting of cast-in-situ reinforced concrete shallow foundations, such as pad or strip footings, would be applicable for the proposed development at this site. The suitable founding material is Class IV Sandstone (Unit 3a) or better rock (instead of a boulder or a floater). We recommend a minimum embedment depth of 0.3m into underlying Class IV Sandstone or better rock for shallow footings should be adopted for all new structures or underpinning works.
- Any structure footings on top of or at bottom of a cliff/boulder or steep slope should be assessed by project Geotechnical Engineer for stability and additional measures.
- The construction, including filling, excavation, safe batter/support, vibration control measures, landslide mitigation measures, seepage/inflow management, and drainage works, should be implemented in accordance with the recommendations provided in Section 6.
- P{reliminary assessment indicates the proposed works are unlikely to have Acid Sulfate Soils (ASS) issue.
- It is recommended that an experienced Geotechnical Engineer should be engaged to inspect footing excavations to ensure the foundation base have been taken to suitable materials of appropriate bearing capacity and adequate embedment depth.
- It is recommended the final civil and structural design drawings for the proposed development should be provided to us for further assessment and confirmation of suitable mitigation measures on landslip risks, foundation system and embedment depth, retaining walls and drainage systems.

8. LIMITATIONS

This report should be read in conjunction with the "Limitations of Geotechnical Investigation Statement" attached as Appendix F, which provides important information regarding geotechnical investigation, assessment and reporting. If the actual subsurface conditions exposed during construction vary significantly from those discussed in this report, this report should be reviewed, and the undersigned should be contacted immediately for an inspection and further advices.

For and on behalf of

ESWNMAN Pty Ltd

Jiameng Li
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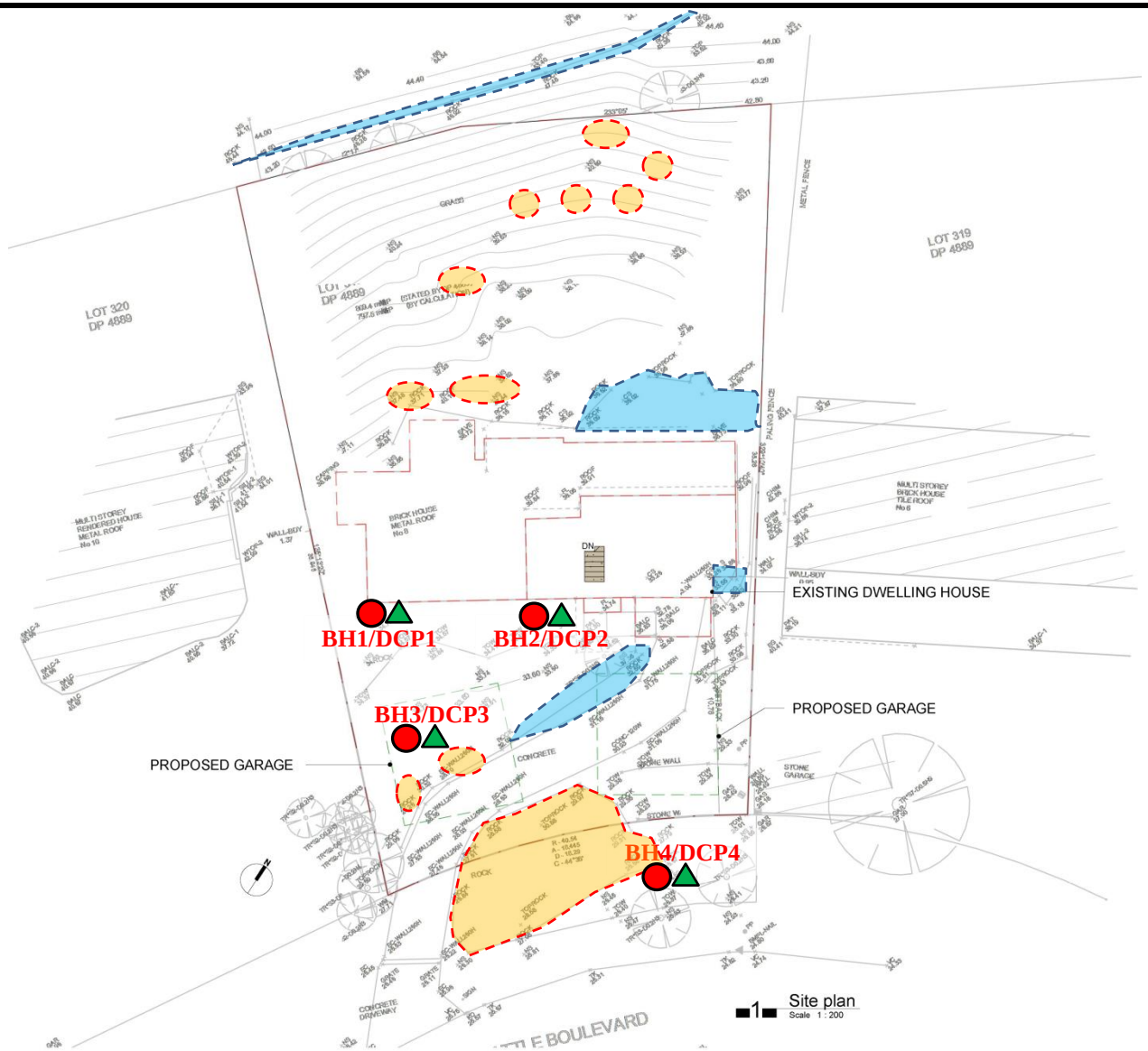
ESWNMAN
25 YEARS EXPERIENCE

APPENDIX A

SITE LOCATION PLAN



LEGEND

- Approximate Location of Borehole (BH)
- Approximate Location of Dynamic Cone Penetrometer (DCP) Test
- Approximate Location of Sandstone Outcrops
- Area with some sandstone boulders

Image source: An architectural drawing titled "Site Plan, Proposed Alterations & Additions to Existing Dwelling, No. 8 Battle Boulevard, Seaforth, NSW 2092, Lot 319 in DP4889" prepared by HR Building Design.

PROJECT: 8 Battle Boulevard, Seaforth, NSW 2092	**DRAWN BY:** J.L.	ESWNMAN 25 YEARS EXPERIENCE	**CLIENT:** Mr Dylan Fan
PROJECT NO: ESWN-PR-2019-423	**DATE:** 7th August 2019		**TITLE:** Site Location Plan — FIGURE 1

APPENDIX B

SITE PHOTOGRAPHS

		
Photograph 1 Sandstone outcrop along concrete path within front portion	**Photograph 2** Sandstone exposed at front corner of existing building	**Photograph 3** Sandstone outcrops in vicinity of north-eastern corner of existing building
		
Photograph 4 Sandstone cliff in vicinity of site rear boundary facing north	**Photograph 5** Sandstone boulders present within front yard	**Photograph 6** Sandstone boulder adjacent to the rear of north-western corner of existing building

Appendix B Site Photographs (1 of 2)

		
Photograph 7 Sandstone boulder at northern side of existing concrete path within front portion	**Photograph 8** Sandstone block wall at rear of the site	**Photograph 9** Test pit excavated at location of BH1 adjacent to south-western corner of existing building
		
Photograph 10 Dynamic Cone Penetrometer(DCP) Test at location of BH1/DCP1	**Photograph 11** DCP test at location of DCP2 in front of existing building	**Photograph 12** DCP test at location of DCP4 within front yard

Appendix B Site Photographs (2 of 2)

APPENDIX C

ENGINGGERING BOREHOLE LOGS AND EXPLANATORY NOTES

BOREHOLE NUMBER BH1

ESWNMAN 25 YEARS EXPERIENCE
ESWNMAN Pty Ltd
PO Box 6, Ashfield, NSW 1800
Telephone: 02-79015582

CLIENT Mr Dylan Fan **PROJECT NAME** Geotechnical Investigation

PROJECT NUMBER ESWN-PR-2019-423 **PROJECT LOCATION** 8 Battle Boulevard, Seaforth, NSW

DATE STARTED 6/8/19 **COMPLETED** 6/8/19 **R.L. SURFACE** 34.8 **DATUM** m AHD

DRILLING CONTRACTOR ESWNMAN Pty Ltd **SLOPE** 90° **BEARING** ---

EQUIPMENT Hand Auger & DCP Test **HOLE LOCATION** Refer to Figure 1 Site Location Plan

HOLE SIZE 70mm **LOGGED BY** Y.N. **CHECKED BY** J.L.

NOTES South-western corner of existing building

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Additional Observations
HA	Not Encountered	34.5	0.5		SC	Gravelly SAND, medium grained, brown, some clay, moist.		FILL
		34.0	1.0		SC	Clayey SAND, medium grained, brown, moist, medium dense.		RESIDUAL SOILS
		33.5						DCP test indicates top of rock at 1.4m depth
		33.0	1.5			Borehole BH1 terminated at 1.4m		
			2.0					

BOREHOLE NUMBER BH2

ESWNMAN Pty Ltd
PO Box 6, Ashfield, NSW 1800
Telephone: 02-79015582

CLIENT Mr Dylan Fan **PROJECT NAME** Geotechnical Investigation

PROJECT NUMBER ESWN-PR-2019-423 **PROJECT LOCATION** 8 Battle Boulevard, Seaforth, NSW

DATE STARTED 6/8/19 **COMPLETED** 6/8/19 **R.L. SURFACE** 34.7 **DATUM** m AHD

DRILLING CONTRACTOR ESWNMAN Pty Ltd **SLOPE** 90° **BEARING** ---

EQUIPMENT Hand Auger & DCP Test **HOLE LOCATION** Refer to Figure 1 Site Location Plan

HOLE SIZE 70mm **LOGGED BY** Y.N. **CHECKED BY** J.L.

NOTES Grassed area adjacent to front wall

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Additional Observations
HA	Not Encountered	34.5	0.0		SC	SAND, medium grained, brown, some clay, moist, loose to very loose.		FILL
		34.0	0.5					
			1.0			- encountered sandstone gravel at 1.3m depth		
		33.5			SC	Clayey SAND, medium grained, brown, moist, medium dense.		RESIDUAL SOILS
		33.0	1.5					DCP test indicates top of rock at 1.9m depth
			2.0			Borehole BH2 terminated at 1.8m		

BOREHOLE NUMBER BH3

ESWNMAN Pty Ltd
PO Box 6, Ashfield, NSW 1800
Telephone: 02-79015582

CLIENT Mr Dylan Fan **PROJECT NAME** Geotechnical Investigation

PROJECT NUMBER ESWN-PR-2019-423 **PROJECT LOCATION** 8 Battle Boulevard, Seaforth, NSW

DATE STARTED 6/8/19 **COMPLETED** 6/8/19 **R.L. SURFACE** 33.5 **DATUM** m AHD

DRILLING CONTRACTOR ESWNMAN Pty Ltd **SLOPE** 90° **BEARING** ---

EQUIPMENT Hand Auger & DCP Test **HOLE LOCATION** Refer to Figure 1 Site Location Plan

HOLE SIZE 70mm **LOGGED BY** Y.N. **CHECKED BY** J.L.

NOTES Front yard

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Additional Observations
HA	Not Encountered	33.0	0.5		SC	Gravelly SAND, medium grained, brown, some clay, moist.		FILL
								DCP test indicates top of rock/boulder at 0.9m depth
		32.5	1.0			Borehole BH3 terminated at 0.9m		
		32.0	1.5					
		31.5	2.0					

BOREHOLE NUMBER BH4

ESWNMAN Pty Ltd
PO Box 6, Ashfield, NSW 1800
Telephone: 02-79015582

CLIENT Mr Dylan Fan **PROJECT NAME** Geotechnical Investigation

PROJECT NUMBER ESWN-PR-2019-423 **PROJECT LOCATION** 8 Battle Boulevard, Seaforth, NSW

DATE STARTED 6/8/19 **COMPLETED** 6/8/19 **R.L. SURFACE** 26.6 **DATUM** m AHD

DRILLING CONTRACTOR ESWNMAN Pty Ltd **SLOPE** 90° **BEARING** ---

EQUIPMENT Hand Auger & DCP Test **HOLE LOCATION** Refer to Figure 1 Site Location Plan

HOLE SIZE 70mm **LOGGED BY** Y.N. **CHECKED BY** J.L.

NOTES Front yard

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Additional Observations
HA	Not Encountered	26.5			SC	SAND, medium grained, brown, some clay, moist, some boulders exposed on ground surface in vicinity.		FILL
		26.0	0.5		GP	Sandy GRAVEL, medium grained, brown, some clay, moist.		
		25.5	1.0		SC	Clayey SAND, medium grained, brown, moist, medium dense to dense.		RESIDUAL SOILS
		25.0	1.5					DCP test indicates top of rock at 1.8m depth
						Borehole BH4 terminated at 1.7m		
			2.0					

Explanatory Notes – Description for Soil

In engineering terms soil includes every type of uncemented or partially cemented inorganic material found in the ground. In practice, if the material can be remoulded by hand in its field condition or in water it is described as a soil. The dominant soil constituent is given in capital letters, with secondary textures in lower case. The dominant feature is assessed from the Unified Soil Classification system and a soil symbol is used to define a soil layer .

METHOD

Method	Description
AS	Auger Screwing
BH	Backhoe
CT	Cable Tool Rig
EE	Existing Excavation/Cutting
EX	Excavator
HA	Hand Auger
HQ	Diamond Core-63mm
JET	Jetting
NMLC	Diamond Core –52mm
NQ	Diamond Core –47mm
PT	Push Tube
RAB	Rotary Air Blast
RB	Rotary Blade
RT	Rotary Tricone Bit
TC	Auger TC Bit
V	Auger V Bit
WB	Washbore
DT	Diatube

WATER


Water level at date shown


Partial water loss


Water inflow


Complete water loss

NFGWO: The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

NFGWE: The borehole/test pit was dry soon after excavation. Inflow may have been observed had the borehole/test pit been left open for a longer period.

SAMPLING

Sample	Description
B	Bulk Disturbed Sample
D	Disturbed Sample
Jar	Jar Sample
SPT	Standard Penetration Test
U50	Undisturbed Sample –50mm
U75	Undisturbed Sample –75mm

UNIFIED SOIL CLASSIFICATION

The appropriate symbols are selected on the result of visual examination, field tests and available laboratory tests, such as, sieve analysis, liquid limit and plasticity index.

USC Symbol	Description
GW	Well graded gravel
GP	Poorly graded gravel
GM	Silty gravel
GC	Clayey gravel
SW	Well graded sand
SP	Poorly graded sand
SM	Silty sand
SC	Clayey sand
ML	Silt of low plasticity
CL	Clay of low plasticity
OL	Organic soil of low plasticity
MH	Silt of high plasticity
CH	Clay of high plasticity
OH	Organic soil of high plasticity
Pt	Peaty Soil

MOISTURE CONDITION

Dry - Cohesive soils are friable or powdery
Cohesionless soil grains are free-running

Moist - Soil feels cool, darkened in colour
Cohesive soils can be moulded
Cohesionless soil grains tend to adhere

Wet - Cohesive soils usually weakened
Free water forms on hands when handling

For cohesive soils the following codes may also be used:

MC>PL Moisture Content greater than the Plastic Limit.
MC~PL Moisture Content near the Plastic Limit.
MC<PL Moisture Content less than the Plastic Limit.

PLASTICITY

The potential for soil to undergo change in volume with moisture change is assessed from its degree of plasticity. The classification of the degree of plasticity in terms of the Liquid Limit (LL) is as follows:

Description of Plasticity	LL (%)
Low	<35
Medium	35 to 50
High	>50

COHESIVE SOILS - CONSISTENCY

The consistency of a cohesive soil is defined by descriptive terminology such as very soft, soft, firm, stiff, very stiff and hard. These terms are assessed by the shear strength of the soil as observed visually, by hand penetrometer values and by resistance to deformation to hand moulding.

A Hand Penetrometer may be used in the field or the laboratory to provide an approximate assessment of the unconfined compressive strength (UCS) of cohesive soils. The undrained shear strength of cohesive soils is approximately half the UCS. The values are recorded in kPa as follows:

Strength	Symbol	Undrained Shear Strength, C_u (kPa)
Very Soft	VS	< 12
Soft	S	12 to 25
Firm	F	25 to 50
Stiff	St	50 to 100
Very Stiff	VSt	100 to 200
Hard	H	> 200

COHESIONLESS SOILS - RELATIVE DENSITY

Relative density terms such as very loose, loose, medium, dense and very dense are used to describe silty and sandy material, and these are usually based on resistance to drilling penetration or the Standard Penetration Test (SPT) 'N' values. Other condition terms, such as friable, powdery or crumbly may also be used.

Term	Symbol	Density Index	N Value (blows/0.3 m)
Very Loose	VL	0 to 15	0 to 4
Loose	L	15 to 35	4 to 10
Medium Dense	MD	35 to 65	10 to 30
Dense	D	65 to 85	30 to 50
Very Dense	VD	>85	>50

COHESIONLESS SOILS PARTICLE SIZE DESCRIPTIVE TERMS

Name	Subdivision	Size
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 µm to 2.36 mm
	medium	200 µm to 600 µm
	fine	75 µm to 200 µm

Description for Rock

The rock is described with strength and weathering symbols as shown below. Other features such as bedding and dip angle are given.

METHOD

Refer soil description sheet

WATER

Refer soil description sheet

ROCK QUALITY

The fracture spacing is shown where applicable and the Rock Quality Designation (RQD) or Total Core Recovery (TCR) is given where:

$$TCR\ (\%) = \frac{\text{length of core recovered}}{\text{length of core run}}$$

$$RQD\ (\%) = \frac{\text{Sum of Axial lengths of core > 100mm long}}{\text{length of core run}}$$

ROCK MATERIAL WEATHERING

Rock weathering is described using the abbreviations and definitions used in AS1726. AS1726 suggests the term "Distinctly Weathered" (DW) to cover the range of substance weathering conditions between (but not including) XW and SW. For projects where it is not practical to delineate between HW and MW or it is deemed that there is no advantage in making such a distinction, DW may be used with the definition given in AS1726.

Symbol	Term	Definition
RS	Residual Soil	Soil definition on extremely weathered rock; the mass structure and substance are no longer evident; there is a large change in volume but the soil has not been significantly transported
XW	Extremely Weathered	Rock is weathered to such an extent that it has 'soil' properties, ie. It either disintegrates or can be remoulded in water
HW	Highly Weathered	The rock substance is affected by weathering to the extent that limonite staining or bleaching affects the whole rock substance and other signs of chemical or physical decomposition are evident. Porosity and strength is usually decreased compared to the fresh rock. The colour and strength of the fresh rock is no longer recognisable.
DW	*Distinctly Weathered (see AS1726 Definition below)*	
MW	Moderately Weathered	The whole of the rock substance is discoloured, usually by iron staining or bleaching, to the extent that the colour of the fresh rock is no longer recognisable
SW	Slightly Weathered	Rock is slightly discoloured but shows little or no change of strength from fresh rock
FR	Fresh	Rock shows no sign of decomposition or staining

"Distinctly Weathered: Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to the deposition of weathering products in pores." (AS1726)

ROCK STRENGTH

Rock strength is described using AS1726 and ISRM - Commission on Standardisation of Laboratory and Field Tests, "Suggested method of determining the Uniaxial Compressive Strength of Rock materials and the Point Load Index", as follows:

Term	Symbol	Point Load Index $Is_{(50)}$ (MPa)
Extremely Low	EL	<0.03
Very Low	VL	0.03 to 0.1
Low	L	0.1 to 0.3
Medium	M	0.3 to 1
High	H	1 to 3
Very High	VH	3 to 10
Extremely High	EH	>10

● Diametral Point Load Index test

■ Axial Point Load Index test

DEFECT SPACING/BEDDING THICKNESS

Measured at right angles to defects of same set or bedding.

Term	Defect Spacing	Bedding
Extremely closely spaced	<6 mm	Thinly Laminated
	6 to 20 mm	Laminated
Very closely spaced	20 to 60 mm	Very Thin
Closely spaced	0.06 to 0.2 m	Thin
Moderately widely spaced	0.2 to 0.6 m	Medium
Widely spaced	0.6 to 2 m	Thick
Very widely spaced	>2 m	Very Thick

DEFECT DESCRIPTION

Type:	Definition:
B	Bedding
BP	Bedding Parting
F	Fault
C	Cleavage
J	Joint
SZ	Shear Zone
CZ	Crushed Zone
DB	Drill Break

Planarity:	Roughness:
P – Planar	R – Rough
Ir – Irregular	S – Smooth
St – Stepped	Sl – Slickensides
U – Undulating	Po – Polished

Coating or Infill:	Description
Clean	No visible coating or infilling
Stain	No visible coating or infilling but surfaces are discoloured by mineral staining
Veneer	A visible coating or infilling of soil or mineral substance but usually unable to be measured (<1mm). If discontinuous over the plane, patchy veneer
Coating	A visible coating or infilling of soil or mineral substance, >1mm thick. Describe composition and thickness

The inclinations of defects are measured from perpendicular to the core axis.

Graphic Symbols for Soil and Rock

Graphic symbols used on borehole and test pit reports for soil and rock are as follows. Combinations of these symbols may be used to indicate mixed materials such as clayey sand.

Soil Symbols

Main Components


CLAY


SILT


SAND


GRAVEL


BOULDERS / COBBLES


PEAT (Organic)

Minor Components


Clayey


Silty


Sandy


Gravelly

Other Symbols


TOPSOIL


FILL


ASPHALT


CONCRETE


NO CORE

Rock Symbols

Sedimentary Rocks


SANDSTONE


SILTSTONE


CLAYSTONE, MUDSTONE


SHALE


LAMINITE


CONGLOMERATE


BRECCIA


TILL


COAL


LIMESTONE

Igneous Rocks


PLUTONIC IGNEOUS (eg: Granite)


VOLCANIC IGNEOUS (eg: Basalt)


PYROCLASTIC IGNEOUS (eg: Ignimbrite)

Metamorphic Rocks


SLATE, PHYLLITE, SCHIST


GNEISS


QUARTZITE

Engineering classification of shales and sandstones in the Sydney Region - A summary guide

The Sydney Rock Class classification system is based on rock strength, defect spacing and allowable seams as set out below. All three factors must be satisfied.

CLASSIFICATION FOR SANDSTONE

Class	Uniaxial Compressive Strength (MPa)	Defect Spacing (mm)	Allowable Seams (%)
I	>24	>600	<1.5
II	>12	>600	<3
III	>7	>200	<5
IV	>2	>60	<10
V	>1	N.A.	N.A.

CLASSIFICATION FOR SHALE

Class	Uniaxial Compressive Strength (MPa)	Defect Spacing (mm)	Allowable Seams (%)
I	>16	>600	<2
II	>7	>200	<4
III	>2	>60	<8
IV	>1	>20	<25
V	>1	N.A.	N.A.

1. ROCK STRENGTH

For expedience in field/construction situations the uniaxial (unconfined) compressive strength of the rock is often inferred, or assessed using the point load strength index (Is_{50}) test (AS 4133.4.1 - 1993). For Sydney Basin sedimentary rocks the uniaxial compressive strength is typically about 20 x (Is_{50}) but the multiplier may range from about 10 to 30 depending on the rock type and characteristics. In the absence of UCS tests, the assigned Sydney Rock Class classification may therefore include rock strengths outside the nominated UCS range.

2. DEFECT SPACING

The terms relate to spacing of natural fractures in NMLC, NQ and HQ diamond drill cores and have the following definitions:

Defect Spacing (mm)	Terms Used to Describe Defect Spacing[1]
>2000	Very widely spaced
600 – 2000	Widely spaced
200 – 600	Moderately spaced
60 – 200	Closely spaced
20 – 60	Very closely spaced
<20	Extremely closely spaced

[1]After ISO/CD14689 and ISRM.

3. ALLOWABLE SEAMS

Seams include clay, fragmented, highly weathered or similar zones, usually sub-parallel to the loaded surface. The limits suggested in the tables relate to a defined zone of influence. For pad footings, the zone of influence is defined as 1.5 times the least footing dimension. For socketed footings, the zone includes the length of the socket plus a further depth equal to the width of the footing. For tunnel or excavation assessment purposes the defects are assessed over a length of core of similar characteristics.

Source: Based on Pells, P.J.N, Mostyn, G. and Walker, B.F. (1998) – Foundations on sandstone and shale in the Sydney region. Australian Geomechanics Journal, No 33 Part 3

APPENDIX D

RESULTS OF DYNAMIC CONE PENETROMETER(DCP) TEST

RESULTS OF DYNAMIC CONE PENETROMETER TEST

ESWNMAN
25 YEARS EXPERIENCE

Client:	Mr Dylan Fan	Ref No:	ESWN-PR-2019-423
Project:	Geotechnical Investigation	Date Tested:	6/08/2019
Location:	8 Battle Boulevard, Seaforth, NSW	Tested By:	Y.N./J.L.

Depth (mm)	DCP No.				Depth (mm)	DCP No.			
	DCP1	DCP2	DCP3	DCP4		5	6	7	8
0-100	0	0	0	0	0-100				
100-200	0	1	1	0	100-200				
200-300	1	1	2	2	200-300				
300-400	2	1	3	2	300-400				
400-500	3	1	6	3	400-500				
500-600	3	1	3	2	500-600				
600-700	1	1	2	2	600-700				
700-800	1	1	3	2	700-800				
800-900	2	1	4	3	800-900				
900-1000	1	1	Bounce	9	900-1000				
1000-1100	2	1		9	1000-1100				
1100-1200	3	5		14	1100-1200				
1200-1300	4	7		5	1200-1300				
1300-1400	12	5		6	1300-1400				
1400-1500	Bounce	2		5	1400-1500				
1500-1600		2		4	1500-1600				
1600-1700		4		10	1600-1700				
1700-1800		4		12/40mm	1700-1800				
1800-1900		6/20mm		Bounce	1800-1900				
1900-2000		Bounce			1900-2000				
2000-2100					2000-2100				
2100-2200					2100-2200				
2200-2300					2200-2300				
2300-2400					2300-2400				
2400-2500					2400-2500				
2500-2600					2500-2600				
2600-2700					2600-2700				
2700-2800					2700-2800				
2800-2900					2800-2900				
2900-3000					2900-3000				
3000-3100					3000-3100				
3100-3200					3100-3200				
3200-3300					3200-3300				
3300-3400					3300-3400				
3400-3500					3400-3500				
3500-3600					3500-3600				
3600-3700					3600-3700				
3700-3800					3700-3800				
RL (m, AHD)	34.8	34.7	33.5	26.6	RL (m, AHD)				

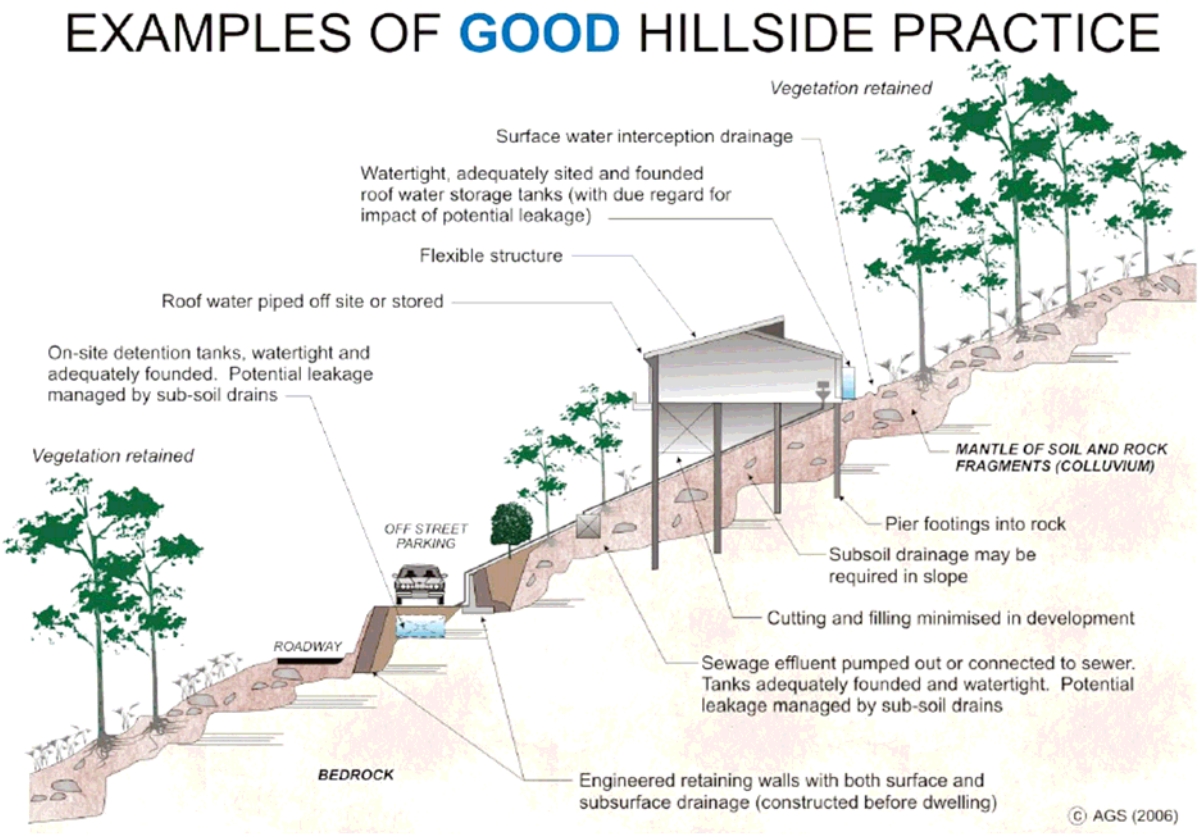
Notes:
DCP testing equipment designed and conducted in accordance with AS1289.6.3.2

APPENDIX E

SOME AGS GUIDELINES FOR HILLSIDE CONSTRUCTION

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	


EXAMPLES OF GOOD HILLSIDE PRACTICE
Vegetation retained
Surface water interception drainage
Watertight, adequately sited and founded roof water storage tanks (with due regard for impact of potential leakage)
Flexible structure
Roof water piped off site or stored
On-site detention tanks, watertight and adequately founded. Potential leakage managed by sub-soil drains
Vegetation retained
MANTLE OF SOIL AND ROCK FRAGMENTS (COLLUVIUM)
OFF STREET PARKING
Pier footings into rock
Subsoil drainage may be required in slope
Cutting and filling minimised in development
ROADWAY
Sewage effluent pumped out or connected to sewer. Tanks adequately founded and watertight. Potential leakage managed by sub-soil drains
BEDROCK
Engineered retaining walls with both surface and subsurface drainage (constructed before dwelling)
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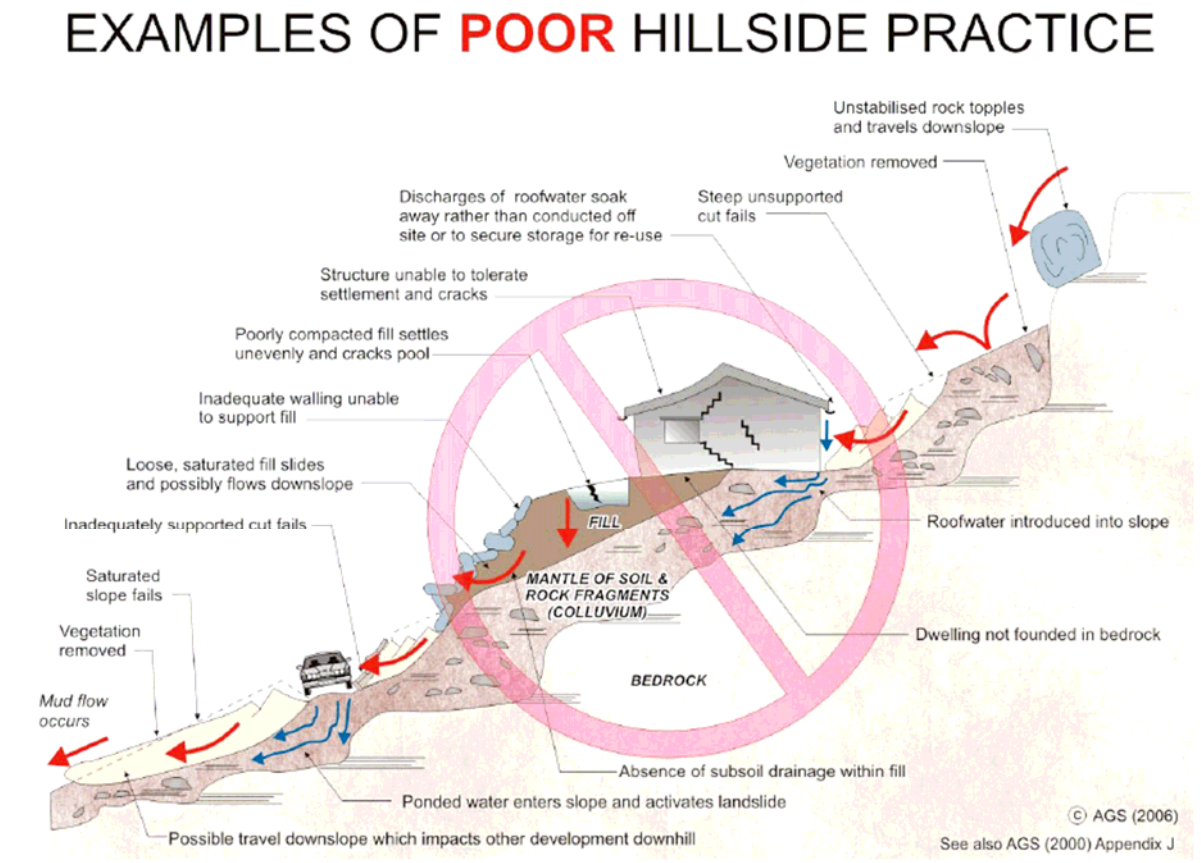
EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Loose, saturated fill slides and possibly flows downslope
Inadequately supported cut fails
FILL
Roofwater introduced into slope
Saturated slope fails
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Vegetation removed
Dwelling not founded in bedrock
BEDROCK
Mud flow occurs
Absence of subsoil drainage within fill
Ponded water enters slope and activates landslide
Possible travel downslope which impacts other development downhill
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See also AGS (2000) Appendix J

APPENDIX F

LIMITATIONS OF GEOTECHNICAL INVESTIGATION

General

In making an assessment of a site from a limited number of boreholes or test pits there is the possibility that variations may occur between testing locations. Site exploration identifies specific subsurface conditions only at those points from which samples have been taken. The risk that variations will not be detected can be reduced by increasing the frequency of testing locations. The investigation program undertaken is a professional estimate of the scope of investigation required to provide a general profile of the subsurface conditions. The data derived from the site investigation program and subsequent laboratory testing are extrapolated across the site to form an inferred geological model and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour with regard to the proposed development. Despite investigation the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies.

The borehole/test pit logs are the subjective interpretation of subsurface conditions at a particular location, made by trained personnel. The interpretation may be limited by the method of investigation, and cannot always be definitive.

Subsurface conditions

Subsurface conditions may be modified by changing natural forces or man-made influences. A geotechnical report is based on conditions which existed at the time of subsurface exploration.

Construction operations at or adjacent to the site, and natural events such as rainfall events, floods, or groundwater fluctuations, may also affect subsurface conditions, and thus the continuing adequacy of a geotechnical report. The geotechnical engineer should be kept appraised of any such events, and should be consulted to determine if additional tests are necessary.

Assessment and interpretation

A geotechnical engineer should be retained to work with other appropriate design professionals explaining relevant geotechnical findings and in reviewing the adequacy of their drawings/plans and specifications relative to geotechnical issues.

Information and documentations

Final logs are developed by geotechnical engineers based upon their interpretation of field description and laboratory results of field samples. Customarily, only the final logs are included in geotechnical engineering reports. These logs should not under any circumstances be redrawn for inclusion in architectural or other design drawings. To minimise the likelihood of bore/profile log misinterpretation, contractors should be given access to the complete geotechnical engineering report prepared or authorised for their use. Providing the best available information to contractors helps prevent costly construction problems.

Construction phase service (CPS)

During construction, excavation is frequently undertaken which exposes the actual subsurface conditions. For this reason geotechnical consultants should be retained through the construction stage, to identify variations if they are exposed and to conduct additional tests which may be required and to deal quickly with geotechnical problems if they arise.

Report

The report has been prepared for the benefit of the client and no other parties. ESWNMAN PTY LTD assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of ESWNMAN PTY LTD or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

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ESWNMAN PTY LTD will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.