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PRELIMINARY GEOTECHNICAL INVESTIGATION AND LANDSLIDE RISK ASSESSMENT

For

173 SEAFORTH CRESCENT, SEAFORTH NSW 2092

PREPARED FOR: Titus Theseira

REFERENCE: REF-18-6460-A

DATE: 17th August 2018

CONTROLLED DOCUMENT

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Table Of Contents

List Of Figures

List Of Tables

Appendices

1. INTRODUCTION

Envirotech Pty Ltd was commissioned by Titus Theseira to undertake a Preliminary Geotechnical Investigation and Landslide Risk Assessment for the proposed alterations and additions to 173 Seaforth Crescent, Seaforth NSW

1.1 Overview

The objectives of the investigation were to provide information on the surface and subsurface conditions, local geology, and to deliver geotechnical guidance and recommendations relating to the suitability of the site for the proposed scope of works. This report also evaluates the effect of the proposed development on the stability of the site including risk to property and life.

1.2 Proposed Development

Details of development are as follows;

- New extension to existing residence;
- Construction of a new balcony, foyer, porch and covered walkway;
- Proposed suspended driveway; and
- New garage.

1.3 Scope of Works

The scope of works comprised the following;

- Review of available reports and geological maps held within our files;
- Walkover observations of the site;
- Assessment of the existing site conditions and local geology;
- Drilling of two (2) boreholes utilising mechanical hand auger at accessible locations;
- Insitu Dynamic Cone Penetrometer (DCP) testing at borehole locations;
- Engineering logs;
- Engineering assessment and recommendations; and
- Geotechnical slope risk assessment.

1.4 Legislative Requirements

This assessment has been prepared in general accordance with the following guidelines and standards;

- Australian Standard 1726 (2017) Geotechnical site investigations;
- Australian Standard 2159 (2009) Piling –Design and installation;
- Australian Standard 2870 (2011) Residential slabs and footings;
- Australian Standard 3798 (2007) Guidelines on earthworks for commercial and residential developments;
- Australian Standard 4678 (2002) Earth-retaining structures and;
- Australian Standard 1170.4-2007 'Structural design actions. Part 4: Earthquake actions in Australia'.
- Landslide Risk Management (Australian Geomechanics Society, 2007)

1.5 Context of Report

This report is to be read in its entirety and individual sections should not be reviewed to provide any level of information independently. Each section of the report relates to the rest of the document and as such is to be read in conjunction, including its appendices and attachments. Particular attention is drawn to the limitations of inherent site investigation and the importance of verifying the subsurface conditions inferred herein.

2. DESKTOP STUDY

A range of online resources in conjunction with Envirotech desktop files were accessed for the desktop study. Appendix B displays the soil landscape notes for the location. Appendix C displays the maps for the desktop study.

2.1 Primary Soil Landscapes

Undulating to rolling rises and low hills and Hawkesbury Sandstone. Local relief 20 – 120m, slopes 20%. Rock outcrop >50%. Broad ridges, gently to moderately inclined slopes, wide rock benches with low broken scarps, small hanging valleys and areas of poor drainage. Open and closed-heathland, scrub and occasional low eucalypt open-woodland.

2.2 Dominant Soil Materials

Topsoil consists of loose, stony, yellowish-brown sandy loam or blackish-brown loose sandy loam. Subsoil consists of yellow-brown, light sandy clay loam with apedal massive to weakly pedal structure and porous earthy fabric. Deep subsoil consists of fine sandy clay loam and medium angular blocky puggy clays. The underlying earthy, mottled, pale clayey sands overly soft friable deeply weathered pale yellow to orange sandstones which become sandier with depth. Figure 1 displays a typical soil profile within the site location.

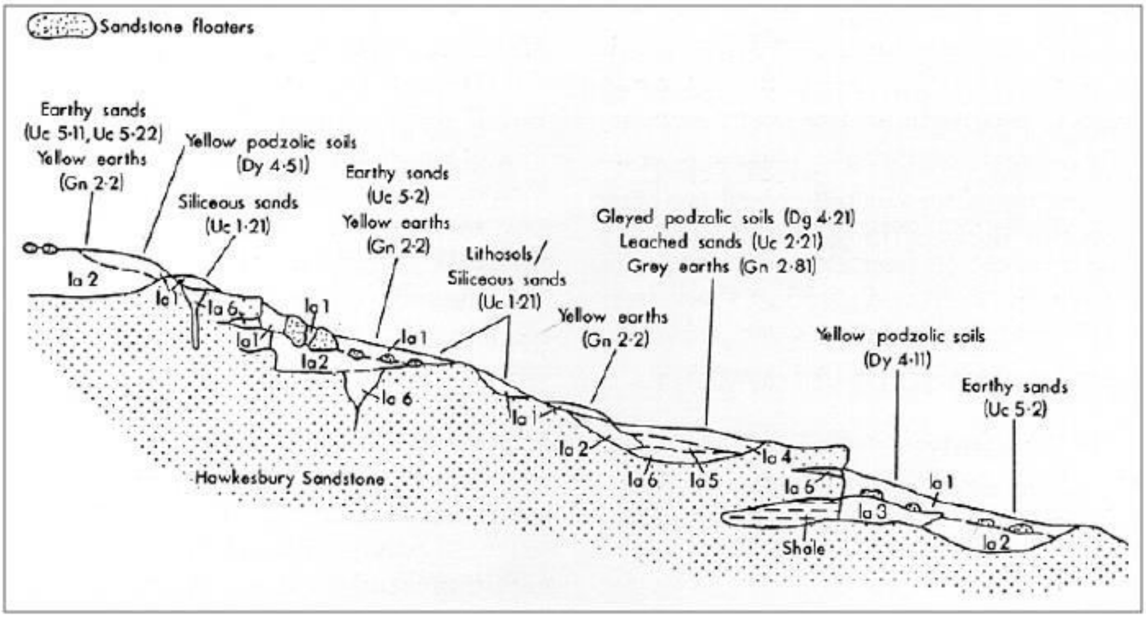


Figure 1 Soil Landscape Illustrating the Dominant Soil Profiles

2.3 Acid Sulphate Soil Map

With reference to Manly Local Environmental Plan 2013 Acid Sulphate Soils Map – Sheet CL1_002 the site is classified as **Class 5**.

2.4 Heritage map

With reference to Manly Local Environmental Plan 2013 Heritage Map – Sheet HER_002 the site is **not** listed as historical.

2.5 Land Zoning Map

With reference to Manly Local Environmental Plan 2013 Land Zoning Map – Sheet LZN_002 the site is zoned as **E3** Environmental Management.

3. METHODOLOGY

3.1 Fieldwork

A site visit was made on the 9th August 2018 by a geotechnical engineer from Envirotech. A preliminary walkover of the site was conducted during the site visit. The fieldwork consisted of a visual assessment and drilling of two (2) boreholes by mechanical hand auger (due to access restrictions) at accessible locations (rear of property) within the site footprint. No subsurface investigation was undertaken at the front of the property due to access restrictions.

DCP testing was undertaken at the borehole locations. Pocket penetrometer testing was undertaken at selected depths on the undisturbed samples taken from the boreholes.
No sampling was undertaken during the site visit.

Appendix A displays location of boreholes and Insitu testing undertaken.

3.2 Laboratory

No laboratory testing was undertaken for the purpose of this report.

4. Site Description

The site was located at 173 Seaforth Crescent, Seaforth NSW. The site was situated on a moderately steep sloping block (Figure 2). At the time of the site inspection displayed existing dual level residential property with a moderate to steep sloping concrete driveway leading to a basement garage. A raised existing carport resides on the western boundary of the property. An inground swimming pool, terraced (retained) landscaped garden areas and paved courtyards are present at the rear of the property. An existing inclinator featured along the western side of the property.

Figure 2 Site Location

4.1 Geology

With reference to the Sydney 1:100,000 Geological Series Sheet 9130 Edition 1 (1983) the site forms part of the Wianamatta Group displaying medium to coarse-grained quartz sandstone, very minor shale and laminate lenses.

4.2 Subsurface Conditions

A summary of the subsurface strata is presented in the following tables;

Table 1 A Summary of Subsurface Profile (BH01)

Depth (m)	Material Description
0.00 – 0.40	FILL: TOPSOIL; Admixed sand and gravel, grey to dark-grey, organics (roots), fine to coarse sand and gravel, slightly moist
0.40 – 1.10 (LOI)	FILL: Clayey SAND; orange-brown becoming increasingly orange, low plasticity, organics (roots), fine to medium sands, slightly moist to moist, moisture content < plastic limit

Note: LOI – Limit of Investigation

Table 2 A Summary of Subsurface Profile (BH02)

Depth (m)	Material Description
0.00 – 0.40	FILL: TOPSOIL; Admixed sand and gravel, grey to dark-grey, organics (roots), fine to coarse sand and gravel, slightly moist
0.40 – 0.70	FILL: Clayey SAND; orange, low plasticity, organics (roots), fine to medium sands, slightly moist to moist, moisture content < plastic limit
0.70 – 1.10 (LOI)	FILL: SAND; brown, low plasticity, trace organics (roots), fine to medium sands, trace coarse gravels up to 20mm, slightly moist to moist, moisture content < plastic limit

Note: LOI – Limit of Investigation

Appendix E displays results of detailed logs. Appendix F details the Insitu DCP results.

The following figures present the undisturbed recovered material from the boreholes;

Figure 3 Undisturbed Borehole Sample (BH01)

Figure 4 Undisturbed Borehole Sample (BH02)

5. Laboratory results

No laboratory testing was undertaken for the purpose of this report.

6. Groundwater

No groundwater was observed within the drilled boreholes. Furthermore, no surface water was observed during the site visit.

It is likely, during sustained rain periods, that seepage (within retained areas) and surface water run-off will migrate along the natural ground slope from the front of the property toward the rear of the property. Diverted flows should be directed (where possible) to Council, or other approved, stormwater systems to prevent water accumulating in areas surrounding retaining structures or footings. Rainfall and local surface water runoff collecting within excavations during construction should be manageable by using conventional sump and pump methods. Suitable sediment control for all discharges should be included.

7. Recommendations

7.1 Site Classification

The classification of a site involves several geotechnical factors such as depth of bedrock, the nature and extent of subsurface soils and any specific problems (slope stability, soft soils, filling, reactivity, etc.).

During the site investigation subsurface conditions (BH01 & BH02) presented evidence of uncontrolled sand fill greater than 0.8m in depth. In accordance with AS2870-2011 the site may be classified as **"Class P".**

Nevertheless, we foresee proposed excavated works will enter the bedrock strata (sandstone) and that footings for the structures will be founded into rock. However, if controlled fill is used as foundation material the site may be given an alternative site classification if assessed in accordance with engineering principles.

7.2 Site Preparation

Local geology and site conditions generally feature shallow rock however the extent of investigation displayed uncontrolled fill greater than 1.10m. The borehole investigation was limited to the rear of the property where several levels of retained areas are present to manage the natural slope profile of the site. The recovered material from the boreholes is assumed backfill material for the retaining walls.

DCP results estimate that the natural ground profile (bedrock) at the rear of the property is at depths greater than 2m (see Appendix F for DCP results). Although no subsurface investigation was undertaken within the existing building footprint (including front of dwelling) it is assumed shallow bedrock would be encountered within these areas. Considering this, the site should be stripped of all surface vegetation, organic topsoil, uncontrolled fill and other deleterious materials to expose the underlying rock. Removal of soil overburden should be performed in a manner that reduces the risk of sedimentation occurring in the council stormwater system, open waters and on neighboring land.

All spoil on site should be properly controlled by erosion control measures to prevent transportation of sediments off-site. Appropriate soil erosion control methods should be adopted in accordance with local council requirements. Erosion and sediment control may be aided my minimizing the disturbance footprint.
Material removed from the site will need to be managed in accordance with the provision of current legislation and may include material type classification in accordance with NSW EPA (2014) Waste Classification Guideline and disposal at facilities appropriately licensed to receive the materials.

7.3 Excavation and Vibration

It is likely that most excavation works will encounter very low to low strength sandstone. In light of this;

- Overlying admixed sandy soils and vegetation including small trees may be removed by conventional earthmoving equipment such as an excavator with bucket.
- Excavation of loose or rippable sandstone blocks may be removed by an excavator with a tooth bucket or single ripper attachment.
- Consolidated sandstone (i.e. medium strength or stronger) to be removed may require vibratory rock breaking equipment or similar. Due to the slope instability risk of the site, we

recommend demolition methods not involving impact be implemented where possible. This may include the use of hydraulic rock splitters rather than rock breakers.

- If vibratory rock breaking equipment is required we recommend that, prior to the use of vibratory equipment, the excavation perimeter is saw cut with the aid of an excavator mounted rock saw or by drill and split techniques to minimise transmission of vibrations to adjoining structures.
- Following sawing of the perimeter of the excavation, sandstone bedrock may be broken up using a vibratory hammer suited to an excavator. Induced vibrations in structures adjacent to the excavation are to be examined to ensure that they do not exceed a peak particle velocity (PPV) of 5mm/sec.

Excavation works should be carried out by an experienced operator who is aware of factors affecting vibration and transmission of vibration such as orientation of the hammer, duration of hammering and speed of the vibration of the hammer. At the completion of rock excavation, inspection shall be made by an experienced geotechnical engineer to determine the necessity and extent of the permanent rock support measures based on the encountered strength, bedding, and possible joint sets/crushed zone and defect distance on excavation face, if there is any.

Prior to all excavation works, it is recommended that dilapidation surveys be undertaken out on the surrounding properties (if any) as a means of protecting all parties involved in or affected by the proposed works.

7.4 Retaining Structures

Adopted geotechnical strength and stiffness parameters for design of excavation support are provided in the following table;

Table 3 Adopted Design Excavation Material Parameters

Material	Unit Weight (kN/m^3)	Undrained Shear Strength C_u(kPa)	Effective Strength Parameters		Elastic Parameters	
			Cohesion c′ (kPa)	Friction Angle φ′	Elastic Modulus E′ (MPa)	Poisson Ratio ν
Engineered Fill	20	50	10	27	5-10	0.25
Natural Soft Clay	18	25	0	25	1-3	0.25
Natural Stiff Clay	20	75	10	27	5-10	0.25
Class V S. S	22	-	50	30	1-5 (GPa)	0.30
Class IV S. S	24	-	100	30	10 (GPa)	0.30
Class III S.S or better	24	-	200	35	15 (GPa)	0.35

Note: S.S – Sandstone

7.4.1 Temporary Supports

Temporary shoring may be required where;

– Space limitations do not allow for batters

- Surcharge loads are applied near the edge of excavations
- Soft/wet ground conditions are encountered
- Significant seepage or water inflow occurs

Any temporary excavations into soil and weathered rock exceeding 1.0 m depth should be supported by suitably designed and installed shoring system (in accordance with AS4678 Earth Retaining Structures). The soil pressure can be calculated by;

- A qualified and suitably experienced engineer using finite Rankine formula for SAND and Terzaghi formula for CLAY. If groundwater is to be retained an external dewatering system must be adopted or water pressures be included in the calculations by the engineer.
- Adopting 10H where H is the effective vertical height in meters I.e. an excavation with an effective vertical height of 4.0m would require a shoring system with a capacity rated to 10*4.0 = 40KPa.

We understand that deep excavations will form part of the development. Shallow rock is expected to be encountered within the excavated footprint. The low strength sandstone may be cut to a high angle (approaching vertical) and remain free standing during the construction phase.

If temporary shoring is utilised, it is typically adequate to select a shoring system which won't retain water and monitor the ground water in and beside the excavation to ensure compliance.

Alternatively, excavations may be battered back to slopes no greater than 1V:2H for temporary batters (unsupported for less than I month) and 1V:3H for longer term unsupported slopes up to 6 months. Suitable erosion, sediment and disturbance prevention plans should be designed and implemented for all unsupported slopes.

7.4.2 Permanent Supports

All permanent retaining structures must be designed by a qualified and suitably experienced engineer in accordance with all applicable standards, legislation and guidelines. Full hydrostatic pressure should be assumed from surface level to account for events such as flooding. Given the presence of shallow rock, excavations may be battered back to almost vertical given that the slope is stabilised through the use of engineered design and/or vegetation. Excavation into expected sandstone bedrock can generally maintain grades between vertical and 8(V):1(H) and may be permanently retained. A recommended environmental and risk analysis should be performed to ensure the risks from erosion, run off and slope failure are managed and within acceptable limits.

7.4.3 Retaining Wall Design Parameters

The following table presents the recommended design parameters for retaining structures. For the design of flexible retaining structures, where some lateral movement is acceptable, an active earth pressure coefficient is recommended. Should it be critical to limit lateral deformation of a retaining structure, adopted at rest earth pressure coefficient should be considered.

Table 4 Retaining Wall Design Parameters

Material	Unit Weight (kN/m3)	Active Earth pressure Coefficient (K_a)	At Rest Earth pressure Coefficient (K_o)
Engineered Fill	20	0.35	0.50
Soft to Firm Silty Clays	18	0.35	0.50
VL Strength S. S	22	0.25	0.40
M Strength S. S	24	0.25	0.40
MH Strength S. S	26	0.17	0.29

Note: S.S – Sandstone, VL – Very low, M – Medium, MH – Medium to High

The earth pressure coefficients provided have been calculated assuming zero friction between the wall and soil, that the wall is perfectly vertical (90°), the surrounding surface level is perfectly horizontal (0°) and an over consolidation ratio (OCR) equal to 1. The retaining wall designer should make an independent assessment of the parameters appropriate to the conditions and methodology used.

7.5 General

It is recommended that excavated rock faces be inspected during construction by a geotechnical engineer to determine whether any additional support, such as rock bolts or shotcrete or changes to batter angles are required. Support options may include a reinforced shotcrete wall and/or rock bolting subject to inspection and approval by an experienced geotechnical engineer. Minimum 10cm thick shotcrete retaining wall with 10×10 mesh may be adopted.
Anchors could be inclined up to a maximum of 30° below horizontal, if required to intercept bedrock /higher strength bedrock. Rock bolts may be designed for ultimate bond stress (without factor of safety) of 75 kPa for low strength sandstone and 300 kPa for medium strength or better sandstone. Required length of anchors needs to be determined after inspection of excavation face based on the defect distance.
The following should be noted during anchor design and construction:

- The contractor should adopt design values including an appropriate factor of safety relevant to the installation methodology and anchor type adopted,
- Anchor holes must be clean prior to grouting, and
- Anchors should be check stressed to 125% of the nominal working load and then locked off at 60% to 80% of the working load.

Requirements of rock bolting (if required) will need to be detailed and approved after inspection in completion of excavation by suitably experienced and qualified geotechnical engineer. Appropriate drainage should be provided between excavation face and retaining walls (e.g. strip drains and ag-line in free draining gravel).

At the completion of rock excavation/cut, if topsoil/vegetative overburden is encountered along the top line of the excavation (up to depth of 0.5m), sandstone block retaining wall shall be required to retain the overburden material. If depth of the overburden soil is more than 0.5m, it shall be battered by 1(V):2.5(H).

The retaining wall designer should consider the additional surcharge loading from existing structures, construction equipment, backfill compaction and ground water.

Backfill should comprise of select fill meeting the requirements of controlled fill (Class 1) and compacted to provide a uniform density over the full width of the wall. The following requirements should be met in accordance with AS 4678;

- The select fill should be frictional, free of organic material, contaminants and deleterious substances.
- Particle size of material should be defined as in Table D5 (AS 4678).
- Backfill should be placed and compacted in maximum 100 mm thick layers.
- The Plasticity Index should be less than 12.
- Care should be taken to ensure excessive compaction stresses are not transferred to retaining walls therefore the use of hand-held compaction equipment would be appropriate.
- Appropriate drainage should be provided between backfill/soil exposure and retaining walls (e.g. strip drains and ag-line in free draining gravel).

Use of heavy machinery should be avoided, where possible, within 2 m of the crest of any open soil excavation to prevent excessive local surcharge loads, vibrations and undue settlement within exposed soils.

Careful consideration of nearby structures (e.g. footings, services, utilities, etc) must be given when they are within the excavation zone of influence. The excavation zone of influence extends as a triangle from the base of the excavation to ground level at 1V:2H (see figure 5). If a service falls within this zone a qualified and suitably experienced engineer should design a shoring system and develop an installation methodology which limits the settlement and horizontal movement, so the structure will not be affected.

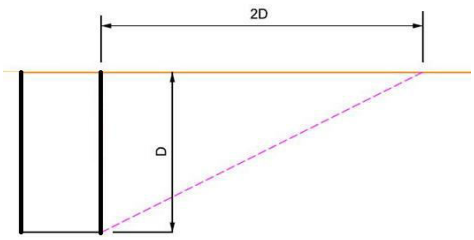


Figure 5 Excavation Zone of Influence

7.6 Foundations

On completion of excavation works, we estimate minimum Class IV sandstone bedrock is expected to be present at founding depths. We therefore recommend the structure be uniformly supported on footings founded within the Class IV rock profile. Pad and strip footings and piles founded within the bedrock may be designed based on the allowable end bearing pressures outlined in the table below.

For piles, we recommend a minimum socket of 0.3 m into the appropriate stratum to achieve the allowable end bearing pressures. For rock sockets longer than 0.3 m we recommend adopting assigned allowable shaft adhesion values set out in the table provided the socket is satisfactorily cleaned and roughened (Class R2 or better).

For all footings, both shallow and piles, the lowest quality bedrock within 1.5 times the width/diameter of the footing/pile will give the allowable bearing pressure for the design of the footings. The allowable bearing pressures and adhesion values set out in the following table are based on serviceability criteria and should result in settlements of less than 1% of the footing diameter/width.

Table 5 Footing Design Parameters

Pells (1998) et al Rock Class	Allowable Bearing Pressure (kPa)	Allowable Shaft Adhesion (compression) (kPa)	Allowable Shaft Adhesion (tension/uplift) (kPa)
Class V	1000	100	50
Class IV	1500	150	75
Class III	3000	300	150

7.7 Earthquake

AS 1170.4 ‘Structural design actions, Part4: Earthquake actions in Australia’ provides advice regarding structural design against potential seismic events.

In accordance with Table 4.1 of AS 1170.4, the following parameters can be adopted:

- Site subsoil can be classified as ‘Class B_e – Rock’;
- An acceleration coefficient of 0.08 can be given; and a
- site factor of 1.0 can be adopted.

8. LANDSLIDE RISK ASSESSMENT

8.1 Slope Stability

Assessing the stability of a slope (i.e. Landslide Risk Assessment) requires careful consideration of a wide range of inputs by an experienced and suitably qualified professional. The primary outcome of a Landslide Risk Assessment is to identify signs of stress in the landscape, the potential mechanisms for stress to form, the likelihood of distress causing a landslide and the risk to life and property a landslide will cause.

The most common considerations are:

- The slope of the land;
- Local and broad topography;
- Cut and fill;
- Existing vegetation (type, density and existing slip evidence);
- Cleared vegetation;
- Soil moisture changes; and
- Foundation type.

The Australian Geomechanics Society published quantitative measures for performing a Risk Analysis (Australian Geomechanics Vol 42 No 1, 2007). This approach has been adopted for assessing the risk of a landslide.

NOTE: This assessment only investigates the risk associated with construction of the proposed new infrastructure. It does not consider the current risk state of the site and its surrounds, nor any existing structures or infrastructure. Figure 6 displays the common type of landslides and Figure 7 presents the features of the type of landslide.

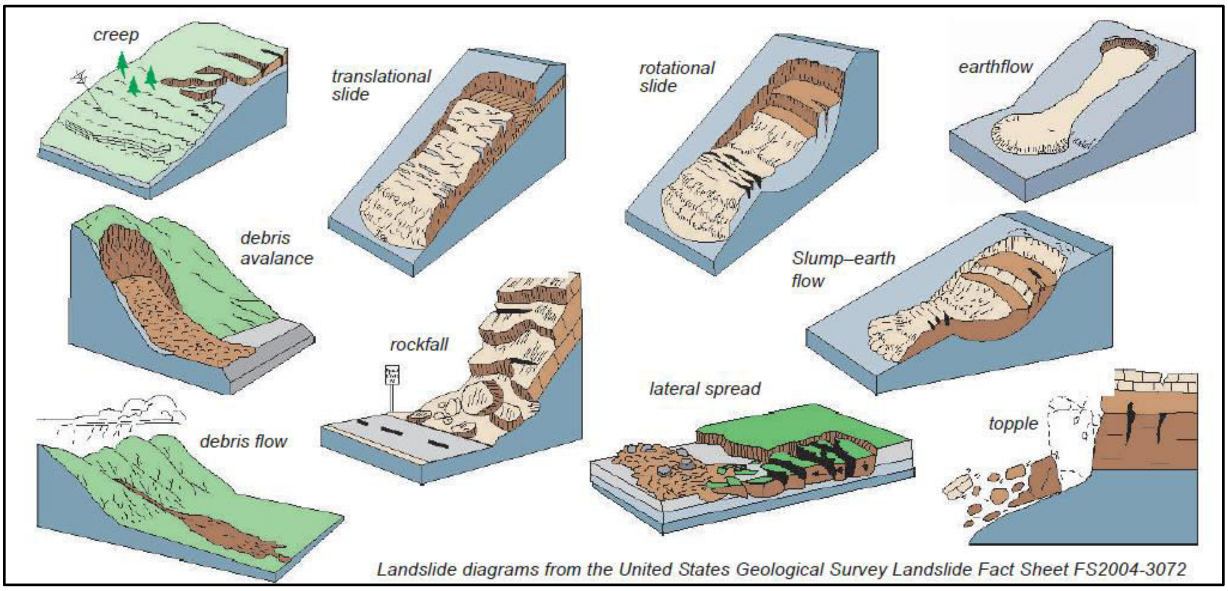


Figure 6 Types of Landslides

TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			Predominantly Coarse	Predominantly Fine
FALLS		Rock fall	Debris fall	Earth fall
TOPPLES		Rock topple	Debris topple	Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide	Earth slide
	TRANSLATIONAL			
LATERAL SPREADS		Rock spread	Debris spread	Earth spread
FLOWS		Rock flow (Deep creep)	Debris flow (Soil creep)	Earth flow
COMPLEX	Combination of two or more principle types of movement			

Figure 7 Landslide Features

8.2 Topography

With reference to the Lambert Soil Profile the general topographic profile within the area consists of undulating to rolling low hills Local relief 20 – 120m and slopes generally < 20% although slopes measured up to 25% at the site. The site inclines from the north (open water) towards the south.

Broad convex crests and plateau surfaces. Gently to moderately inclined slopes, often associated with small hanging valleys. Characteristic sandstone bedrock that outcrops as wide benches (10 – 100m), with broken scarps 1 -4m high. Small, poorly drained seepage areas are common.

Figure 8 below shows the cross-section elevation of the slope of the site.

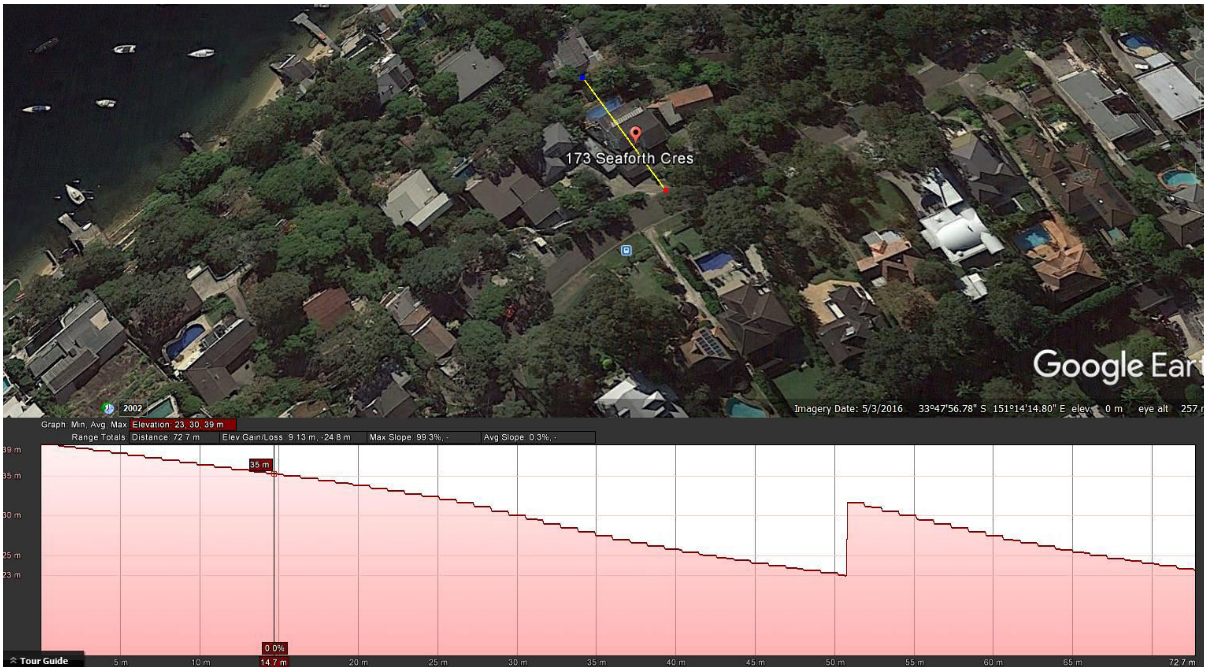


Figure 8 Site Cross Section Slope Elevation

The site was well landscaped with low to medium sized trees and shrubs bordering the property at the rear of the site. Low lying vegetation and shrubs occupied the retained areas of the property. No evidence of erosion was identified within the site. The retaining walls consisted of sandstone blocks and pre-cast concrete crib construction. Soil moisture was observed as slightly moist to moist although minimal soil movement (shrink-swell) is anticipated due to the sandy loam soils.

8.3 Landslide Risk Assessment

The primary failure modes considered in the assessment are 'debris flow' and 'rockfalls'. The risk matrix (Table 6) is adopted when assessing landslide susceptibility. Specific values for the consequence and likelihood are displayed in Appendix G.

Table 6 Risk Matrix Summary

LIKELIHOOD	CONSEQUENCE				
	1	**2**	**3**	**4**	**5**
A	VH	VH	VH	H	M/L
B	VH	VH	H	M	L
C	VH	H	M	M	VL
D	H	M	L	L	VL
E	M	L	L	VL	VL
F	L	VL	VL	VL	VL

VERY HIGH (VH)
HIGH (H)
MEDIUM (M)
LOW (L)
VERY LOW (VL)

The landslide risk assessment (Appendix G) displays an **acceptable** risk for loss of life for the person(s) - risk level **suitable** for new developments. Risk to property is considered to be **low** and usually **acceptable** to regulators. No immediate mitigation measures are required for this site provided slopes are left undisturbed however it is advised that slopes are monitored (irrespective of whether construction will take place).

8.4 Discussion and Recommendations

The following recommendations must be adhered to and are explicitly provided for the existing conditions currently observed at the time the site inspection was made:

- Where applicable, new building structures should be founded into competent bedrock adopting an appropriate footing system;
- The effects of storm-water runoff should be adequately controlled, especially to prevent serious gully erosion. Envirotech can provide professional stormwater advice if required;
- Cut and fill should be avoided wherever possible;
- All retaining walls over 1.0m must be designed by a suitably qualified and experienced engineer;
- Temporary and permanent supports should be implemented in conjunction with Section 7.4 of this report;
- Retention of loose material and installation of suitable drainage should be implemented;
- All retaining walls must have gravel, geotextile material and drainage installed professionally;

- Ground cover should be maintained whenever possible. If erosion is identified, a sediment and erosion control plan should be determined and actioned;
- Trees and other vegetation removal should be kept to a minimum as the underlying root system provides structure and stability to the underlying soils. The removal of mature trees may also influence soil suction and shrink-swell properties of the soils – Refer to AS 2870 'Residential Slabs and Footings' Appendix H – Guide to Design of Footings for Trees; and
- The practice notes in Appendix H of this report should always be followed.

This assessment is based on the proposed additions;

- Constructed by suitably experienced and qualified professionals; and
- Not compromising the integrity of the slope during excavation.

Based on the assessment, assumptions presented and in accordance with AGS Guidelines, the site is suitable for the proposed development without the requirement for mediation measures. Notwithstanding, it is the responsibility of the client and stockholders to ultimately assess whether the risk is acceptable.

9. LIMITATIONS

EnviroTech Pty. Ltd. Pty. Ltd. has undertaken the following report in accordance with the scope of works set out between EnviroTech Pty. Ltd. and the client. EnviroTech Pty. Ltd. derived the data in this report primarily from the site and soil assessment conducted on the date of site inspection. The impacts of future events may require future investigation of the site and subsequent data analysis, together with a re-evaluation of the conclusions and recommendations of this report.

In preparing this report, EnviroTech Pty. Ltd has relied upon, and assumed accurate, certain site information provided by the client and other persons. Except as otherwise stated in the report, we have not attempted to verify the accuracy or completeness of any such information. EnviroTech Pty. Ltd. accepts no liability or responsibility whatsoever for or in respect to any use or reliance upon this report by any third party.

The information contained within this report have been prepared exclusively for the client. Envirotech have prepared the report to address the risk associated with scale of the works. The report has been prepared with a degree of care and skill ordinarily exercised in similar investigations by reputable members of the environmental industry in Australia. No other warranty, expressed or implied, is made or intended. This report is to be read in its entirety including attachments and appendices and should not read in individual sections.

A third party should not rely upon the information prior to making an assessment that the scope of work conducted meets their specific needs. Envirotech cannot be held liable for third party reliance on this document.

Envirotech's professional opinions are based upon its professional judgment, experience, training and results from analytical data. In some cases, further testing and analysis may be required, thus producing different results and/or opinions. Envirotech Pty Ltd has limited its investigation to the scope agreed upon with its client.

10. REFERENCES

- AS 4678-2002 'Earth-retaining structures'
- AS 3798-2007 'Guidelines on Earthworks for Commercial and Residential Developments', Standards Association of Australia
- Australian Standard 2159 (2009) Piling –Design and installation
- AS 2870 'Residential Slabs and Footings'
- AS 1170.4-2007 'Structural design actions. Part 4: Earthquake actions in Australia'
- Australian Standard 1726 (2017) Geotechnical site investigations
- Council policies, guidelines and requirements
- Pells et al 'Foundations on Sandstone and Shale in the Sydney Region' (1998)
- NSW Resources and Geoscience (https://resourcesandgeoscience.nsw.gov.au/data/assets/image/0006/343527/Sydney 100K_Geological_Sheet_9130_1st_edition_1983.jpg)
- NSW Spatial Information Exchange (http://maps.six.nsw.gov.au/)
- NSW Espade (http://www.environment.nsw.gov.au/eSpadeWebapp/)

Appendix A – Site and Borehole Location

Site Location

Borehole and DCP Test locations

Note: Borehole not to size. Borehole/test location approximate.
DCP undertaken in all locations.

Appendix B – Soil Landscape

la	LAMBERT

Landscape— undulating to rolling rises and low hills on Hawkesbury Sandstone. Local relief 20-120 m, slopes 20%. Rock outcrop >50%. Broad ridges, gently to moderately inclined slopes, wide rock benches with low broken scarps, small hanging valleys and areas of poor drainage. Open and closed-heathland, scrub and occasional low eucalypt open-woodland.

Soils— shallow (<50 cm) discontinuous *Earthy Sands (Uc5.11, Uc5.22)* and *Yellow Earths (Gn2.2)* on crests and insides of benches; shallow (<20 cm) *Siliceous Sands/Lithosols (Uc1.2)* on leading edges; shallow to moderately deep (<150 cm) *Leached Sands (Uc2.21), Grey Earths (Gn2.81)* and *Gleyed Podzolic Soils (Dg4.21)* in poorly drained areas; localised *Yellow Podzolic Soils (Dy4.1, Dy5.2)* associated with shale lenses.

Limitations— very high soil erosion hazard, rock outcrop, seasonally perched watertables, shallow, highly permeable soil, very low soil fertility.

LOCATION

Exposed plateau surfaces, convex ridges and coastal headlands of the Hornsby Plateau. Typical areas include much of Brisbane Water National Park and the Lambert Peninsula in Ku-ring-gai Chase National Park. Smaller occurrences are found at Terrey Hills and in the Manly Warringah area, Dover Heights and La Perouse.

LANDSCAPE

Geology

Hawkesbury Sandstone, which consists of medium to coarse-grained quartz sandstone with minor shale and laminite lenses.

Topography

Undulating to rolling low hills. Local relief 20-120 m and slopes <20%. Broad convex crests and plateau surfaces. Gently to moderately inclined sideslopes, often associated with small hanging valleys. Characteristic sandstone bedrock that outcrops as wide benches (10-100 m), with broken scarps 1-4 m high. Small, poorly drained seepage areas are common.

Vegetation

Predominantly uncleared open-heathlands, closed-heathlands and scrublands, with patches of low eucalypt woodland. The heathlands and scrublands are often exposed to strong winds. Their shallow, poorly drained soils fluctuate between being saturated or dry. Bushfires are frequent. Isolated lines and patches of trees are occasionally associated with joint crevices.

Shrub sheoak *Allocasuarina distyla* and/or heath banksia *Banksia ericifolia* are usually dominant. Other shrubs such as spiky hakea *Hakea teretifolia* may be locally dominant in areas subject to seepage or prolonged saturation. Associated shrubs include various spider flowers *Grevillea* spp., billy buttons *Kunzea* spp., eggs and bacon *Pultenaea* spp., teatree *Leptospermum* spp. and native heath *Epacris* spp.

Isolated occurrences of low eucalypt open-woodland with dry sclerophyll shrub understorey are found at sites with deeper soils and unimpeded soil drainage. Trees often have a mallee habit. Red bloodwood *Eucalyptus gummifera*, yellow-top ash *E. luehmanniana*, yellow bloodwood *E. eximia*, scribbly gum *E. haemastoma* and narrow-leaved apple *Angophora bakeri* are common mallee species.

Growth of introduced species in urban areas is stunted. Native trees rarely attain a height of 10 m.

Land use

Most of this unit is bushland managed by the National Parks and Wildlife Service. This includes Brisbane Water National Park, Ku-ring-gai Chase National Park, and Muogamarra Nature Reserve. National Parks and isolated vacant and crown land are used for recreational activities such as bushwalking. Urban residential areas include Dover Heights, Balgowlah Heights and Cromer.

Existing Erosion.

Severe sheet erosion can occur when bushfires destroy or damage vegetative ground cover. This is particularly so if the fires are followed by heavy rains (Atkinson, 1984). Poorly planned and maintained roads, fire trails, walking tracks and bridle trails are subject to severe erosion. Many gullies and rills on tracks and roads are eroded, exposing bedrock. Erosion can be severe and widespread in areas frequented by four-wheel drive vehicles, horses and trail bikes.

Associated Soil Landscapes

Hawkesbury (**ha**) soil landscape occurs in areas of steeper slopes. Small areas of North Head (**nh**) soil landscape and Newport (**np**) soil landscape are also included.

SOILS

Dominant Soil Materials

la1— Loose, stony, yellowish-brown sandy loam. This is stony brown loamy sand to sandy loam with apedal single-grained structure and porous sandy fabric. It generally occurs as topsoil (A1 horizon).

Colour, which can vary from olive brown (2.5Y 4/4) to dark brown (10YR 3/4) is commonly a yellowish-brown (10YR 5/4, 10YR 5/6, 10YR 5/8). The pH ranges from strongly acid (pH 4.0) to moderately acid (pH 5.5). Subrounded sandstone fragments and quartz pebbles are common and are occasionally concentrated as a stone line at depth. Charcoal fragments and roots are common.

la2— Earthy, yellow-brown, light sandy clay loam. This is commonly a yellow-brown, light sandy clay loam with apedal massive to weakly pedal structure and porous earthy fabric. This material occurs as subsoil (B horizon) or occasionally as an A2 horizon.

Texture can range from clayey sand to sandy clay loam. Texture often increases gradually with depth. Peds when present, are usually rough-faced and sub-angular blocky. They range in size from 10 mm to 50 mm. Porosity often decreases with depth. Colour ranges from yellowish-brown (10YR 5/6, 6/6) to brownish-yellow (10YR 6/8). The pH ranges from strongly acid (pH 4.0) to moderately acid (pH 5.5). Sandstone and ironstone fragments are common, but charcoal fragments and roots are rare.

la3— Angular blocky puggy clay. This is a fine sandy clay loam to medium clay with strongly developed angular blocky to occasionally prismatic structure when dry and apedal massive structure when wet. This material occurs as deep subsoil (B horizon) on shale lenses.

Peds are predominantly rough-faced (10-50 mm) and porous with isolated clusters of smooth faces and dense peds. Secondary sub-angular and polyhedral peds are common. When moist, this material is moderately sticky, and is apedal massive and plastic. It is equivalent to Buchanan's (1980) puggy clay. Colour in well-drained positions is commonly a yellowish-brown (10YR 6/6-6/8). In areas subject to prolonged saturation or seepage, colour varies from light yellow orange (10YR 8/4) to pale grey (10YR 8/2). Red, orange and grey mottles are common.

The pH ranges from extremely acid (pH 3.5) to moderately acid (pH 5.5). Platy, iron coated ironstone fragments are common. Roots and charcoal fragments are usually absent.

la4— Blackish-brown, loose sandy loam. This is a dark loamy sand to sandy loam with apedal single-grained structure and porous sandy fabric. It usually occurs as topsoil (A1 horizon).

This material is often water repellent. Colour usually ranges from greyish yellow brown (10YR 4/2) to brownish-black (10YR 3/2). The pH ranges between strongly acid (pH 4.0) and slightly acid (pH 6.0).

Sandstone and ironstone fragments, charcoal fragments, roots and decaying plant remains are common.

la5— Earthy, mottled, pale clayey sands. This is pale coloured clayey sand with apedal massive structure and porous earthy fabric. It generally occurs as subsoil in wet areas (B or C horizon).

Texture can vary from loamy sand to sandy clay loam, with clayey sands and sandy loams being the most common. Surface condition is loose and fabric is sandy. This material is characterised by pallid/grey soil colours such as light yellow (2.5Y 7/4) and bright yellowish-brown (2.5Y 7/6). In wet situations there are often rusty piped mottles around root traces. The pH ranges from extremely acid (pH 3.5) to moderately acid (pH 5.5). Sandstone fragments, charcoal fragments and roots are usually absent.

la6— Friable sandstone. This is soft, friable, deeply weathered, sandstone with a coarse sugary appearance. It commonly occurs as deeply weathered parent material (C horizon) in joint lines and beneath perched watertables.

Texture is commonly clayey sand which often becomes sandier with depth. Structure is usually apedal and massive and the fabric is sandy or occasionally earthy. Colour can vary from light grey (10YR 8/1) to dull yellow-orange (10YR 7/2-7/4). Pale yellow and orange mottles may be present. Rusty mottles occasionally occur which follow root traces. This material can be crushed by hand and the disrupted material has a feel and appearance similar to sugar crystals. The pH ranges from extremely acid (pH 3.5) to moderately acid (pH 5.0). Occasional bands of dark red (2.5YR 3/6) mottles associated with platy, angular, ironstone fragments occur. These ironstone fragments often occur in undisturbed and stratified bands. Strongly weathered fragments of sandstone are found at depth. Roots are rare and charcoal fragments are absent.

Associated Soil Materials

Litter and decomposing organic debris. This material consists of easily recognisable remnants of leaves, flowers, bark and twigs. Distribution is variable and depends on exposure, fire regime, location of nearby species and surface wetness. Fungal and root mats are common. There is a sharp even boundary with the mineral soil.

White loose sand. This material is composed almost entirely of quartz sand grains and is found in recently deposited surface washes such as small debris dams and fans located on breaks of slope.

Dark peaty sand. In poorly drained areas heavy accumulations of organic matter are associated with shallow, dark, peaty sands.

Occurrence and Relationships

Crests and plateaux. Generally 20-100 cm of earthy, yellow-brown, light sandy clay loam (**la2**) occurs as both topsoil and subsoil, with texture characteristically increasing gradually with depth (*Earthy Sands* (*Uc5.11, Uc5.22*), *Yellow Earths* (*Gn2.21*)). This material may merge with friable sandstone (**la6**), or with sandstone bedrock. Total soil depth is <100 cm.

Occasionally up to 30 cm of loose, stony, yellow-brown sandy loam (**la1**) overlies 10-40 cm of **la2**. Total soil depth is <100 cm. The boundary between the soil materials may be gradual (*Yellow Earths* (*Gn2.2*)) or clear (*Yellow Podzolic Soils* (*Dy2.61, Dy4.51*)). A stone line is often present.

Plateau surfaces and larger benches are often characterised by areas of exposed bedrock with shallow (<30 cm), discontinuous pockets or islands of up to 10 cm of brownish-black sandy loam (**la4**) which overlies up to 10 cm of **la1**. Total soil depth is usually <60 cm. The boundary between the soil materials is gradational (*Siliceous Sands/Earthy Sands/Lithosols* (*Uc1.21, Uc5.11*)).

Sideslopes. The soils on sideslopes are discontinuous, with up to 50% of the surface covered by sandstone rock outcrop. On the benches, a variety of shallow soils occur (<50 cm). Soils in crevices such as joint lines may be >100 cm deep.

Outside of benches. The leading edges of most benches, adjacent to rock outcrops, have up to 20 cm of **la1** and/or **la4** overlying bedrock (*Siliceous Sands/Lithosols* (*Uc1.2*)). In other locations, up to 20 cm of **la4** overlies up to 20 cm of **la1** and up to 50 cm of **la2**. Total soil depth is <60 cm. Boundaries between soil materials are gradational (*Yellow Earths, Earthy Sands* (*Gn2.24*)).

Inside of benches. Up to 20 cm of **la1** or **la4** overlies up to 50 cm of **la2**. Total soil depth is usually <100 cm and the boundary between the soil materials is gradual (*Earthy Sands* (*Uc5.2*), *Yellow Earths* (*Gn2.2*)). Where occasional shale lenses have influenced soil formation, up to 20 cm of **la4** and/or **la1** overlie up to 50 cm of white puggy clay (**la3**) (*Yellow Podzolic Soils* (*Dy4.11, Dy5.21, Dy5.51*)). Total soil depth is <60 cm. Boundaries between the soil materials are clear to sharp.

Wet areas. Up to 20 cm of la4 overlies up to 50 cm of earthy, mottled, pale clayey sands (**la5**). **la3** may substitute for **la5** or occur below **la5**. Total soil depth rarely exceeds 100 cm. The boundary between the soil materials is gradual (*Leached Sands* (*Uc2.21*), *Grey Earths* (*Gn2.81*)) to sharp (*Gleyed Podzolic Soils* (*Dg4.21*)).

Drainage depressions and hanging valleys. Close to drainage depressions up to 20 cm of **la4** overlies up to 60 cm of **la5** and occasionally up to 30 cm of **la6**. Total soil depth is <100 cm. Boundaries between soil materials are gradual (*Leached Sands* (*Uc2.21*), *Grey Earths* (*Gn2.81*)). In other areas litter, decomposing organic debris and white loose sand commonly overlie up to 60 cm of **la1** (*Siliceous Sands* (*Uc1.2*)). Secondary depositional yellow earth material (**la2**) is often found adjacent to drainage lines (Paton, 1978).

Hanging valleys. The deep subsoil of the hanging valleys usually consists of **la6**, especially in waterlogged and swampy areas.

LIMITATIONS TO DEVELOPMENT

Urban Capability

Low to moderate capability for urban development.

Rural Capability

Land not capable of being cultivated or grazed.

Landscape Limitations

Seasonal waterlogging
Rock outcrop
Shallow depth
Erosion hazard
Perched watertables (localised)

Soil Limitations

la1 High permeability
Low available water capacity
Stoniness
Low fertility

la2 High permeability
Low available water capacity
Stoniness
Low fertility
Strongly acid
Very high aluminium toxicity

la3 Low wet strength
Low permeability
Stoniness (localised)
Very low fertility
Very strongly acid
High aluminium toxicity

la4 Stoniness (localised)
High organic matter (localised)
Low fertility
Very strongly acid
High aluminium toxicity

la5 Low available water capacity
Very low fertility
Strongly acid
High aluminium toxicity

la6 Low available water capacity
Low permeability (localised)
Stoniness (localised)
Very low fertility
Strongly acid
Very high aluminium toxicity

Fertility

The soils of this unit are shallow, stony, moderately acid, have low available water capacity, very low to low CEC and often are severely deficient in nitrogen and phosphorus. In many areas these soils are poorly drained. The subsoil has very high aluminium toxicity.

Erodibility

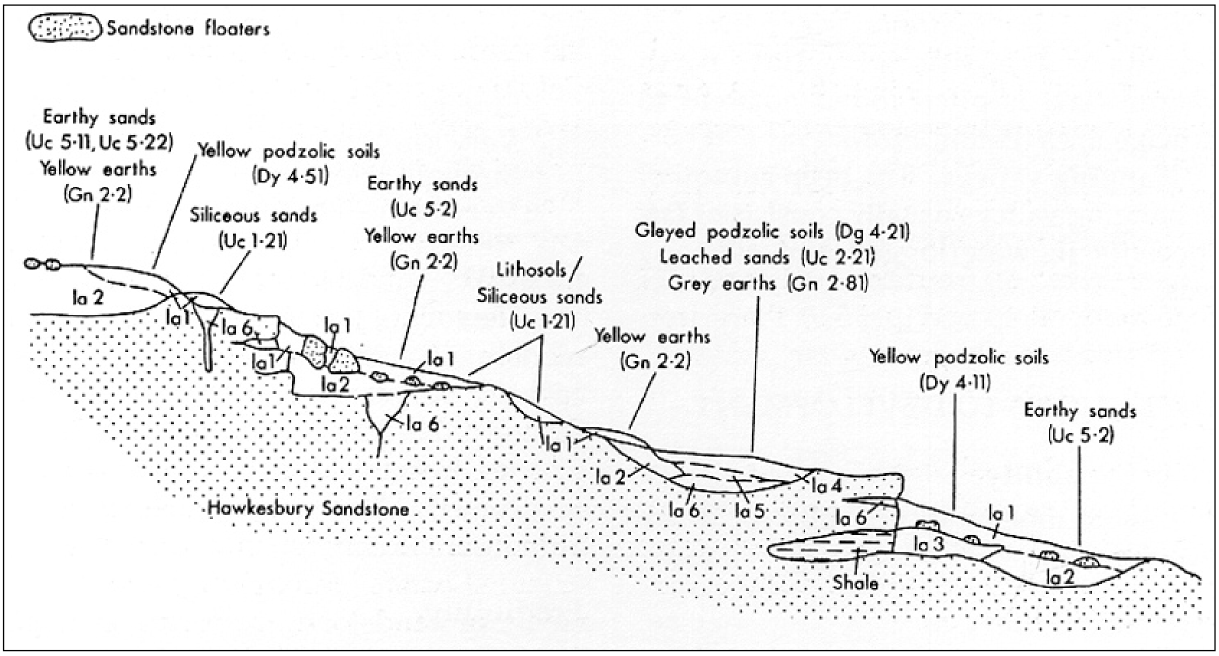
Soil materials **la1— la4** are moderately erodible. They consist of either well-drained coarse sand with moderate (**la2**) to high (**la1**, **la4**) amounts of organic matter or weakly cemented earths and clays (**la3**). Most aggregates are stable or prone only to slaking. The clays in **la3** are occasionally dispersible and this material is then considered to be highly erodible. However, **la5** and **la6** have low erodibility as they are firmly cemented by clays and/or iron oxides.

Erosion Hazard

The soil erosion hazard for non-concentrated flows is usually very high, but ranges from low to extreme. Calculated soil losses for the first twelve months of urban development range up to 17 t/ha for topsoils and 197 t/ha for exposed subsoils. The soil erosion hazard from channelled flow is extreme.

Surface Movement Potential

The sandy shallow soils are stable to slightly reactive. Only in isolated instances where la3 is >100 cm thick would the reactivity be moderate.



Schematic cross-section of Lambert soil landscape illustrating the occurrence and relationship of the dominant soil materials.

Appendix C – Desktop Study

Manly Local Environmental Plan 2013

Acid Sulfate Soils Map
Landslide Risk Map
Sheet CL1_002

Acid Sulfate Soils

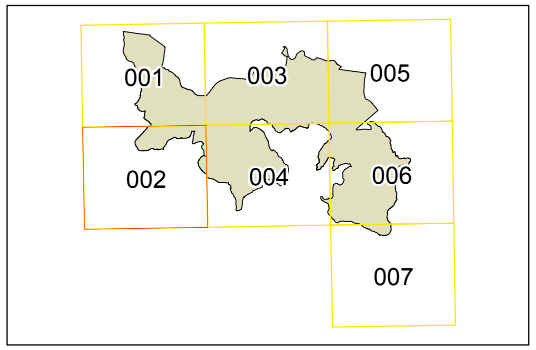
- 1 Class 1
- 2 Class 2
- 3 Class 3
- 4 Class 4
- 5 Class 5

Landslide Risk

- Landslide Risk

Cadastre

- Cadastre - Base Data 18/12/2008



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Projection: GDA 1994
Zone 56

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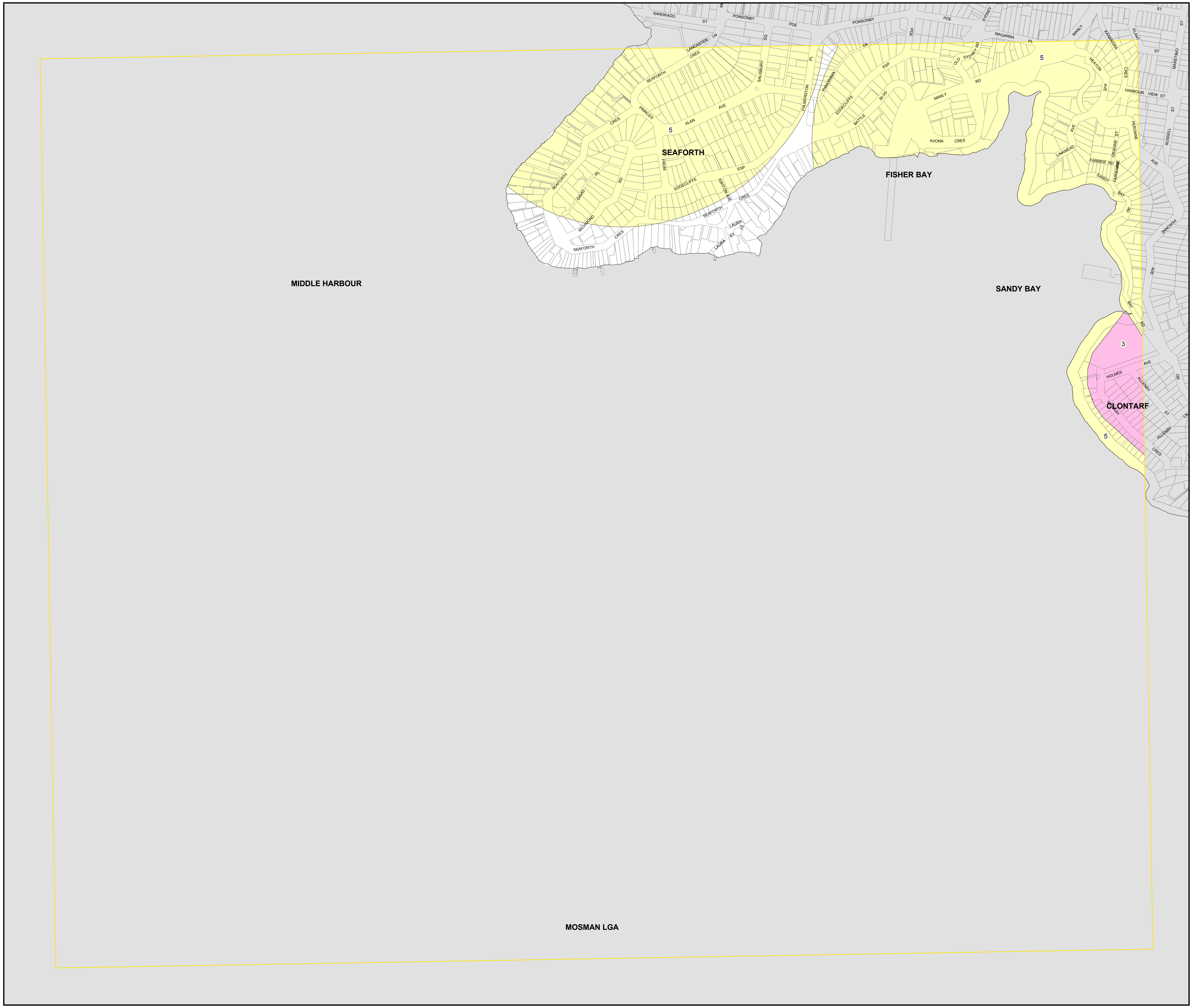


Manly Local Environmental Plan 2013

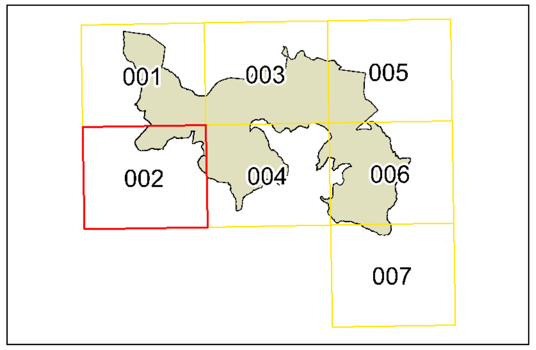
Heritage Map - Sheet HER_002

Heritage

- Conservation Area - General
- Item - General
- Item - Archaeological
- Item - Landscape

Cadastre

Cadastre - Base Data 18/12/2008
© Land and Property Information (LPI)
Addendum Data 16/06/2014
© Manly Council



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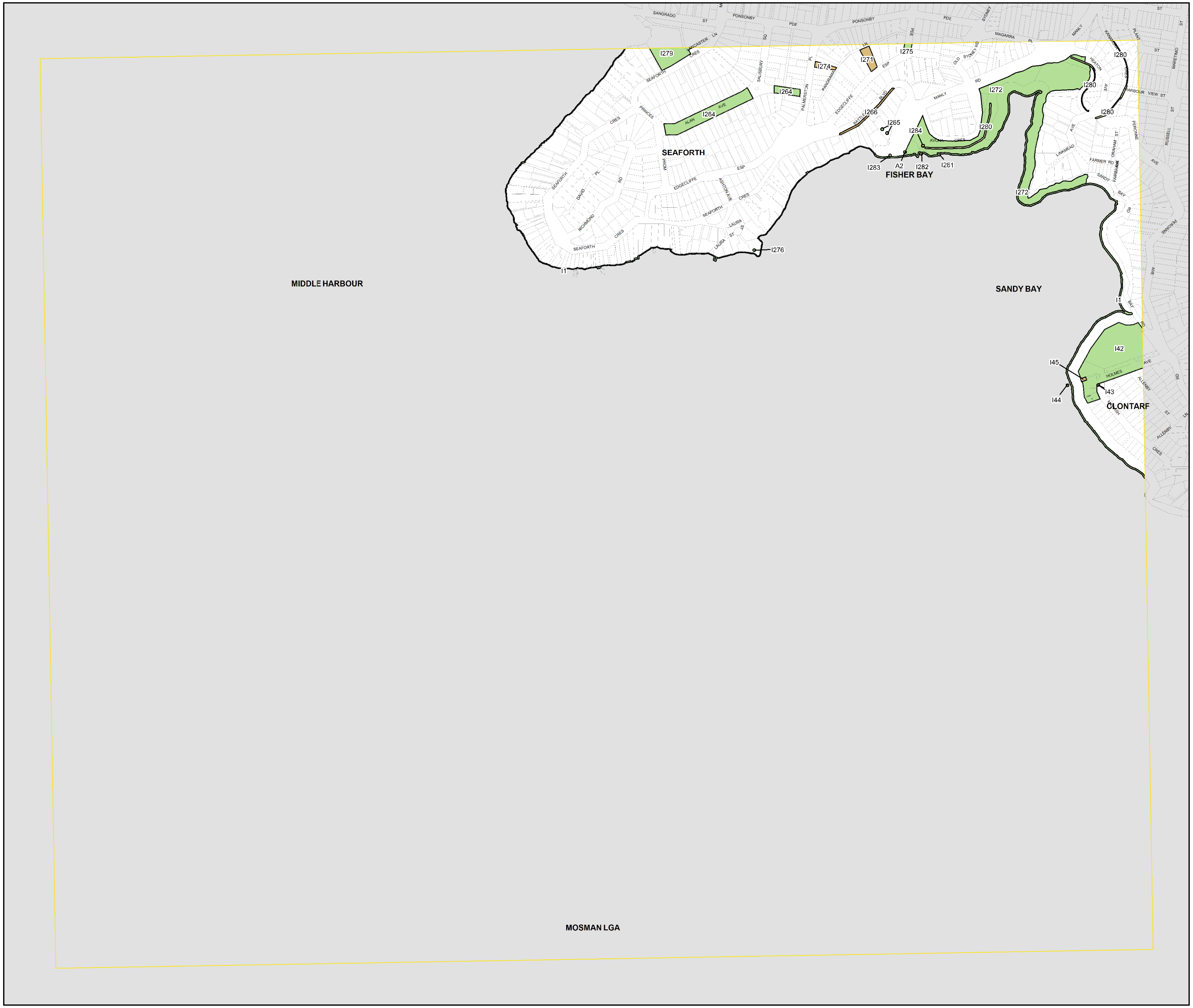


Manly Local Environmental Plan 2013

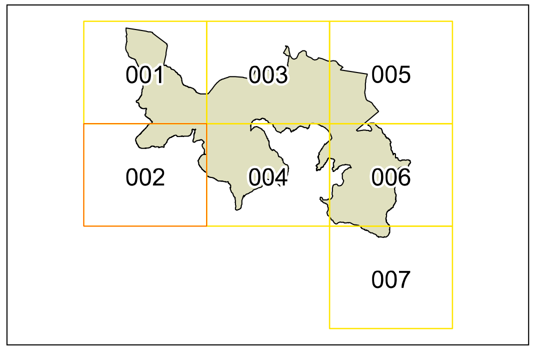
Land Zoning Map - Sheet LZN_002

Zone

	Zone
B1	Neighbourhood Centre
B2	Local Centre
B6	Enterprise Corridor
E1	National Parks and Nature Reserves
E2	Environmental Conservation
E3	Environmental Management
E4	Environmental Living
R1	General Residential
R2	Low Density Residential
R3	Medium Density Residential
RE1	Public Recreation
RE2	Private Recreation
SP1	Special Activities
SP2	Infrastructure
SP3	Tourist
W1	Natural Waterways
DM	Deferred Matter

Cadastre

Cadastre - Base Data 18/12/2008



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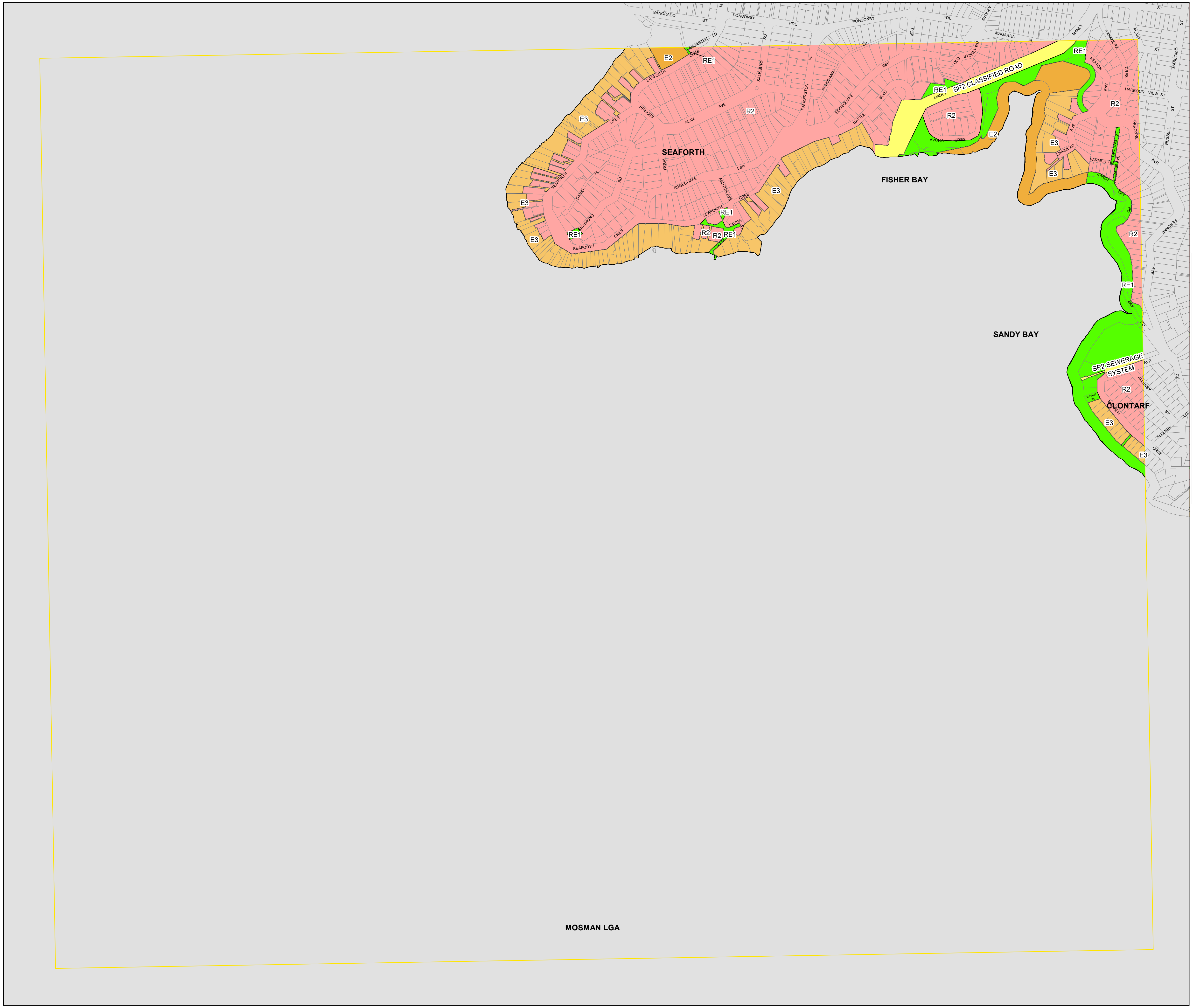

Appendix D – Geotechnical Explanatory Notes

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Explanatory Notes

Soil Description

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 as follows:

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 the pocket penetrometer values and by resistance to deformation to hand moulding.

A Pocket Penetrometer may be used in the field or the laboratory to provide approximate assessment of unconfined compressive strength of cohesive soils. The values are recorded in kPa, as follows:

Strength	Symbol	Pocket Penetrometer Reading (kPa)
Very Soft	VS	< 25
Soft	S	20 to 50
Firm	F	50 to 100
Stiff	St	100 to 200
Very Stiff	VSt	200 to 400
Hard	H	> 400

COHESIONLESS SOILS – RELATIVE DENSITY

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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.

The Standard Penetration Test (SPT) is carried out in accordance with AS 1289, 6.3.1. For completed tests the number of blows required to drive the split spoon sampler 300 mm are recorded as the N value. For incomplete tests the number of blows and the penetration beyond the seating depth of 150 mm are recorded. If the 150 mm seating penetration is not achieved the number of blows to achieve the measured penetration is recorded. SPT correlations may be subject to corrections for overburden pressure and equipment type.

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

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Rock Description

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

ROCK QUALITY

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

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

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

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

ROCK MATERIAL WEATHERING

Rock weathering is described using the following abbreviation and definitions used in AS1726:

Abbreviation	Term
RS	Residual soil
XW	Extremely weathered
DW	Distinctly weathered
SW	Slightly weathered
FR	Fresh

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:	Description
B	Bedding
F	Fault
C	Cleavage
J	Joint
S	Shear Zone
D	Drill break

Planarity/Roughness:

Class	Description
I	rough or irregular, stepped
II	smooth, stepped
III	slickensided, stepped
IV	rough or irregular, undulating
V	smooth, undulating
VI	slickensided, undulating
VII	rough or irregular, planar
VIII	smooth, planar
IX	slickensided, planar

The inclination if defects are measured from perpendicular to the core axis.

WATER

Water level at date shown

Partial water loss

Water inflow

Complete water loss

Groundwater not observed: 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.

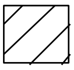
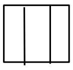
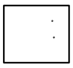
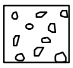
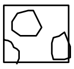
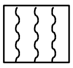
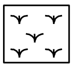
Groundwater not encountered: The borehole/test pit was dry soon after excavation; however groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

Graphic Symbols for Soils and Rocks

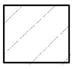
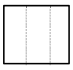
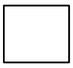
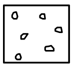
Typical symbols for soils and rocks are as follows. Combinations of these symbols may be used to indicated mixed materials such as clayey sand.

Soil Symbols

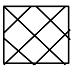
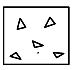
Main components

	CLAY
	SILT
	SAND
	GRAVEL
	BOULDERS / COBBLES
	TOPSOIL
	PEAT

Minor Components

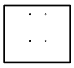
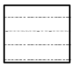
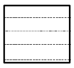
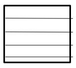
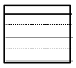
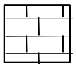
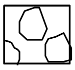
	Clayey
	Silty
	Sandy
	Gravelly

Other

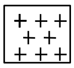
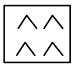
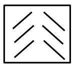
	FILL
	BITUMEN
	CONCRETE

Rock Symbols

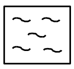
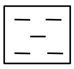
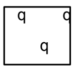
Sedimentary Rocks

	SANDSTONE
	SILTSTONE
	CLAYSTONE, MUDSTONE
	SHALE
	LAMINITE
	COAL
	LIMESTONE
	CONGLOMERATE

Igneous Rocks

	GRANITE
	BASALT
	UNDIFFERENTIATED IGNEOUS

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.

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UNIAXIAL COMPRESSIVE STRENGTH (UCS)

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.

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.

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 et al (1978), as revised by Pells et al (1998).
Pells, P.J.N, Mostyn, G. and Walker, B.F. – Foundations on Sandstone and Shale in the Sydney Region. Australian Geomechanics Journal, No 33 Part 3, December 1998.

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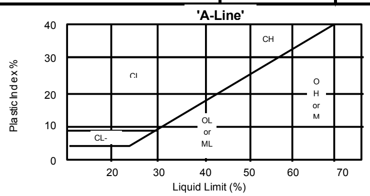
Summary of Soil Logging Procedures

Coarse Material: grain size - colour - particle shape - secondary components - minor constituents - moisture condition - relative density - origin - additional observations.

Fine Material: plasticity - colour - secondary components - minor constituents - moisture w.r.t. plasticity - consistency - origin - additional observations.

Guide to the Description, Identification and Classification of Soils

Major Divisions				SYMBOL	Typical Names
> 200mm		BOULDERS			
60 to 200mm		COBBLES			
COARSE GRAINED SOILS	More than 50% by dry mass less than 60mm is greater that 0.076mm	GRAVEL	More than 50% of coarse fraction > 2.36mm	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
				GP	Poorly graded gravels and gravel-sand mixtures, little or no fines, uniform gravels.
		Gravelly Soils		GM	Silty gravels, gravel-sand-silt mixtures.
				GC	Clayey gravels, gravel-sand-clay mixtures
		SANDS	More than 50% of coarse fraction < 2.36mm	SW	Well-graded sands, gravelly sands, little or no fines.
				SP	Poorly graded sands and gravelly sands; little or no fines, uniform sands.
		Sandy Soils		SM	Silty sands, sand-silt mixtures.
				SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	More than 50% by dry mass less than 60mm is less than 0.076mm		Liquid Limit < 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts
				CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays.
				OL	Organic silts and organic silty clays of low plasticity.
			Liquid Limit > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
				CH	Inorganic clays of high plasticity, fat clays.
				OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS				Pt	Peat and other highly organic soils.



Grain sizes			
Gravel		Sand	
Coarse -	63 to 20mm	Coarse -	2.36 to 0.6mm
Medium -	20 to 6 mm	Medium -	0.6 to 0.2mm
Fine -	6 to 2.36mm	Fine -	0.2 to 0.075mm

GEOLOGICAL ORIGIN:-

Fill - artificial soils / deposits

Alluvial - soils deposited by the action of water

Aeolian - soils deposited by the action of wind

Topsoil - soils supporting plant life containing significant organic content

Residual - soils derived from insitu weathering of parent rock.

Colluvial - transported debris usually unsorted, loose and deposited

Field Identification of Fine Grained Soils - Silt or Clay?

Dry Strength - Allow the soil to dry completely and then test its strength by breaking and crumbling between the fingers. High dry strength - Clays; Very slight dry strength - Silts.

Toughness Test - the soil is rolled by hand into a thread about 3mm in diameter. The thread is then folded and re-rolled repeatedly until it has dried sufficiently to break into lumps. In this condition inorganic clays are fairly stiff and tough while inorganic silts produce a weak and often soft thread which may be difficult to form and readily breaks and crumbles.

Dilatancy Test - Add sufficient water to the soil, held in the palm of the hand, to make it soft but not sticky. Shake horizontally, striking vigorously against the other hand several times. Dilatancy is indicated by the appearance of a shiny film on the surface of the soil. If the soil is then squeezed or pressed with the fingers, the surface becomes dull as the soil stiffens and eventually crumbles. These reactions are pronounced only for predominantly silt size material. Plastic clays give no reaction.

Descriptive Terms for Material Portions

COARSE GRAINED SOILS		FINE GRAINED SOILS	
% Fines	*Term/Modifier*	*% Coarse*	*Term/Modifier*
< 5	Omit, or use "trace"	< 15	Omit, or use "trace"
> 5, < 12	"with clay/silt" as applicable	> 15, < 30	"with sand/gravel" as applicable
> 12	Prefix soil as "silty/clayey"	> 30	Prefix as "sandy/gravelly"

Moisture Condition

for non-cohesive soils:

Dry -	runs freely through fingers.
Moist -	does not run freely but no free water visible on soil surface.
Wet -	free water visible on soil surface.

for cohesive soils:

MC > PL	Moisture content estimated to be greater than the plastic limit.
MC ~ PL	Moisture content estimated to be approximately equal to the plastic limit. The soil can be moulded
MC < PL	Moisture content estimated to be less than the plastic limit. The soil is hard and friable, or powdery.

The plastic limit (PL) is defined as the moisture content (percentage) at which the soil crumbles when rolled into threads of 3mm dia.

Consistency - For Clays & Silts

Description	*UCS(kPa)*	*Field guide to consistency*
Very soft	< 25	Exudes between the fingers when squeezed in hand
Soft	25 - 50	Can be moulded by light finger pressure
Firm	50 - 100	Can be moulded by strong finger pressure
Stiff	100 - 200	Cannot be moulded by fingers. Can be indented by thumb.
Very stiff	200 - 400	Can be indented by thumb nail
Hard	> 400	Can be indented with difficulty by thumb nail
Friable	-	Crumbles or powders when scraped by thumbnail

Relative Density for Gravels and Sands

Description	*SPT "N" Value*	*Density Index (ID) Range %*
Very loose	0 - 4	< 15
Loose	4 - 10	15 - 35
Medium dense	10 - 30	35 - 65
Dense	30 - 50	65 - 85
Very dense	> 50	> 85

Summary of Rock Logging Procedures

Description order: constituents - rock name - grain size - colour - weathering - strength - minor constituents - additional observations.
- minor constituents - moisture w.r.t. plasticity - consistency - origin - additional observations.

Definition - Sedimentary Rock

Conglomerate	more than 50% of the rock consists of gravel (> 2mm) sized fragments
Sandstone	more than 50% of the rock consists of sand (0.06 to 2mm) sized grains
Siltstone	more than 50% of the rock consists of silt sized granular particles and the rock is not laminated
Claystone	more than 50% of the rock consists of clay or mica material and the rock is not laminated
Shale	more than 50% of the rock consists of clay or silt sized particles and the rock is laminated

Weathering

Residual Soil	RS	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a change in volume but the soil has not significantly transported.
Extremely Weathered	EW	Rock is weathered to such an extent that it has 'soil' properties; ie. it either disintegrates or can be remoulded, in water
Distinctly Weathered	DW	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 deposition of weathering products in pores.
Slightly Weathered	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh	FR	Rock shows no sign of decomposition or staining.

Stratification

thinly laminated	< 6mm	medium bedded	0.2 - 0.6m
laminated	6 - 20mm	thickly bedded	0.6 - 2m
very thinly bedded	20 - 60mm	very thickly bedded	> 2m
thinly bedded	60mm - 0.2m		

Discontinuities

order of description: depth - type - orientation - spacing - roughness / planarity - thickness - coating

	Type	Class	Roughness/Planarity	Class	Roughness/Planarity
B	Bedding	I	rough or irregular, stepped	VI	slickensided, undulating
F	Fault	II	smooth, stepped	VII	rough or irregular, planar
C	Cleavage	III	slickensided, stepped	VIII	smooth, planar
J	Joint	IV	rough or irregular, undulating	IX	slickensided, planar
S	Shear Zone	V	smooth, undulating		
D	Drill break				

Rock Strength

Term		Is (50)	Field Guide
Extremely Low	EL		Easily remoulded by hand to a material with soil properties.
		0.03	
Very low	VL		May be crumbled in the hand. Sandstone is "sugary" and friable
		0.1	
Low	L		A piece of core 150 mm long x 50 mm dia. may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.
		0.3	
Medium	M		A piece of core 150 mm long x 50 mm dia. can be broken by hand with considerable difficulty. Readily scored with knife.
		1	
High	H		A piece of core 150 mm long x 50 mm dia. core cannot be broken by unaided hands, can be slightly scratched or scored with knife.
		3	
Very High	VH		A piece of core 150 mm long x 50 mm dia. May be broken readily with hand held hammer. Cannot be scratched with pen knife.
		10	
Extremely High	EH		A piece of core 150 mm long x 50 mm dia. Is difficult to break with hand held hammer. Rings when struck with a hammer.

* - rock strength defined by point load strength (Is 50) in direction normal to bedding

Degree of fracturing

fragmented	The core is comprised primarily of fragments of length less than 20mm, and mostly of width less than the core diameter
highly fractured	Core lengths are generally less than 20mm - 40mm with occasional fragments.
fractured	Core lengths are mainly 30mm - 100mm with occasional shorter and longer lengths
slightly fractured	Core lengths are generally 300mm - 1000mm with occasional longer sections and shorter sections of 100mm – 300mm.
unbroken	The core does not contain any fracture.

- spacing of all types of natural fractures, but not artificial breaks, in cored bores.

The fracture spacing is shown where applicable and the Rock Quality Designation is given by:

$$RQD\ (\%) = \frac{\text{sum of unbroken core pieces 100 mm or longer}}{\text{total length considered}}$$

Appendix E – Borehole Logs

GEOTECHNICAL BOREHOLE BH01

envirotech Consulting Group

PROJECT NUMBER 18-6460
PROJECT NAME Geotechnical Investigation
CLIENT Titus Theseira
ADDRESS 173 Seaforth Crescent, Seaforth NSW

DRILLING DATE 09-08-2018
DRILLING COMPANY Envirotech Pty Ltd
DRILLER BH
DRILLING METHOD Mechanical Hand Auger
TOTAL DEPTH 1.1m

COORDINATES N/A
COORD SYS N/A
SURFACE ELEVATION ~ 30m
LOGGED BY BH
CHECKED BY SD

COMMENTS

Depth (m)	Pocket Penetrometer kPa	DCP (0–25)	Samples	Graphic Log	USCS	Material Description	Additional Observations
			No Sampling		ML	TOPSOIL: Admix sand and gravel, grey to dark-grey, fine to coarse sands and gravels, with organics (roots), slightly moist	
0.5	120				SC	FILL: Clayey SAND with organics (roots), orange, fine to medium sands, medium dense, slightly moist to moist, moisture content < plastic limit	Roots present up to ~0.7m
1	280						
	290						
						Termination Depth at:1.1 m	

Disclaimer This log is intended for geotechnical purposes.
produced by ESlog.ESdat.net on 15 Aug 2018

GEOTECHNICAL BOREHOLE BH02

PROJECT NUMBER 18-6460
PROJECT NAME Geotechnical Investigation
CLIENT Titus Theseira
ADDRESS 173 Seaforth Crescent, Seaforth NSW

DRILLING DATE 09-08-2018
DRILLING COMPANY Envirotech Pty Ltd
DRILLER BH
DRILLING METHOD Mechanical Hand Auger
TOTAL DEPTH 1.1m

COORDINATES N/A
COORD SYS N/A
SURFACE ELEVATION ~ 30m
LOGGED BY BH
CHECKED BY SD

COMMENTS

Depth (m)	Pocket Penetrometer kPa	DCP (0–25)	Samples	Graphic Log	USCS	Material Description	Additional Observations
			No Sampling		ML	TOPSOIL: Admix sand and gravel, grey to dark-grey, fine to coarse sands and gravels, with organics (roots), slightly moist	
0.5	370				SC	FILL: Clayey SAND, orange, low plasticity, trace organics (roots), fine to medium sands, medium dense, slightly moist to moist, moisture content < plastic limit	Roots present up to ~0.7m
1					SP	FILL: SAND, brown, low plasticity, trace organics (roots), trace coarse gravels up to 20mm, fine to medium sands, moist, medium dense, moisture content < plastic limit	DCP refusal at 1-1.1m
						Termination Depth at:1.1 m	

Disclaimer This log is intended for geotechnical purposes.
produced by ESlog.ESdat.net on 15 Aug 2018

Appendix F – DCP Results

1, 23 Rowood Road, Prospect NSW 2148
P. 1300 888 324 F. 02 8834 0760
W: www.envirotech.com.au
E: info@envirotech.com.au

Test No:	BH01	BH02					
Location:	Refer to Plan	Refer to Plan					
Start Level:	~ 30m AHD – Surface Ground Level						
Depth (m)	**Number of blows per 100mm**						
0 – 0.1	4	2					
0.1 – 0.2	3	3					
0.2 – 0.3	1	3					
0.3 – 0.4	1	6					
0.4 – 0.5	1	5					
0.5 – 0.6	5	4					
0.6 – 0.7	4	3					
0.7 – 0.8	3	3					
0.8 – 0.9	4	22					
0.9 – 1.0	4	4 - R					
1.0 – 1.1	4						
1.1 – 1.2	8						
1.2 – 1.3	7						
1.3 – 1.4	9						
1.4 – 1.5	14						
1.5 – 1.6	8						
1.6 – 1.7	5						
1.7 – 1.8	6						
1.8 – 1.9	8						
1.9 – 2.0	9 - R						

NOTE: R – Refusal (Inferred rock)

Appendix G – Landslide Risk Assessment

Risk to Life Assessment

Method based on AGS 2007 Guildlines

PROJECT DETAILS **Risk assessment is based on the recommendations in section 6 being implimented and maintained.**

Project	**173 Seaforth Crescent, Seaforth NSW 2092**			Job. No.	**18-6460**
Author	**BH**	Reviewed	**SD**	Created	**16/08/2018**

STEP 1 : ENTER SITE AND DESIGN DATA

Hazard Type	**Debris Flow**

$P_{(H)}$	Annual probability of landslide	**0.0001**

INDICATIVE VALUE	RECURRENCE INTERVAL	DESCRIPTION	DESCRIPTOR	LEVEL
10^{-1}	10 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	100 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	1000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	10,000 years	The enent might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	100,000 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

$P_{(S:H)}$	Probability of spatial impact impacting building location taking into	**0.89**

LOW (L)

FACTOR	DESCRIPTION	UNITS	VALUE
W_1	Likely slide/fall width	m	**5**
W_2	Width of allotment / investigation area	m	**20**
W_3	Width of dwelling / investigation element	m	**15**
L_{1Min}	Minimum run-out length	m	**5**
L_{1Max}	Maximum run-out length	m	**30**
L_2	Length of allotment / investigation area	m	**45**
L_3	Length of dwelling / investigation element	m	**20**
L_{PMin}	Probability of runout being 0 - 5 m long	(0 - 1)	**0.70**
L_{PMax}	Probability of runout being 5 - 30 m long	(0 - 1)	0.50
W_F	Likelihood of across slope strike on risk element	(0 - 1)	**1.00**
$L_{F\ Min}$	Likelihood of downslope strike on risk element for minimum run-out distance	(0 - 1)	0.56
$L_{F\ Max}$	Likelihood of downslope strike on risk element for maximum run-out distance	(0 - 1)	1.00
$L_{F\ Design}$	Likelihood of downslope strike (integrated) on risk element run-out distance	(0 - 1)	**0.89**

$P_{(T:S)}$	Temporal spatial probability given the spatial impact	**0.19**

FACTOR	DESCRIPTION	UNITS	VALUE
T_1	Percentage of time person(s) are on-site	%	75%
T_2	Percentage of dwelling / element that person(s) occupy	%	25%

$V_{(D:T)}$	Vulnerability of the individual (ie. probability of loss of life given the impact)	**0.05**

CASE	DESCRIPTION	RANGE IN DATA	RECOMMENDED VALUE	COMMENTS
Person in open space	If struck by a rockfall	0.1 - 0.7	0.50	0.05
	If buried by debris	0.8 - 1.0	1.00	Death by asphyxia almost certain
	If not buried	0.1 - 0.5	0.10	High chance of survival
Person in a vehicle	If vehicle is buried / crushed	0.9 - 1.0	1.00	Death is almost certain
	If the vehicle is damaged only	0.0 - 0.3	0.30	High chance of survival
Persons in building	If the building collapses	0.9 - 1.0	1.00	Death is almost certain
	If the building is inundated with debris and the person is buried	0.8 - 1.0	1.00	Death is highly likely
	If the debris strikes the building only	0.0 - 0.1	0.05	Very high chance of survival

STEP 2 : RISK EVALUATION

$R_{(LoL)}$	Risk (annual probability of loss of life of an individual)	**8.33E-07**

Risk Assessment	**Acceptable risk for loss of life for the person(s). Risk level suitable for new developments.**

Risk to Property Assessment

Method based on Australian Geomechanics Vol. 42 No 1, March 2007

PROJECT DETAILS

Project	173 Seaforth Crescent, Seaforth NSW 2092			Job. No.	18-6460
Author	BH	Reviewed	SD	Created	16/08/2018

STEP 1 : LIKELIHOOD

LEVEL	D			
INDICATIVE VALUE	**RECURRENCE INTERVAL**	**DESCRIPTION**	**DESCRIPTOR**	**LEVEL**
10^{-1}	10 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	100 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	1000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	10,000 years	The enent might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	100,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}	0.0001	The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

STEP 2 : CONSEQUENCE

LEVEL	4		
INDICATIVE VALUE	**DESCRIPTION**	**DESCRIPTOR**	**LEVEL**
200%	Structure completely destroyed or large scale damage requiring major engineering works for stabilisation.	CATASTOPHIC	1
60%	Extensive damage to most of structure, or extending beyond site boundaries requiring significant stabilisation works	MAJOR	2
20%	Moderate damage to some of structure, or significant part of site requiring large stabilisation works.	MEDIUM	3
5%	Limited damage to part of structure, or part of site requiring some reinstatement/stabilisation works.	MINOR	4
1%	Little damage.	INSIGNIFICANT	5

STEP 3 : Risk Matrix

LIKELYHOOD	CONSEQUENCE				
	1	**2**	**3**	**25**	**5**
A	VH	VH	VH	10	M/L
B	VH	VH	H	50	L
C	VH	H	M	100	VL
D	H	M	L	25	VL
E	M	L	L	0.7	VL
F	L	VL	VL	0.5	VL
LOW (L)	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required. The recommendations in section 8 must be followed for this risk level to apply.				

Appendix H – Practice Note Guidelines for 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

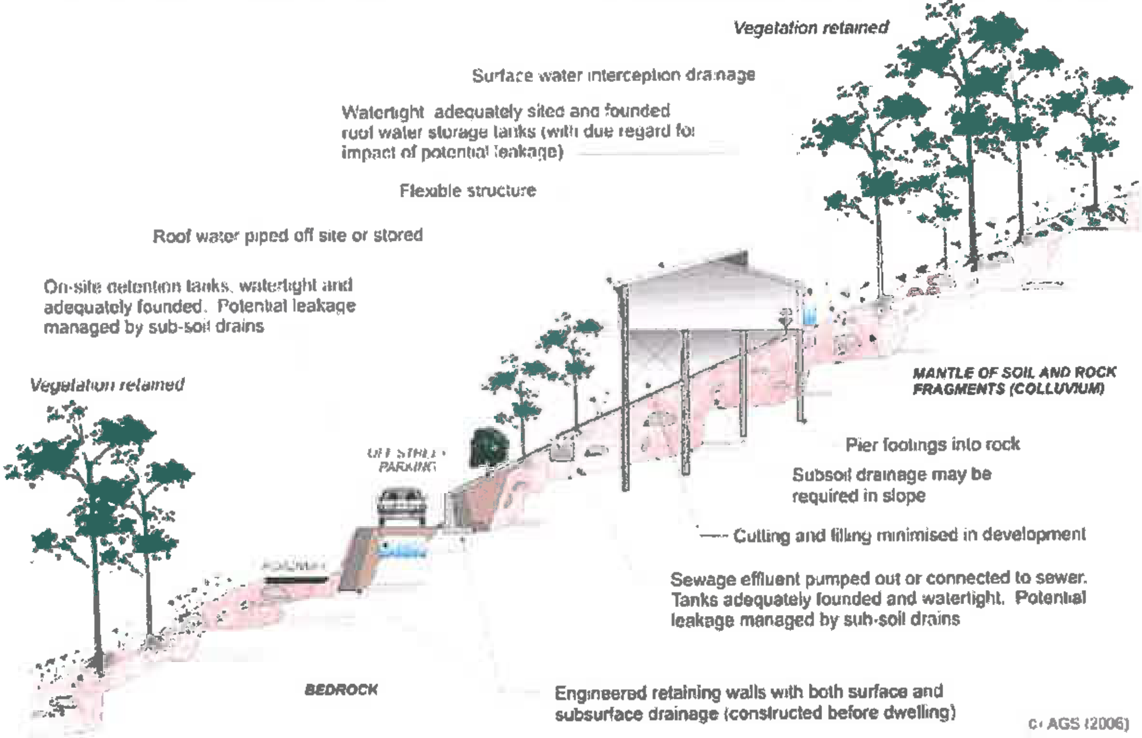
Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
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.

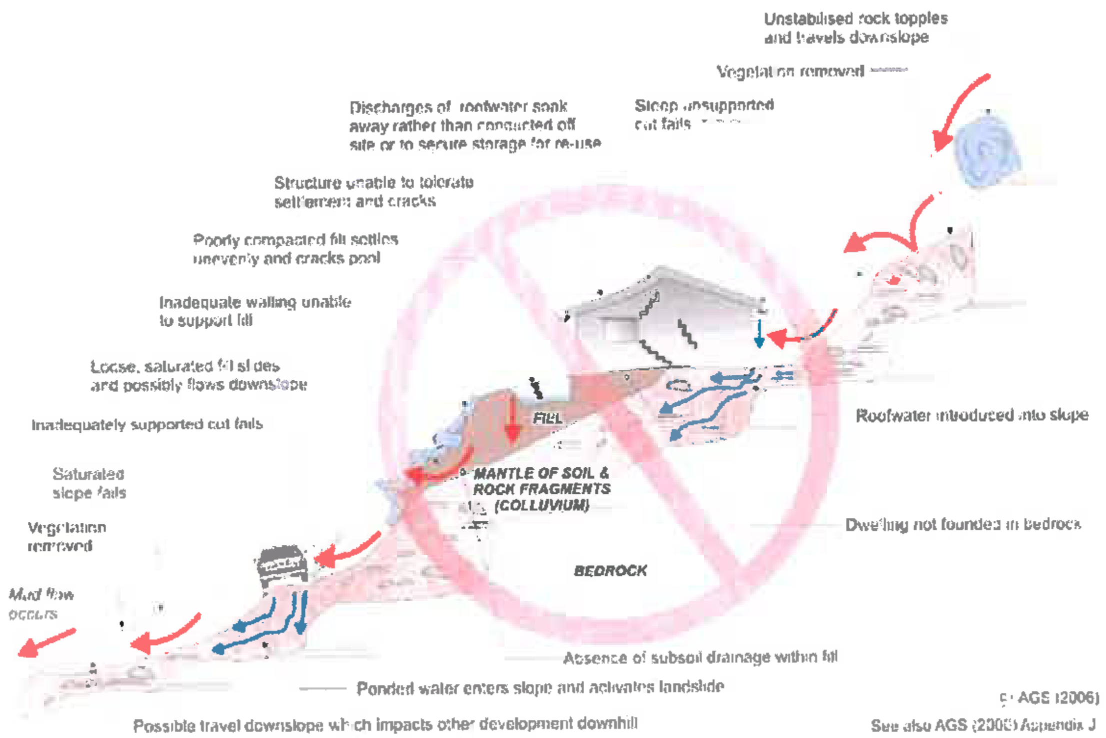
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	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.	

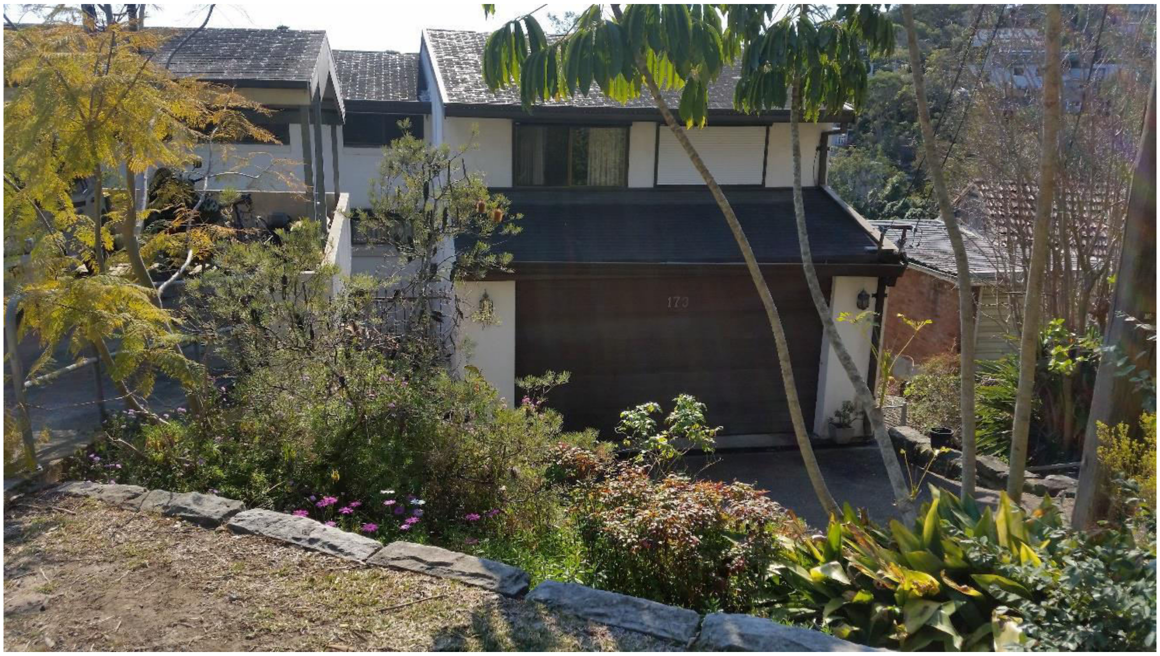
EXAMPLES OF GOOD HILLSIDE PRACTICE



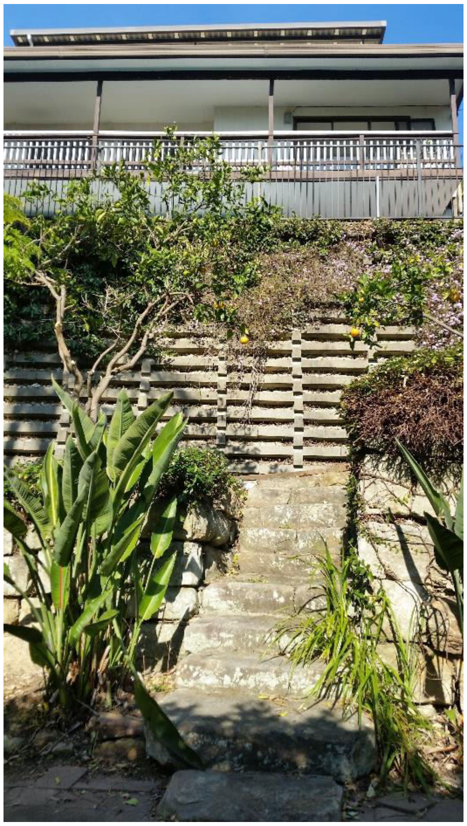
EXAMPLES OF POOR HILLSIDE PRACTICE



Appendix I – Site Photographs



Front of property looking north

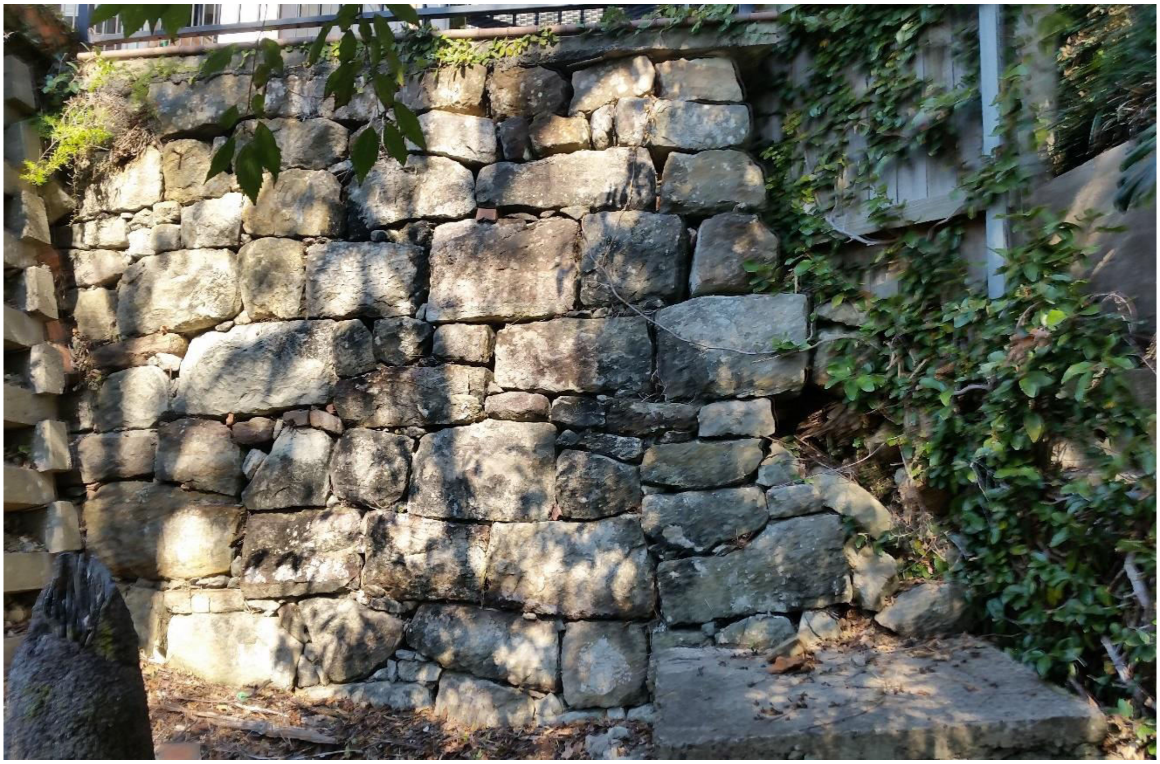


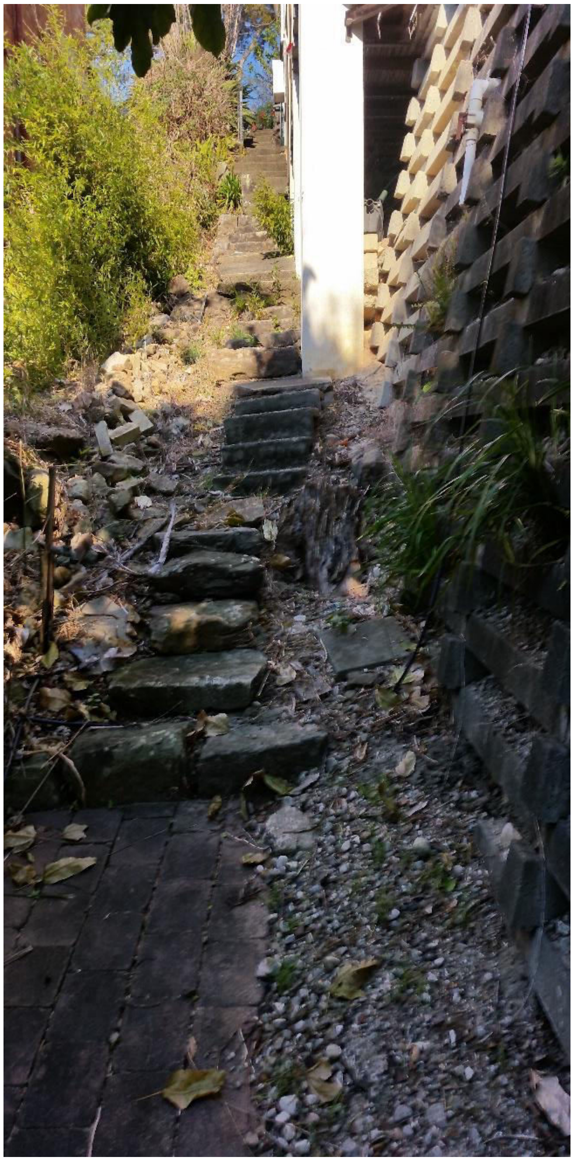
Rear of property looking up slope


Rear of property – Retained landscape areas looking west

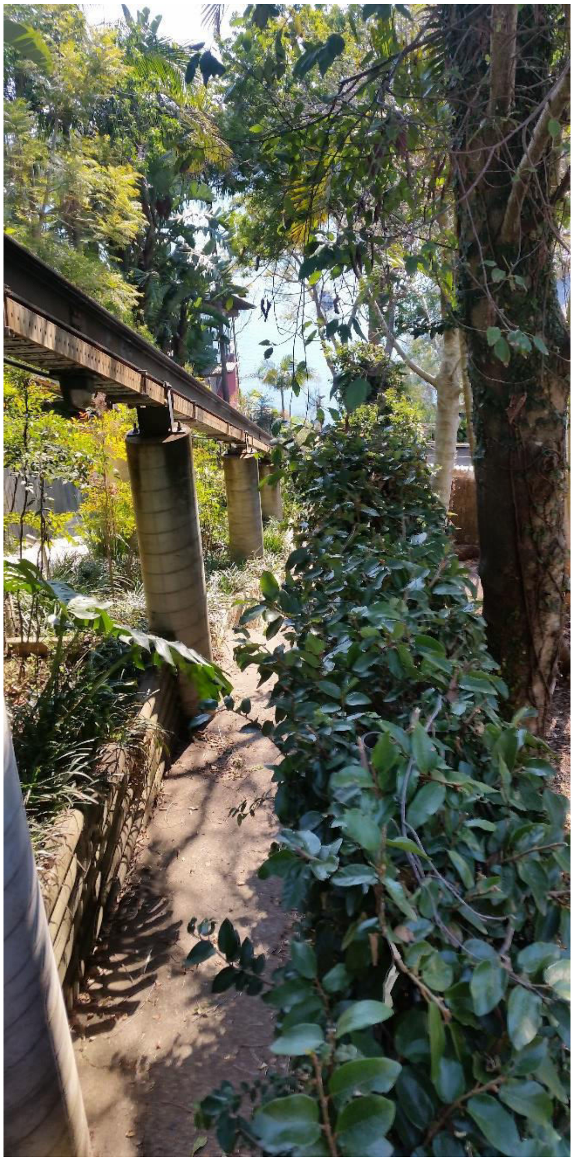

Rear of property – Retained landscape areas looking east


Pre-cast concrete crib retaining wall


Sandstone block retaining wall



Sandstone flagged stair access eastern side



Inclinator situated western side