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GEOTECHNICAL REPORT

for

PROPOSED SUBDIVISION AND CONSTRUCTION OF AN ACCESS DRIVEWAY AND NEW DWELLINGS

at

14 MIRROOL STREET, NORTH NARRABEEN, NSW

Prepared For

Mick Wykrota

Project No.: 2016-049

November 2023

Document Revision Record

Issue No	Date	Details of Revisions
0	18 March 2022	Original issue
1	20 February 2023	Revised design
2	20 November 2023	Revised design

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for____

Name of Applicant

Address of site ___14 Mirrool Street, North Narrabeen, NSW

Declaration made by geotechnical engineer or engineering geologist or coastal engineer (where applicable) as part of a geotechnical report

I, ***__Troy Crozier***___________ *on behalf of* ***___Crozier Geotechnical Consultants*** 20/02/2023 certify that I am a ~~geotechnical engineer or~~ engineering geologist ~~or coastal engineer~~ as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above ~~organisation/~~company to issue this document and to certify that the ~~organisation/~~company has a current professional indemnity policy of at least $2million.

I:

☐ have prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

✓ am willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

✓ have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with Section 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. I confirm that the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy for Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.

☐ have examined the site and the proposed development/alteration in detail and I am of the opinion that the Development Application only involves Minor Development/Alteration that does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.

☐ have examined the site and the proposed development/alteration is separate from and is not affected by a Geotechnical Hazard and does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.

☐ have provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: Geotechnical Report for Proposed Property Sub-Division and Construction of an Access Driveway and two new dwellings.

Report Date: 20 November 2023 **Project No.:** 2016-049

Author: Kieron Nicholson and Troy Crozier

Author's Company/Organisation: Crozier Geotechnical Consultants

Documentation which relate to or are relied upon in report preparation:

Proposed Lot Subdivision (Lot 1 (9A), Lot 2 (9B) and Lot 3 (9C). Design by Bo Piotrowski, Drawing Number 001B, Dated 30/11/23.

Proposed Cut and Fill on Lot 9C – Design by Bo Piotrowski, Drawing Number: 002SP, Dated: 22/11/22.

Concept Architectural Drawings-Bo Piotrowski Architect – Lot 3, Drawing Number 001SD, Dated 26 September 2023

✓ I am aware that the above Geotechnical Report, prepared for the abovementioned site is to be submitted in support of a Development Application for this site and will be relied on by Pittwater Council as the basis for ensuring that the Geotechnical Risk Management aspects of the proposed development have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature ....

Name ...**Troy Crozier**..

Chartered Professional Status...**RPGeo (AIG)**

Membership No.: ...**10197**..................................

Company... **Crozier Geotechnical Consultants**

REGISTERED PROFESSIONAL GEOSCIENTIST
AUSTRALIAN INSTITUTE OF GEOSCIENTISTS
TROY CROZIER
10,197

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1(a) - Checklist of Requirements For Geotechnical Risk Management Report for Development Application

Development Application for ______________________________

Name of Applicant

Address of site ___14 Mirrool Street, North Narrabeen, NSW

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Geotechnical Report. This checklist is to accompany the Geotechnical Report and its certification (Form No. 1).

Geotechnical Report Details:

Report Title: Geotechnical Report for Proposed Property Sub-Division and Construction of an Access Driveway and New Dwellings

Report Date: 20/11/2023 **Project No.:** 2016-049

Author: Kieron Nicholson and Troy Crozier

Author's Company/Organisation: Crozier Geotechnical Consultants

Please mark appropriate box

✓ Comprehensive site mapping conducted ____20/02/2023___________

☐ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)

☐ Subsurface investigation required

✓ No Justification …… Instability visible above ground

Yes Date conducted ………………………………………………

☐ Geotechnical model developed and reported as an inferred subsurface type-section

☐ Geotechnical hazards identified

☐ Above the site

☐ On the site

☐ Below the site

✓ Beside the site

✓ Geotechnical hazards described and reported

✓ Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009

✓ Consequence analysis

✓ Frequency analysis

✓ Risk calculation

✓ Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009

✓ Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009

✓ Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009

✓ Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified conditions are achieved.

☐ Design Life Adopted:

✓ 100 years

☐ Other …

✓ Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified

✓ Additional action to remove risk where reasonable and practical have been identified and included in the report.

☐ Risk assessment within Bushfire Asset Protection Zone.

I am aware that Pittwater Council will rely on the Geotechnical Report, to which this checklist applies, as the basis for ensuring that the geotechnical risk management aspects of the proposal have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated, and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature ………………………………………………

Name …**Troy Crozier**………………………………

Chartered Professional Status…**RPGeo (AIG)**…………

Membership No. …**10197**…………………………

Company… **Crozier Geotechnical Consultants**

REGISTERED PROFESSIONAL GEO… AUSTRALIAN INSTITUTE OF GEOSCIENTISTS TROY CROZIER 10,197

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CROZIER
GEOTECHNICAL CONSULTANTS

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Date: 20 November 2023

Project No.: 2016-049

GEOTECHNICAL REPORT FOR PROPOSED SUBDIVISION AND CONSTRUCTION OF ACCESS DRIVEWAY AND TWO DWELLINGS 14 MIRROOL STREET, NORTH NARRABEEN, NSW

1. INTRODUCTION:

This report details the results of a geotechnical assessment carried out for the proposed subdivision, new driveway and the construction of two new dwellings at 14 Mirrool Street, North Narrabeen, NSW. The assessment was undertaken by Crozier Geotechnical Consultants (CGC) at the written request of the client Mick and Eva Wykrota.

CGC has previously undertaken geotechnical assessment of a potentially unstable boulder and for a previous development proposal assessing only the proposed subdivision within the site and the results of those assessments are detailed in the following reports:

> *'Site Inspection Report, 14 Mirrool Street, North Narrabeen, Inspection of unstable boulder and recommendations for stabilising dated: 25th May 2016'*

> *'Proposed Subdivision and Construction of an Access Driveway at 14 Mirrool Street, North Narrabeen, NSW, Project No.: 2016-049, Dated 20 February 2023'*

The site is located within the H1 (highest category) landslip hazard zone as identified within Northern Beaches (Pittwater) Councils Geotechnical Risk Management Map therefore a risk assessment in accordance with Pittwater guidelines is required.

Based on the above Council requirements a proposal (Proposal No. P21-636, Dated: 11 January 2022) was submitted to the client and subsequently accepted. Additional development proposals have been addressed in this updated report subsequent to the February 2023 report referenced above.

The assessment comprised:

a) A detailed geotechnical inspection and mapping of the site and inspection of accessible adjacent land, with identification of geotechnical conditions including potential hazards related to the existing site, by a Senior Engineering Geologist including a photographic record of site conditions.

The following plans and drawings were supplied and relied on for the work:

- Proposed Lot Subdivision (Lot 1 (9A), Lot 2 (9B) and Lot 3 (9C). Design by Bo Piotrowski, Drawing Number 001B, Dated 30/11/23.
- Proposed Cut and Fill on Lot 9C – Design by Bo Piotrowski, Drawing Number: 002SP, Dated: 22/11/22.
- Concept Architectural Drawings-Bo Piotrowski Architect – Lot 3, Drawing Number 001SD, Dated 26 September 2023, Revision A.

2. PROPOSED WORKS:

It is understood that the works involve the proposed subdivision of 14 Mirrool Street into three blocks, a larger central block (Lot 2) and two smaller blocks within each end the parcel of land (Lot 1 and Lot 3). It is further understood that is proposed to construct new structures within each block. Development approval is understood to have been granted for the new dwelling within Lot 1 (which is currently partially constructed and approved under DA No.336/09) however modifications to the approved DA within that Lot are also proposed and included in the current DA. The modifications to the approved DA do not include additional excavation and are above ground works with a negligible geotechnical component. It is further understood that development within Lot 2 within the central portion of the site is approved under a separate DA, therefore has not formed part of this assessment. Development within Lot 3 within the north of the site is also proposed.

Excavation to approximately 1.2m is proposed along with fill up to around 1.5m depth for the proposed new driveway providing access between all lots, however the earthworks are to provide a uniform subgrade, rather than representing vertical cuts potentially requiring future support.

Excavation to approximately 2.0m depth appears to be required for the development within Lot 3 to allow the construction of a new retaining wall to the north of the proposed new dwelling within the Lot.

3. SITE FEATURES:

3.1. Description:

The site is rectangular in shape and covers an area of approximately 3560m^2 in plan as determined from the provided survey. It is located on the high north side of the Mirrool Street within moderately to steeply south dipping topography and the elevation varies between a high of approximately RL50.0m adjacent to the northwest corner and a low of RL18.0m near the southeast corner of the site. It has north/south and east/west boundaries of 30.5m and 117.0m respectively as determined from the survey plan provided. An aerial photograph of the site and its surrounds is provided below (Photograph 1), as sourced from NSW website Six Maps.

Photograph 1: Aerial photo of site (outlined red) and surrounds.

The site contains a partially constructed garage adjacent to the southern boundary. The remainder of the site is undeveloped and comprises exposed bedrock and dense vegetation.

General views of the site are provided in Photograph 2 and 3.

Photograph 2: View looking west from the north end of the site.

Photograph 3: View looking north from the south end of the site.

The site is bordered to the north, east, south and west by 105 and 107 Woorarra Avenue, Mirrool Street, 12 Mirrool Street and 111 Woorarra Avenue respectively.

No.105 contains a two and three storey clad and rendered house with front garden, rear deck and driveway. The house structure is approximately 26m from the shared boundary. The property is above the site and shares similar south sloping topography.

No.107 contains a one and two storey clad and masonry house with front garden, rear deck, driveway and pool. The house structure is approximately 23m from the shared boundary. The property is above the site and shares similar south sloping topography.

No.111 contains a two and three storey house with front garden, rear deck and driveway. The deck structure appears approximately 2-3m from the shared boundary. The property is above the site and shares similar sloping topography.

Mirrool Street is unformed and comprises a moderately south dipping bare earth alignment with drainage measures installed on the east side of the road.

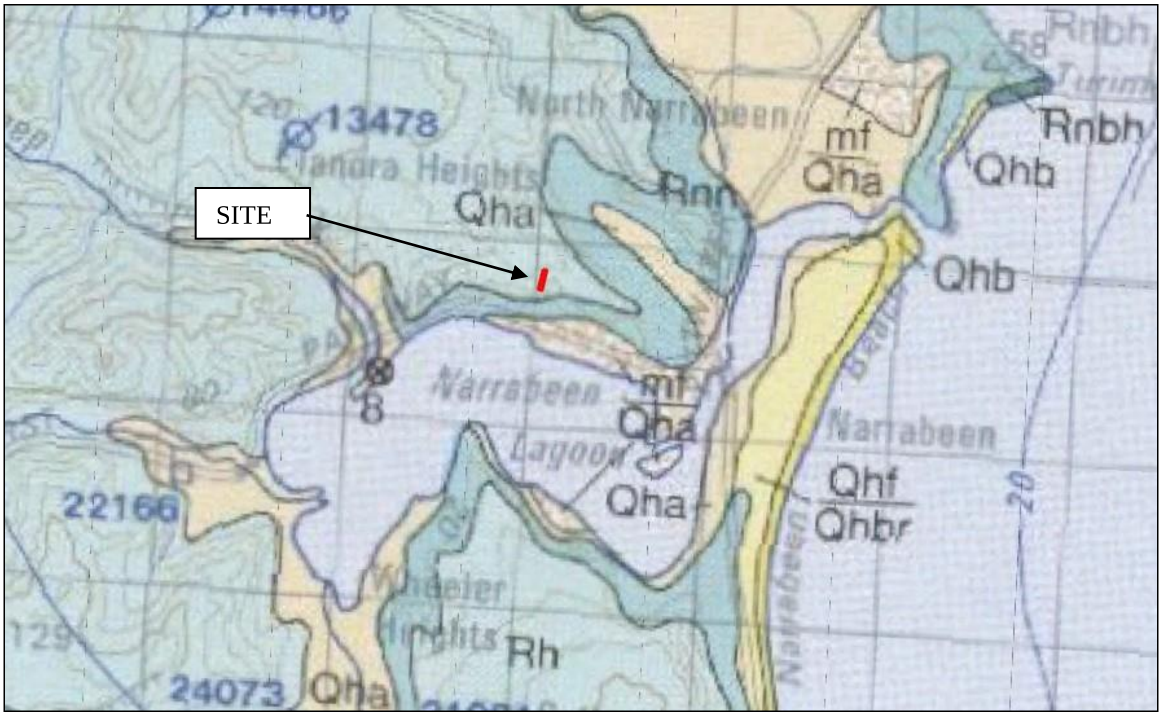
The property to the south of the site (No. 12 Mirrool Street) contained a two storey clad and timber structure which appeared to be in good condition.

3.2. Geology:

Reference to the Sydney 1: 100,000 Geological Series sheet (9130) indicates that the site is underlain by Hawkesbury Sandstone (Rh) which is of Triassic Age. The rock unit typically comprises medium to coarse grained quartz sandstone with minor lenses of shale and laminite.

Morphological features often associated with the weathering of Hawkesbury Sandstone are the formation of near flat ridge tops with steep angular side slopes that consist of sandstone terraces and cliffs in part covered with sandy colluvium. The terraced areas often contain thin sandy clay to clayey sand residual soil profiles with intervening rock (ledge) outcrops. The outline of the cliff areas are often rectilinear in plan view, controlled by large bed thickness and wide spaced near vertical joint patterns. The dominant sub-vertical defect orientations being south-east and north-east. Many cliff areas are undercut by differential weathering along sub-horizontal to gently west dipping bedding defects or weaker sandstone/siltstone/shale horizons. Slopes are often steep (15º to 23°) and are randomly covered by sandstone boulders.

An extract of the relevant geological map is provided as Extract 1.



Extract 1: Extract of Sydney 1:100 000 Geological Sheet

4. FIELD WORK

4.1 Methods:

The field assessment comprised a walk over inspection and mapping of the site and adjacent properties on 16 March 2022 and a second inspection on the 20 February 2023 by a Senior Engineering Geologist. It included a photographic record of site conditions as well as limited geological/geomorphological mapping of the site and adjacent land with examination of soil slopes, bedrock outcrops, vegetation and drainage measures installed.

Mapping of the site was restricted to observations made from the accessible areas within the site or the adjacent (unformed) Mirrool Road. Inspection of the north end of the site was restricted due to site conditions. Explanatory notes are included in Appendix: 1.

4.2. Stability Assessment:

Inspection undertaken of the site indicated that fill has been stockpiled within the north of the site within the smaller proposed subdivision. Following a recent heavy rainfall event one of the fill stockpiles appears to have slumped. The fill stockpiles and slumping are shown in Photographs 4 and 5.

Photograph 4: View under the slumped stockpile in the north of the site

Photograph 5: View of one of the intact stockpiles

Inspection of the areas of the two smaller proposed subdivisions was restricted by dense vegetation however detached boulders appeared to be present within the slope although signs of imminent movement were not observed.

Further downgradient and within the larger block a large potentially unstable boulder was observed and is shown in Photograph 6.

CGC has previously undertaken detailed assessment of this boulder (See Section 1) and it was assessed as being a significant hazard with "Unacceptable" risk. The stabilising measures recommended in CGC previous report have not yet been constructed. The boulder does not appear to have moved since the inspection undertaken in March 2022 previously however it is not considered stable and will require works to stabilise.

Photograph 6: View of a potentially unstable boulder within the south of the proposed subdivision.

Directly adjacent to the unformed Mirrool Street a cut has been made within the larger subdivision running broadly north south. The cut appears to be around 2.5m in height and comprises a combination of fill (up to approximately 1.0m in thickness), below which clay soils appear to be present in turn underlain by extremely low strength bedrock.

Some minor slumping of the cut was observed however significant failure did not appear imminent.

Photograph 7: View of the cut batter

Observations of adjacent properties to the north and west were limited due to site conditions however no indications of significant cracking or movement were evident within the visible structures in these properties.

Some limited channel erosion was observed within the unformed Mirrool Street however drainage has been constructed within the east side of Mirrool Street which flows into a drainage system near the base of the site.

The property to the south of the site (No. 12 Mirrool Street) contained a two storey clad and timber structure which appeared to be in good condition.

4.3. Ground Model

Based on the observed conditions within the existing excavations within the site it is anticipated that the excavations required for the driveway and Lot 3 will be through fill and residual clay soils. Groundwater is not anticipated however seepages are likely to be encountered at the residual soil/bedrock interface if encountered in open excavations.

4.4. Site Specific Risk Assessment:

Based on our inspection of the site detailed in Section 4.2 we have identified the following credible geological/geotechnical hazards which need to be considered in relation to the existing site and the proposed subdivision. The hazards are:

A. Landslip (<5m^3) of existing fill piles within the north of the site
B. Landslip (<3m^3 soil slide) within excavation.
C. Landslip (≈225 tonnes) of large boulder within the south of the site

A qualitative assessment of risk to life and property related to these hazards is presented in Table A and B Appendix: 3, based on methods outlined in Appendix: C of the Australian Geomechanics Society (AGS) Guidelines for Landslide Risk Management 2007. AGS terms and their descriptions are provided in Appendix: 4.

Hazard A was estimated to have a **Risk to Life** of **2.60 x 10^{-9}** for a single person, while the **Risk to Property** was considered to be **'Very Low'**.

Hazard B was estimated to have a **Risk to Life** of up to **3.91 x 10^{-8}** for a single person, while the **Risk to Property** was considered to be **'Low'**.

Hazard C was estimated to have a **Risk to Life** of up to **2.34 x 10^{-4}** for a single person, while the **Risk to Property** was considered to be **'High'**.

In respect to the subdivision, new driveway construction and developments within the Lot 1 and Lot 3 DA submission, the existing risk to life is 'Unacceptable' levels when assessed against the criteria of the AGS. The Risk to Property to the partially completed dwelling was assessed as 'High' due to the existing unstable boulder adjacent. It should be noted that the assessed risks have for the proposed works increase where works re-commence on the garage/new residence within Lot 1, the occupancy will increase which will impact magnitude of risk.

CGC has previously provided an assessment and possible remediation strategies for the boulder. Based on that assessment and subsequent inspections it was determined that the boulder would unlikely impact the proposed new driveway and that providing the boulder is stabilised using one or more of the measures recommended, the driveway and subdivision development achieve the 'Acceptable Risk Management' criteria and that geotechnical risk within the wider site can be reasonably avoided. It is strongly recommended that the stabilisation of the boulder is completed before (re) commencement of construction works within the site.

4.5. Design & Construction Recommendations:

Design and the construction recommendations are tabulated below:

4.5.1. New Footings:	
Site Classification as per AS2870 – 2011 for new footing design	- Class 'P' due to potential slope movement.
Type of Footing	Strip/pad footings or shallow piles to extend to bedrock.
Sub-grade material and Maximum Allowable Bearing Capacity	Very low strength sandstone or stronger – 800kPa
Site sub-soil classification as per *Structural design actions AS1170.4 – 2007, Part 4: Earthquake actions in Australia*	B_e – Rock site
Remarks: All footings should be founded off bedrock of similar strength to prevent differential settlement. Piles should be socketed at least one diameter into weathered bedrock to provide stability within the slope. All new footings must be inspected by an experienced geotechnical professional before concrete or steel are placed to verify their bearing capacity and the in-situ nature of the founding strata. This is mandatory to allow them to be 'certified' at the end of the project.	

4.5.2. Excavation:	
Depth of Excavation	Up to 2.0m
Distance to Neighbouring Properties	Within 1.5m from western boundary (Lot 3), 10.0m from northern boundary and 8.0m to western and eastern site boundaries for proposed new road. Approximately 6.0m from southern boundary for Lot 3 shared with Lot 2.
Type of Material to be Excavated (Probable)	Fill Residual soils Sandstone bedrock-variable strength and depths

Guidelines for un-surcharged batter slopes for this site are tabulated below:

Material	Safe Batter Slope (H:V)*	
	Short Term/ Temporary	Long Term/ Permanent
Fill/Natural Soils and extremely weathered sandstone.	1.5:1	2:1
Very Low Strength bedrock	1:1	1.25:1
Low to Medium Strength bedrock	Vertical	Vertical

*Subject to geotechnical inspection

Remarks:

Seepage at the bedrock surface or along defects in the soil can also reduce the stability of batter slopes and invoke the need to implement additional support measures. Where safe batter slopes are not implemented the stability of the excavation cannot be guaranteed until the installation of permanent support measures. This should also be considered with respect to safe working conditions. All excavations should be inspected at regular intervals by a geotechnical specialist.

Equipment for Excavation	Fill/Natural Soils	Hand Tools or excavator with bucket
	ELS bedrock (fragments of intact bedrock in clayey matrix)	Hand tools or excavator-Medium strength rock fragments may require hand held breaker to remove)
	VLS bedrock	Hand Tools or excavator with bucket and ripper

ELS – extremely low strength, VLS – very low strength, LS – low strength, MS – medium strength

Recommended Vibration Limits (Maximum Peak Particle Velocity (PPV))	Not applicable unless bedrock encountered in excavation
Vibration Calibration Tests Required	Subject to ground conditions within the Lot 3 excavation
Full time vibration Monitoring Required	Subject to ground conditions within the Lot 3 excavation
Geotechnical Inspection Requirement	Yes, recommended that these inspections be undertaken as per below mentioned sequence: • Installation of support measures • At completion of the excavation
Dilapidation Surveys Requirement	Not applicable

Remarks:

Water ingress into exposed excavations can result in erosion and stability concerns in both soil and rock portions. Drainage measures will need to be in place during excavation works to divert any surface flow away from the excavation crest and any batter slope.

4.5.3. Retaining Structures:

Required	Temporary excavation support may be required as well as permanent retaining structures as part of the proposed developments.
Types	Soldier pile style wall (either reinforced concrete or post beam) with steel reinforced concrete walls prior to and post excavation, in accordance with Australian Standard AS 4678-2002 Earth Retaining Structures. Sand bags could be used to provide temporary support in settlement sensitive areas if required.

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

Material	Unit Weight (kN/m3)	Long Term (Drained)	Earth Pressure Coefficients		Passive Earth Pressure Coefficient *
			Active (Ka)	At Rest (K_0)	
Fill	20	$\phi' = 30°$	0.41	0.50	N/A
Silty/Sandy Clay	22	$\phi' = 34°$	0.28	0.50	N/A
VLS bedrock	22	$\phi' = 38°$	0.15	0.20	200 kPa

Remarks:

In suggesting these parameters it is assumed that the retaining walls will be fully drained with suitable subsoil drains provided at the rear of the wall footings. If this is not done, then the walls should be designed to support full hydrostatic pressure in addition to pressures due to the soil backfill. It is suggested that the retaining walls should be back filled with free-draining granular material (preferably not recycled concrete) which is only lightly compacted in order to minimize horizontal stresses.

Retaining structures near site boundaries or existing structures should be designed with the use of at rest (K_0) earth pressure coefficients to reduce the risk of movement in the excavation support and resulting surface movement in adjoining areas. Backfilled retaining walls within the site, away from site boundaries or existing structures, that may deflect can utilize active earth pressure coefficients (Ka).

4.5.4. Drainage and Hydrogeology		
Groundwater Table or Seepage identified in open excavations		No
Excavation likely to intersect	Water Table	No
	Seepage	Minor (≤1 L/min), on defects and at soil/rock interface, with the potential to increase during intense or prolonged rainfall events
Site Location and Topography		High north side of the road, within moderately south dipping topography
Impact of development on local hydrogeology		Negligible
Onsite Stormwater Disposal		Recommended that stormwater disposed off site.
Remarks: As the excavation faces are expected to encounter some seepage, an excavation trench should be installed at the base of excavation cuts to below floor slab/ pavement finished levels to reduce the risk of resulting dampness issues. Trenches, as well as all new building gutters, down pipes and stormwater intercept trenches should be connected to a stormwater system designed by a Hydraulic Engineer which discharges to the Council's stormwater system off site or to the Pittwater foreshore.		

4.6. Conditions Relating to Design and Construction Monitoring:

To comply with Councils conditions and to enable us to complete Forms: 2b and 3 required as part of construction, building and post-construction certificate requirements of the Councils Geotechnical Risk Management Policy 2009, it will be necessary for Crozier Geotechnical Consultants to;

1. Review and approve the structural design drawings for compliance with the recommendations of this report prior to construction,
2. Inspect all new footings and earthworks to confirm compliance to design assumptions with respect to allowable bearing pressure, basal cleanness and the stability prior to the placement of steel or concrete as per section 4.5 of this report.
3. Inspect any unsupported cuts to assess stability.
4. Inspect completed works to ensure construction activity has not created any new hazards.

The client and builder should make themselves familiar with the Councils Geotechnical Policy and the requirements spelled out in this report for inspections during the construction phase. Crozier Geotechnical Consultants cannot sign Form: 3 of the Policy if it has not been called to site to undertake the required inspections.

4.7. Design Life of Structure:

We have interpreted the design life requirements specified within Councils Risk Management Policy to refer to structural elements designed to support the house, the adjacent slope, control stormwater and maintain the risk of instability within the 'Acceptable' limits as defined by the Councils policy. Specific structures and features that may affect the maintenance and stability of the site in relation to the proposed and existing development are considered to comprise:

- stormwater and subsoil drainage systems,
- retaining walls and soil slope erosion and instability,
- maintenance of trees/vegetation on this and adjacent properties,

Man-made features should be designed and maintained for a design life consistent with surrounding structures (as per AS2870 – 2011 (50 years)). In order to attain a design life of 50 years, which is considered to be remnant design life of the existing development, within the 'Acceptable' risk management criteria as required by the Councils Risk Management Policy, it will be necessary for the property owner to adopt and implement a maintenance and inspection program.

A recommended program is given in Table: 1 below and should also include the following guidelines.

- The conditions on the block don't change from those present at the time this report was prepared, except for the changes due to this development.
- There is no change to the property due to an extraordinary event external to this site, and the property is maintained in good order and in accordance with the guidelines set out in;
  - a) CSIRO sheet BTF 18
  - b) Australian Geomechanics "Landslide Risk Management" Volume 42, March 2007.
  - c) AS 2870 – 2011, Australian Standard for Residential Slabs and Footings

Table 1: Recommended Maintenance and Inspection Program

Structure	**Maintenance/ Inspection Item**
Stormwater drains.	Owner to inspect to ensure that the drains and pipes are free of debris & sediment build-up. Clear surface grates and litter.
Retaining Walls or remedial measures	Owner to inspect walls for deviation from as constructed condition.
Large Trees on or adjacent to site	Arbourist to check condition of trees and remove branches as required

N.B. Provided the above schedule is maintained the design life of the property should conform to AS2870.

Where changes to site conditions are identified during the maintenance and inspection program, reference should be made to relevant professionals (e.g. structural engineer, geotechnical engineer or Council).

It is assumed that Council will control development on neighbouring properties, carry out regular inspections and maintenance of the road verge, stormwater systems and large trees on public land adjacent to the site so as to ensure that stability conditions do not deteriorate with potential increase in risk level to the site. Also individual Government Departments will maintain public utilities in the form of power lines, water and sewer mains to ensure they don’t leak and increase either the local groundwater levels or landslide potential.

5. COMMENTS:

5.1. Geotechnical Assessment:

The site inspection and Risk Assessment identified that the only significant risk was to the partially completed dwelling within Lot 1 in the event of a boulder roll. The likelihood of the boulder impacting the dwelling is high with unacceptable risk however the risk to the adjacent driveway is low due to the distance and anticipated travel distance of the boulder which will likely be further hindered by the surficial soils below the boulder which will reduce the kinetic energy of any roll.

It should also be noted that although there is a risk of boulder roll within the site, there is no significant hazards posed to the northern two proposed subdivision blocks or road reserve. There were minor landslip risks in the form of fill stockpiles. However, a separate investigation and report is required for any future development works within this area prior to construction.

Due to the relatively limited excavation proposed within Lot 3, and subject to the finalised excavation perimeters, pre-excavation support may be required where the excavation falls within 2.0m of the shared boundaries due to the anticipated fill residual soils within this area. Further assessment will be necessary following commencement of earthworks to determine safe batter slopes and required retaining measures based on ground conditions encountered (which are currently unknown).

The recommendations and conclusions in this report are based on surface observations only. However, based on the nature of the proposal it is considered the site is suitable for the proposed developments however additional works may be required to allow assessment of any required retaining measures to be included in the CC application.

The risks associated with the proposed works within Lot 1 were considered 'Unacceptable' when assessed against the requirements of AGS and Pittwater Council however they can be reduced to an 'Acceptable' level with negligible impact to properties or struct1ures provided the recommendations of this report, previous assessments by CGC and any future geotechnical directive are implemented. As such the site is considered suitable for the proposed construction works provided that the recommendations outlined in this report are followed.

Prepared by:	Checked by:
Kieron Nicholson	Troy Crozier
Senior Engineering Geologist	Principal
	MIE Aust, CPEng
	MAIG, RPGeo – Geotechnical and Engineering
	Registration No.: 10197

6. REFERENCES:

1. Australian Geomechanics Society 2007, “Landslide Risk Assessment and Management”, Australian Geomechanics Journal Vol. 42, No 1, March 2007.
2. Geological Society Engineering Group Working Party 1972, “The preparation of maps and plans in terms of engineering geology” Quarterly Journal Engineering Geology, Volume 5, Pages 295 - 382.
3. E. Hoek & J.W. Bray 1981, “Rock Slope Engineering” By The Institution of Mining and Metallurgy, London.
4. C. W. Fetter 1995, “Applied Hydrology” by Prentice Hall.
5. V. Gardiner & R. Dackombe 1983, “Geomorphological Field Manual” by George Allen & Unwin.
6. Australian Standard AS1170.4 – 2007, Part 4: Earthquake actions in Australia

Appendix 1

CROZIER GEOTECHNICAL CONSULTANTS

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NOTES RELATING TO THIS REPORT

Introduction

These notes have been provided to amplify the geotechnical report in regard to classification methods, specialist field procedures and certain matters relating to the Discussion and Comments section. Not all, of course, are necessarily relevant to all reports.

Geotechnical reports are based on information gained from limited subsurface test boring and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Description and classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, Geotechnical Site Investigation Code. In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. Sandy clay) on the following bases:

Soil Classification	Particle Size
Clay	less than 0.002 mm
Silt	0.002 to 0.06 mm
Sand	0.06 to 2.00 mm
Gravel	2.00 to 60.00mm

Cohesive soils are classified on the basis of strength either by laboratory testing or engineering examination. The strength terms are defined as follows:

Classification	Undrained Shear Strength kPa
Very soft	Less than 12
Soft	12 - 25
Firm	25 – 50
Stiff	50 – 100
Very stiff	100 - 200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration tests (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	SPT "N" Value (blows/300mm)	CPT Cone Value (Qc – MPa)
Very loose	less than 5	less than 2
Loose	5 – 10	2 – 5
Medium dense	10 – 30	5 -15
Dense	30 – 50	15 – 25
Very dense	greater than 50	greater than 25

Rock types are classified by their geological names. Where relevant, further information regarding rock classification is given on the following sheet.

Sampling

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling to allow information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Drilling Methods

The following is a brief summary of drilling methods currently adopted by the company and some comments on their use and application.

Test Pits – these are excavated with a backhoe or a tracked excavator, allowing close examination of the insitu soils if it is safe to descent into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) – the hole is advanced by a rotating plate or short spiral auger, generally 300mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling – the hole is advanced by pushing a 100mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling soils, since moisture content is unchanged and soil structure, strength, etc. is only marginally affected.

Continuous Spiral Flight Augers – the hole is advanced using 90 – 115mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPT's or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling - the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

Rotary Mud Drilling – similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. From SPT).

Continuous Core Drilling – a continuous core sample is obtained using a diamond-tipped core barrel, usually 50mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests (abbreviated as SPT) are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedures is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" – Test 6.3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube under the impact of a 63kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150mm of say 4, 6 and 7
  as 4, 6, 7 then N = 13
- In the case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm then as 15, 30/40mm.

The results of the test can be related empirically to the engineering properties of the soil. Occasionally, the test method is used to obtain samples in 50mm diameter thin wall sample tubes in clay. In such circumstances, the test results are shown on the borelogs in brackets.

Cone Penetrometer Testing and Interpretation

Cone penetrometer testing (sometimes referred to as Dutch Cone – abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in Australia Standard 1289, Test 6.4.1.

In tests, a 35mm diameter rod with a cone-tipped end is pushed continually into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separte 130mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected buy electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) their information is plotted on a computer screen and at the end of the test is stored on the computer for later plotting of the results.

The information provided on the plotted results comprises: -

- Cone resistance – the actual end bearing force divided by the cross-sectional area of the cone – expressed in MPa.
- Sleeve friction – the frictional force on the sleeve divided by the surface area – expressed in kPa.
- Friction ratio - the ratio of sleeve friction to cone resistance, expressed in percent.

There are two scales available for measurement of cone resistance. The lower scale (0 – 5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main scale (0 – 50 MPa) is less sensitive and is shown as a full line. The ratios of the sleeve friction to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios 1% - 2% are commonly encountered in sands and very soft clays rising to 4% - 10% in stiff clays.

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

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

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

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

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

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

Dynamic Penetrometers

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

Two relatively similar tests are used.

- Perth sand penetrometer – a 16mm diameter flattened rod is driven with a 9kg hammer, dropping 600mm (AS1289, Test 6.3.3). The test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
- Cone penetrometer (sometimes known as Scala Penetrometer) – a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS 1289, Test 6.3.2). The test was developed initially for pavement sub-grade investigations, and published correlations of the test results with California bearing ratio have been published by various Road Authorities.

Laboratory Testing

Laboratory testing is generally carried out in accordance with Australian Standard 1289 "Methods of Testing Soil for Engineering Purposes". Details of the test procedure used are given on the individual report forms.

Borehole Logs

The bore logs presented herein are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable, or possible to justify on economic grounds. In any case, the boreholes represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes, the frequency of sampling and the possibility of other than 'straight line' variations between the boreholes.

Details of the type and method of sampling are given in the report and the following sample codes are on the borehole logs where applicable:

D	Disturbed Sample	E	Environmental sample	DT	Diatube
B	Bulk Sample	PP	Pocket Penetrometer Test		
U50	50mm Undisturbed Tube Sample	SPT	Standard Penetration Test		
U63	63mm " " " " "	C	Core		

Ground Water

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

- In low permeability soils, ground water although present, may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report.
- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made. More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be interference from a perched water table.

Engineering Reports

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. A three-storey building), the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty-storey building). If this happens, the Company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface condition, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- unexpected variations in ground conditions – the potential for this will depend partly on bore spacing and sampling frequency,
- changes in policy or interpretation of policy by statutory authorities,
- the actions of contractors responding to commercial pressures,

If these occur, the Company will be pleased to assist with investigation or advice to resolve the matter.

Site Anomalies

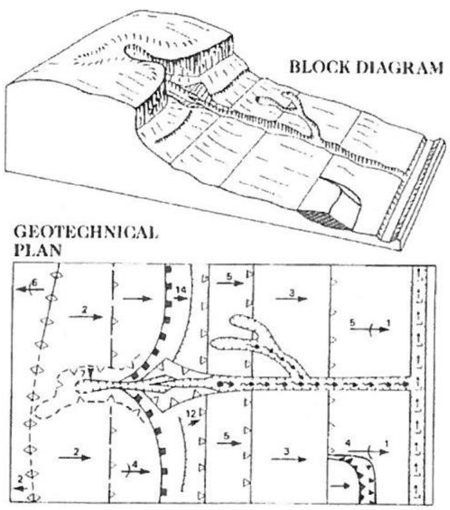
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some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

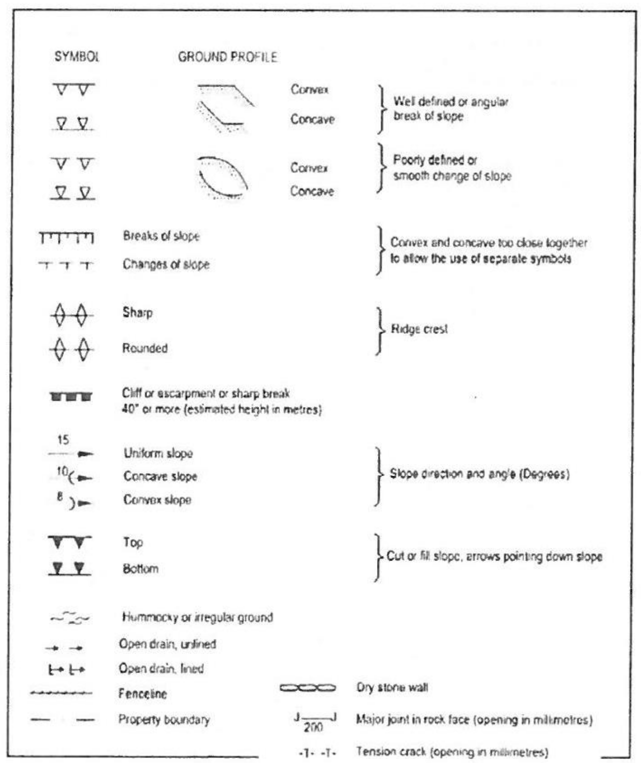
Reproduction of Information for Contractual Purposes

Attention is drawn to the document "Guidelines for the Provision of Geotechnical Information in Tender Documents", published by the Institution of Engineers Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a special ally edited document. The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

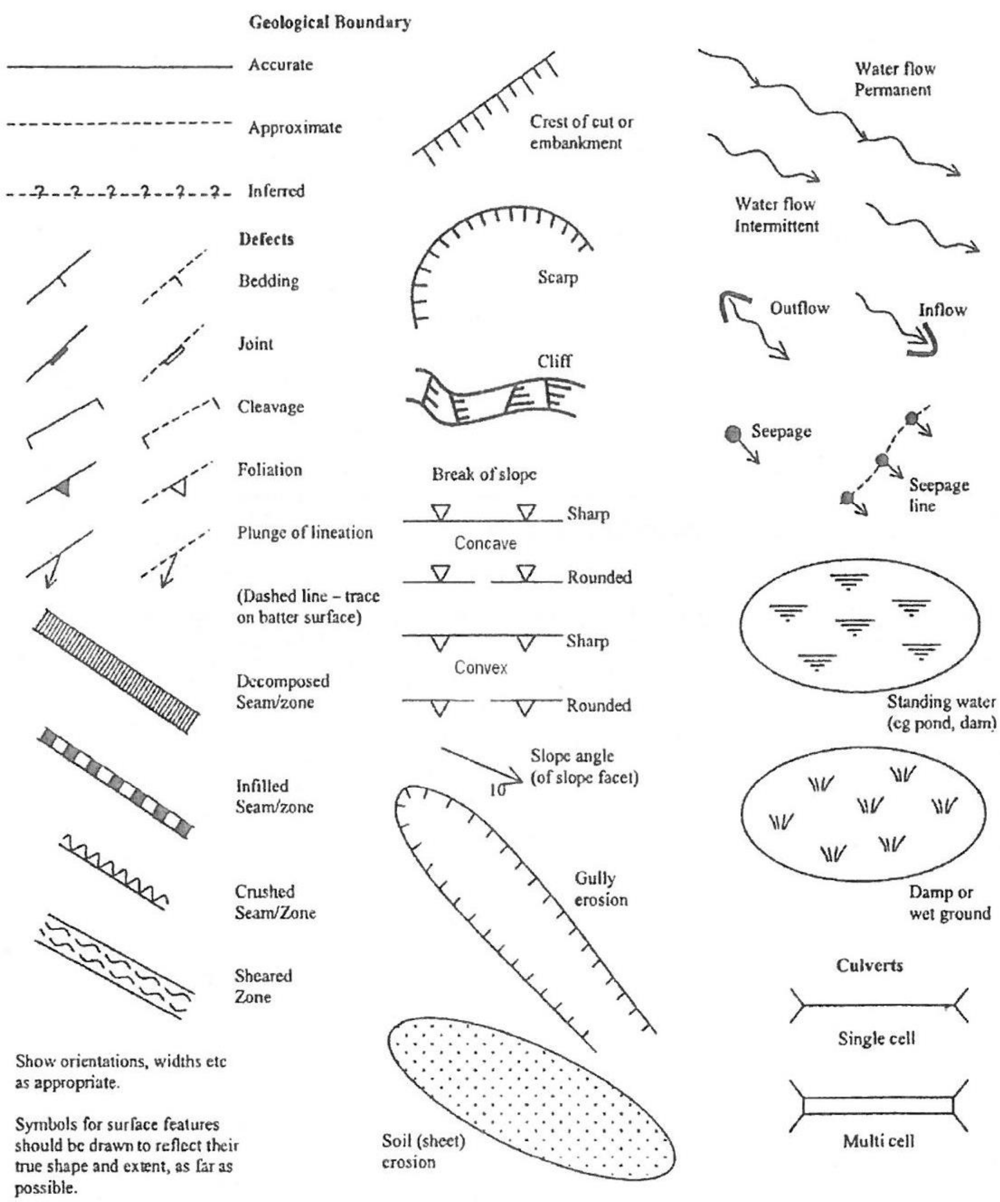
The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.





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

APPENDIX E - GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING SYMBOLS AND TERMINOLOGY



Examples of Mapping Symbols (after Guide to Slope Risk Analysis Version 3.1 November 2001, Roads and Traffic Authority of New South Wales).

Appendix 2

<u>**TABLE : A**</u>

Landslide risk assessment for Risk to life

HAZARD	Description	Impacting	Likelihood of Slide	Spatial Impact of Slide		Occupancy	Evacuation	Vulnerability	Risk to Life
A	Landslip (<5m^3) of existing fill piles within the north of the site		Appears fill piles contained within north of site, recent heavy rain triggered a slide	a) Landslip would impact edge of Mirrool Road		a) Person on Mirrool Road 0.25/day average	a) Possible to not evacuate	a) Person in open space, not buried	
			Likely	**Prob. of Impact**	**Impacted**				
		a) Mirrool Road (currently unformed)	0.01	0.10	0.01	0.0104	0.5	0.05	**2.60E-09**
B	Landslip (<3m3 soil slide) within excavations		Appears vertical cuts up to 2.0m in soils will be required	a) Cut on edge of Mirrool Road, edge only impacted b) Boundary and garden may be impacted		a) Person on Mirrool Road 0.25hr/day average b) Person in garden 1 hr/day	a) Possible to not evacuate b) Possible to not evacuate	a) Person in open space, not buried	
			Likely	**Prob. of Impact**	**Impacted**				
		a) Mirrool Road (currently unformed)	0.01	0.75	0.01	0.0104	0.5	0.10	**3.91E-08**
			Possible						
		b) 111 Woorarra Avenue (Garden)	0.001	0.50	0.01	0.0417	0.5	0.05	**5.21E-09**
C	Landslip (boulder roll 225 tonnes)		Large boulder potentially unstable	a) Directly upslope, within 10m of dwelling b) up and across slope (>25m) may travel to north-east corner of structure		a) Person indwelling 20hrs/day avg. b) Person indwelling 20hrs/day avg.	a) Likely to not evacuate b) Possible to not evacuate	a) Person in building, crushed b) Person in building, crushed	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Dwelling Lot 1 (partially completed)	0.001	0.75	0.50	0.8333	0.75	1.00	**2.34E-04**
		b) Dwelling 12 Mirrool	0.001	0.20	0.20	0.8333	0.50	1.00	**1.67E-05**

* hazards considered in current condition and/or without remedial/stabilisation measures or poor support systems

* likelihood of occurrence for design life of 100 years

* Spatial Impact - Probaility of Impact refers to slide impacting structure/area expressed as a % (i.e. 1.00 = 100% probability of slide impacting area if slide occurs).
Impacted refers to expected % of area/structure damaged if slide impacts (i.e. small, slow earth slide will damage small portion of house structure such as 1 bedroom (5%), where as large boulder roll may damage/destroy >50%)

* neighbouring houses considered for impact of slide to bedroom unless specified, due to high occupancy and lower potential for evacuation.

* considered for person most at risk, where multiple people occupy area then increased risk levels

* for excavation induced landslip then considered for adjacent premises/buildings founded off shallow footings, unless indicated

* evacuation scale from Almost Certain to <u>not</u> evacuate (1.0), Likely (0.75), Possible (0.5), Unlikely (0.25), Rare to not evacuate (0.01). Based on likelihood of person knowing of landslide and completely evacuating area prior to landslide impact.

* vulnerability assessed using Appendix F - AGS Practice Note Guidelines for Landslide Risk Management 2007

TABLE : B

Landslide risk assessment for Risk to Property

HAZARD	Description	Impacting	Likelihood		Consequences		Risk to Property
A	Landslip (<5m3) of existing fill piles within the north of the site	a) Mirrool Road (currently unformed)	Possible	The event could occur under adverse conditions over the design life.	Insignificant	Little Damageor no impact to neighbouring properties, no significant stabilising required .	Very Low
B	Landslip (<3m3 soil slide) within excavations	a) Mirrool Road (currently unformed)	Likely	Event will probably occur under adverse circumstances over the design life.	Insignificant	Little Damageor no impact to neighbouring properties, no significant stabilising required .	Low
		b) 111 Woorarra Avenue	Possible	The event could occur under adverse conditions over the design life.	Insignificant	Little Damageor no impact to neighbouring properties, no significant stabilising required .	Very Low
C	Landslip (boulder roll 225 tonnes)	a) Dwelling Lot 1 (partially completed)	Possible	The event could occur under adverse conditions over the design life.	Major	Extensive damage to most of site/structures or MEDIUM damage to neighbouring properties, significant stabilising to support site .	High
		b) Dwelling 12 Mirrool	Unlikely	The event might occur under very adverse circumstances over the design life.	Medium	Moderate damage to some of structure or significant part of site or MINOR damage to neighbouring property, requires large stabilising works .	Low

* hazards considered in current condition, without remedial/stabilisation measures and during construction works.
* qualitative expression of likelihood incorporates both frequency analysis estimate and spatial impact probability estimate as per AGS guidelines.
* qualitative measures of consequences to property assessed per Appendix C in AGS Guidelines for Landslide Risk Management.
* Indicative cost of damage expressed as cost of site development with respect to consequence values: Catastrophic : 200%, Major: 60%, Medium: 20%, Minor: 5%, Insignificant: 0.5%.
* Cost of site development estimated at $5,000,000

TABLE: 2

Recommended Maintenance and Inspection Program

Structure	Maintenance/ Inspection Item	Frequency
Stormwater drains.	Owner to inspect to ensure that the open drains, and pipes are free of debris & sediment build-up. Clear surface grates and litter. Owner to check and flush retaining wall drainage pipes/systems	Every year or following each major rainfall event. Every 7 years or where dampness/moisture
Retaining Walls. or remedial measures	Owner to inspect walls for deveation from as constructed condition and repair/replace. Replace non engineered rock/timber walls prior to collapse	Every two years or following major rainfall event. As soon as practicable
Large Trees on or adjacent to site	Arborist to check condition of trees and remove as required. Where tree within steep slopes (>18°) or adjacent to structures requires geotechincal inspection prior to removal	Every five years
Slope Stability	Geotechnical Engineering Consultant to check on site stability and maintenance	Five years after construction is completed.

N.B. Provided the above shedule is maintained the design life of the property should conform with Councils Risk Management Policy.

Appendix 3

APPENDIX A

DEFINITION OF TERMS

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES WORKING GROUP ON LANDSLIDES, COMMITTEE ON RISK ASSESSMENT

Risk – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

Hazard – A condition with the potential for causing an undesirable consequence (*the landslide*). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.

Elements at Risk – Meaning the population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

Probability – The likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible outcome, and 1 indicating that an outcome is certain.

Frequency – A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.

Likelihood – used as a qualitative description of probability or frequency.

Temporal Probability – The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.

Vulnerability – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

Consequence – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

Risk Analysis – The use of available information to estimate the risk to individuals or populations, property, or the environment, from hazards. Risk analyses generally contain the following steps: scope definition, hazard identification, and risk estimation.

Risk Estimation – The process used to produce a measure of the level of health, property, or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis, and their integration.

Risk Evaluation – The stage at which values and judgements enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental, and economic consequences, in order to identify a range of alternatives for managing the risks.

Risk Assessment – The process of risk analysis and risk evaluation.

Risk Control or Risk Treatment – The process of decision making for managing risk, and the implementation, or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

Risk Management – The complete process of risk assessment and risk control (*or risk treatment*).

Individual Risk – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.

Societal Risk – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental, and other losses.

Acceptable Risk – A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

Tolerable Risk – A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible.

In some situations risk may be tolerated because the individuals at risk cannot afford to reduce risk even though they recognise it is not properly controlled.

Landslide Intensity – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.

Note: Reference should also be made to Figure 1 which shows the inter-relationship of many of these terms and the relevant portion of Landslide Risk Management.

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	**Notional Boundary**					
10^{-1}	5×10^{-2}	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	5×10^{-3}	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	5×10^{-4}	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	5×10^{-5}	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	5×10^{-6}	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	**Notional Boundary**			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

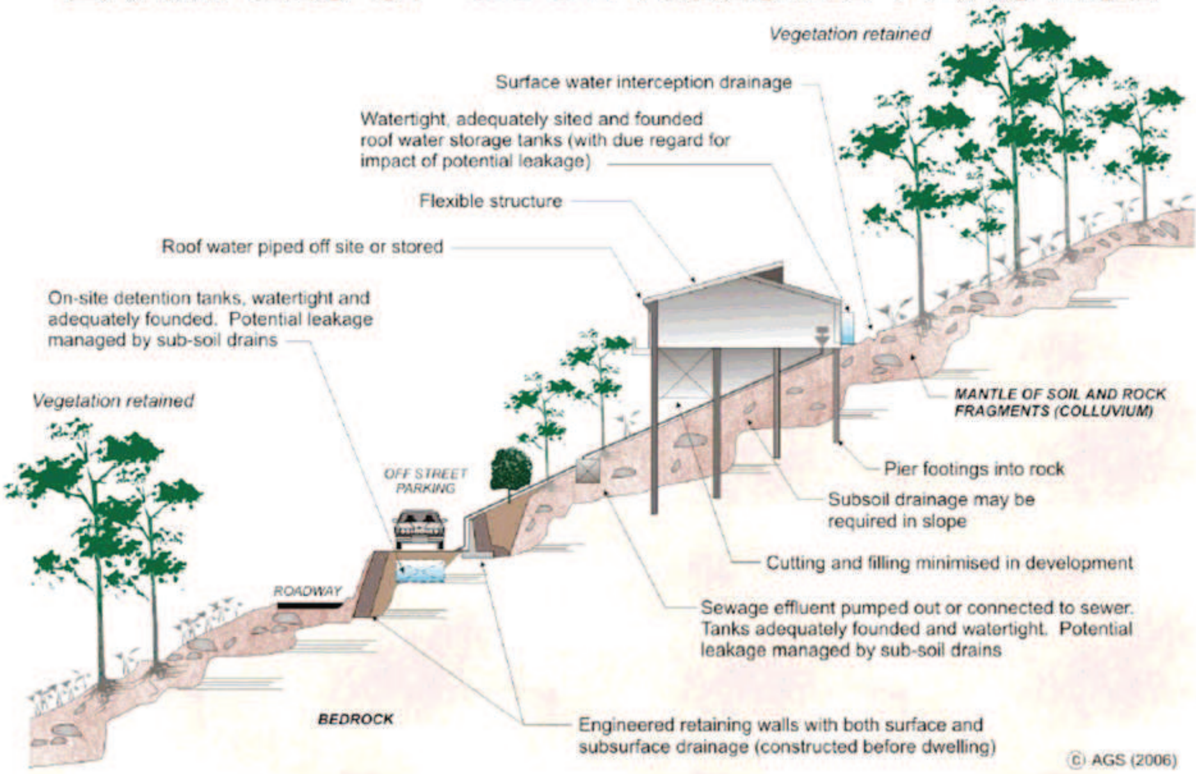
Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

Appendix 4

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