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

REPORT ON GEOTECHNICAL ASSESSMENT

for

PROPOSED ALTERATIONS AND ADDITIONS

at

1100 BARRENJOEY ROAD, PALM BEACH

Prepared For

Nicholas Sprout

Project No.: 2019-100
July, 2019

Document Revision Record

Issue No	Date	Details of Revisions
0	18th July, 2019	Original issue

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for________________________________

Name of Applicant

Address of site 1100 Barrenjoey Road, Palm Beach

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** _______*

on this the _18th July 2019___ 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 Assessment for Proposed Alterations and Additions

Report Date: 18th July 2019 **Project No.:** 2019-100

Author: T. Crozier

Author's Company/Organisation: Crozier Geotechnical Consultants

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

Design Drawings by koughDESIGN, Project No.: 2019-013, Drawing No.: A000, A001, A004 to A007,
A009, A010, A100, A109, A110, A200, A201, A203 to A205, A300, Revision: A, Dated: 5th June 2019.
Site Survey Plan by True North Surveys, Job Ref.: 8928, Dated: 2nd May 2019

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 ____1100 Barrenjoey Road, Palm Beach________________________________

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 Assessment for Proposed Alterations and Additions
Report Date: 17th July 2019 **Project No.:** 2019-100
Author: T. Crozier
Author's Company/Organisation: Crozier Geotechnical Consultants

Please mark appropriate box

■ Comprehensive site mapping conducted __9th July 2019______
(date)

□ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200

■ (as appropriate)

Subsurface investigation required

- ■ No Justification ....no ground works proposed in development......
- □ 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 ...50 years ....
specify

■ 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 GEOSCIENTIST
AUSTRALIAN INSTITUTE OF GEOSCIENTISTS
TROY CROZIER

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

GEOTECHNICAL ASSESSMENT FOR PROPOSED ALTERATIONS AND ADDITIONS
1100 BARRENJOEY ROAD, PALM BEACH, NSW

1. INTRODUCTION:

This report details the results of a geotechnical assessment carried out for proposed alterations and additions at 1100 Barrenjoey Road, Palm Beach, NSW. The assessment was undertaken by Crozier Geotechnical Consultants (CGC) at the request of Kough Design on behalf of the client Nicholas Sprout.

It is understood that alterations and additions to the existing residential house are proposed and constitute minor alteration to the existing first floor level with a small building extension to the north in the location of an existing timber deck. Minor internal alteration and some external landscaping are also proposed. The works require no bulk excavation, retention or filling and may require some minor footings only.

The site is located within the H1 (highest category) landslip hazard zone as identified within Northern Beaches Councils Pittwater LEP/DCP (Geotechnical Risk Management Policy for Pittwater - 2009). To meet the Councils Policy requirements for land classified as H1 undertook and inspection and provide a geotechnical report which meets the requirements of Paragraph 6.5 of that policy.

The proposed works are considered minor from a geotechnical perspective and involve no significant geotechnical component, This report therefore includes a description of the site conditions, landslide risk assessment and provides recommendations for construction and site maintenance to ensure stability is maintained for a design life of 100 years.

The investigation and reporting were undertaken as per the Tender P19-208, Dated: 21st June 2019.

The geotechnical investigation included:

a) Detailed geotechnical inspection of the entire site and adjacent land, with identification of geotechnical conditions including landslip hazards related to the existing site and proposed structures with photographic record of site conditions

The following plans and diagrams were supplied for this work;

- Design Drawings by koughDESIGN, Project No.: 2019-013, Drawing No.: A000, A001, A004 to A007, A009, A010, A100, A109, A110, A200, A201, A203 to A205, A300, Revision: A, Dated: 5th June 2019.
- Site Survey Plan by True North Surveys, Job Ref.: 8928, Dated: 2nd May 2019

2. SITE FEATURES:

2.1. Description:

The site is a rectangular shaped block located on the high east side of Barrenjoey Road. The front edge of the site is located within gently sloping topography with the rear majority formed over the base of a steep west dipping slope. The site has front west and rear east boundaries of 20.12m with north and south boundaries of 90.96m, as referenced from the provided survey plan.

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

Photograph: 1 ï site and surrounding properties

The site rises from a low of approximately RL = 2.74m at the front south-west corner of the property to a high of approximately RL = 30m at the north-east corner. It is currently occupied by a three level timber residence at the front of the block that steps up the base of the slope with landscaped gardens and lawns within the rear three quarters of the block. General views of the site are provided in Photograph: 2 to 4 below.

Photo: 2 – General view of front of site, facing east.

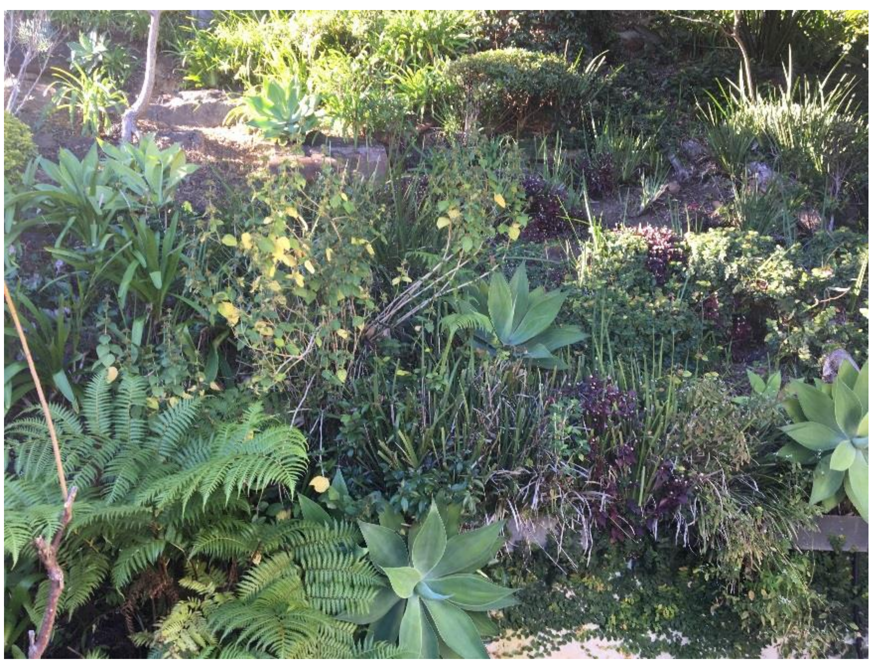

Photo: 3 – General view of landscaped slope at rear of house, facing east.

Photo: 4 – General view of upper portion of site, facing north-east.

2.2. Geology:

Reference to the Sydney 1: 100,000 Geological Series sheet (9130) indicates that the majority of the site is underlain by Newport Formation (Rnn) of the Upper Narrabeen Group. Newport Formation (Upper Narrabeen Group) is of middle Triassic Age and typically comprises interbedded laminite, shale and quartz to lithic quartz sandstones and pink clay pellet sandstones.

Narrabeen Group rocks are dominated by shales and thin siltstone/sandstone beds and often form rounded convex ridge tops with moderate angle (<20°) side slopes. These side slopes can be either concave or convex depending on geology, internally they comprise interbedded shale and siltstone beds with close spaced bedding partings that have either close spaced vertical joints or in extreme cases large space convex joints. The shale often forms deeply weathered profiles with silty or medium to high plasticity clays and a thin silty colluvial cover.

3. FIELD WORK:

3.1. Methods:

The field investigation comprised a walk over inspection and mapping of the site and adjacent properties on the 9th July 2019 by a Senior Engineering Geologist. It included a photographic record of site conditions as well as geological/geomorphological mapping of the site and adjacent land including examination of existing site structures and slopes. Explanatory notes are included in Appendix: 1.

3.2. Field Observations:

The site is situated on the high east side of Barrenjoey Road, which is a near level bitumen paved street with narrow lawn reserve extending up to the sites front boundary. There were no indications of landslip instability or geotechnical hazard that may impact the site within the road reserve.

The front edge of the site is gently sloping and contains a concrete driveway at the south-east corner, Photo: 5, that provides access to two garage doors at lower level of the house. To the north is a concrete paved terrace containing a buried sandstone boulder with another paved driveway to parking bay located adjacent to the north side boundary.

Photo: 5 - Lower Ground level, viewed from street

Photo: 6 - Parking bay on north boundary

The existing house is a ôTô shaped timber residential structure in plan view that is formed with three levels that essentially step up the block along the southern side boundary. The Lower Ground level, located to the front, is a part of a two storey portion that appears founded at the base of a shallow excavation along the south boundary and to the rear eastern side.

The Ground Floor is formed over the Lower Ground and also extends north as an ôLô shaped structure, see Photo: 6, that is formed slightly (<2.0m) above ground surface levels and supported via timber posts to unknown footings. One portion of the structure is supported off a sandstone boulder located within the slope, see Photo: 7.

Photo: 7 ï House supported off boulder

Photo: 8 ï Retaining wall at rear of First Floor

The First Floor level is located to the east and partly above the Ground Floor and is also supported above ground surface levels via timber posts. The rear eastern side of this level is formed into the base of an excavation that is supported via a shotcrete/concrete retaining wall that is up to 2.0m in height, see Photo: 8. A sandstone boulder is located to the rear south-east of the First Floor level, supported off the crest of the shotcrete retaining wall. The wall appeared in good condition with no signs of cracking, deformation or excess deterioration whilst the existing house appears in good condition.

To the rear of the house, extending approximately 15m east, are steep (up to 35°) soil slopes with extensive low vegetation/gardens and timber stairs. A sandstone boulder is located within the slope, upslope of the existing First Floor level, buried into the slope. The timber stairs and soil slopes show signs of soil creep movement however there were no signs of surface stormwater erosion, seepage or previous/impending landslip instability.

Above the garden slope the site becomes undulating and moderately (<18°) sloping with scattered medium to large trees, undulating and sloping lawns and numerous medium to large (>100t) sandstone boulders. The boulders are buried into the hill slope and increase in concentration and ground coverage towards the rear of the site. There were no signs of surface erosion, excess creep within tree trunks or signs of recent or impending movement within the sandstone boulders, which all appeared significantly buried within the hill slope.

The neighbouring property to the north (No. 1110) contains a commercial development across the front half which is formed in part at the base of an excavation with moderately sloping lawns and driveways to the rear. The excavation is supported via a concrete retaining wall that also supports the front northern side of the site, see Photo: 9.

The neighbouring property to the south, No. 1098, contains a two storey brick and timber residential house at the front, elongated across the block within a narrow raised terrace with steep undeveloped and natural slopes rising up towards the rear, see Photo: 10.

Photo: 9 - No. 1110 at common boundary with site

Photo: 10 ï No. 1098 ï adjacent to boundary

The neighboring properties to the rear (No. 136 and 138 Pacific Road) contain residential house structures on the front half of the blocks with landscaped and natural garden slopes to the rear including numerous buried sandstone boulders.

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

4. COMMENTS:

4.1. Geotechnical Assessment:

The site investigation identified that the existing house is in good condition and supported off variable footings which appear to include a raft slab for the front western portion and then timber posts to unknown footings for the remainder. One footing was identified as being supported off a boulder located within the slope. There were no indications of significant movement in the boulder or house structure however an assessment of previous movement in building footings is not possible without previous records due to the flexible nature of the house structure.

The soil/garden slope located to the rear of the house is steep and shows signs of soil creep however there were no indications of previous landslip instability. One boulder is located within this slope however there are no indications of its movement within the slope. The rear of the site contains numerous large boulders across a moderate slope however all boulders appear significantly buried and show no signs of previous or impending movement.

The proposed works involve internal alterations, minor landscaping and a small extension to the First Floor level of the house. These works are located above ground surface levels and in areas which contain existing development structures therefore the works are considered óMinorô from a geotechnical perspective and require no excavation, filling or retention.

The steep soil/garden slope to the rear of the existing house is considered to present a long term slope stability hazard for shallow earth slides whilst future erosion and soil creep could destabilize the sandstone boulder upslope of the house under adverse conditions.

However, the proposed works are considered suitable for the site and may be completed with negligible impact to existing nearby structures within the site or neighbouring properties provided the recommendations of this report are implemented in the design and construction phases.

4.2. Site Specific Risk Assessment:

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

A. Landslip (earth slide $<3m^3$) of soils from steep soil slope at rear of house
B. Boulder roll/slide (up to $3m^3$) from boulder within slope to rear of house

A qualitative assessment of risk to life and property related to this hazard is presented in Table A and B, Appendix: 2, and is based on methods outlined in Appendix: C of the Australian Geomechanics Society (AGS) Guidelines for Landslide Risk Management 2007. AGS terms and their descriptions are provided in Appendix: 4.

Hazard A was estimated to have a **Risk to Life** of up to **3.13 x 10^{-6} for a single person,** while the **Risk to Property** was considered to be óLowô.

Hazard B was estimated to have a **Risk to Life** of up to **3.09 x 10^{-8} for a single person,** while the **Risk to Property** was considered to be óLowô.

The risk related to these existing hazards is considered to achieve the óAcceptableô risk level and where the recommendations of this report are followed the probability of failure reduces in all situations and as such the risk will remain within the óAcceptableô risk management criteria of Councils policy for the design life of the existing development, taken as 50 years. Therefore, the project is considered suitable for the site provided the recommendations of this report are implemented.

4.3. Design & Construction Recommendations:

Design and the construction recommendations are tabulated below:

5.3.1. New Footings:	
Site Classification as per AS2870 ï 2011 for new footing design	Class ćPô for footings due to slope condition
Type of Footing	Pile/pad recommended
Sub-grade material and Maximum Allowable Bearing Capacity	- Very Stiff Clay: 200kPa* - Hard Clay: 400kPa* - Weathered, ELS-VLS Bedrock: 700kPa*
Site sub-soil classification as per *Structural design actions AS1170.4 – 2007, Part 4: Earthquake actions in Australia*	B_e ï Rock Site
Remarks: All new footings must be inspected by an experienced geotechnical professional before concrete or steel are placed to verify the bearing capacities and stability. This is mandatory to allow them to be ćertifiedô at the end of the project. Individual structures should not be founded on materials with varying bearing and settlement characteristics unless the potential for differential movement has been allowed for in structural design.	

4.4. Conditions Relating to Design and Construction Monitoring:

To allow certification as part of construction, building and post-construction activity for this project, 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 Construction Certificate.
2. Inspect all new footings to confirm compliance to design assumptions with respect to allowable bearing pressure and stability prior to the placement of steel or concrete.
3. Inspect completed works to ensure no new landslip hazards have been created by site works and that all required stabilisation and drainage measures are in place.

The client and builder should make themselves familiar with the requirements spelled out in this report for inspections during the construction phase. Crozier Geotechnical Consultants cannot provide certification for the Occupation Certificate if it has not been called to site to undertake the required inspections.

4.5. 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 etc, the adjacent slope, control stormwater and maintain the risk of instability within acceptable limits. 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 ï 2011 (100 years)). It will be necessary for the structural and geotechnical engineers to incorporate appropriate design and inspection procedures during the construction period. Additionally the property owner should adopt and implement a maintenance and inspection program.

If this maintenance and inspection schedule are not maintained the design life of the property cannot be attained. A recommended program is given in Table: C in Appendix: 3 and should also include the following guidelines.

- The conditions on the block donโt 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
- The property is maintained in good order and in accordance with the guidelines set out in;

a) CSIRO sheet BTF 18

b) Australian Geomechanics ñLandslide Risk Managementò Volume 42, March 2007.

c) AS 2870 ï 2011, Australian Standard for Residential Slabs and Footings

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). Where the property owner has any lack of understanding or concerns about the implementation of any component of the maintenance and inspection program the relevant engineer should be contacted for advice or to complete the component.

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 donôt leak and increase either the local groundwater level or landslide potential.

5. CONCLUSION:

The site inspection did not identify any signs of previous or impending landslip instability or significant geotechnical hazards with all large boulders located upslope of the house significantly buried within the soil slopes and showing no signs of recent movement.

The existing house appears at least 20 years of age and shows no signs of previous impact or slope movement. Soil creep within the steep garden slope to the rear of the house could result in a shallow and small earth slide whilst the buried boulder directly up from the house could undergo movement in extreme conditions. However, both potential hazards appear stable at present.

The proposed works involve alterations and additions to the existing house and landscaping that involve no bulk excavation, filling or retention and may only require some new footings. The works are therefore considered óMinorô from a geotechnical perspective and will not create any new landslip hazards.

The existing potential landslip hazards were assessed to present risks within the óAcceptableô risk management criteria and therefore require no further assessment or stabilising measures.

It is recommended that all new footings be founded within residual soils of similar strength to reduce the potential differential settlement and soil creep impact. New footings will require inspection to verify their bearing capacity and the in-situ nature if they are to be ócertifiedô at the end of the project.

The risks associated with the site and proposed development can be maintained within óAcceptableô levels provided the recommendations of this report, including maintenance 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:

Troy Crozier
Principal
MAIG, RPGeo ï Geotechnical and Engineering
Registration No.: 10197

7. REFERENCES:

1. Australian Geomechanics Society 2007, ñLandslide Risk Assessment and Managementò, Australian Geomechanics Journal Vol. 42, No 1, March 2007.
2. Geological Society Engineering Group Working Party 1972, ñThe preparation of maps and plans in terms of engineering geologyò Quarterly Journal Engineering Geology, Volume 5, Pages 295 - 382.
3. C. W. Fetter 1995, ñApplied Hydrologyò by Prentice Hall. V. Gardiner & R. Dackombe 1983, ñGeomorphological Field Manualò by George Allen & Unwin
4. Australian Standard AS 2870 ï 1996, Residential Slabs and Footings ï Construction
5. Australian Standard AS1170.4 ï 2007, Part 4: Earthquake actions in Australia

CROZIER
GEOTECHNICAL CONSULTANTS

Appendix 1

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

NOTES RELATING TO THIS REPORT

Introduction

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

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

Description and classification Methods

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

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

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

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

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

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

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

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

Sampling

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

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

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

Drilling Methods

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

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

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

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

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

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

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

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

Standard Penetration Tests

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

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

The test results are reported in the following form.

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

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

Cone Penetrometer Testing and Interpretation

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

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

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

The information provided on the plotted results comprises: -

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

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

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

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

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.

Appendix 2

TABLE : A

Landslide risk assessment for Risk to life

HAZARD	Description	Impacting	Likelihood of Slide	Spatial Impact of Slide		Occupancy	Evacuation	Vulnerability	Risk to Life
A	Landslip (earth slide <3m³) from steep soil slope to rear of house		Slope is steep (>35°) and shows signs of creep movement though no signs of previous landslip	a) bedroom located directly down slope, covers 1/5 of slope base, impact 75% of room b) deck and poath at base of slope, cover 1/3 of slope base, impact 50%		a) Person in bedroom 10hrs/day avge. b) Person on deck and path 0.5hrs/day avge	a) Almost Certain to not evacuate b) Possible to not evacuate	a) Person in building, damage only b) Person in open space, buried	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Proposed Bedroom	0.001	0.20	0.75	0.4167	1.0	0.1	**3.13E-06**
		b) New deck and path	0.001	0.33	0.50	0.0208	0.5	1.0	**1.72E-06**
B	Landslip (boulder slide <3m³) from buried boulder in slope above house		Boulder is buried into steep slope	a) building directly down slope of boulder, if fails likely impact, impact 1/3		a) Person in ensuite 0.5hrs/day avge	a) Almost Certain to not evacuate	a) Person in building, minor damage only	
			Unlikely	**Prob. of Impact**	**Impacted**				
		a) Existing ensuite	0.0001	0.90	0.33	0.0208	1.0	0.05	**3.09E-08**

* 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 (earth slide <3m³) from steep soil slope to rear of house	a) Proposed Bedroom	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
		b) New deck and path	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
B	Landslip (boulder slide <3m³) from buried boulder in slope above house	a) Existing ensuite	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low

* hazards considered in current condition, without remedial/stabilisation measures and during construction works.

* qualitative expression of likelihood incorporates both frequency analysis estimate and spatial impact probability estimate as per AGS guidelines.

* qualitative measures of consequences to property assessed per Appendix C in AGS Guidelines for Landslide Risk Management.

* Indicative cost of damage expressed as cost of site development with respect to consequence values: Catastrophic : 200%, Major: 60%, Medium: 20%, Minor: 5%, Insignificant: 0.5%.

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.	Every year or following each major rainfall event.
Retaining Walls.	Owner to inspect walls for deveation from as constructed condition and repair/replace.	Every two years or following major rainfall event.
	Replace non engineered rock/timber walls prior to collapse	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	Every 10 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.