Don Fox Planning

martens consulting engineers

Preliminary Geotechnical Assessment:

Combined Rezoning and Sub-division Development Application – Elanora Conference Centre and part of Warriewood Ingleside Escarpment Reserve

ENVIRONMENTAL

WATER

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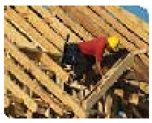
PROJECT MANAGEMENT



P0802241JR01-V3
June 2009

Limitations Statement

The sole purpose of this report and the associated services performed by Martens & Associates Pty Ltd is to provide a preliminary geotechnical investigation of the subject site in accordance with the scope of services set out in the contract / quotation between Martens & Associates Pty Ltd and Don Fox Planning (hereafter known as the Client). That scope of works and services were defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

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Head Office
6/37 Leighton Place
Hornsby, NSW 2077, Australia
ACN 070 240 890 ABN 85 070 240 890
Phone: +61-2-9476-9999
Fax: +61-2-9476-8767
Email: mail@martens.com.au
Web: www.martens.com.au

Document and Distribution Status								
Author(s)			**Reviewer(s)**		**Project Manager**		**Signature**	
Mr Gray Taylor			Dr Daniel Martens		Dr D. Martens			
			Document Location					
Revision No.	**Status**	**Release Date**	File Copy	MA Library	Don Fox Planning	Void	Void	Void
1	Draft	19.05.09	1E, 1P, 1H	-	1P			
2	Draft	02.06.09	1E, 1P, 1H	-	1P			
3	Final	11.06.09	1E, 1P, 1H	1H	1P			

Distribution Types: F = Fax, H = hard copy, P = PDF document, E = Other electronic format. Digits indicate number of document copies.

All enquiries regarding this project are to be directed to the Project Manager.

Contents

1 Introduction

1.1 Purpose

This report provides the findings of a preliminary geotechnical investigation completed as part of preparations for the combined rezoning and subdivision development application for the Elanora Conference Centre and part of the Warriewood Ingleside Escarpment Reserve.

The objective of the assessment is to determine site geotechnical conditions and any associated risks which may affect the site and the proposed development or neighbouring properties. To this extent, a range of issues have been reviewed as part of the assessment, including slope stability, soil strength, local geology and excavation requirements. Recommendations to minimise identified risks are provided accordingly.

The assessment is prepared in accordance with the following guidelines:

- Australian Geomechanics Society *Guidelines for Landslide Risk Management* (2007);
- Australian Standard 1796 (1993) *Geotechnical Site Investigations*;
- Australia Standard 1289.6.3.2 (1997), *Determination of the Penetration Resistance of a Soil using the 9kg Dynamic Cone Penetrometer; and*
- Pittwater Council's (2007) *Geotechnical Risk Management Policy.*

1.2 Background

Pittwater Council and the Uniting Church Australia have agreed to undertake land transactions to allow the Council to acquire environmentally sensitive bushland on the Warriewood-Ingleside Escarpment for conservation purposes. The sub-division of Lot 62 DP 30255, Lot 70 DP 32253 and Lot 2 DP 1093237 is to enable the land 'swap' between the Council and the Uniting Church.

1.3 Proposal

The proposed areas are shown in Figure 1 and on Sheet 1 of Attachment A while the proposed sub-division and rezoning will involve the following:

- Area 1, being land within the Elanora Conference Centre, will be transferred to Council by the Church for conservation purposes.

- Area 2, being an area of escarpment land currently owned by Council and within Lot 2 DP 1093237, will be transferred to the Church by the Council.

- Area 3, being part of Lot 62 DP 30255, within the Elanora Conference Centre Land, will be transferred to Council but leased back to the Church allowing the Church to have exclusive use of 'Area' for low impact outdoor activities.

- Area 4, being land within the Elanora Conference Centre including Lot 70 DP 32253, will be transferred to Council by the Church for conservation purposes.

- Areas 1, 3 and 4 are to be rezoned from Special Uses 5(a) to 7(a) Environmental Protection.

- Area 2 currently zoned 7(a) Environmental Protection to be rezoned to allow its use by the Uniting Church.

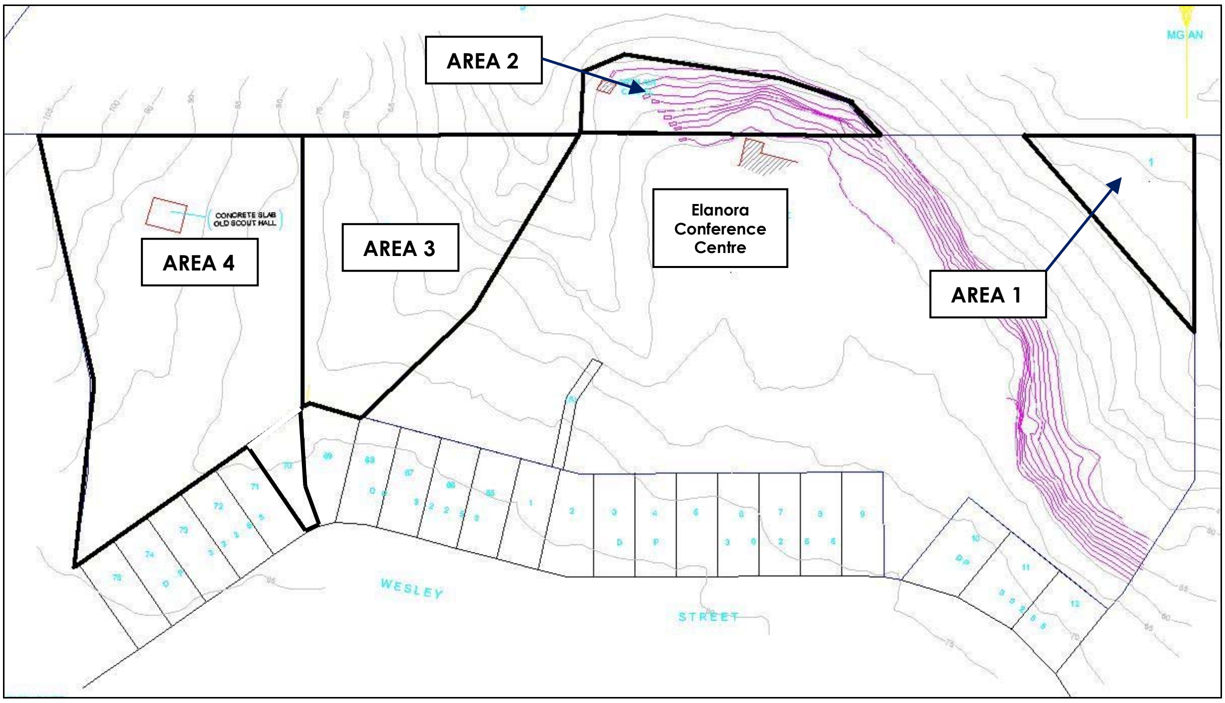

Figure 1: Areas of rezoning and sub-division.

2 Site description

2.1 Field Investigations

Site investigations were undertaken on the 27th November 2008, and 9th April 2009. Works conducted during the field investigations included a walkover inspection of the site to assess existing site conditions and local topography, geology, soil characteristics, hydrology and vegetation.

2.2 Location and Site Description

The subject site is situated on the northern side of Wesley Street at Elanora Heights NSW and consists of Lot 62 DP30255, Lot 70 DP32253 and Lot 2 DP1093237. A site plan showing the locations of each allotment is provided in Attachment A and is located within the Pittwater Council Government Area.

The site occupies an area of approximately 35 ha and bounded by residential allotments to the south and forest/bushland to the west, north and east. The site forms part of the Former Heydon Estate within the northern portion of the site with access off the eastern side of Ingleside. The remainder of the site consists primarily of the Elanora Conference Centre with access from Wesley Street. The site is generally covered in maintained grasses around the conference centre and open forest and dense undergrowth on the remainder of the site.

2.3 Topographic and Drainage

The majority of the site is undulating and characterised by dissected hill slope and ridges. It contains irregular moderate slopes of approximate 0-20% usually having northerly, north westerly and north easterly aspects surrounding the conference centre. Some steeper slopes up to 20-50% are presented in areas upslope and downslope of the sandstone outcrop/embankment and along the upper portions of Mullet Creek and its embankment. Steeper slopes (vertical) make up the sandstone outcrop/embankment and lower regions of Mullet Creek.

The site is situated in the Narrabeen Lakes catchment. At the time of inspection, we did not observe any evidence that surface flow has caused any significant erosion on the site surrounding the conference centre. Sheet flow and the conference centre drainage system ultimately drains over the upper regions of the site into Mullet Creek which in turn drains to Narrabeen Lakes.

2.4 Geology and subsurface conditions

2.4.1 Geological Map

The Sydney 1:100,000 Geological Sheet 9130(1983) and the Soil Landcapes of the Sydney 1:100,000 Sheet (1989) describes the site geology as Hawkesbury Sandstone consisting of medium to coarse grained quartz sandstone with very minor shale and laminite lenses.

2.4.2 Soils

The Soil Landcapes of the Sydney 1:100,000 Sheet (1989) indicates that the site is situated on two distinct soil landscapes being Gymea in the upper portions of the site and Watagan in the lower and steeper areas of the site. Both soils landscapes are described in Table 1 below in relation to the site:

Table 1: Soil Landscape Description.

Soil Landscape	Geology	Dominant Soil Material	General Topography	Limitations and Notes
Gymea (gy)	Hawkesbury Sandstone	Sandy loam overlaying yellowish/brown clayey sands and sandy clays and clays at depth.	Undulating to rolling hills with slopes 10-25%. Sideslopes with narrow to wide outcropping sandstone rock benches often forming broken escarpments of less than 5m in height.	Localised steep slopes, rock outcropping and shallow permeable soils.
Watagan (wn)	Hawkesbury Sandstone	Sandy loam overlying brown sandy clays and yellowish fine sandy clays and light to medium clays at depth.	Slope gradients are generally steeper than 25%. Crests and ridges are convex and narrow with steep hillslopes with talus slopes containing sandstone boulders. Occasional sandstone benches and colluvial benches and slopes with gradients >70% often have cliffs and scarps >10m high.	Mass movement hazard, steep slopes and rock outcropping

3 Geotechnical Assessment

3.1 Geotechnical Risk Management Guidelines

The geotechnical risk assessment for the proposed development has been conducted in accordance with the principles outlined in Pittwater Council's (2007) Geotechnical Risk Management Policy.

The objectives of Council's (2007) Geotechnical Risk Management Policy relevant to the proposed development include assurances of the following:

- That geotechnical and related structural matters are adequately investigated and documented by applicants or proponents of activities prior to the lodgement of any development application or Part V activities to carry out any development subject to the guidelines;
- Establishment of whether or not the proposed development activity is appropriate to be carried out, and the conditions that should be applied if it is to be carried out, having regard to the results of the geotechnical and related structural investigations;
- That, in the event that a proposed development activity is only appropriate to be carried out subject to geotechnical and related structural engineering conditions, those conditions are able to be met and are identified by the applicants prior to the lodgement of the development application including all appropriate constraints and remedial maintenance actions required prior to, during and after the carrying out of the development;
- To ensure that effective controls exist to guarantee that a development is carried out in accordance with the policy;
- To ensure geotechnical and related structural engineering information and certificates required to be lodged are carried out by suitably qualified professionals; and
- That developments are only carried out if geotechnical and related structural engineering risks, and, where appropriate, coastal process risks, are identified and can be effectively addressed and managed for the life of the development.

3.2 Existing Hazard Mapping / Classification

Pittwater Council Geotechnical Hazard Mapping, 2007 (Figure 2) indicates that the site is presently located within Hazard Zone H1 and H3 with the risks being the potential for causing movement of rock, debris or earth, which may cause injury or death or damage to, or destruction of property.

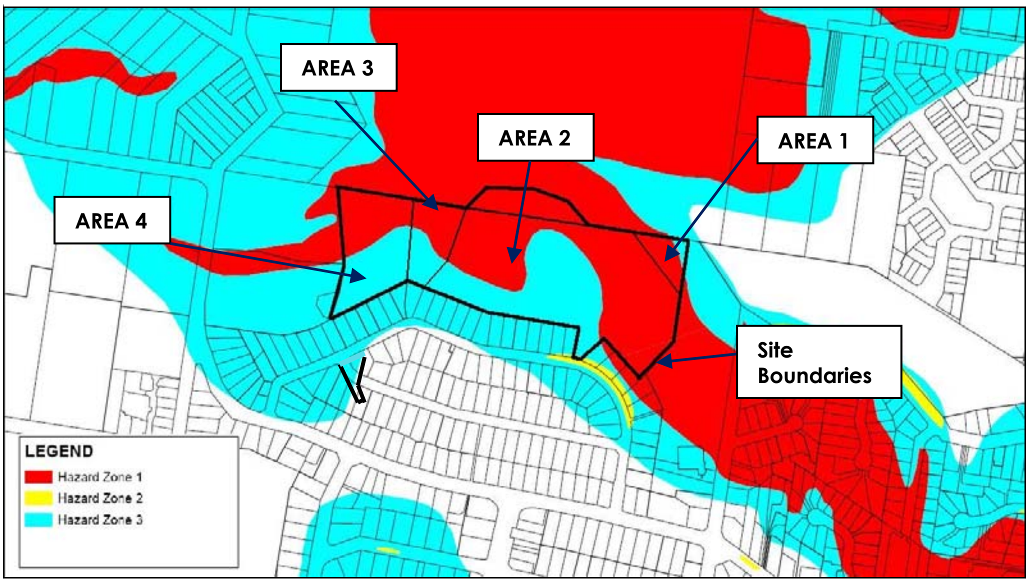

Figure 2: Pittwater Council's Geological Hazard Mapping in relation to site.

The four (4) main areas involved in the sub-division are mapped as follows:

- AREA 1: Upper and steeper slopes zoned as H1 with lower flatter slopes zoned as H3.
- AREA 2: Entire area zoned as H1.
- AREA 3: Upper and flatter slopes zoned as H3 with lower steeper slopes zoned as H1.
- AREA 4: Upper and flatter slopes zoned as H3 with lower steeper slopes zoned as H1.

Geotechnical hazard zones for the site are provided in Attachment A-Site Plan.

3.3 Site Investigations

Works conducted during the field investigations revealed that the site could be broken up into four (4) principal geotechnical / morphological zones in relation to parameters such as soil type, slopes and hazards.

Zones are described in Table 2 below with zone locations and approximate boundaries provided in Attachment A and images provided as Plates Attachment B.

Table 2: Principal geotechnical / morphological zones within the study area.

Zone	Description	Geology / Soils	Slope (%)
A	Large portion of Zone A used as conference centre such as buildings, swimming pool, playing fields and parking. Portion of Zone A in Area 4 used previously for Scout Hall and vehicle access track. Zone is well vegetated with open forest and medium dense undergrowth in Area1 and 4 with managed gardens, scattered open forest and grasses surrounding the conference centre.	Soils are generally silty sands and clayey sands/sandy clays overlying sandstone. Minor sandstone outcropping and floaters (Plate 1). Soil Landscape = gy	Min=2-7% Max= 20%
B	Zone made up of the soils/area upslope of the sandstone escarpment/outcropping. Little development in this zone. Zone is well vegetated with open forest and medium dense undergrowth.	Soils are sandy loams and sandy clays with clays at depth. Zone has large areas of sandstone floaters visible on surface with minor areas of sandstone outcropping (Plate 6). Soil Landscape = wn	Min=10% Max= 50% (Plate 3)
C	Zone consists of sandstone escarpment/outcropping. Height of escarpment varies from between 2-5m in the vicinity of the conference centre to >5-8m (waterfall) along Mullet Creek. Escarpment forms the northern boundary of Area 2.	Zone has very limited or shallow soil profile similar to Zone B with detritus soils derived from plants and mainly consists of sandstone outcropping, floaters and escarpment (Plates 4 and 5). Soil Landscape =wn	Min=50% Max= Vertical and overhangs
D	Zone made up of the soils/area downslope slope of the sandstone escarpment/outcropping. No development in this zone. Zone is well vegetated with open forest and medium dense undergrowth.	Soils are sandy loams and sandy clays with clays at depth. Zone has large areas of sandstone floaters and rocks (fallen from Zone C-Plate 7) visible on surface with minor areas of sandstone outcropping. Soil Landscape = wn	Min=10% Max= 50%

NOTES:
[1] gy = Gymea soil landscape, wn = Watagan soil landscape; [2] Refer to Section 3.4.2 for more detail.

3.3.1 *Groundwater*

Groundwater was not specifically investigated as part of the field works. We do note that a shallow groundwater table is expected in the lower portions of the site based on the parent geology and position in the landscape. An ephemeral groundwater table is also likely to be found at the soil rock interface during and after periods of sustained or heavy rainfall events. Longer term seepage through joints and bedding planes is also expected follow rainfall events.

DNR groundwater borehole search indicates that groundwater upslope and in close proximity ranges from 14.9m to 21.3m (76.8 to 86.7 mAHD) below ground level as shown in Figure 3 below.

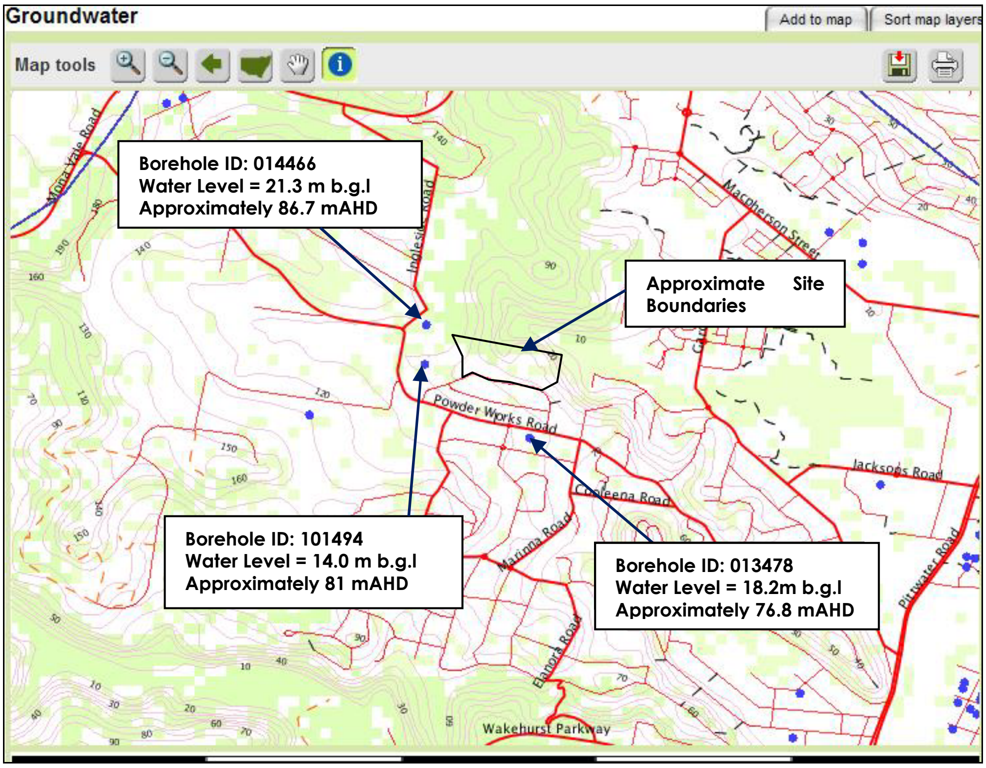

Figure 3: NSW Department of Water and Energy groundwater bore database search results for the Ingleside area.

Review of the groundwater database information for the local area indicates that groundwater is likely to occur within the Hawkesbury sandstone bedrock complex. Groundwater levels may be affected by variable soil profiles, in terms of depth and texture, controlled by the sandstone bedrock structure.

3.4 Slope Instability Assessment

3.4.1 Field Observations

Walkover and visual inspections of the land surface, vegetation and soil conditions revealed evidence of past instability at the site. Irregular slope formations of the majority of the land suggest that it may have been subject to past or present slope movements.

Some areas in the steeper portions of the site with distorted and inclined vegetation and soil exposures provide evidence of past or ongoing soil creep. Significant trees leaning downslope and bare roots on the steeper slopes in the heavily vegetated areas indicate of possible relic or active mass movements.

A number of scarps ranging from approximate 5m to 30m in length and 5-8m in height were observed in some steeper areas of the site.

3.4.2 Risk Assessment Mapping

A slope instability risk assessment of the site has been undertaken based on the walkover and visual inspections of the site conducted on 27th of November 2008 and 9th April 2009. For the purpose of the risk assessment, the site was divided into the 4 morphologic zones. We consider that there are four potential forms of slope instability affecting the site:

(1) soil creep
(2) shallow rotational slide
(3) boulder movement
(4) rock fall.

Geotechnical risks have been assessed by utilising Attachment G of the Landslide Risk Management Concepts and Guidelines (Australian Geomechanics Society, 2007). Qualitative risk measures of likelihood and consequence to property were used to estimate a level of risk to the proposed development. Boundaries of zones are shown in Attachment A. A slope instability risk assessment for each zone is provided in Table 3.

3.4.3 Risk Management

On the basis of the qualitative risk assessment undertaken, preliminary risk management recommendations are provided in Table 4. We note that these are preliminary and will depend on the ultimate use of the land and may be subject to change should land usage or usage intensity change in the future.

Table 3: Instability risk to property assessment of existing site conditions (i.e. untreated).

Zone	Relevant Cross Sections	Associated risk	Likelihood		Consequence to Property[1]		Risk level	
			Descriptor	Level	Descriptor	Level	Level	Overall
A	A-A' B-B' C-C'	(1) Soil creep	Almost Certain	A	Insignificant	5	Low	**Low**
		(2) Shallow rotational slide	Unlikely	D	Medium	3	Low	
B	A-A' B-B' C-C'	(1) Soil creep	Almost Certain	A	Insignificant	5	Low	**Medium**
		(2) Shallow rotational slide	Possible	C	Medium	3	Medium	
		(3) Boulder Movement	Possible	C	Medium	3	Medium	
C	A-A' B-B' C-C'	(1) Soil creep	Almost Certain	A	Insignificant	5	Low	**High**
		(2) Boulder Movement	Possible	C	Major	2	High	
		3) Rock Fall	Possible	C	Major	2	High	
D	A-A' B-B'	(1) Soil creep	Almost Certain	A	Insignificant	5	Low	**Medium**
		(2) Shallow rotational slide	Unlikely	D	Minor	3	Medium	
		(3) Boulder Movement	Possible	C	Minor	2	Medium	
		(4) Rock Fall	Possible	C	Minor	2	Medium	

NOTES: [1] Made on the basis should property be located in this zone without adequate site treatment.

Table 4: Geotechnical risk management recommendations.

Zone	Risks	Treatment / Recommendation
A	Soil Creep	1, 2, 3, 4
	Shallow Rotational Slide	1, 2, 3, 4
B	Soil Creep	1, 2, 3, 4
	Shallow Rotational Slide	1, 2, 3, 4
	Boulder Movement	2, 4, 5, 6
C	Soil Creep	1, 2, 3, 4
	Boulder Movement	2, 4, 5, 6
	Rock fall	7, 8, 9
D	Soil Creep	1, 2, 3, 4
	Shallow Rotational Slide	1, 2, 3, 4
	Boulder Movement	2, 4, 5, 6
	Rock fall	7, 8, 9

Recommended Treatment Systems

1. No specific treatment required.
2. Retain vegetation where possible.
3. Reduce shallow groundwater flows where possible.
4. Prevent excessive stormwater ingress for all new building works.
5. Routine monitoring to confirm boulder stability.
6. Inspect boulders within 20 m of higher usage areas (eg. walking tracks) and undertake a more detailed risk to life assessment and determine requirements for boulder stabilisation where risk is unacceptable.
7. Rock climbing and abseiling should be avoided on exposed rock scarps unless further assessment is undertaken of risk to life by such activities.
8. Inspect rock faces within 20 m of rock faces where there is a potential for rock fall within 20 m of higher usage areas (eg. walking tracks) and undertake a more detailed risk to life assessment and determine requirements for risk reduction where risk is unacceptable.
9. Avoid vegetation removal unless absolutely necessary.

4 Recommendations

4.1 General

On the basis of our site inspections undertaken by Martens & Associates Pty Ltd, we consider that the main risk area of instability is along the sandstone escarpment consisting of rock fall and wedge failure. Vegetation management and retention structures will therefore be required to ensure on-going site stability and minimise associated risks in these areas if buildings are proposed. We also recommend regular monitoring of the stability of boulders which have the potential to affect users of the Irrawong track.

4.2 Walking Tracks

The main potential use of the sub-divided areas will be for low impact recreational/outdoor activities such as walking tracks. To minimise risk to life and property the walking tracks should avoid all rock overhangs and unstable boulders and outcropping. No climbing/abseiling on rock faces should be undertaken without a detailed investigation of the rock face. Vegetation clearing for potential bush tracks should be avoided as this can potentially lead to further instability of the area. Where vegetation removal is required it should take into account the slope of the land and surrounding geology i.e. boulder instability upslope and downslope of track and areas of outcropping and the effect the removal of vegetation will have on it in terms of stability.

4.3 Drainage

Any new stormwater drainage outlets should be constructed with an appropriately sized energy dissipater/level spreader to ensure dispersion of water is not concentrated and is evenly spread on the slope hill face.

4.4 Limitation Statements

Occasionally, sub-surface conditions between zones and below the surface may be found to be different (or may be interpreted to be different) from those expected. Variation can also occur with groundwater conditions, especially after climatic changes. If such differences appear to exist, we recommend that you contact Martens & Associates for further advice. Should any development be proposed in any of the areas we recommend that a more detailed geotechnical assessment be undertaken in accordance with Pittwater Council's (2007) Geotechnical Risk Management Policy for the proposed development.

5 References

Australian Geomechanics Society (March 2007), *Guidelines for Landslide Risk Management*.

Australian Standard 1289 6.3.2 (1997) *Methods of testing soils for engineering purposes - Soil strength and consolidation tests DCP*.

Australian Standard 1796 (1993) *Geotechnical Site Investigations*.

Australian Standard 2870 (1996) *Residential Slabs and Footings*.

Pittwater Council (2007) *Geotechnical Risk Management Policy*

6 Attachment A – Site Plan

martens
6/37 Leighton Place
Hornsby, NSW 2077 Australia
Phone: (02) 9476 9999
Fax: (02) 9476 8767
Email: mail@martens.com.au
Internet: http://www.martens.com.au

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CLIENT/PROJECT: DON FOX PLANNING, ELANORA CONFERENCE CENTRE

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All measurements in mm unless otherwise specified.

TITLE: GEOTECHNICAL CONSTRAINTS SITE PLAN

PROJECT MANAGER: DR DANIEL MARTENS

DRAWING NUMBER: P0802241JD01_V1

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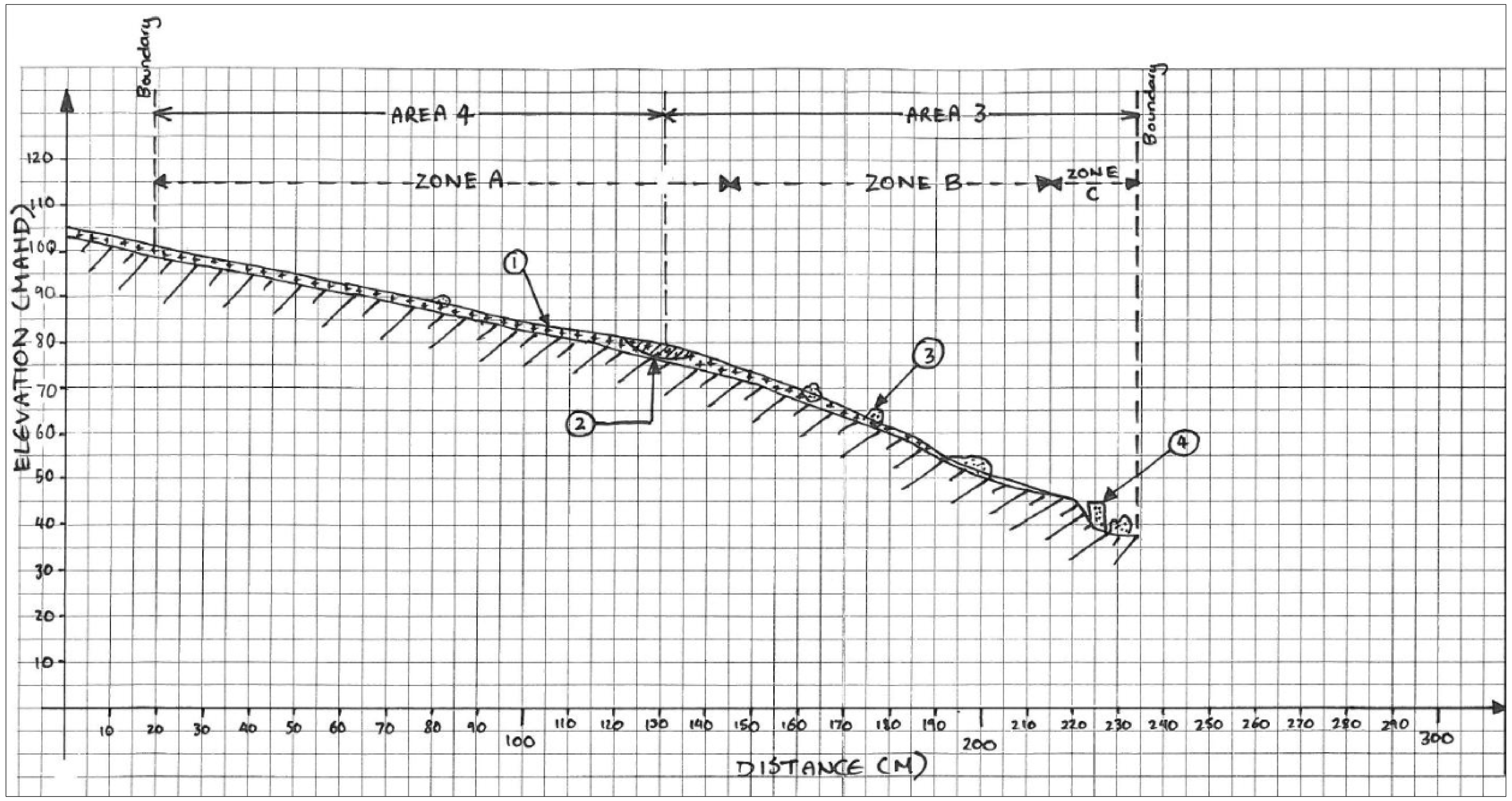


LEGEND:

LEGEND:

SANDSTONE BEDROCK

SANDSTONE FLOATERS/ OUTCROPPING

SILTY SANDS, CLAYEY SANDS & SANDY CLAYS AT DEPTH

GEOTECHNICAL RISKS:

1 SOIL CREEP

2 SHALLOW ROTATIONAL SLIDE

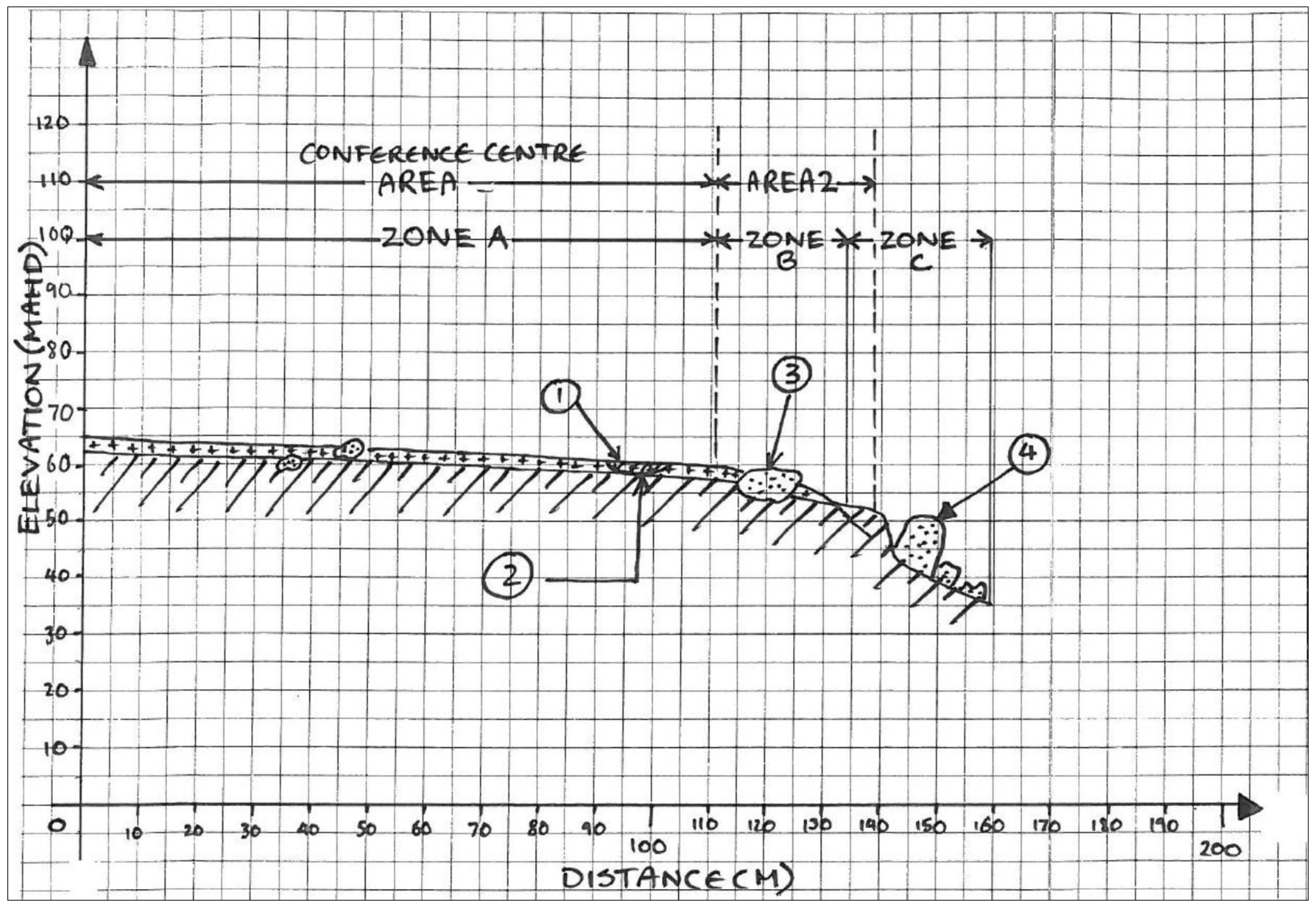
3 BOULDER MOVEMENT

4 ROCKFALL / ESCARPMENT MOVEMENT

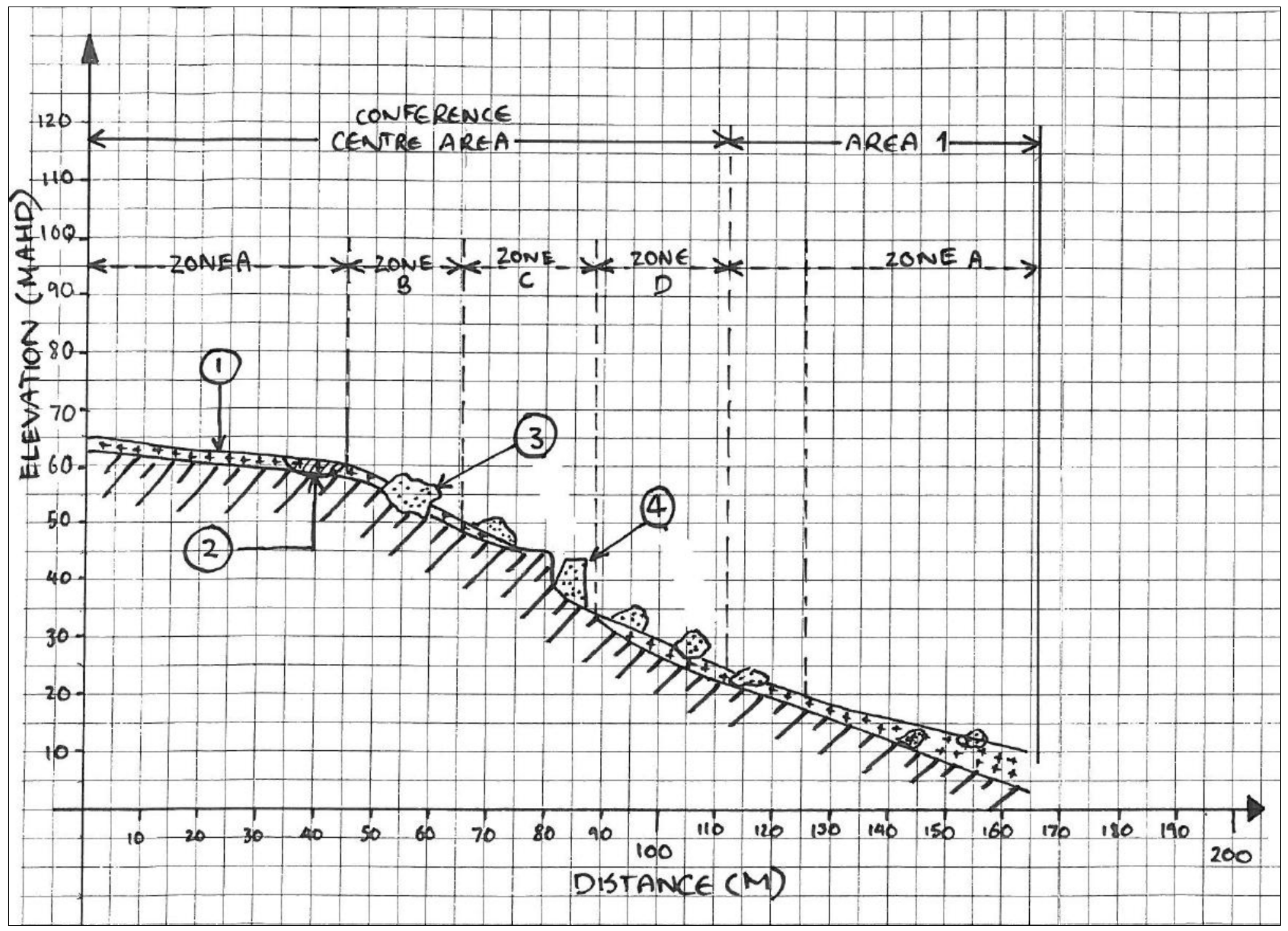
NOTES: SOIL DEPTHS AND DEPTH OF SANDSTONE BEDROCK IS APPROXIMATE ONLY

BOUNDARIES OF ZONES AND AREAS ARE APPROXIMATE ONLY.

CROSS SECTION B–B'



CROSS SECTION C–C'



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martens

6/37 Leighton Place
Hornsby, NSW 2077 Australia
Phone: (02) 9476 9999
Fax: (02) 9476 8767
Email: mail@martens.com.au
Internet: http://www.martens.com.au

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REV.	DESCRIPTION	DATE	ISSUED
1	GEOTECHNICAL ASSESSMENT	10.05.2009	GT

7 Attachment B – Plates

Plate 1: Image looking east at shallow profile in upper regions of Zone A upslope of conference centre.

Plate 2: View looking south at sandstone boulders and outcropping in Zone B immediately downslope of conference centre.

Plate 3: View looking east at typical slope and vegetation in Zone B.

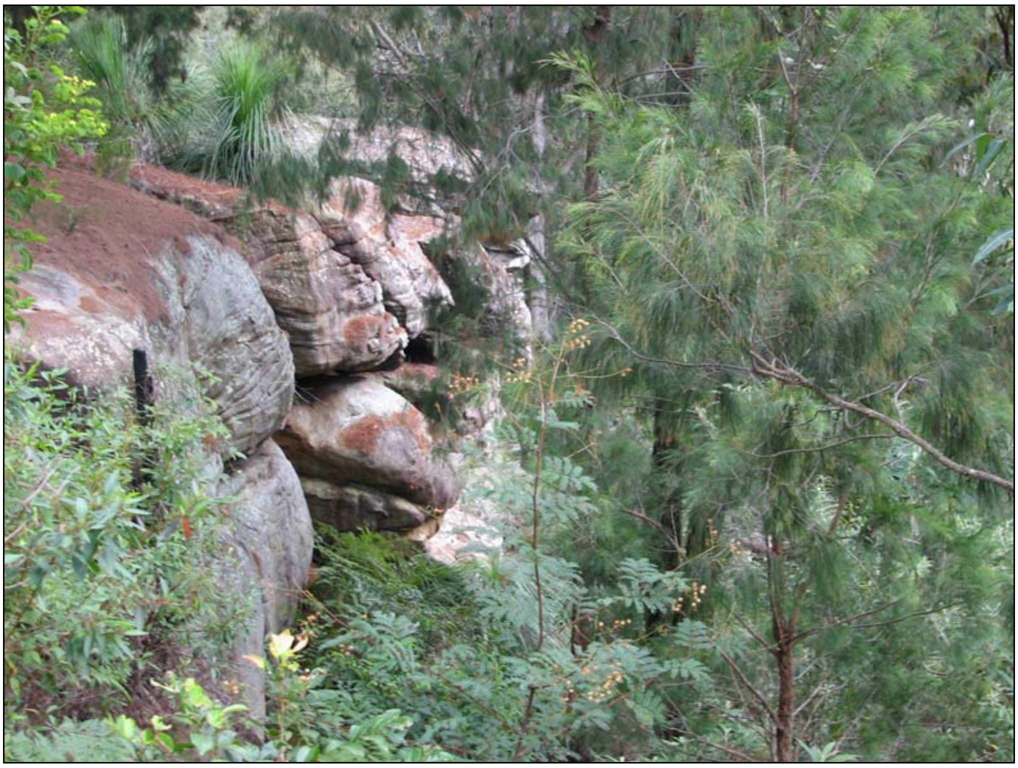


Plate 4: View looking west at sandstone/bedrock escarpment in Zone C and northern boundary of Area 2.

Plate 5: View looking east at sandstone/bedrock escarpment in Zone C and northern boundary of Area 2.

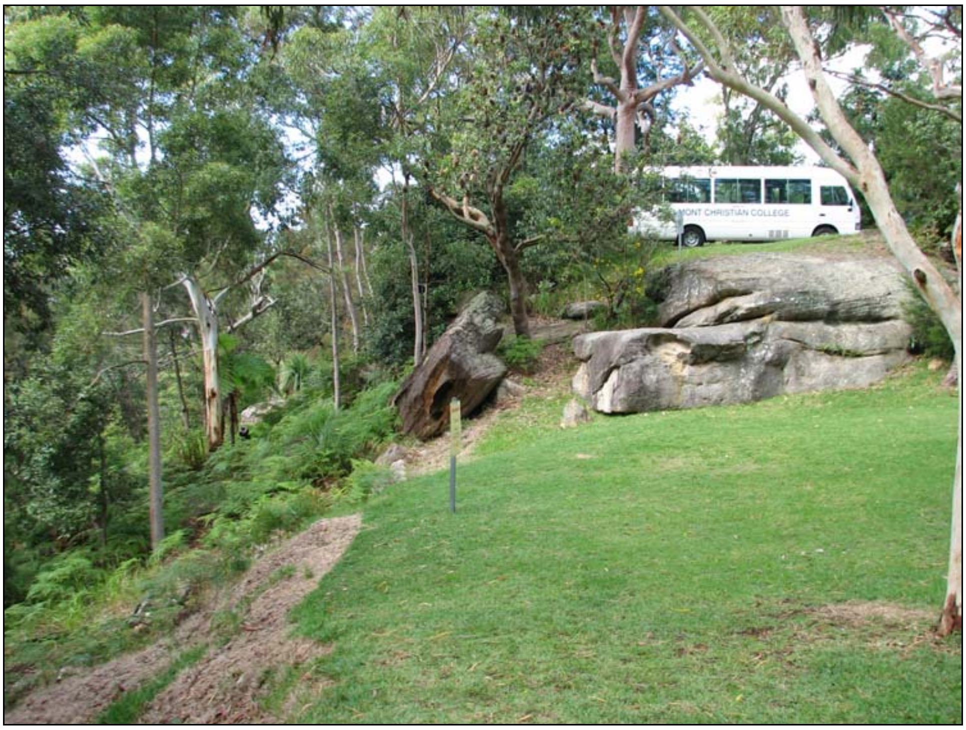


Plate 6: View looking east at sandstone boulder and outcropping at interface of Zone A of Zone B.

Plate 7: View looking south west at boulders/rock fall from escarpment in Zone D.

Plate 8: Dam 1 wall facing north.

Plate 9: Dam 2 wall facing north.

8 Attachment C – Geotechnical Risk Management Policy Forms 1 and 1 (a)

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER
FORM NO. 1 – To be submitted with Development Application

Development Application for Don Fox Planning
Name of Applicant
Address of site Elanora Conference Centre

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

I, Dr D. Martens on behalf of Martens & Associates
(Insert Name) (Trading or Company Name)

on this the 9/6/09 certify that I am a geotechnical engineer or engineering geologist or coastal engineer as defined by the Geotechnical Risk Management Policy for Pittwater 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:

Please mark appropriate box

X Prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines and the Pittwater Council Policy

X 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 and the Pittwater Council Geotechnical Risk Management Policy

X Have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with paragraph 6.3 (Property Located in Zone H3) of the Pittwater Council Geotechnical Risk Management Policy. I confirm that the results of the risk assessment are compliance with the Geotechnical Risk Management Policy and further detailed geotechnical reporting is not required for the subject site which is zoned H3.

X Have examined the site and the proposed development/alteration in detail and am of the opinion that the Development Application only involves Minor Development/Alterations that do not require a Detailed Geotechnical Risk Assessment and hence my report is in accordance with the Geotechnical Risk Management Policy requirements for Minor Development/Alterations.

Provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: Preliminary Geotechnical Assessment: Combined rezoning & sub-division application – Elanora Conference Centre & Part of Warriewood Ingleside Escarpment Reserve
Report Date: JUNE 2009
Author: Mr G. Taylor & Dr D. Martens

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

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 Dr Daniel Martens

Chartered Professional Status CPEng, FIE Aust, NPER

Membership No. 2185379

Company Martens & Associates

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER
FORM NO. 1(a) - Checklist Of Requirements For Geotechnical Risk Management Report for Development Application

Development Application for Don Fox Planning
Name of Applicant
Address of site Elanora Conference Centre.

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: Preliminary Geotechnical Assessment
Report Date: June 2009
Author: Mr G. Taylor & Dr D. Martens

Please mark appropriate box

- [x] Comprehensive site mapping conducted 9/04/09 (date)
- [x] Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
- [x] Subsurface investigation required
  - No Justification ....
  - Yes Date conducted 9/4/09 ....
- [x] Geotechnical model developed and reported as an inferred subsurface type-section
- [x] Geotechnical hazards identified
  - [x] Above the site
  - [x] On the site
  - [x] Below the site
  - [x] Beside the site
- [x] Geotechnical hazards described and reported
- [x] Risk assessment conducted in accordance with Council's Policy
  - [ ] Consequence analysis
  - [x] Frequency analysis
- [x] Risk calculation
- [x] Risk assessment for property conducted in accordance with Council's Policy
- [x] Risk assessment for loss of life conducted in accordance with Council's Policy
- [x] Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater
- [x] Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified conditions are achieved.
- [x] Design Life Adopted:
  - [x] 100 years
  - [ ] Other .... (specify)
- [x] Development Conditions to be applied to all four phases as described in Pittwater Geotechnical Risk Management Policy have been specified
- [x] Additional action to remove risk where reasonable and practical have been identified and included in the report.
- [x] 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 Dr D. Martens
Chartered Professional Status CPEng, FIEAust, NPER
Membership No. 2185379
Company Martens & Associates.

9 Attachment D - Notes About This Report

Information

Important Information About Your Report

Subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Martens to help you interpret and understand the limitations of your report. Not all of course, are necessarily relevant to all reports, but are included as general reference.

Engineering Reports - Limitations

Geotechnical reports are based on information gained from limited sub-surface site testing and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretative rather than factual documents, limited to some extent by the scope of information on which they rely.

Engineering Reports – Project Specific Criteria

Engineering reports are prepared by qualified personnel and are based on the information obtained, on current engineering standards of interpretation and analysis, and on the basis of your unique project specific requirements as understood by Martens. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the Client.

Where the report has been prepared for a specific design proposal (eg. a three storey building), the information and interpretation may not be relative if the design proposal is changed (eg. to a twenty storey building). Your report should not be relied upon if there are changes to the project without first asking Martens to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Martens will not accept responsibility for problems that may occur due to design changes if they are not consulted.

Engineering Reports – Recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption often cannot be substantiated until project implementation has commenced and therefore your site investigation report recommendations should only be regarded as preliminary.

Only Martens, who prepared the report, are fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Martens cannot be held responsible for such misinterpretation.

Engineering Reports – Use For Tendering Purposes

Where information obtained from this investigation is provided for tendering purposes, Martens recommend 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 specially edited document. Attention is drawn to the document 'Guidelines for the Provision of Geotechnical Information in Tender Documents', published by the Institution of Engineers, Australia.

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.

Engineering Reports – Data

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings *etc* are customarily included in a Martens report and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These data should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Engineering Reports – Other Projects

To avoid misuse of the information contained in your report it is recommended that you confer with Martens before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Subsurface Conditions - General

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical aspects, relevant standards 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 will depend partly on test point (eg. excavation or borehole) spacing and sampling frequency which are often limited by project imposed budgetary constraints.

- Changes in guidelines, standards and policy or interpretation of guidelines, standards and policy by statutory authorities.

- The actions of contractors responding to commercial pressures.

- Actual conditions differing somewhat from those inferred to exist, because no professional, no matter how qualified, can reveal precisely what is hidden by earth, rock and time.

  The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions

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

Subsurface Conditions - Changes

Natural processes and the activity of man create subsurface conditions. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Reports are based on conditions which existed at the time of the subsurface exploration.

Decisions should not be based on a report whose adequacy may have been affected by time. If an extended period of time has elapsed since the report was prepared, consult Martens to be advised how time may have impacted on the project.

Subsurface Conditions - Site Anomalies

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

Report Use By Other Design Professionals

To avoid potentially costly misinterpretations when other design professionals develop their plans based on a report, retain Martens to work with other project professionals who are affected by the report. This may involve Martens explaining the report design implications and then reviewing plans and specifications produced to see how they have incorporated the report findings.

Subsurface Conditions - Geoenvironmental Issues

Your report generally does not relate to any findings, conclusions, or recommendations about the potential for hazardous or contaminated materials existing at the site unless specifically required to do so as part of the Company's proposal for works.

Specific sampling guidelines and specialist equipment, techniques and personnel are typically used to perform geoenvironmental or site contamination assessments. Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Martens for information relating to such matters.

Responsibility

Geotechnical reporting relies on interpretation of factual information based on professional judgment and opinion and has an inherent level of uncertainty attached to it and is typically far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded.

To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Martens to other parties but are included to identify where Martens' responsibilities begin and end. Their use is intended to help all parties involved to recognize their individual responsibilities. Read all documents from Martens closely and do not hesitate to ask any questions you may have.

Site Inspections

Martens will always be pleased to provide engineering inspection services for 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. Martens is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction.

Soil Data

Explanation of Terms (1 of 3)

Definitions

In engineering terms, soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material does not exhibit any visible rock properties and can be remoulded or disintegrated by hand in its field condition or in water it is described as a soil. Other materials are described using rock description terms.

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

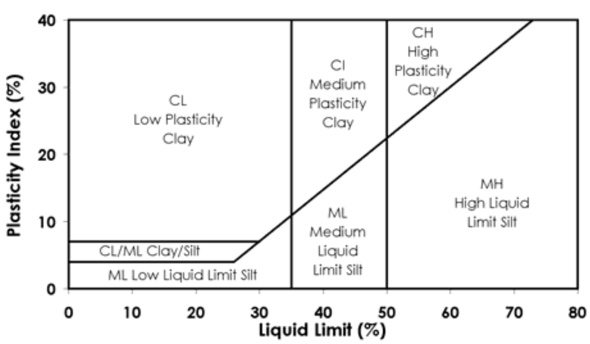
Particle Size

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. sandy clay). Unless otherwise stated, particle size is described in accordance with the following table.

Division	Subdivision	Size
BOULDERS		>200 mm
COBBLES		60 to 200 mm
GRAVEL	Coarse	20 to 60 mm
	Medium	6 to 20 mm
	Fine	2 to 6 mm
SAND	Coarse	0.6 to 2.0 mm
	Medium	0.2 to 0.6 mm
	Fine	0.075 to 0.2 mm
SILT		0.002 to 0.075 mm
CLAY		< 0.002 mm

Plasticity Properties

Plasticity properties can be assessed either in the field by tactile properties, or by laboratory procedures.



Moisture Condition

Dry — Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.

Moist — Soil feels cool and damp and is darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.

Wet — As for moist but with free water forming on hands when handled.

Consistency of Cohesive Soils

Cohesive soils refer to predominantly clay materials.

Term	C_u (kPa)	Approx SPT "N"	Field Guide
Very Soft	<12	2	A finger can be pushed well into the soil with little effort.
Soft	12 - 25	2 to 4	A finger can be pushed into the soil to about 25mm depth.
Firm	25 - 50	4 – 8	The soil can be indented about 5mm with the thumb, but not penetrated.
Stiff	50 - 100	8 – 15	The surface of the soil can be indented with the thumb, but not penetrated.
Very Stiff	100 - 200	15 – 30	The surface of the soil can be marked, but not indented with thumb pressure.
Hard	> 200	> 30	The surface of the soil can be marked only with the thumbnail.
Friable	-		Crumbles or powders when scraped by thumbnail

Density of Granular Soils

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

Relative Density	%	SPT 'N' Value (blows/300mm)	CPT Cone Value (q_c Mpa)
Very loose	< 15	< 5	< 2
Loose	15 – 35	5 - 10	2 -5
Medium dense	35 – 65	10 - 30	5 - 15
Dense	65- 85	30 - 50	15 - 25
Very dense	> 85	> 50	> 25

Minor Components

Minor components in soils may be present and readily detectable, but have little bearing on general geotechnical classification. Terms include:

Term	Assessment	Proportion of Minor component In:
Trace of	Presence just detectable by feel or eye, but soil properties little or no different to general properties of primary component.	Coarse grained soils: < 5 % Fine grained soils: < 15 %
With some	Presence easily detectable by feel or eye, soil properties little different to general properties of primary component.	Coarse grained soils: 5 – 12 % Fine grained soils: 15 – 30 %

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Soil Agricultural Classification Scheme

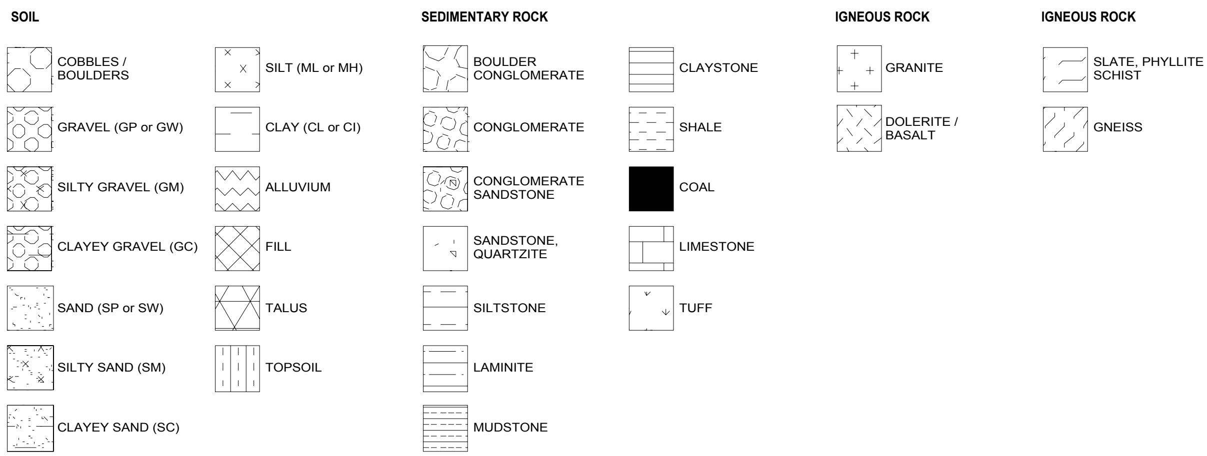
In some situations, such as where soils are to be used for effluent disposal purposes, soils are often more appropriately classified in terms of traditional agricultural classification schemes. Where a Martens report provides agricultural classifications, these are undertaken in accordance with descriptions by Northcote, K.H. (1979) *The factual key for the recognition of Australian Soils*, Rellim Technical Publications, NSW, p 26 - 28.

Symbol	Field Texture Grade	Behaviour of moist bolus	Ribbon length	Clay content (%)
S	Sand	Coherence nil to very slight; cannot be moulded; single grains adhere to fingers	0 mm	< 5
LS	Loamy sand	Slight coherence; discolours fingers with dark organic stain	6.35 mm	5
CLS	Clayey sand	Slight coherence; sticky when wet; many sand grains stick to fingers; discolours fingers with clay stain	6.35mm - 1.3cm	5 - 10
SL	Sandy loam	Bolus just coherent but very sandy to touch; dominant sand grains are of medium size and are readily visible	1.3 - 2.5	10 - 15
FSL	Fine sandy loam	Bolus coherent; fine sand can be felt and heard	1.3 - 2.5	10 - 20
SCL-	Light sandy clay loam	Bolus strongly coherent but sandy to touch, sand grains dominantly medium size and easily visible	2.0	15 - 20
L	Loam	Bolus coherent and rather spongy; smooth feel when manipulated but no obvious sandiness or silkiness; may be somewhat greasy to the touch if much organic matter present	2.5	25
Lfsy	Loam, fine sandy	Bolus coherent and slightly spongy; fine sand can be felt and heard when manipulated	2.5	25
SiL	Silt loam	Coherent bolus, very smooth to silky when manipulated	2.5	25 + > 25 silt
SCL	Sandy clay loam	Strongly coherent bolus sandy to touch; medium size sand grains visible in a finer matrix	2.5 - 3.8	20 - 30
CL	Clay loam	Coherent plastic bolus; smooth to manipulate	3.8 - 5.0	30 - 35
SiCL	Silty clay loam	Coherent smooth bolus; plastic and silky to touch	3.8 - 5.0	30- 35 + > 25 silt
FSCL	Fine sandy clay loam	Coherent bolus; fine sand can be felt and heard	3.8 - 5.0	30 - 35
SC	Sandy clay	Plastic bolus; fine to medium sized sands can be seen, felt or heard in a clayey matrix	5.0 - 7.5	35 - 40
SiC	Silty clay	Plastic bolus; smooth and silky	5.0 - 7.5	35 - 40 + > 25 silt
LC	Light clay	Plastic bolus; smooth to touch; slight resistance to shearing	5.0 - 7.5	35 - 40
LMC	Light medium clay	Plastic bolus; smooth to touch, slightly greater resistance to shearing than LC	7.5	40 - 45
MC	Medium clay	Smooth plastic bolus, handles like plasticine and can be moulded into rods without fracture, some resistance to shearing	> 7.5	45 - 55
HC	Heavy clay	Smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; firm resistance to shearing	> 7.5	> 50

Soil Data

Explanation of Terms (3 of 3)

Symbols for Soil and Rock



Unified Soil Classification Scheme (USCS)

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 63 mm and basing fractions on estimated mass)					USCS	Primary Name
COARSE GRAINED SOILS More than 50 % of material less than 63 mm is larger than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than 2.0 mm.	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	Gravel
				Predominantly one size or a range of sizes with more intermediate sizes missing	GP	Gravel
			GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)	GM	Silty Gravel
				Plastic fines (for identification procedures see CL below)	GC	Clayey Gravel
		SANDS More than half of coarse fraction is smaller than 2.0 mm	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of intermediate sizes missing.	SW	Sand
				Predominantly one size or a range of sizes with some intermediate sizes missing	SP	Sand
			SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)	SM	Silty Sand
				Plastic fines (for identification procedures see CL below)	SC	Clayey Sand

		IDENTIFICATION PROCEDURES ON FRACTIONS < 0.2 MM					
		DRY STRENGTH (Crushing Characteristics)	**DILATANCY**	**TOUGHNESS**	**DESCRIPTION**	**USCS**	**Primary Name**
FINE GRAINED SOILS More than 50 % of material less than 63 mm is smaller than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	None to Low	Quick to Slow	None	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	ML	Silt
		Medium to High	None	Medium	Inorganic clays of low to medium plasticity, gravely clays, sandy clays, silty clays, lean clays	CL	Clay
		Low to Medium	Slow to Very Slow	Low	Organic slits and organic silty clays of low plasticity	OL	Organic Silt
		Low to Medium	Slow to Very Slow	Low to Medium	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	MH	Silt
		High	None	High	Inorganic clays of high plasticity, fat clays	CH	Clay
		Medium to High	None	Low to Medium	Organic clays of medium to high plasticity	OH	Organic Silt
HIGHLY ORGANIC SOILS		Readily identified by colour, odour, spongy feel and frequently by fibrous texture				Pt	Peat

Low Plasticity – Liquid Limit W_L < 35 % Medium Plasticity – Liquid limit W_L 35 to 60 % High Plasticity - Liquid limit W_L > 60 %

Rock Data

Explanation of Terms (1 of 2)

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Definitions

Descriptive terms used for Rock by Martens are given below and include rock substance, rock defects and rock mass.

Rock Substance — In geotechnical engineering terms, rock substance is any naturally occurring aggregate of minerals and organic matter which cannot, unless extremely weathered, be disintegrated or remoulded by hand in air or water. Other material is described using soil descriptive terms. Rock substance is effectively homogeneous and may be isotropic or anisotropic.

Rock Defect — Discontinuity or break in the continuity of a substance or substances.

Rock Mass — Any body of material which is not effectively homogeneous. It can consist of two or more substances without defects, or one or more substances with one or more defects.

Degree of Weathering

Rock weathering is defined as the degree in rock structure and grain property decline and can be readily determined in the field.

Term	Symbol	Definition
Residual Soil	Rs	Soil derived from the weathering of rock. The mass structure and substance fabric are no longer evident. There is a large change in volume but the soil has not been significantly transported.
Extremely weathered	EW	Rock substance affected by weathering to the extent that the rock exhibits soil properties - ie. it can be remoulded and can be classified according to the Unified Classification System, but the texture of the original rock is still evident.
Highly weathered	HW	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and other signs of chemical or physical decomposition are evident. Porosity and strength may be increased or decrease compared to the fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original rock substance is no longer recognisable.
Moderately weathered	MW	Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance and the original colour of the fresh rock is no longer recognisable.
Slightly weathered	SW	Rock substance affected by weathering to the extent that partial staining or discolouration of the rock substance usually by limonite has taken place. The colour and texture of the fresh rock is recognisable.
Fresh	Fr	Rock substance unaffected by weathering

Rock Strength

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance is the direction normal to the bedding. The test procedure is described by the International Society of Rock Mechanics.

Term	Is (50) MPa	Field Guide	Symbol
Extremely weak	< 0.03	Easily remoulded by hand to a material with soil properties.	EW
Very weak	0.03 - 0.1	May be crumbled in the hand. Sandstone is 'sugary' and friable.	VW
Weak	0.1 - 0.3	A piece of core 150mm long x 50mm diameter may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.	W
Medium strong	0.3 - 1	A piece of core 150mm long x 50mm diameter can be broken by hand with considerable difficulty. Readily scored with a knife.	MS
Strong	1 - 3	A piece of core 150mm long x 50mm diameter cannot be broken by unaided hands, can be slightly scratched or scored with a knife.	S
Very Strong	3 - 10	A piece of core 150mm long x 50mm diameter may be broken readily with hand held hammer. Cannot be scratched with pen knife.	VS
Extremely strong	> 10	A piece of core 150mm long x 50mm diameter is difficult to break with hand held hammer. Rings when struck with a hammer.	ES

Rock Data

Explanation of Terms (2 of 2)

Degree of Fracturing

This classification applies to diamond drill cores and refers to the spacing of all types of natural fractures along which the core is discontinuous. These include bedding plane partings, joints and other rock defects, but excludes fractures such as drilling breaks.

Term	Description
Fragmented	The core is comprised primarily of fragments of length less than 20mm, and mostly of width less than core diameter.
Highly fractured	Core lengths are generally less than 20mm-40mm with occasional fragments.
Fractured	Core lengths are mainly 30mm-100mm with occasional shorter and longer sections.
Slightly fractured	Core lengths are generally 300mm-1000mm with occasional longer sections and occasional sections of 100mm-300mm.
Unbroken	The core does not contain any fractures.

Rock Core Recovery

TCR = Total Core Recovery

$$= \frac{\text{Length of core recovered}}{\text{Length of core run}} \times 100\%$$

SCR = Solid Core Recovery

$$= \frac{\sum \text{Length of cylindrical core recovered}}{\text{Length of core run}} \times 100\%$$

RQD = Rock Quality Designation

$$= \frac{\sum \text{Axial lengths of core} > 100\,\text{mm long}}{\text{Length of core run}} \times 100\%$$

Rock Strength Tests

- ▼ Point load strength Index (Is50) - axial test (MPa)
- ▶ Point load strength Index (Is50) - diametrall test (MPa)
- ● Unconfined compressive strength (UCS) (MPa)

Defect Type Abbreviations and Descriptions

Defect Type (with inclination given)

BP	Bedding plane parting
X	Foliation
L	Cleavage
JT	Joint
F	Fracture
SZ	Sheared zone (Fault)
CS	Crushed seam
DS	Decomposed seam
IS	Infilled seam
V	Vein

Coating or Filling

Cn	Clean
Sn	Stain
Ct	Coating
Fe	Iron Oxide

Planarity

Cu	Curved
Ir	Irregular
Pl	Planar
St	Stepped
Un	Undulating

Roughness

Po	Polished
Ro	Rough
Sl	Slickensided
Sm	Smooth
Vr	Very rough

Inclination

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

Sampling

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

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

Undisturbed samples may be taken by pushing a thin-walled sample tube into the soils and withdrawing a soil sample 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. Other sampling methods may be used. Details of the type and method of sampling are given in the report.

Drilling Methods

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

Hand Excavation – in some situations, excavation using hand tools such as mattock and spade may be required due to limited site access or shallow soil profiles.

Hand Auger - the hole is advanced by pushing and rotating either a sand or clay auger generally 75-100mm in diameter into the ground. The depth of penetration is usually limited to the length of the auger pole, however extender pieces can be added to lengthen this.

Test Pits - these are excavated with a backhoe or a tracked excavator, allowing close examination of the *in-situ* soils if it is safe to descend 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 in 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 - 115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or *in-situ* 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, 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 SPTs 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 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 procedure is described in AS 1289 Methods of Testing Soils for Engineering Purposes - Test F3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150 mm 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:

(i) In the case where full penetration is obtained with successive blow counts for each 150mm of say 4, 6 and 7 blows:

as 4, 6, 7
N = 13
(ii) In a 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

as 15, 30/40 mm.

The results of the tests can be related empirically to the engineering properties of the soil. Occasionally, the test method is used to obtain samples in 50mm diameter thin walled sample tubes in clays. 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 AS 1289 - Test F4.1.

In the test, a 35mm diameter rod with a cone tipped end is pushed continuously 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 separate 130mm long sleeve, immediately behind the cone. Tranducers in the tip of the assembly are connected by 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) the information is output on continuous chart recorders. The plotted results given in this report have been traced from the original records.

The information provided on the charts 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 of 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 (A) 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 (B) scale (0 - 50 Mpa) is less sensitive and is shown as a full line.

The ratios of the sleeve resistance to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 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/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 calculation 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 CONE (HAND) PENETROMETERS

Hand 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 16 mm diameter flat ended rod is driven with a 9kg hammer, dropping 600mm (AS 1289 - Test F 3.3). This 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 the Scala Penetrometer) - a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS 1289 - Test F 3.2). The test was developed initially for pavement sub-grade investigations, with correlations of the test results with California bearing ratio published by various Road Authorities.

LABORATORY TESTING

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

TEST PIT / BORE LOGS

The test pit / bore log(s) presented herein are an engineering and/or geological interpretation of the sub-surface conditions and their reliability will depend to some extent on frequency of sampling and the method of excavation / drilling. Ideally, continuous undisturbed sampling or excavation / 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' variation between the boreholes.

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 prior 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 advisable in low permeability soils or where there may be interference from a perched water table.