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GEOTECHNICAL REPORT

for

PROPOSED ALTERATIONS AND ADDITIONS

at

74 ELANORA ROAD, ELANORA HEIGHTS, NSW

Prepared For

James Horton

Project No.: 2024-205

November, 2024

Document Revision Record

Issue No	Date	Details of Revisions
0	14th November 2024	Original issue

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for______________James Horton____

Name of Applicant

Address of site _74 Elanora Road, Elanora Heights__ ______ ________________________________

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 __14th November 2024___ certify that I am an engineering geologist as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above company to issue this document and to certify that the company has a current professional indemnity policy of at least $2million.

I:

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

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

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

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

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

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

Geotechnical Report Details:

Report Title: Geotechnical Report for Proposed Alterations and Additions

Report Date: 14th November 2024 **Project No.:** 2024-205

Author: Josh Cotton

Author's Company/Organisation: Crozier Geotechnical Consultants

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

Architectural: Studio Friend, Drawing No.: SK00, SK05 – SK08, SK10, Dated: 2/10/2024

Survey: J McClure Detailed Surveys, Reference No.: 003/15, Dated: 18/01/2015

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**

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 James Horton
Name of Applicant
Address of site 74 Elanora Road, Elanora Heights

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

Geotechnical Report Details:

Report Title: Geotechnical Report for Proposed Alterations and Additions
Report Date: 14th November 2024 **Project No.:** 2024-205
Author: Josh Cotton
Author's Company/Organisation: Crozier Geotechnical Consultants

Please mark appropriate box

- ■ Comprehensive site mapping conducted 31st October 2024 (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 ....Very minor works.........
  - ☐ 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**

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Date: 14th November 2024
Project No: 2024-205

GEOTECHNICAL REPORT FOR PROPOSED ALTERATIONS AND ADDITIONS
74 ELANORA ROAD, ELANORA HEIGHTS, NSW

1. INTRODUCTION:

This report details the results of a landslip assessment required by Northern Beaches Council for proposed alterations and additions at 74 Elanora Road, Elanora Heights, NSW. The assessment was undertaken by Crozier Geotechnical Consultants (CGC) at the written request of Mark Barrow (Studio Friend) on behalf of the client James Horton.

It is understood that the proposed works involve the partial demolition of the rear northwestern corner of the first floor level with subsequent construction of a northwestern extension and new rear outdoor fire pit area. Further works include a minor western shower extension to the ground floor level along with internal alterations. The proposed works are understood to only require minor excavation for new footings, with the western extension to be positioned within existing rock excavations.

The site is located within the H1 (highest category) landslip hazard zone as identified within Northern Beaches Councils precinct (Geotechnical Risk Management Policy for Pittwater – 2009). This report has been prepared to meet the Council Policy Requirements of Paragraph 6.5. This geotechnical report is provided in support of the Development Application (DA) and assesses the landslip risk to ensure ‘Acceptable’ risk levels are achieved and can be maintained for the remnant design life of the existing structure.

The investigation comprised:

a) A detailed geotechnical inspection and mapping of the site and adjacent properties by a Geotechnical Engineer.
b) Review of CGC database on local geotechnical conditions

The following plans were supplied and relied upon for the work:

- Architectural Drawings – Studio Friend, Drawing No.: SK00, SK05 – SK08, SK10, Dated: 2/10/2024
- Survey Drawing – J McClure Detailed Surveys, Reference No.: 003/15, Dated: 18/01/2015

2. SITE FEATURES:

2.1. Description:

The site is a broadly trapezoidal shaped block located on the high western side of the road within moderate (≈17°) northeast to east dipping topography with the site levels varying from RL92.02m at the northwestern corner to RL76.30m at the northeastern corner of the site. The site contains a main dwelling (No.74) at the rear and a recently constructed secondary dwelling (No.74a) within the front of the block. Therefore, it is understood that the site has been subdivided within the last ten years as the survey provided details site dimensions prior to this subdivision (No.74 – No.74a).

2.2. Geology:

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

Morphological features often associated with the weathering of Hawkesbury Sandstone are the formation of near flat ridge tops with steep angular side slopes that consist of sandstone terraces and cliffs in part covered with sandy colluvium. The terraced areas often contain thin sandy clay to clayey sand residual soil profiles with intervening rock (ledge) outcrops.

3. FIELD WORK:

3.1. Methods:

The field investigation comprised a walk over inspection and mapping of the site and limited inspection of adjacent properties on the 31st October 2024 by a Geotechnical Engineer which included a photographic record of site conditions as well as geological/geomorphological mapping of the site and adjacent land.

Explanatory notes are included in Appendix: 1.

3.2. Field Observations:

The site is located at upperslope between the crest of Elanora Heights to the southwest and the lower level portions of Elanora and North Narrabeen to the east.

Elanora Road comprises a bitumen sealed road which appears to be constructed using a cut and fill method, with the roadway cut into the upslope (western) side of the road and fill placed on the eastern side. The road dips gently north in front of the site and contains a concrete kerb for stormwater control and collection. There were no signs of significant deformation or settlement in the roadway to suggest significant geotechnical concerns.

The site is accessed via a concrete driveway which extends along the southern side boundary, with a car parking space located at the approximate midpoint of the site. Pedestrian access to the site structure is provided via a timber and metal staircase of recent construction. The timber structure has been constructed adjacent to an approximate 4.1m high vertically cut sandstone bedrock outcrop, with a 0.8m high, dry stack retaining wall positioned at the crest of the outcrop which retains an upper garden and lawn.

This bedrock outcrop comprises medium to coarse grained sandstone which has been vertically cut in places by apparent rock hammering techniques. Defects were identified in the unit along the southern face which comprised a 20 – 80mm thick, clean, bedding defect at 1.5m depth and a 50mm thick, clay infilled bedding defect at 2.9m depth, these defects form an upper, middle and lower portion to the southern face of the outcrop. The upper portion of the outcrop appears to be partially detached with the eastern end gently dipping (≈10˚) east, laminations and undercutting of the sandstone were also identified within this upper eastern portion. Detached boulders were identified adjacent to the lower eastern portion of the outcrop but are associated with the excavation process. An image of this outcrop is shown in Photograph 1.

Photograph 1: View of the sandstone bedrock outcrop adjacent to the site parking space, facing northwest

The main site structure comprises a one and two storey rendered brick dwelling with two storeys to the front and one storey to the rear due to site topography. The main structure appeared to be in a stable condition with no significant cracking identified on external walls. Guttering and drainage systems were identified across the house with downpipes discharging into a water tank adjacent to the southern side of the house and into an open drain adjacent to the northern side of the house. The northern open drain extends to a strip drain adjacent to the northern side boundary.

The rear of the site is accessed by a concrete pathway along the north side boundary with concrete stairs extending to a rear grassed area, outdoor pergola structure and metal chicken coop. The pergola is formed with timber vertical and horizontal members and a metal roof, the timber posts bear onto the outdoor tiles of the rear patio. The chicken coop is formed with timber vertical members which bear onto the Ground Surface Level (GSL).

Sandstone bedrock is exposed between 0.30m and 0.90m from the rear of the ground floor of the main structure. It appears that this bedrock has been cut sub-vertically with lower portions extending closer to the structure in more southern portions. A battered, dry stack sandstone block retaining wall bears onto the top of the sandstone bedrock unit. It also appears that the overlying patio extends to bear onto this retaining wall along with the adjacent grassed lawn. Photograph 2 shows this area of the site.

Photograph 2: View of the exposed sandstone bedrock and overlying retaining wall adjacent to the rear wall of the main structure, facing south

The rear boundary of the site comprises steeply dipping terrain of outcropping bedrock, boulders, residual and colluvial soils across a maximum height of approximately 2.0m. A steeply dipping (≈60˚), 80mm wide, clean joint was identified in the outcropping bedrock at the rear boundary of the site, as shown in Photographs 3 and 4.

Photograph 3: View of exposed bedrock at the rear of the site facing west

Photograph 4: Joint within exposed bedrock at the rear of the site facing southwest

The neighbouring property to the north (No.76) contains a brick and weatherboard dwelling situated within a battle-axe style block. The main structure appears to be of an approximate 80-year construction age, however appeared to be in a stable condition with no signs of cracking or credible settlement issues. The rear of the property contains outcropping sandstone bedrock and boulders, a low retaining wall adjacent to the main structure and timber sleepers providing access to the nature reserve beyond the rear of the block. Sandstone bedrock also outcrops to the front of the main structure, with the outcrops comprising ≤2.5m high, low to medium strength sandstone bedrock with undercutting in regions to a maximum lateral distance of approximately 1.5m. However, no signs of impending geotechnical instability were identified within the property.

The neighbouring property to the south (No. 72) contains a one and two storey brick dwelling of an approximate 60- year construction age positioned towards the front of the block. Inspection from the site indicated that the structure is founded on sandstone bedrock, with no signs of cracking or settlement identified across the structure. Guttering and drainage measures extend from the house along the shared boundary with the site to the stormwater system in the road reserve. The rear of the property contains a fibro shed and grassed lawns with sandstone bedrock outcropping across the rear. No signs of impending geotechnical instability were identified within the property.

The neighbouring property to the east (No.74a) contains a recently constructed one and two storey clad building accessed via the concrete driveway shared with the site. The main structure appeared to be in a stable condition with no signs of instability. Exposed bedrock outcrops within the front southeastern corner of the property and comprises 2.0m high fractured sandstone with honeycombing and horizontal to sub-horizontal undercutting to ≤0.5m. A sub-horizontal (≈20˚) bedding defect was also identified within southern portions of the outcrop as shown in Photograph 5. Sandstone bedrock/boulders also outcrop within the rear of the property as an approximate 3.0m high cliff extends along the shared boundary of No.74a and the site, however limited inspection of this region was undertaken due to access restrictions.

Photograph 5: View of outcropping fractured bedrock within the southeastern corner of No.74

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 signs of large-scale slope instability or other major geotechnical concerns which would impact the site.

4. COMMENTS:

4.1. Geotechnical Model:

Based on conditions exposed within the site and from previous investigations nearby, the sub-surface conditions within the site are expected to comprise minor fill/colluvial soils with some minor residual soils which overlie sandstone bedrock. Detached boulders were identified embedded within the surficial soils in particularly within the rear of the site. The bedrock unit outcrops across the site and surrounding areas and is broadly classified as medium to coarse grained, low to medium strength quartz sandstone with some fracturing and defects.

4.2. Geotechnical Assessment:

The geotechnical inspection did not identify any signs of previous or impending large scale or deep-seated landslip instability within the site or adjacent properties. The existing main residential structure appears to be ≥50 years of age and shows no signs of slope movement whilst there are no indications of excess surface stormwater flow, groundwater seepage or erosion.

The proposed works involve alterations and additions to the existing structure which will include a rear northwestern extension to the first floor level, a new rear patio and fireplace area and internal alterations. The proposed works will also include the construction of a western extension for a new shower which is understood to require minimal to no excavation as it will be positioned adjacent to an existing excavation.

New footings should extend through any fill or colluvial material to bear onto sandstone bedrock to avoid potential for differential settlement. This is inclusive of the northwestern extension as it will overlie an existing dry stack sandstone block retaining wall. This retaining wall is considered unsuitable to support additional loading, therefore new footings must extend to bear directly onto the bedrock unit below.

Provided these recommendations are followed, it is considered that the proposed works will not create any new landslip instability hazards.

The recommendations and conclusions in this report are based on an assessment utilizing only surface observations and a limited inspection of neighbouring properties.

4.3. Slope Stability & Risk Assessment:

Based on our site mapping and understanding of the proposed works no credible geological/geotechnical landslip hazards were identified which need to be considered in relation to the existing site and proposed development works. As such a risk assessment is not required as the works are considered separate from, and not affected by a geotechnical landslip hazard.

4.4. Design Life of Structure:

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

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

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

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

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

Table 1: Recommended Maintenance and Inspection Program

Structure	Maintenance/ Inspection Item	Frequency
Stormwater drains.	Owner to inspect to ensure that the 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 or remedial measures	Owner to inspect walls for deviation from as constructed condition.	Every two years or following major rainfall event
Large Trees on or adjacent to site	Arbourist to check condition of trees and remove branches as required	Every five years

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

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

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

5. CONCLUSION:

The inspection and assessment identified no obvious slope movement, excess surface stormwater flow or seepage, erosion or instability within the site or adjacent properties. The entire site and surrounding slopes have been assessed as per the Northern Beaches Council - Geotechnical Risk Management Policy for Pittwater and no credible landslip hazards were identified whilst the proposed works are relatively minor from a geotechnical perspective and should not create any landslip hazards. Therefore, the proposed works are separate from and not affected by a geotechnical hazard, and no further reporting is expected to be required as part of these works.

It is considered that the site will meet the ‘Acceptable’ risk management criteria for the design life of the development, taken as 50 years, provided the property is maintained as per the recommendations of this report.

Prepared by:

Josh Cotton
Geotechnical Engineer

Reviewed by:

Troy Crozier
Principal
MAIG. RPGeo: Geotechnical and Engineering

6.0. REFERENCES:

1. Australian Geomechanics Society 2007, “Landslide Risk Assessment and Management”, Australian Geomechanics Journal Vol 42, No 1, March 2007.
2. Geotechnical Risk Management Policy for Pittwater, 2009.

CROZIER
GEOTECHNICAL CONSULTANTS

Appendix 1

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NOTES RELATING TO THIS REPORT

Introduction

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

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

Description and classification Methods

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Standard Penetration Tests

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

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

The test results are reported in the following form.

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

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

Cone Penetrometer Testing and Interpretation

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

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

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

The information provided on the plotted results comprises: -

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

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

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

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

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

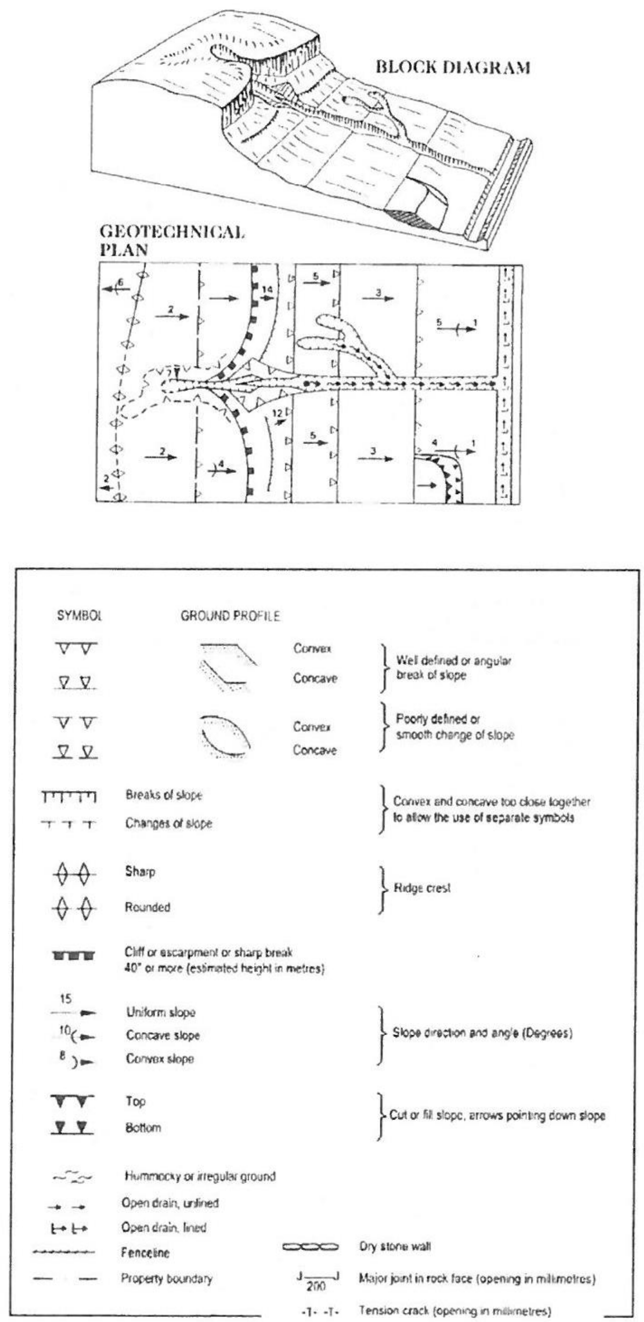
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some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

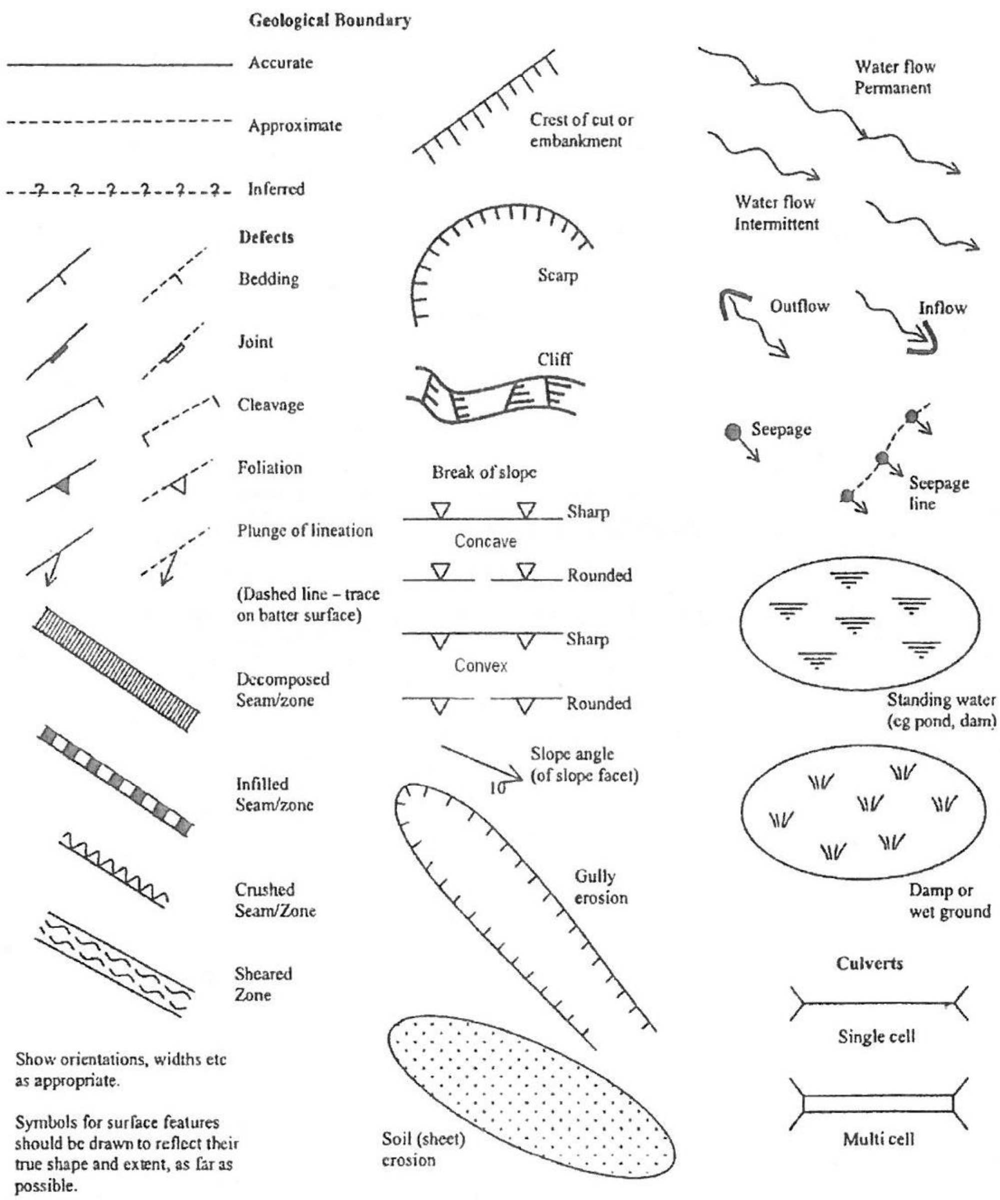
Site Inspection

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.



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

APPENDIX E - GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING SYMBOLS AND TERMINOLOGY



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