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Job No: 4365/
Our Ref: 4365/1AB

2 July 2002

Ryde City Council
Civic Centre
Devlin Street
RYDE NSW 2112

Attention: Ms S Wotton

Dear Madam

re: **Ryde Council Instability Risk Zones**
City of Ryde
Stability Assessment
Final Report

This report presents the results of a slope stability assessment carried out at the in the City of Ryde.

In 1991, Coffey Partners International Pty Ltd identified three slope instability risk zones, (high, moderate and low risk) in the City of Ryde. The medium risk zone was in turn divided into three categories, designated M1, M2 and M3. This slope stability assessment was conducted in order to provide additional information on the M3 slope instability risk zone.

Should you have any questions relating to this report, please do not hesitate to contact Mr Emged Rizkalla or the undersigned.

Yours faithfully
GEOTECHNIQUE PTY LTD

MATTHEW CUPITT
Engineering Geologist

Reviewed by

INDRA JWORCHAN
Senior Geotechnical Engineer

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APPENDICES

1.0 INTRODUCTION

This report presents the results of a slope stability assessment carried out in the City of Ryde. The assessment was commissioned by Ms S Wotton of Ryde City Council, in a facsimile dated 14 June 2002 and was carried out in general accordance with Geotechnique Pty Ltd proposal, ER.pb/Q1453 dated 6 June 2002.

In 1991, Coffey Partners International Pty Ltd (Coffey) nominated three slope instability risk zones, High, Moderate and Low risk, in the City of Ryde (Reference 1). The Moderate Risk zone was then divided into three categories, designated M1, M2 and M3. This slope stability assessment was carried out to provide additional information on the M3 slope instability risk zone.

2.0 EXISTING INFORMATION

2.1 Coffey Partners International Pty Ltd Report

Coffey (Reference 1) undertook a study in 1991 in order to designate zones having different levels of risk, with respect to land instability and erosion potential in the City of Ryde. The outcome of this study was to divide the area into three risk zones, described as follows:

LOW RISK ZONE — Areas where either the natural slopes are typically less than 10 degrees, or where the surface is underlain at relatively shallow depth by material which is considered to have sufficient strength that the risk of slope failure is low to very low.

MODERATE RISK ZONE — Areas where either the natural slopes are typically steeper than 10 degrees, or where the surface is underlain by lower strength foundation materials, or steep cliffs. Zone M1 is characterised by slope angles generally in excess of 10 degrees in areas underlain by shale, where there is some evidence to indicate concern of the possibility of slope instability. Zone M2 is characterised by slope angles generally in the range of 5 to 10 degrees in areas underlain by shale.

HIGH RISK ZONE — Local areas where the combination of generally steep slopes and low strength foundation materials have either resulted in slope failure or appear to be present to such a degree that a higher risk of instability exists.

The risk zones were indicated on a map at a scale of approximately 1:15,000. It must be accepted that the boundaries shown between the slope instability risk zones are approximate and that it cannot be excluded that slope instability problems may exist, or may be created by development outside the zoned areas. A certain degree of judgement has been applied in drawing zone boundaries, so as not to make them excessively conservative. It is considered that areas adjacent to a zone boundary should be regarded with caution and at least, those properties crossed by a boundary should be regarded as lying within the higher risk zone.

The development constraints and assessed damage potential for each risk zone presented in Coffey's report, are reproduced as follows:

Low Risk Zone

It is considered that development of areas designated Low Risk is unlikely to be affected by slope failure problems due to natural features. Specific geotechnical investigation of these areas is not considered necessary, unless development involves major slope modifications.

Moderate Risk Zone

Areas designated as Moderate Risk exhibit sufficiently steep slopes and residual/slopewash cover overlying shale, that some concern exists of the possibility of slope instability, particularly in the case of uncontrolled development. Moderate Risk Zone is grouped into three subgroups as follows:

ZONE M1

It is recommended that in areas designated M1, where slope angles generally exceed 10 degrees and where there is some evidence to indicate concern of the possibility of slope instability, proposed development should be subject to geotechnical assessment by a suitably qualified Geotechnical Engineer or Engineering Geologist. This should involve an initial inspection of surface features, with sub-surface investigations required where conditions are confirmed to be adverse.

ZONE M2

In areas designated M2, where slope angles are generally in the range of 5 to 10 degrees, it is recommended that Council officers initially assess whether individual building applications warrant geotechnical assessment. In these areas, it is generally recommended that the height of uncontrolled fill and excavations are restricted to a maximum of 1.0m, unless supported by an engineered retaining structure. In addition, structures in these areas should be founded on weathered shale, below any residual/slopewash materials.

ZONE M3

The development of areas designated as Moderate Risk, located on steep slopes and cliff lines in sandstone terrain, should ensure that structures are founded on insitu sandstone, not potentially unstable detached blocks of sandstone. Where development is proposed adjacent to a steep escarpment, it is recommended that the proposed development is initially assessed by Council officers, who would then decide whether or not a geotechnical assessment is required. As the majority of the areas designated M3 fall within the Lane Cove River State Recreation Area, such investigations would rarely be required.

High Risk Zone

In the areas designated High Risk, where features indicate active, recent or potential slope instability, development should be regarded with concern. It is recommended that any proposed development within these areas should be subject to geotechnical investigation of surface features, supported by sub-surface investigation to define the geotechnical parameters that are required to more accurately define the degree of risk associated with such development.

2.2 Geological Map

The Geological Map of Sydney (1:100,000) indicates that the City of Ryde is underlain by the Wianamatta group of rocks (Ashfield Shale), Hawkesbury Sandstone and Quaternary sediments. Ashfield shale comprises dark grey to black shale and laminite. Hawkesbury Sandstone comprises medium to coarse grained quartz sandstone, very minor shale and laminite lenses. The shale country typically forms gently undulating topography, with only limited areas having natural slopes steeper than 10 degrees.

The shale is almost horizontally bedded and overlies Hawkesbury Sandstone, which outcrops in steep cliff faces along the Parramatta and Lane Cove Rivers.

Quaternary sediments are associated with inlets along the Parramatta and Lane Cove Rivers. Many of these low-lying areas have been used for fill disposal and sports fields have been constructed on the fill in a number of areas.

2.3 Soil and Landscape Map

The Soils and Landscape Series Map of Sydney (1:100,000) indicates that the majority of the City of Ryde belongs to the Glenorie Group. Some parts however, belong to the Lucas Heights and Hawkesbury Groups, the latter group is observed along the Lane Cove River.

The Glenorie Group is characterised by undulating to rolling hills on Wianamatta Group shales, with local relief of 50m to 80m, ground slopes of 5% to 20%, narrow ridges, hill crests and valleys. The sub-surface soil in this group is likely to be impermeable (localised), highly plastic and moderately reactive clay, varying in thickness from less than 1.0m on crests to more than 2.0m on lower slopes.

However, landscapes in some portions of the City of Ryde belong to the Lucas Heights Group and Hawkesbury Group. The Lucas Heights Group is characterised by gently undulating crests and ridges on plateau surfaces of alternating bands of shale and fine grained sandstone, with local relief to 30m and ground surface slopes of less than 10%. Rock outcrop is absent. The sub-surface soil is likely to be moderately deep (0.5m to 1.5m) and stoney.

The Hawkesbury Group is characterised by rugged, rolling to very steep hills on Hawkesbury Sandstone, with local relief of 40m to 200m, ground surface slopes of more than 25%, rock outcrop of more than 50%, narrow crests and ridges, narrow incised valleys, steep side slopes with rocky benches and broken scarp and boulders. The sub-surface soil in this group is likely to be shallow, less than 0.5m, stoney, highly permeable and susceptible to extreme erosion and mass movement hazards.

3.0 LANDSLIDE RISK MANAGEMENT CONCEPTS AND GUIDELINES - 2000

The Australian Geomechanics Society recognised that there are significant deficiencies in the guidelines entitled "Geotechnical Risks Associated with Hillside Development -1985" (used in preparation of Coffey's report) and recommended new guideline entitled "Landslide Risk Management Concepts and Guidelines – 2000" (Reference 3). It is considered that the risk assessment methods for landslides and slopes in the guidelines are applicable in practical terms and form a useful tool to complement engineering judgement. The Australian Geomechanics Society also recommends that the 2000 guidelines should be adopted and use of the 1985 methods be discontinued. It is our assessment that the "Landslide Risk Management Concepts and Guidelines – 2000" is appropriate for landslide risk management projects in the City of Ryde and therefore reference should be made to the guidelines (Reference 3) for detailed procedures/explanations. The salient features of these guidelines are listed in this report.

3.1 Risk Management Process

The risk management process comprises three components:

- Risk analysis
- Risk evaluation
- Risk treatment

The process involves answering the following questions:

- What might happen?
- How likely is it?
- What damage or injury may result?
- How important is it?
- What can be done about it?

Part of the process involves comparing the assessed risks (of property loss and damage, and loss of life) against acceptance criteria.

Recommended terminologies used in landslide risk management are presented in Appendix A of this report (reproduced from the 2000 guidelines).

3.1.1 Risk Analysis

To ensure that the risk analysis addresses the relevant issues and to quantify the limits or limitation of the analysis, it is necessary to define:

- The site.
- Geographic limits.
- Whether the analysis will be limited to addressing only property loss or damage or will also address injury to persons and loss of life.
- The nature and extent of the investigation that will be completed.
- The type of analysis that will be carried out.
- The basis for assessment of acceptable and tolerable risks.

Risk Analysis involves:

- Hazard (landslide) identification
- Estimation of travel distance and velocity
- Frequency analysis
- Consequence analysis
- Risk estimation
- Sensitivity analysis and uncertainty

Hazard Identification - Hazard (landslide) identification requires understanding of the slope processes and relationship of those processes to geomorphology, geology, hydrogeology, climate and vegetation. From this understanding it will be possible to:

- Classify the types of potential landsliding.
- Assess the physical extent of each potential landslide being considered.
- Assess the likely initiating event(s), the physical characteristics of the materials involved and the slide mechanism.
- Estimate the resulting anticipated travel distance and velocity of the movement.
- Address the possibility of fast acting processes, from which it is more difficult to escape.

Frequency Analysis - Frequency analysis is the key step in Risk Analysis and can be expressed as:

- The annual frequency of occurrence of landsliding in a nominated part of the landscape (as study area or particular slope facet) based on previous rates of occurrence.
- The probability of an existing landslide moving or a particular slope, cut or fill failing in a given period (e.g. a year), based on an understanding and analysis of the controls on stability.
- The driving forces exceeding the resisting forces in probability or reliability terms, expressing it as an annual frequency.

Different levels of site investigation (inspection to investigation to assess sub-surface and groundwater conditions) may be used to assess the frequency. Each level of investigation allows increased understanding of the landslide hazards and therefore of the frequency or probability of occurrence. There are a variety of methods in estimating frequency from disparate sets of information that may be assembled (Reference 3).

Consequence Analysis - The consequences of landslides may not be limited to property damage and injury/loss of life. Other consequences include:

- Public outrage
- Political effects
- Loss of business confidence
- Effect on reputation
- Social upheaval
- Consequential costs, such as litigation

Many of these may not be readily quantifiable and will require considerable judgement if they are to be included in the assessment. Consideration of such consequences may form part of the risk evaluation process by the client/owner/regulator.

The consequence analysis involves assessing:

- Elements at risk
- Temporal probability
- Vulnerability

Risk Estimation – Risk estimation may be carried out quantitatively, semi-quantitatively or qualitatively. Wherever possible, the risk estimate should be based on a quantitative analysis, even though the results may be summarised in a qualitative terminology. The methods of risk estimation are detailed in Reference 3.

Sensitivity Analysis and Uncertainty – As estimates made for an analysis will be imprecise, sensitivity analysis is useful to evaluate the effects of changing assumptions and estimates. Wherever possible, such assumptions and the resulting sensitivity should be stated or expressed in the report.

3.1.2 Risk Assessment/ Risk Evaluation

The main objectives of risk evaluation are usually to decide whether to accept or treat the risks and to set priorities. The decision is usually the responsibility of the owner/client/regulator. Risk comparisons, discussion of treatment options and explanation of the risk management process can help the client make a decision.

Risk evaluation involves making judgements about the significance and acceptability of the estimated risk. Evaluation may involve comparison of the assessed risks with other risks or with risk acceptance criteria related to financial, loss of life or other values. Risk evaluation may include consideration of issues such as environmental effects, public reaction, politics, business or public confidence and fear of litigation. In a simple situation where the client/owner is the only affected party, risk evaluation may be a simple value judgement. In more complex situations, value judgements on acceptable risk appropriate to the particular situation are still made as part of an acceptable process of risk management.

Risk acceptance for a quantitative analysis is likely to be based, at least partly, on quantitative values with the consideration of the uncertainty and defensibility of the assessment. For a qualitative or semi-quantitative assessment, the acceptance criteria may be qualitative. With the wide variety of issues which need to be considered and the varying attitudes to risk, it may not be possible to pre-define acceptance criteria (Reference 3).

Qualitative terminology, for use in assessing risk to property, is presented in Appendix B of this report (reproduced from the 2000 guidelines).

Assessment of the risk may involve consideration of values for property or financial losses and loss of life.

It is important to distinguish between acceptable risks that society desires to achieve, particularly for new projects, and tolerable risks, which they will live with, even though they would prefer lower risks. This applies to both property and loss of life.

Acceptable and tolerable risks for property loss and damage must be determined by the client, owner and if appropriate, regulator.

There are no established individual or social risk acceptance criteria for loss of life due to landslides, in Australia or internationally. However, general principles and information from other engineering industries (petroleum and dams) may be used to obtain broad-spectrum appreciation of the risks and acceptance criteria for landslide. Nonetheless, the decision on risk acceptability (or tolerance) must be made by the client, owner, regulator and those at risk. Reference 3 provides general principles applied when considering tolerable risk criteria.

Assessing the risk from individual slopes may need to be considered along with the risks from other slopes to which the public is exposed.

There are a number of limitations to risk assessment for slopes and landslides:

- The judgement content of the inputs to any analysis may result in values of estimated risks with considerable inherent uncertainty.
- The variety of approaches that can reasonably be adopted to analyse landslide risk can result in significant difference in outcome for the same situation, when considered separately by different practitioners.

- To complete a risk assessment, time and skills are required to make and interpret the field observations and to develop insight and understanding of the slope process applicable. Greater experience and understanding of the processes will improve the reliability of the analysis.
- Revising an analysis can lead to a significant change, due to increased data, a different method, or changing circumstances.
- The consequences of an inability to recognise a significant hazard will be underestimation of the risk.
- The results of an assessment are seldom verifiable, though peer review can be useful.
- It is possible that the cost of the analysis may outweigh the benefit of the technique in making a decision, especially where complex detailed sets of data are required. However, this is really an issue of matching the analysis method to the scale of the problem and resources available.
- There may be difficulty in completing a quantitative analysis due to the difficulty of obtaining sufficient data for reliable evaluation of the frequency of events.
- It is difficult to accurately analyse risk for low probability events.

3.1.3 Risk Management / Risk Treatment

At the end of the evaluation procedure, it is up to the client or policy makers to decide whether to accept the risk or not, or to decide that more detailed study is required. The landslide risk analyst can provide background data or normally acceptable limits as guidance to the decision makers, but should not make the decision. Part of the specialist advice would be to identify the options and methods for treating the risk. Typical options would include:

- Accept the risk
- Avoid the risk
- Reduce the likelihood
- Reduce the consequences
- Monitoring and warning systems
- Transfer the risk
- Postpone the decision

Guidance on good engineering practice for hillside design and construction is presented in Appendix C of this report (reproduced from the 2000 guidelines).

3.1.4 Hazard Zoning

Risk assessment principles can be applied to producing maps showing hazard zones. This involves

- Generation of maps summarising observations on geology, geomorphology and in particular, the distribution of landslide processes, including use of local records, interpretation of photographs and field observations. Engineered slopes should also be identified. This is known as the process map.
- Collection of information on the landslide hazards identified from the above.
- Analysis of potential hazards, including first time slides, deep seated existing slides, rock debris flows, cuts and fills.

- Identification of areas that may be impacted by such hazards.
- Transformation of the process map to a hazard map, identifying the potential for spatial impact and probability of occurrence for all the hazards.

4.0 PRESENT STUDY

4.1 Methodology

The present study was limited to Coffey's Moderate Risk Zone M3 and involved:

- Review of available information, including geological and soil landscaping maps, geotechnical and stability reports.
- Field inspection of specific areas, outlined in the project brief and confirmed during design meeting.
- Discussions with Council officers during the design meeting.
- Assessing likelihood and consequences of landslides.
- Determining level of landslide risk.
- Preparing a map showing zones with varying levels of risk.

4.2 Risk Assessment

Results of the present study are detailed below:

Scope Definition Coffey identified three slope instability risk zones, High, Moderate or Low risk, in the City of Ryde (Reference 1). The Moderate Risk zone was then divided into three categories, designated M1, M2 and M3. This slope stability assessment is required to provide additional information on the M3 slope instability risk zone.

Hazard Identification Moderate Risk Zone M3 is located on steep slopes and cliff lines in Hawkesbury sandstone terrain. The sandstone cliff faces are 3.0m to 15m high, sloping at 60 to 80 degrees and show rock discontinuities, including bedding planes and joints. Deep seated sliding is rare in Hawkesbury Sandstone. Instability of natural slopes in this geological sequence usually takes the form of rock falls and/or toppling failure of large blocks of sandstone, which have become detached from the main rock mass over the geological time scale. There is evidence of rock falls at the base of rock cliffs, indicating rock fall hazards in risk zone M3. We do not anticipate landslides and rock flows within this zone.

Furthermore, there is potential that footings founded on boulders and detached sandstone blocks may move, causing damage to existing and/or proposed developments (structures)

Likelihood Based on site conditions and evidence of past rock falls, it is our assessment that rock falls are likely to occur in risk zone M3. However, estimation of frequency and travel distances was outside the scope of this present study.

Consequences Rock fall hazard in risk zone M3 may impact on either the National Park Reserve or residential properties. Rock falls within the National Park Reserve are assessed to cause little damage to property (insignificant). However, rock falls in residential properties are assessed to cause limited to moderate damage to part of structure or part of a site, requiring some reinstatement/stabilisation works (Minor - Medium).

Risk Evaluation/ Risk Assessment There are no significant manmade structures within the National Park Reserve and hence, the level of risk to property due to rock falls is low to very low. The level of risk to property in residential properties is assessed to be moderate.

Risk Treatment It is our assessment that the level of risk in the National Park Reserve may be accepted as it is, and to do nothing at this stage. In residential properties, the risk management/treatment options would include the following:

- reduce the likelihood of rock falls by removing or stabilising potentially unstable rock blocks.
- development in this zone should ensure that structures are founded on insitu sandstone, not potentially unstable detached blocks of sandstone.
- where development is proposed adjacent to a steep escarpment, it is recommended that the proposed development is initially assessed by Council officers, who would decide whether or not a geotechnical assessment is required.

Client Decision It is up to the client to decide whether to accept the risk or not (treat the risk) or to decide that more detailed study is required before arriving at a decision.

Assessment of risk of injury or loss of life due to landslides (rock falls) was beyond the scope of the present study. We suggest that the risk to loss of life due to landslide (rock fall) in risk zone M3, especially in residential properties, should be considered in overall risk management.

Risk assessment presented in this section is general in nature. Hazard identification likelihood and consequence are site dependent and hence, site specific assessment may be required when determining development constraints at a specific site.

4.3 Risk Zoning

The outcome of the present study was to divide the Coffey Risk Zone M3 into two sub-zones, designated L3a and M3a detailed as follows:

Risk Zone L3a Steep slopes, boulders and cliff lines in sandstone terrain within the National Park Reserve area. These areas are unlikely to be developed and are assessed to have a very low to low risk to property. It is our assessment that the level of risk in the National Park Reserve may be accepted as it is, and to do nothing at this stage.

Risk Zone M3a Steep slopes, boulders and cliff lines in sandstone terrain, affecting individual properties. This zone is assessed to have a moderate risk to property. The risk management treatment options for Zone M3a include the following:

- reduce the likelihood of rock falls by removing or stabilising potentially unstable rock blocks.
- development in this zone should ensure that structures are founded on insitu sandstone, not potentially unstable detached blocks of sandstone.
- where development is proposed adjacent to a steep escarpment, it is recommended that the proposed development is initially assessed by Council officers, who would decide whether or not a geotechnical assessment is required.

Risk Zones L3a and M3a are indicated on Drawing Nos 4365/1-1 to 4365/1-5 in Appendix D of this report. Drawing Nos 4365/1-1 to 4365/1-4 show the hazard zones for four areas, at a larger scale (1:4000), as requested by Council. Drawing No 4365/1-5 shows the hazard zones for the entire area and present study.

5.0 CONCLUSION

As Coffey's (1991) assessment of the risk of slope instability is based on the Australian Geomechanics Society guidelines "Geotechnical Risks Associated with Hillside Development -1985", there is no direct correlation between Coffey's risk level and that of the Australian Geomechanics Society guidelines, "Landslide Risk Management Concepts and Guidelines – 2000". However, based on review of Coffey's basis of risk zoning, the Coffey's risk level may be approximately correlated with the measure of likelihood of landslides in the Australian Geomechanics Society guidelines "Landslide Risk Management Concepts and Guidelines – 2000" as follows:

Coffey Partners International (1991)	**Australian Geomechanics Society Landslide Risk Management Concepts and Guidelines - 2000**
Low Risk	Not Credible to Rare
Moderate Risk	Unlikely
High Risk	Possible to Almost Certain

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References

1. Coffey Partners International Pty Ltd (1991) – Instability Risk Zoning, Ryde Municipal Council, Report No S9378/1-AC.
2. Walker B. F., Dale, M., Fell, R., Jeffery, R., Leventhal, A., McMahon, M., Mostyn, G. & Phillips, A. (1985) – Geotechnical Risks Association with Hillside Development, Australian Geomechanics News, No 10, pp 29-35.
3. Australian Geomechanics Sub-committee on Landslide Risk Management (2000) – Landslide Risk Management Concepts and Guidelines, Australian Geomechanics, Vol 37, No 2, pp 1-44..

DEFINITIONS OF TERMS

(AGS GUIDELINES 2000)

APPENDIX A

APPENDIX A

DEFINITION OF TERMS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

LANDSLIDE RISK ASSESSMENT

(AGS GUIDELINES 2000)

APPENDIX B

APPENDIX G

LANDSLIDE RISK ASSESSMENT - EXAMPLE OF QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

Qualitative Measures of Likelihood

Level	Descriptor	Description	Indicative Annual Probability
A	ALMOST CERTAIN	The event is expected to occur	$>\approx 10^{-1}$
B	LIKELY	The event will probably occur under adverse conditions	$\approx 10^{-2}$
C	POSSIBLE	The event could occur under adverse conditions	$\approx 10^{-3}$
D	UNLIKELY	The event might occur under very adverse circumstances	$\approx 10^{-4}$
E	RARE	The event is conceivable but only under exceptional circumstances.	$\approx 10^{-5}$
F	NOT CREDIBLE	The event is inconceivable or fanciful	$<10^{-6}$

Note: "≈" means that the indicative value may vary by say ±[illegible] order of magnitude, or more.

Qualitative Measures of Consequences to Property

Level	Descriptor	Description
1	CATASTROPHIC	Structure completely destroyed or large scale damage requiring major engineering works for stabilisation.
2	MAJOR	Extensive damage to most of structure, or extending beyond site boundaries requiring significant stabilisation works.
3	MEDIUM	Moderate damage to some of structure, or significant part of site requiring large stabilisation works.
4	MINOR	Limited damage to part of structure, or part of site requiring some reinstatement/stabilisation works.
5	INSIGNIFICANT	Little damage.

Note: The "Description" may be edited to suit a particular case.

Qualitative Risk Analysis Matrix – Level of Risk to Property

LIKELIHOOD	CONSEQUENCES to PROPERTY				
	1: CATASTROPHIC	2: MAJOR	3: MEDIUM	4: MINOR	5: INSIGNIFICANT
A – ALMOST CERTAIN	VH	VH	H	H	M
B – LIKELY	VH	H	H	M	L-M
C – POSSIBLE	H	H	M	L-M	VL-L
D – UNLIKELY	M-H	M	L-M	VL-L	VL
E – RARE	M-L	L-M	VL-L	VL	VL
F – NOT CREDIBLE	VL	VL	VL	VL	VL

Risk Level Implications

Risk Level		Example Implications(1)
VH	VERY HIGH RISK	Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to acceptable levels; may be too expensive and not practical
H	HIGH RISK	Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable levels
M	MODERATE RISK	Tolerable provided treatment plan is implemented to maintain or reduce risks. May be accepted. May require investigation and planning of treatment options.
L	LOW RISK	Usually accepted. Treatment requirements and responsibility to be defined to maintain or reduce risk.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (1) The implications for a particular situation are to be determined by all parties to the risk assessment; these are only given as a general guide.

(2) Judicious use of dual descriptors for Likelihood, Consequence and Risk to reflect the uncertainty of the estimate may be appropriate in some cases.

APPENDIX H

ACCEPTABLE AND TOLERABLE RISK CRITERIA

(a) Summary of Individual Risk Criteria (taken from Fell & Hartford, 1997)

Source	Lower Bound (Acceptable)	Upper Limit (Tolerable)
Health and Safety Executive (1989a)	10^{-6} of dangerous dose equivalent to 0.33×10^{-6}	10^{-5} of dangerous dose equivalent to 0.33×10^{-5}
Health and Safety Executive (1988)	10^{-6} broadly acceptable	10^{-3}, divide between just tolerable and intolerable 10^{-4} any individual member of public from large scale industrial hazard
New South Wales Department of Planning (1994)		10^{-6} residential 5×10^{-5} residential
Hong Kong Government Planning (1994)	Not defined	10^{-5}
BC Hydro (1993)		10^{-4}
ANCOLD (1994) Existing dams		10^{-5} average 10^{-4} person most at risk
USBR (Von Thun, 1996)	None stated	
Finlay and Fell (1997)	10^{-5} to 10^{-6} 10^{-3} to 10^{-4} acceptable for property	10^{-3} tolerated

SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

(AGS GUIDELINES 2000)

APPENDIX C

APPENDIX J

SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

ADVICE	*GOOD ENGINEERING PRACTICE*	*POOR ENGINEERING PRACTICE*
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminant bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	

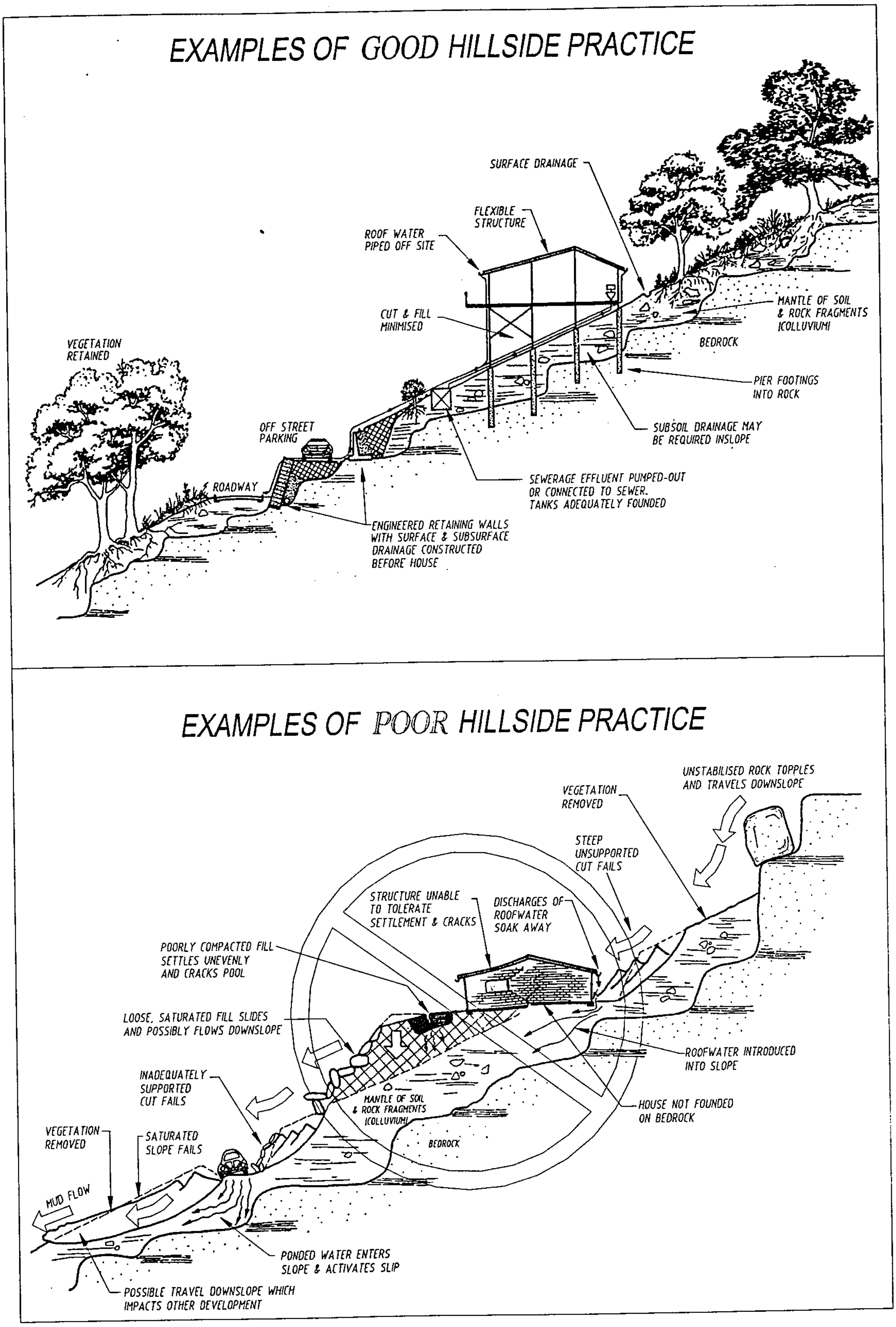


FIGURE J1: Illustrations of Good and Poor Hillside Practice

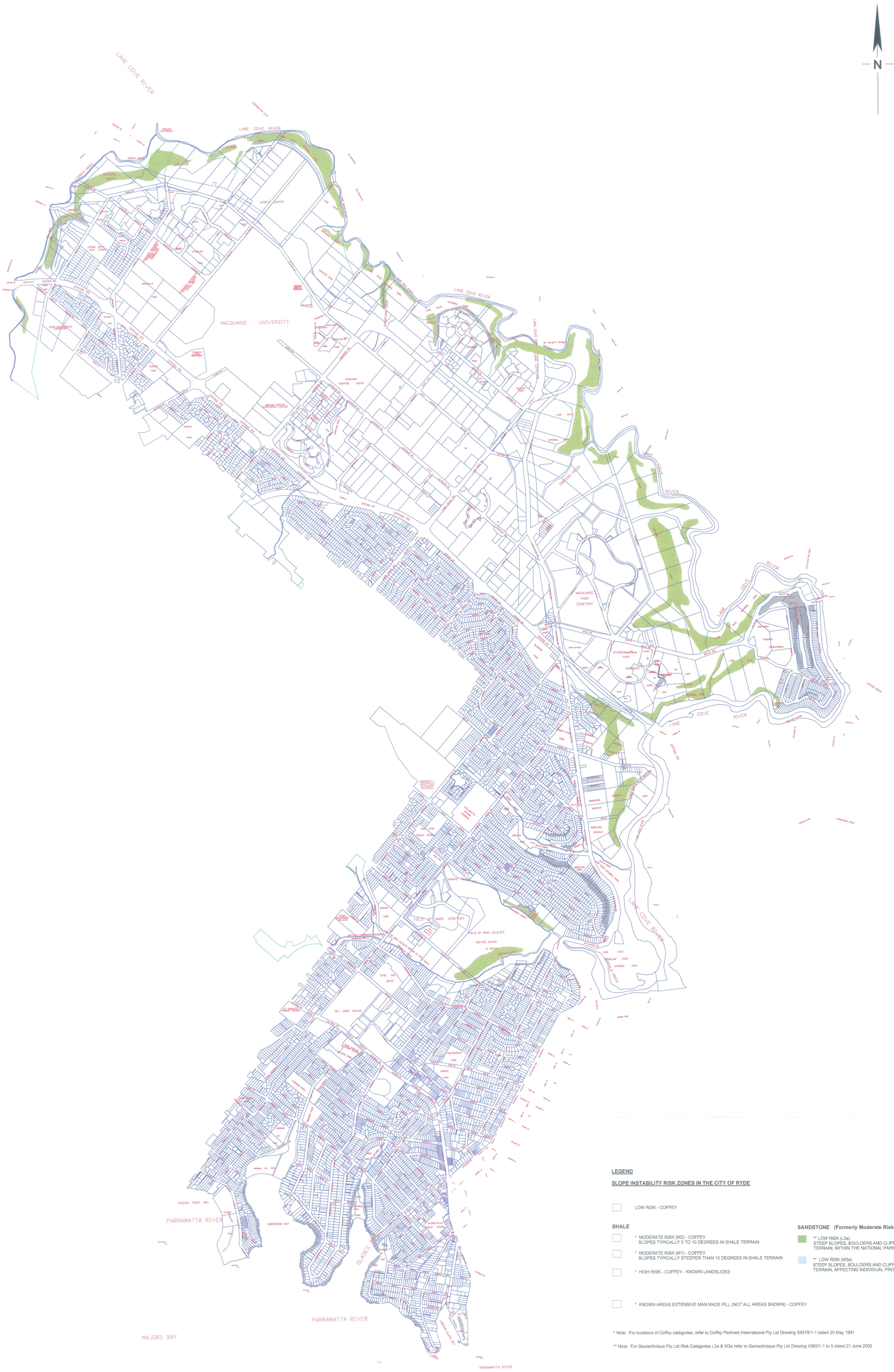
This figure is an extract form LANDSLIDE RISK MANAGEMENT CONCEPTS AND GUIDELINES as presented

SLOPE INSTABILITY RISK ZONE MAP

(DRAWING NOS 4365/1-1 TO 4365/1-5)

APPENDIX D

Instability M3(a) Risk Zone L3(a)



LEGEND

SLOPE INSTABILITY RISK ZONES IN THE CITY OF RYDE

- LOW RISK - COFFEY

SHALE

- * MODERATE RISK (M2) - COFFEY
  SLOPES TYPICALLY 5 TO 10 DEGREES IN SHALE TERRAIN
- * MODERATE RISK (M1) - COFFEY
  SLOPES TYPICALLY STEEPER THAN 10 DEGREES IN SHALE TERRAIN
- * HIGH RISK - COFFEY - KNOWN LANDSLIDES

SANDSTONE (Formerly Moderate Risk (M3) - Coffey)

- ** LOW RISK (L3a)
  STEEP SLOPES, BOULDERS AND CLIFF LINES IN SANDSTONE TERRAIN, WITHIN THE NATIONAL PARK RESERVE AREA.
- ** LOW RISK (M3a)
  STEEP SLOPES, BOULDERS AND CLIFF LINES IN SANDSTONE TERRAIN, AFFECTING INDIVIDUAL PROPERTIES.

- * KNOWN AREAS EXTENSIVE MAN MADE FILL (NOT ALL AREAS SHOWN) - COFFEY

* Note: For locations of Coffey categories, refer to Coffey Partners International Pty Ltd Drawing S9378/1-1 dated 20 May 1991

** Note: For Geotechnique Pty Ltd Risk Categories L3a & M3a refer to Geotechnique Pty Ltd Drawing 4365/1-1 to 5 dated 21 June 2002

(Geotechnique Report No 4635/1-AB Dated 2 July 2002)

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NOTES

1. Site Features are shown at approximate locations and are not to scale.
2. This drawing has been produced using a base plan provided by others to which additional information e.g test pits, borehole locations or notes have been added. Some or all of the information on the plan may not be relevant at the time of producing this drawing.

Ryde City Council
Instability Risk Zones - M3a and L3a
City of Ryde

Drawn By: MC/AC	Drawing No: 4365/1-5
Approved:	Date: 21/06/2002
Scale: 1 : 10,000	File No: Ryde Council-Drawing 5

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Job No: 4365/2
Our Ref: 4365/2-AA
1 October 2002

Ryde City Council
Civic Centre
Devlin Street
RYDE NSW 2112

Attention: Ms S Wotton

Dear Madam

re: **Ryde Council Instability Risk Zones**
City of Ryde
Stability Assessment
Geotechnical Advice

This letter report presents geotechnical advice in accordance with Task 1 of our proposal, Q1496-amended 2, dated 1 August 2002. This advice is given to determine whether or not development on properties identified as lying within areas M3a and L3a in Report No 4365/1-AB, dated 2 July 2002, is restricted because the properties are at risk of the likelihood of landslip. It is understood that Council's primary interest is with privately owned land identified as M3a.

The *Landslide Risk Management Concepts and Guidelines* (2000), prepared by the Australian Geomechanics Sub-committee on Landslide Risk Management of the Australian Geomechanics Society (Reference 1) defines landslide in Appendix B, as follows:

> The term ***landslide*** denotes "the movement of a mass of rock, debris or earth down slope". The phenomena described as landslides are not limited to either "land" or "sliding" and usage of the word has implied a much more extensive meaning than its' component parts suggest.

Reference 1 describes a classification system that has two terms: the first term describes the material type and the second term describes the type of movement.

The material types are ***Rock, Earth*** and ***Debris.*** The terms used should describe the displaced material in the landslide, before it was displaced.

The types of movement describe how the landslide movement is distributed through the displaced mass. The five kinematically distinct types of movement are described in the sequence ***fall, topple, slide spread*** and ***flow.***

Areas within instability risk zones M3a and L3a, identified in our Report No 4365/1-AB, dated 2 July 2002, are at risk of Rock Fall and Rock Topple failures. In addition to these risks, potential damage to property within risk zone M3a may result from movement of footings founded on boulders and detached sandstone blocks.

Based on the foregoing, it is considered that development on properties identified as lying within area M3a, in our Report No 4365/1-AB dated 2 July 2002, should be restricted as the properties are at risk of landslip.

Restriction on these properties may simply entail the provision of a site-specific geotechnical report, identifying potential risks for the proposed development and providing recommendations for remedial works to ensure the stability of the proposed development and surrounding properties.

Should you have any questions relating to this report, please do not hesitate to contact the undersigned.

Yours faithfully
GEOTECHNIQUE PTY LTD

MATTHEW CUPITT
Engineering Geologist

Reference 1: Australian Geomechanics Sub-committee on Landslide Risk Management (2000) – Landslide Risk Management Concepts and Guidelines, Vol 37, No 2, pp 1-44.