The Design of Permanent Slopes For Residential Development

S. A. Crawford
BE, MES, MIPENZ
Principal, Tonkin & Taylor Ltd, Auckland, N.Z.
P. J. Millar
ME (First Class), MIPENZ
Director, Tonkin & Taylor Ltd, Auckland, N.Z.

Summary The NZ Building Code requires a minimum Factor of Safety (FOS) of 1.5 for stability of permanent slopes in building developments. No further qualification is made on how to calculate this FOS, the accuracy of parameters or indeed if there are other more important requirements. NZ Territorial Land Authorities (Councils) vary in their interpretation of the applications of the Code. For example, many require the conservative approach of a FOS $\geq$ 1.5 under full saturation of slopes regardless of soil conditions, geometry and geohydrology. However, this FOS requirement is not mandatory and alternative solutions may be accepted by Territorial Land Authorities. The NZ Building Act allows for consents for difficult sites to be issued under Section 36(2) for land stability. There are also parts of the NZ Earthquake Commission (EQC) Act which need to be taken into account. Much time has been wasted discussing requirements for consent applications on an ad hoc basis. What is needed is a consistent approach to stability assessments, as agreed by Territorial Land Authorities and the geotechnical community.

1 INTRODUCTION

Much work has been done in recent decades to address slope stability issues in residential/land development (refs 1 to 7). However, only a few codes have been produced for earthworks (NZS4431) and urban subdivisional development (NZS4404). These codes have largely avoided the difficult task of producing detailed requirements for stability assessments in NZ. More recent legislation broadly outlines the requirements for stability assessments for subdivisional development (Resource Management Act (RMA) 1991) and building development on lots (Building Act 1991 and the NZ Building Code).

The NZ Consumer Guarantees Act allows unlimited liability for domestic projects (as opposed to commercial projects). Also, there have been recent increases in insurance premiums for consultancies with a history of geotechnical based P.I. claims. Courts of law in NZ rely on expert witness to advise them on "normally accepted geotechnical practice". The need for an industry benchmark is now more pressing for practising geotechnical specialists and approving authorities.

The principal issues to be resolved in stability assessments in NZ include:

- current legislation
- hazard and risk assessment
- investigation, geology, topography, groundwater
- FOS and soil strength parameters
- application to earthquake loadings & risk
- role of peer reviewers.

This paper briefly outlines the current issues and proposed changes for preparation of stability assessments and presents a draft guidelines checklist for the use of geotechnical practitioners and reviewers.

2 CURRENT LEGISLATION

The NZ Building Code was formulated to cover the requirements for buildings in NZ and is generally considered to be the means of applying the RMA and the Building Act. Minor amendments are proposed for the Building Code clauses (B1/VM4) relating to slope stability, which include a reference to a set of national guidelines for slope stability assessment. The NZ Geotechnical Society is currently developing these guidelines.

The general process of hazard identification and the stability assessment of land is outlined in Figure 1. In the event of a natural disaster (including landslip), the Earthquake Commission may cover investigation & remediation of damaged residential properties.

3 HAZARD ASSESSMENT

The use of hazard zoning by regional and district councils appears to vary widely throughout NZ. The RMA requires TLA's to maintain a hazard register, not necessarily in map form. Maps are, however, the most comprehensive and accessible way of recording past problems and likely future conflicts with development of land, as well as showing those areas not currently assessed.

Many authors have presented their views on the need, preparation and effects of hazards zone mapping and the application of Geographical Information Systems (GIS) in New Zealand (ref 6, 7, 9 & 10). An outline of the process of investigation, design and construction observation process is presented in Figure 2.

Reference to these District Hazard Maps is essential for the preparation and review of stability assessments. To this end, wider publication and distribution of the current hazard zone maps should be carried out. There is also a need for a simple national guide to standardise mapping legends, risk categories and allow for coordinated overlapping of grids and hazard zones at boundaries between TLA districts. It may be preferable to utilise the QMAP and GIS approach outlined by Isaac & Turnbull (1997) to allow open access to a national hazard mapping system. Access can be via the Internet.

The Geotechnical Society, EQC or some independent national body, could facilitate this by producing and maintaining lists of hazard maps and key maps to identify those regions in NZ which are covered.

4 GEOTECHNICAL RISK ASSESSMENT

Not all stability assessments need to include a numerical factor of safety . However, qualitative assessments are very dependent on the expertise of the assessor. In order to go some way to standardising assessment, it is recommended that a risk classification procedure be developed for NZ which also addresses the consequences of failure. This should be based on the recommendations (section 4.2) of the BRANZ (1987) document and the *Australian Geomechanics News* article (1985), ie. sites (or parts thereof) could be classified on a scale of "very low risk" to "very high risk". Risk categories are suggested in Table 1.

The higher levels of risk should require *numerical* slope analyses to be carried out as part of the assessment. The risk classification could be reduced if suitably designed remedial works were constructed.

The risk classification could be used by councils for supplementary purposes such as standardising hazard mapping classifications and ease of use for GIS. Other uses could be relating risk classification to:

- Minimum requirements for site investigation
- Geotechnical design for remedial works
- Degree of construction supervision
- Extent of post-construction maintenance

It would also allow prospective purchasers of hillside properties to assess the level of risk associated with a particular site and the need for ongoing routine maintenance of any slope remedial works (e.g. surface and/or subsurface drains).

5 SITE INVESTIGATIONS, GEOLOGY, TOPOGRAPHY & GROUNDWATER

The NZ Building Code (B1/VM4) outlines the topics which the site/lot specific assessment should address, including landform, geology, previous earthworks, site history, flooding, groundwater changes, etc (NZBC clause 2), but concludes that "... ground conditions should be investigated to the extent necessary ... (to) provide sufficient date for the design of the *building*".

The extent of investigation is a function of the complexity of the site, the perceived risk of instability, the hazard to property, assets and human life, and the scale of the development proposed. While it may be too expensive to carry out triaxial testing for the 'normal' house site investigation, for example some relatively inexpensive index tests could be carried out to allow correlation with other fundamental soil properties. On the other hand, for a subdivisional development both types of testing may be desirable. This is not only because of the scale involved (and the larger financial backing) but also to provide soil strength and property data for possible site specific

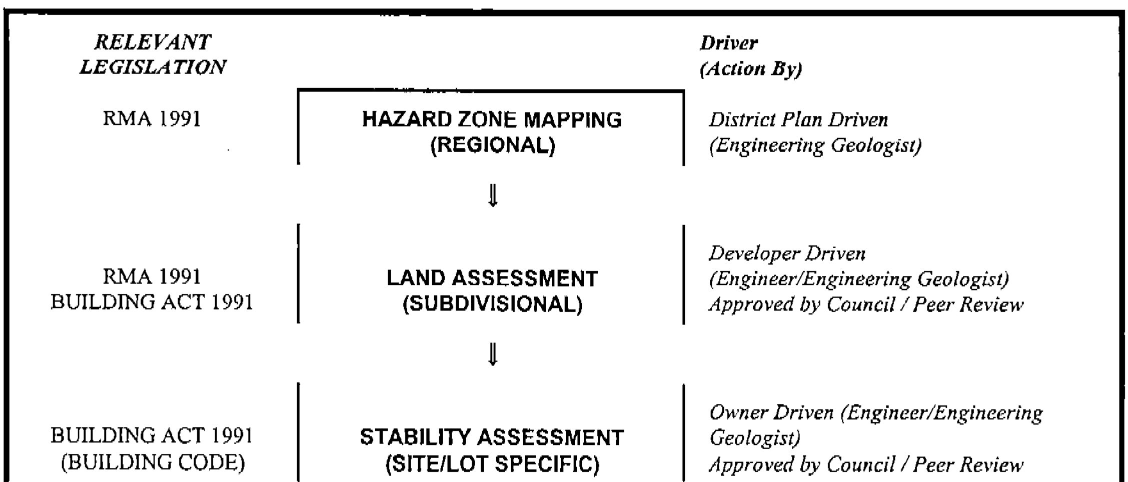

FIGURE 1: PROCESS OF LAND STABILITY ASSESSMENT

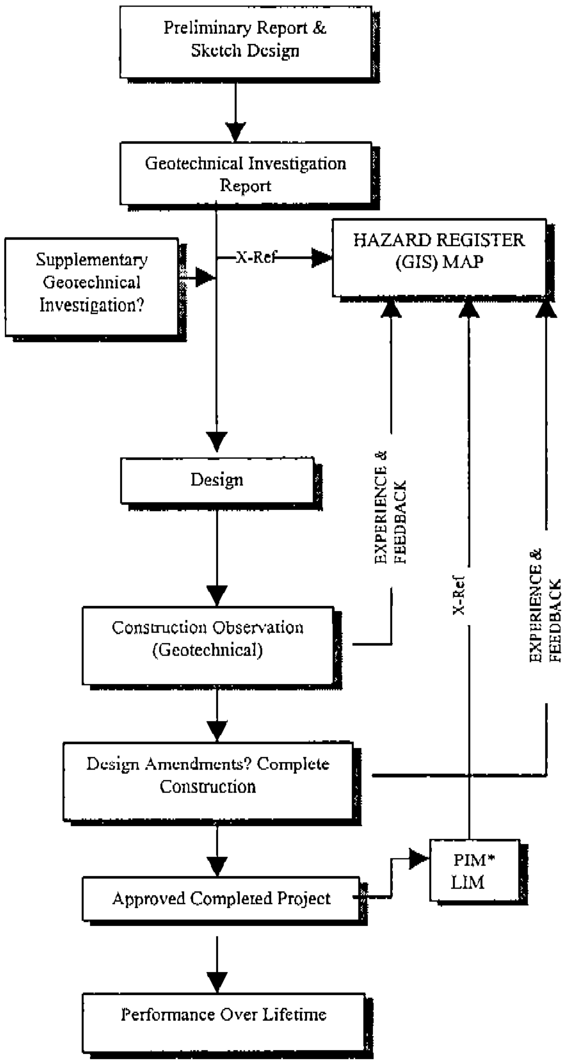

FIGURE 2: GEOTECHNICAL INVESTIGATION, DESIGN & OBSERVATION PROCESS

**PIM = Project Information Memorandum (eg building issues)*
LIM =Land Information Memorandum (eg land issues)

investigations on the subdivision.

While it is up to the geotechnical specialist to determine the methods of investigation to be used on a site, some guidance should be given to outline the options, particularly for non-specialists who may be reviewing the assessments or for the "civil engineer who dabbles in the geotechnical field." It may be appropriate that a staged investigation be carried out to more effectively target potential problem areas. Some guidance of the level of investigation with relation to risk classification is suggested in Table 1.

A *Checklist for Stability Assessments* has been compiled for the use of geotechnical practitioners and council reviewers alike. A number of NZ references which adequately deal with this issue (refs 2, 5).

It is noted that Australia has recently issued a standard for site investigations. The preparation of a similar (or joint ANZ) standard for NZ conditions could be undertaken to encourage uniformity and minimise poor investigations.

6 FACTOR OF SAFETY, SOIL PROPERTIES & GROUNDWATER

The generally accepted minimum factor of safety for slope stability for residential development in NZ has long been 1.5, although lower values are also regularly used for extreme conditions. What is needed, however, is some explanation of what design conditions should apply and what level of risk can be adopted (e.g. worst case groundwater conditions or soil strength parameters or a certain return period rainstorm or "average" soil strength conditions). Indeed, some would ask if a numerical analysis is valid at all. Large parts of NZ are geologically young and many steep slopes in NZ are close to equilibrium as a result of their formation, and consequently have factors of safety close to 1.0. However, as the NZ Building Code stipulates a minimum factor of safety of 1.5, many councils or TLA's feel as though they must comply for "safe" legal reasons. On the other hand, at least one council has stated in their engineering standards, "In most cases, it is unnecessary or impracticable to measure quantitatively the factor of safety against shear failure". Clearly, there is a wide variance of opinion.

The numerical analyses of slopes, particularly existing natural slopes, are very dependent on the selection of soil strength parameters and assumed groundwater levels. The measurement of such soil and water parameters is often very expensive, dependent on time and even weather. Often assumptions have to be made and there is the possibility of input data being manipulated to obtain the "appropriate" result for compliance purposes.

It is essential that an engineering geological assessment is carried out for the whole of the site, and extended area affecting the stability of any development. A decision can then be made on the need for numerical analyses. Selection of critical sections for such analyses can be made and a suitable geotechnical model formulated for analyses. This model should be referenced to drawings showing surface and subsurface site data. Unless this assessment of geology, soil properties and groundwater is carried out, the results of the numerical analyses are likely to be misleading

Until recently, a factor of safety of 1.5 was typically being required by many TLA's, for all sites under conditions of full saturation of the slope. In practice, full saturation may be unlikely to occur on some sites and/or under design life conditions. It is accepted that, if no detailed investigations have been undertaken, the

Table 1: RISK CLASSIFICATION FOR SITES SUBJECT TO INSTABILITY

(This table has been produced to provide a simplified classification which can be readily understood by a lay person and to provide a uniform code of terms for geotechnical professionals)

RISK	EVIDENCE/ TYPE OF INSTABILITY	CONSEQUENCES OF INSTABILITY	IMPLICATIONS FOR DEVELOPMENT	EXTENT OF INVESTIGATION
VERY HIGH	Evidence of active or historic instability - landslip or rock face failure; extensive instability may occur within site or beyond site boundaries.	High risk of loss of life. Catastrophic or extensive significant damage or economic loss.	Unsuitable for development unless major geotechnical work can satisfactorily improve stability. Risk after development may be higher than normally accepted (includes Section 36(2)).	Extensive geotechnical investigation required.
HIGH	Evidence of active creep ancient instability, potentially progressive/ regressive/minor slips or minor rock face instability; significant instability may occur during and after extreme climatic conditions and may extend beyond the site boundaries.	Low risk of loss of life. Significant damage or economic loss.	Development restrictions and/or geotechnical works required. Risk after development may be higher than normally accepted (may include Section 36(2)).	Engineering geological assessment, drilling investigation required.
MEDIUM	Evidence of possible soil creep or a steep soil covered slope; significant instability can be expected if the development does not have due regard for the site conditions.	Virtually nil risk of loss of life. Moderate damage and economic loss.	Development restrictions may be required. Engineering practices suitable to hillside construction necessary. Risk after development generally no higher than normally accepted.	Visual assessment. Hand and possible drill investigation methods.
LOW	No evidence of instability observed; instability not expected unless major site changes occur.	Minor damage, limited to site unless major development occurs.	Good engineering practices suitable for hillside construction required. Risk after development normally acceptable.	Visual assessment. Possible hand investigation methods.
VERY LOW	Typically shallow soil cover with flat to gently sloping topography.	Virtually nil.	Good engineering practices should be followed.	Visual assessment.

requirement for a factor of safety (FOS) exceeding 1.5 for full saturation is generally reasonable.* However, a less conservative approach can be adopted where full saturation is only likely to occur under extreme conditions and a good understanding of ground conditions is available from:

- Detailed engineering geological mapping and subsurface investigations
- Slope geometry being defined
- Defined drainage or geohydrological conditions
- Limited recharge and catchment areas
- Monitoring of groundwater levels
- Back analysis of existing failures
- Low incidence of instability in the area
- Soil properties being known within reasonable confidence limits, i.e. compared to typical parameters for local materials

This approach would encourage more detailed study of the critical factors involved, e.g. a reduced groundwater level can be determined for the design case from extrapolation of monitored seasonal levels, seepage analyses or observation of geological evidence such as weathering, staining, etc.

The designer is responsible for providing convincing evidence that a reduced groundwater condition can be used for the design condition (i.e. FOS $\geq$ 1.5). In such cases a check on the extreme cases of full saturation, or failure of any installed slope drainage measures, is also required to confirm that the FOS $\geq$ 1.2. Variation from these factor of safety guidelines is possible but should be based on an assessment of the level of economic risk and risk to life. Such variations should be subject to specific geotechnical peer review and approval.

7 EARTHQUAKE LOADINGS & RISK

Again the NZ Building Code does not specifically state the need for earthquake slope stability assessment. The NZ Loadings Code (NZS 4203) does, however, identify seismic zones and loading in the absence of site specific seismic assessments. This code identifies loadings for buildings for 450 year return periods, while it is normal practice to design earth structures for 150 year return periods. TLA's vary widely in their interpretations of earthquake requirements.

Proposed Earthquake Provisions

The design loadings for a numerical analysis of a slope

* *It is acknowledged that some subdivisions have been developed on large blocks of land with a stability FOS <1.5. Assessments of these subdivisions should be subject to geotechnical peer review. Approval of such developments should be subject to intensive investigation, geotechnical and seismic modelling, and ongoing monitoring. Consents should be issued under section 36(2) of the Building Act.*

affecting residences should be consistent with the zoning requirements of NZS 4203 and a 150 year return period. Section 4.11 of this code allows for a 0.25 structural performance factor for soil loads on structures rather than 0.67 for building loads. A 50 year return period should be applied for retaining structures located more than 8 m away from a dwelling.

For numerical analyses of the seismic slope stability, a FOS $\geq$ 1.2 should be adopted for the above return periods. It is suggested that potential slope failures which do not extend to within 8 m of a dwelling or cross a property boundary do not need to meet the above seismic slope stability requirements.

Application of the EQC Act (1993)

The Earthquake Commission Act provides insurance cover for land loss and landslip damage for natural disasters. The following comments are of particular relevance to TLA staff:

Landslip Issues

- Property that complies with the land cover provisions, has been subject to consent approval and has construction approved as complying with laws and bylaws, is likely to be covered.
- Unsatisfactory construction (including uncertified fill) undertaken by previous owners, which could not be reasonably known by the current owner, may be covered. Such work carried out by current owner is unlikely to be covered.
- The above do not preclude EQC seeking to recover from TLA's and previous owners if work has not been completed in accordance with accepted practices.
- Damage to property where the owner's agent(s) (builder, engineer, developer) or Council may be reasonably expected to identify a potential hazard may result in EQC seeking recovery.
- Where a property is in imminent danger from a natural disaster that has occurred, EQC may opt to undertake repairs prior to the loss occurring
- Property owners are responsible for mitigating against further damage following initial damage.
- Surface erosion is unlikely to be covered but destabilisation due to undercutting may be covered.
- Slope debris removal costs will only be covered for material within the zone of landslip cover or if it is causing a major risk of further landslip to insured property.
- If uninsured parties or other parties in the vicinity are contributing to a potential hazard (eg soak holes injecting surface stormwater into the groundwater system), EQC has no authority to mitigate these risks. Councils may need to be approached to effect mitigation under their powers provided by the Building Act.
- EQC do not cover betterment for retaining walls and land claims unless the property is in imminent danger. Upgrading to current standards of buildings is covered.
- Dwellings constructed under Clause 36(2) of the Building Act may have claims declined if the damage is caused by nature of the property rather than a specific event.

Stormwater Issues

The Act excludes erosion from the definition of natural slip but provides cover for natural disaster damage by a storm or flood to land only. Damage to residential buildings, from storm and flood, is covered by insurance companies.

Coastal & Riverbank Issues

Current interpretation of the Act by the Commission is that undercutting of cliffs and riverbanks which induces landslip damage to properties is generally covered. There are increasing concerns by EQC advisors that properties, which are inherently at high risk from this type of damage, should require consents authorities (TLA's) to consider the potential for a landslip claim, eg. if cliff top regression of up to 5 m is expected to occur within the design life of the dwelling, then a landslip claim may be expected to be made if the dwelling is located within 8 + 5 m of the edge. Currently, TLA's permit structures within this zone, exposing EQC to a high probability of claim.

Neighbours are responsible for the stability of adjoining properties where a cut is made in natural ground. There have been several instances when TLA's have obtained easements or legal ownership on coastal zones or riverbanks where ongoing erosion has resulted in them taking responsibility for the cost of protection works to mitigate against further erosion. This may have a future impact on potential recovery of costs by EQC.

8 ROLE OF PEER REVIEWERS

The results of the December *1994 NZ Geomechanics News* survey indicate a wide variation in when TLA engineers might expect to require a peer review by a geotechnical specialist. Some guidance on the role of a peer reviewer is given in the article in *NZ Geomechanics News* (Dec. 1995).

There was some common ground by all surveyed that peer review was dependant on the scale of development, the level of risk and the complexity of each site. These issues can be addressed in the assessment and related to Table 1: Risk Classification.

We suggest the use of peer review by TLA's as shown in Table 2. Liability issues for peer reviewers may need to be canvassed with their insurers.

TABLE 2: WHEN IS A PEER REVIEW REQUIRED?			
PROJECT SCALE	**RISK CLASSIFICATION***	**REQUIREMENT FOR REVIEW**	**NOTES**
Small Scale (Lot Specific)	VERY LOW TO LOW RISK	Review by non-specialist	1. Risk Classification to be determined by the geotechnical professional preparing the assessment and to be in accordance with NZ Geotechnical Society Guidelines. (Refer Table 1). 2. Any reviewer (peer or otherwise) should have a checklist of items to be addressed by the Stability Assessment, if only for his or her own professional use. A suggested checklist is appended to this paper
	MEDIUM RISK	Peer review preferred	
	HIGH TO VERY HIGH RISK	Peer review required	
Medium Scale (Small Subdivision, 2 to 20 lots)	VERY LOW TO LOW RISK	Review by non-specialist	
	MEDIUM TO VERY HIGH RISK	Peer review required	
Large Scale (Subdivision, > 20 lots)	VERY LOW TO LOW RISK	Peer review optional	
	MEDIUM TO VERY HIGH RISK	Peer review required	

9 CONCLUSIONS/RECOMMENDATIONS

- The current NZ Building Code (B1/VM4) does not adequately address issues of slope stability and geotechnical investigation. It is proposed that minor modifications to this Code be made including a reference to a new set of guidelines on assessment of slope stability.
- District hazard registers are required of each TLA by the RMA. However, standardisation and coordination of District Hazard Maps is required to produce a nationwide register.
- There is an inconsistent approach to the use of peer review for approving stability assessments.
- The draft *Checklist for Stability Assessments* be adopted for normal practice by TLA approvers and geotechnical practitioners throughout NZ.
- A set of national guidelines for stability assessments be prepared by the NZ Geotechnical Society.
- The use of a risk/consequences classification be adopted for NZ, firstly for hazard mapping and secondly as one of the conclusions reached in a stability assessment. A suggested format is presented in Table 1.
- The nominated FOS (against instability) be adopted for defined soil strength, groundwater and earthquake conditions, i.e. FOS $\geq$ 1.5 for design conditions and a FOS $\geq$ 1.2 for extreme conditions.
- The use of geotechnical peer review by TLA's be carried out as suggested in Table 2.

10 ACKNOWLEDGEMENT

This research project was funded by EQC. Their support for this work is gratefully acknowledged.

11 REFERENCES

1 *Stability of Slopes in Natural Ground,* NZ Geomechanics Society Symposium, (1974).

2 Taylor, D.K., Hawley, J.G., Riddolls, B.W., *Slope Stability in Urban Development,* NZ Geomech. Soc./DSIR Series No. 122 (1977).

3 *Stability of House Sites & Foundations,* Advice to Prospective House Owners, NZ Geomechanics Society/EQ&WDC (1980).

4 *Geomechanics in Urban Planning,* NZ Geomechanics Society Symposium, (1987).

5 *Assessment of Slope Stability at Building Sites,* Worley Consult. & BRANZ Study SR4 (1987).

6 *Geotechnical Issues in Land Development,* NZ Geomech. Symposium, Hamilton (1996).

7 Bell, D.H., Crawford, S.A., Farquhar, G.B., Grocott, G.G., Draft Geotechnical Guidelines for Residential Land Development (1997).

8 Milne, J., The Legal & Planning Framework – RMA & Building Act 1991, Ref 6 (1996).

9 Taylor, D.K., Geotechnical Issues in Land Development, Ref 6 (1996).

10 Isaac, M.J. & Turnbull, I.M., Geological Mapping into the 21st Century-QMAP and GIS, *NZ Geomechanics News* (Dec. 1997).

11 Cook, D., Pickens, G.A., MacDonald, G., "The Role of Peer Review", Report by S.A. Crawford *NZ Geomechanics News* (Dec 1995).

12 Crawford, S.A. & Millar, P.J., "The Design of Permanent Slopes for Residential Buiding Development", EQC Research Project 95/183, *NZ Geomechanics News* (June 1998).

13 Farquhar, G.B. & Crawford, S.A., "Stability Assessments Questionnaire Results, *NZ Geomechanics News* (Dec 1994).

14 Walker, Dale, Fell, Jeffery, Leventhal, McMahon, Mostyn, Phillps, "Geotechnical Risk Associated with Hillside Development", *Australian Geomechanics News, No. 10* (1985).

CHECKLIST FOR STABILITY ASSESSMENTS

FACTUAL INFORMATION

1 INTRODUCTION
- ☐ Report prepared for who?
- ☐ Site Location
- ☐ Outline of proposed development(b)
- ☐ Comment on need for earthquake assessment

2. TOPOGRAPHY
- ☐ Outline current landform (slope shape, height gradient, irregularities, erosion, soil creep/terracettes)
- ☐ Outline surface drainage patterns(b)
- ☐ Review aerial photos
- ☐ Comment on any previous earthworks
- ☐ Comment on any existing instability(c)
- ☐ Additional site features (e.g. vegetation/trees structures(b) retaining walls, roads/driveways, services)

3. SITE HISTORY
- ☐ Outline current/previous landuse
- ☐ Comment on previous siteworks(b)
- ☐ Reference "District Hazard Map"/GIS
- ☐ Comment on previous instability(c)
- ☐ Performance of existing structures
- ☐ Review aerial photos
- ☐ Comment on previous contamination(c)

4. GEOLOGY
- ☐ Describe geological setting
- ☐ Refer to relevant maps
- ☐ Geological influences on stability (e.g. bedding, weak materials, faults)
- ☐ Describe seismic setting

5. INVESTIGATIONS

◆ FIELD
- ☐ Inspection by geotechnical specialist
- ☐ Descriptions of soils/rock in borelogs (Ref.1)
- ☐ Outcrop/cutting descriptions(c)
- ☐ Record Extent of any cracking(c)
- ☐ Other field tests (e.g. CPT, etc.)
- ☐ Monitoring of ground movements(c)
- ☐ Groundwater measurements and observations (seepage, subsurface erosion)(c)

◆ LABORATORY
- ☐ Outline tests undertaken
- ☐ Summarise results
- ☐ Previous testing in local area

6. SUBSURFACE CONDITIONS
- ☐ Geological interpretation(c)
- ☐ Summarise subsoil conditions, e.g. extent of fill(c) topsoil, nature and distribution of soils/rock
- ☐ Describe soil strengths/density, likely behaviour - refer to tests and logs
- ☐ Highlight weak/sensitive/loose soils or rock defects
- ☐ Describe groundwater conditions, subsurface drainage, expected seasonal fluctuation

APPENDICES
- ☐ Borelogs, Testpit Logs, Logs of Exposures (Ref.1)
- ☐ Laboratory Results
- ☐ Specifications for Remedial Works/Fills
- ☐ Site Photos

INTERPRETATION/DISCUSSION

7. SLOPE STABILITY (Ref. 2,3,4)

◆ ENGINEERING GEOLOGICAL ASSESSMENT:
- ☐ Discuss site features
- ☐ Discuss geological setting/influences(e)
- ☐ Influence of rainfall/groundwater
- ☐ Reasons for landform (local, regional)
- ☐ Likely slope failure mechanisms
- ☐ Potential for instability
- ☐ Effects of the development on slopes(f)
- ☐ Consequence of instability
- ☐ Empirical assessment (qualitative)
- ☐ Risk rating applied(g)
- ☐ State whether stability analyses are required

◆ GEOTECHNICAL ENGINEERING ANALYSES
- ☐ Geotechnical slope model correct?
- ☐ Analytical method stated
- ☐ Determination of critical section of slope
- ☐ Assessment of strength parameters
- ☐ Assessment of groundwater profile/rainfall
- ☐ Back analysis of any existing failures
- ☐ External loads due to the development
- ☐ State need for seismic analysis
- ☐ Normal FOS requirements:
  - Static (Design gwt) FOS ≥ 1.5
  - Static (Extreme gwt) FOS ≥ 1.2
  - Seismic (150 year EQ) FOS ≥ 1.2
- ☐ Sensitive analyses for parameters required?
- ☐ Results and comments

8. GEOTECHNICAL EFFECTS OF DEVELOPMENT
- ☐ Slope stability risk increased or reduced?
- ☐ Is the development feasible?
- ☐ Need to drain slopes (surface/subsurface)?
- ☐ Need to remove/upgrade fill?
- ☐ Subsurface drainage beneath fills?
- ☐ Need to retain slopes/secure rock faces?
- ☐ Foundation conditions/requirements
- ☐ Effect of stormwater/effluent disposal
- ☐ Effect of service lines rupture (e.g. SW, sewer)
- ☐ Effect of river/coastal erosion
- ☐ Seismic effects on development and slope
- ☐ Maintenance requirements for life of the development

9. CONCLUSIONS AND RECOMMENDATIONS

10. STATEMENT

Statement by geotechnical assessor as to their ability & qualifications to prepare this geotechnical assessment

DRAWINGS/FIGURES
- ☐ Site Plan(d): ☐ Borehole/Testpit Locations
  - ☐ Outline of Proposed Development

Site Engineering Geological Maps(d)
- ☐ Site Contours Maps(d) } Cuts and fills
- ☐ Cross Sections } indicated
- ☐ Geotechnical Model
- ☐ Stability Analyses Results

REFERENCES

1. Guidelines for the Description of Soils & Rock, NZ Geomechanics Society (1985)
2. Assessment of Slope Stability at Building Sites, BRANZ Study SR4, (1987)
3. Slope Stability in Urban Development, DSIR Series 122 (1981)
4. Stability of House Sites & Foundations, Earthquake & War Damages Commission, NZ Geomechanics Society (1980)
5. Land Assessment for Development Suitability, Burns & Farquhar, NZ Geotechnical Symposium (1996)

NOTES

(a) This checklist is intended as a guide for typical stability investigation & assessments for residential developments. There may be additional requirements for specifically difficult sites, large scale developments and regional hazards
(b) Indicate on site plan
(c) Indicate on site engineering geological map
(d) These plans/maps are best combined if possible
(e) Ref.3 provides a valuable outline of stability problems peculiar to selected areas of NZ
(f) Refer BRANZ document Fig 3 (ref.2 above), Stability House Sites and Foundations (ref. 4 above)
(g) See Table 1, Design of Permanent Slopes for Residential Development, Crawford & Millar (1999)