- Persons in vehicles are less vulnerable than those in the open. Their vulnerability depends on the volume and velocity of the landslide. Experience in Hong Kong (Finlay *et al.,* 1999) indicates that rapid landslides of only a few hundred cubic metres are likely to result in death of the occupants of the vehicle.

It should be noted that whether a person will evacuate from the path of the landslide is covered in temporal spatial probability, not in vulnerability.

C7 RISK ESTIMATION

Standards Australia (2004) HB436:2004 discusses the types of risk analysis which may be summarized as:

- *Qualitative analysis*: "uses words to describe the magnitude of potential consequences and the likelihood that those consequences will occur. These scales can be adapted or adjusted to suit the circumstances, and different descriptions may be used for different risks"
- *Semi-quantitative analysis*: "qualitative scales, such as those described above are given values. The objective is to produce a more expanded ranking scale than is usually achieved in qualitative analysis, not to suggest realistic values for risk such as is attempted in quantitative analysis."
- *Quantitative analysis*: "uses numerical values (rather than descriptive scales used in qualitative and semi-quantitative analysis) for both consequences and likelihood using data from a variety of sources. The quality of the analysis depends on the accuracy and completeness of the numerical values and the validity of the models used."

Appendix G of AGS (2000) presented an example of qualitative terminology and risk matrix that was considered to be suitable for use in landslide risk assessment for property. AGS (2000) recognized that alternative schemes may be used, provided they are defined. As previously noted, AGS (2000) has now been superseded by the Practice Note.

C7.1 QUANTITATIVE RISK ESTIMATION

Reference should be made to Lee and Jones (2004) for a number of examples of risk calculations for a variety of scenarios. Some examples are also given in Roberds (2005) and other invited papers in the same volume. Such examples may be useful for deriving an appropriate model to enable suitable risk estimates.

C7.2 SEMI-QUANTITATIVE AND QUALITATIVE RISK ESTIMATION FOR RISK TO PROPERTY

In the context of risk assessments for residential development with submission to a regulator, adoption of a common preferred qualitative terminology should be mandatory as stipulated in the regulator's policy. If the practitioner considers an alternative scheme to be preferable for a particular hazard/situation, then adoption of this alternative must be justified by detailed documentation of the reasons.

There is considerable benefit to the regulator and the practitioner to use a common terminology. Comparison between different sites and between different practitioners is facilitated. Whilst there may be an inherent difference in assessment between practitioners (for example as shown by Baynes *et al.*, 2002), adoption of a common terminology will facilitate understanding and calibration between practitioners. Use of a scheme developed for a specific site or case makes cross comparisons difficult or confusing.

Although the Practice Note Appendix C scheme uses qualitative terminology to communicate and/or summarise the assessment of risk to property, it is in essence a quantitative scheme since it relies on the best estimates of the likelihood and consequence for the analysis. Risk to life should only be considered quantitatively and the adoption of semi-quantitative methods is considered to be inappropriate.

C7.3 RISK MATRIX FOR PROPERTY LOSS

The preferred Risk Matrix for Property presented in the Practice Note Appendix C has been derived primarily for residential development. It may also be appropriate to apply the scheme to other development,or situations/consequences. If the scheme is modified, or an alternative adopted, then full discussion of the justification and basis for the alternative scheme should be given.

A number of alternative qualitative scales for Likelihood, Consequences and resulting risk matrices and assigned risk levels were examined before deriving the final scheme in the Practice Note. Further discussion is given in Appendix CC of the considerations involved.

The main considerations were:

- The use of the annualised cost of damage to help allocate the risk categories.

- The risk values have been skewed down in favour of consequence (as discussed by de Ambrosis and Mostyn 2004) for the lower value consequences. It is judged that higher consequences are more readily accepted or tolerated at the lower likelihood values.
- Cell A5 (Almost Certain / Insignificant) has been subdivided in recognition of the practicality of hazards that result in very low value consequences and are readily accepted by most owners.
- The recommendation to the regulator that MODERATE risk is tolerable and that LOW (and Very Low) Risk is acceptable for Importance Level 2 and 3 structures (Appendix A, Practice Note) based on the assessment of implied cost impact of damage on most home owners and the fact that most home owners will be risk averse in the light of lack of insurance availability. If insurance was available then an annualised dollar value equivalent to an insurance policy cost would be a reasonable and rational benchmark for acceptability. (Refer to Section C8.2b below).

Alternative qualitative schemas for measures of likelihood and/or consequences may be used but the onus is on the practitioner to fully document the methodology and definitions for the terminology adopted. The documentation should include an explanation as to why the AGS preferred scheme is not appropriate. To avoid confusion, different descriptor terms (words) should be used wherever possible. In addition, the components of any alternative system must be compatible and form a consistent and logical process to allow LRM. It is considered likely that the piecemeal substitution of only one element of the preferred AGS terminology is unlikely to produce a consistent system.

C7.4 ESTIMATION OF RISK OF LOSS OF LIFE

It is widely accepted that Risk to life can only be evaluated quantitatively and this enables direct comparison with tolerable risk criteria. For this reason, AGS (2000, 2002) required life loss risk to be estimated quantitatively as does the Practice Note. Refer also to discussion in Lee and Jones (2004) and Leroi *et al*. (2005).

De Ambrosis and Mostyn (2004) have proposed some qualitative terms for risk to life. This proposal has not been adopted by the Working Group because their table can only be realistically used from right to left. That is, the assessor has to evaluate the conditional probabilities of vulnerability, non-evacuation, temporal probability and spatial probability in order to determine the required value of "Indicative Vulnerability". Since the conditional probabilities are required anyway, it makes more sense to continue to use them for evaluation of the risk to life quantitatively, using the assessed best guess likelihood value applicable to the hazard.

C8 RISK ASSESSMENT

C8.1 RISK EVALUATION

The final step in the Risk Assessment is the Risk Evaluation. The Practitioner has to relate the estimated risks to the risk tolerability criteria and then, if required, determine the appropriate and necessary risk mitigation options to reduce risks to within tolerable limits. The owner and regulator have to decide if risks are tolerable, though pragmatically the ultimate decision resides with the regulator.

If the risk cannot be reliably reduced by mitigation measures to satisfy the tolerable risk criteria, then either the development should not occur or the scope of the development should be modified accordingly.

Individual risk will usually be the governing consideration for most residential developments and should relate to the "individual most at risk". The risk from all landslide hazards which may affect that person should be considered and summed to give the individual risk and this should satisfy the tolerable risk criteria.

In cases where occupancies are likely to include many individuals (such as for schools, hospitals, shopping centres, boarding houses, motels, clubs etc, i.e. Importance Level 3 and Importance Level 4 structures) rather than a family unit in a single residential dwelling, Societal Risk should also be considered. For a family unit in a residential dwelling it is considered to be impractical to consider societal risk for every case and the risk assessment outcome is unlikely to be significantly different.

The example in Appendix CB demonstrates how Societal Risk can be evaluated. More details are given in ANCOLD (2003) and Leroi *et al.* (2005).

Additional considerations by the owner and regulator for determination of whether risks are tolerable may include political issues, social and community considerations, business confidence, environmental impacts and post-disaster uses.