Information Note 17/2025 **August 2025**

Landslide Risk Management and the Role of Quantitative Risk Assessment Techniques

Key Message: **The Geotechnical Engineering Office (GEO) was among the first in the world to apply Quantitative Risk Assessment (QRA) techniques to manage landslide risk as well as to measure the performance of its Hong Kong Slope Safety System. QRA can be a useful tool to address issues that could not be tackled effectively by conventional engineering assessments.**

Introduction

This Information Note explains the concept of landslide risk management in Hong Kong, the application of quantitative risk assessment (QRA) techniques to landslide risk management, and the framework used for evaluating whether the estimated risk levels are tolerable.

What is Risk Management?

Risk management comprises an estimation of the risk, deciding whether or not it is tolerable to the public, and exercising appropriate control measures to reduce the risk where the risk level cannot be tolerated. To choose between risk mitigation measures, it is necessary to weigh costs against benefit in the broad sense.

Landslide risk at a slope is a measure of the chance of a landslide at that slope causing a certain amount of harm within a given time period. For practical purposes, risk may be taken as the product of the probability of an adverse event occurring (e.g. 1 in 10,000 chance of occurrence per year) and the probability of the consequence of a certain severity being realised (e.g. that people will be harmed).

In evaluating the cost-benefit of investment in the Hong Kong's Slope Safety System, it would be desirable to have a rational means of quantifying landslide risk and measuring the performance of the system. QRA is a very useful tool to provide information to achieve these aims. For this reason the Geotechnical Engineering Office (GEO) has been researching the application of QRA since 1993.

Use of QRA for Estimating Risk

QRA is a method of quantifying the order of risk through a systematic examination of the factors contributing to the landslide hazard and affecting the severity of consequence, and establishing probabilities for the individual factors.

In simple terms, the following questions are addressed in a QRA of landslides or slope failures :

(i) What can cause harm? ➔ identify the landslide hazards
(ii) How often? ➔ assess the frequency of failure occurrence
(iii) What can go wrong? ➔ identify the consequence of failure

(iv) How bad? ➔ assess the severity of failure consequence
(v) Is the risk acceptable? ➔ quantify the landslide risk and evaluate its acceptability
(vi) What should be done? ➔ formulate the landslide risk management strategy

The outcome of a QRA is an estimate of the probability of occurrence of different types of adverse consequences, such as the death of individuals (i.e. individual risk), multiple deaths (i.e. societal risk), and damage to property or closure of a major road for a certain period of time (i.e. economic risk). QRA can provide a framework for assessing the cost-effectiveness of risk mitigation options, formulating risk management strategies and facilitating decision-making on resource allocation to reduce risks posed by different types of landslide hazard.

The QRA technique was developed, and is now used worldwide, to estimate risks from industrial plants, such as petro-chemical, etc. Certain types of chemical plants are designated as Potentially Hazardous Installations (PHIs) in Hong Kong and risk estimation using QRA is well established. Guidance on land use planning in the vicinity of PHIs is given in the Hong Kong Planning Standards and Guidelines. Risk management is also practised by major corporations in Hong Kong, including the Hong Kong & China Gas Co. Ltd., MTR Co. Ltd. and China Light & Power Co. Ltd. The GEO has pioneered the application of QRA concepts for the quantification of landslide risk. Such an application is still being developed.

The input to a landslide QRA consists of compiling historical failure statistics, experience and knowledge of the different landslide processes and their consequences, and expert judgement. It is necessary for a QRA to properly allow for the uncertainties associated with the factors which trigger landslides and affect the mobility of landslide debris as well as those factors which lead to different scales of consequence. In view of this, sensitivity analyses are often carried out to evaluate the uncertainties associated with QRA results.

Establishing Tolerable Risk Levels

Risk tolerability criteria are integral parts of risk management because they serve as yardsticks for deciding whether the estimated risk is excessive or can be tolerated. The risk criteria framework adopted by many overseas countries, e.g. the Health and Safety Executive in the United Kingdom, consists of the following three regions :

(i) unacceptable region,

(ii) "as low as reasonably practicable" (ALARP) region, and

(iii) broadly acceptable region (where the risk is, or has been made, so small that no further precaution is necessary).

The legal interpretation of ALARP is well established in English case law in that the “sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble)” is not grossly disproportionate to the benefit obtained. The ALARP principle was also adopted in the UK Health and Safety at Work Act (1974).

Where the risk is estimated by the QRA technique to fall within the ALARP region, a

cost-benefit analysis of the various practicable risk mitigation measures should be carried out. The purpose of such an analysis is to show whether the benefits of a risk mitigation measure outweigh its costs in order to facilitate the assessment of whether it will be appropriate to implement it. In practice, cost-benefit consideration alone cannot be expected to provide a definitive decision, because factors other than risk and cost may be relevant (e.g. community needs, expectations and preferences, etc.) but it provides a useful yardstick.

The Hong Kong Planning Standards and Guidelines give criteria on acceptable and unacceptable risk for PHIs. National standards have been produced in some countries, such as the United Kingdom, Australia, New Zealand and Canada, to provide general guidance on risk management and risk analysis. However, there is as yet no international or national standard specifically for landslide risk assessment. Establishing appropriate risk criteria is by no means a scientific matter alone; in practice, this involves socio-political considerations. Nevertheless, the interim societal risk criteria for natural terrain landslide hazards recommended by the GEO are shown in Figure 1. Two options are available. They serve as a basis for the evaluation of QRA results. It is intended to finalise the risk guidelines when sufficient experience has accrued after a period of trial use.

Application of QRA in Hong Kong

QRA has been applied to global and site-specific landslide studies in Hong Kong. Global QRA was used to assess the risk due to different landslide hazards posed to the community to define the relative contribution of different components to the total landslide risk. This provides a useful and valuable reference for landslide risk management, in particular, in the consideration of resources allocation and policy-making. The GEO was among the first in the world to apply QRA techniques to manage landslide risk as well as to evaluate the performance of the Government's effort in reducing landslide risk.

Site-specific QRA on the other hand is aimed at assessing landslide risk at a given site. It was applied to problems that may not be directly amenable to conventional slope stability analysis, or where a failure is liable to result in serious consequences. It was also used to develop cost-effective mitigation strategy for landslide and boulder fall hazards from natural hillsides at specific sites. Nevertheless, scenarios for which site-specific QRA may prove to be a useful tool have to be judged on a case-by-case basis.

Some references of QRA and its application to landslide risk management in Hong Kong can be found in the Hong Kong Slope Safety Website (https://hkss.cedd.gov.hk/hkss/en/publications-and-resources/publications/list-of-technical-papers/index.html).

Geotechnical Engineering Office
Civil Engineering and Development Department
August 2025

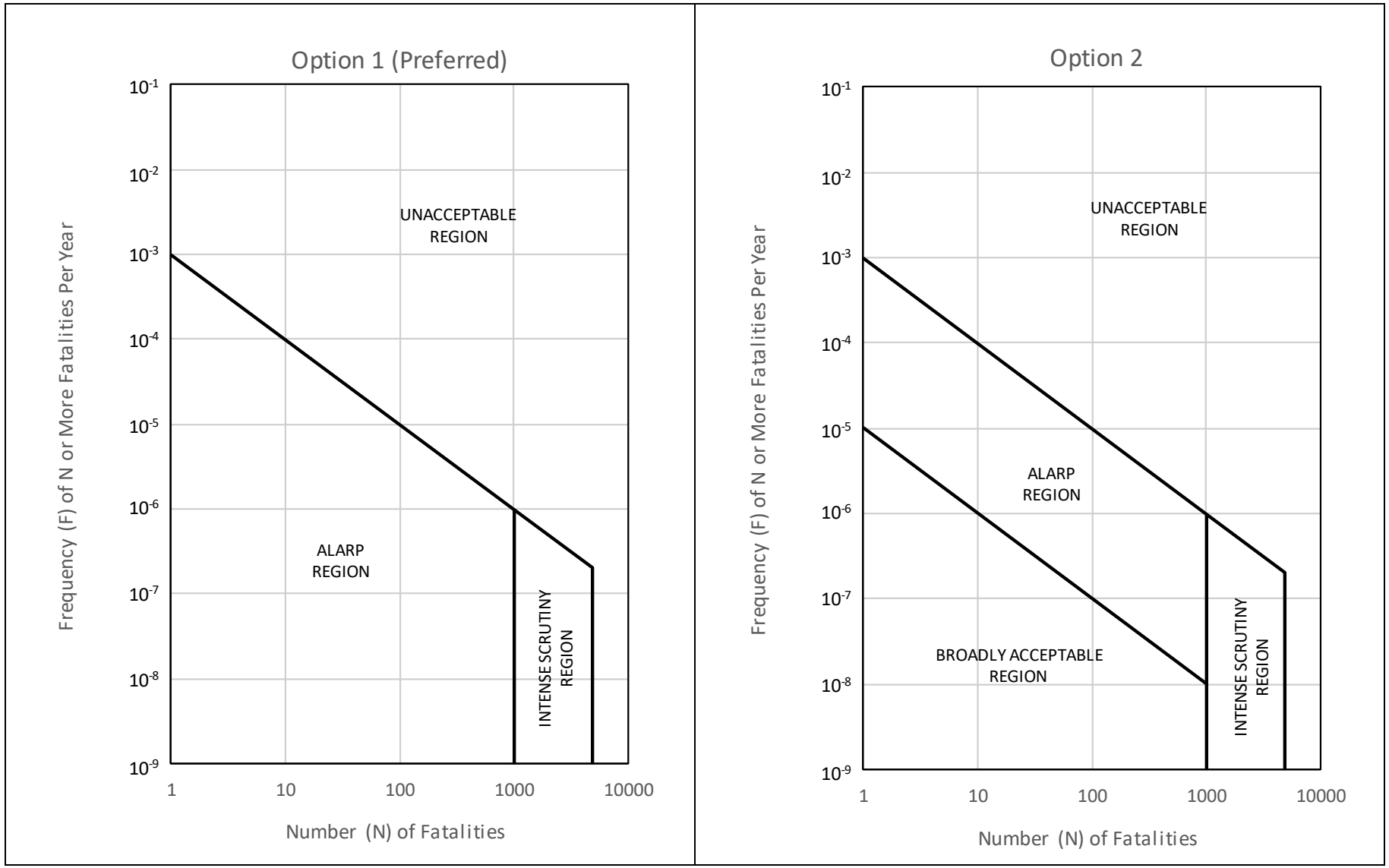

Figure 1 - The Recommended Interim Societal Risk Criteria for Landslides and Boulder Falls from Natural Terrain