The Landslip Preventive Measures (LPM) Programme in the Geotechnical Engineering Office, Civil Engineering Department

Background

Prior to the setting up of the Geotechnical Control Office (renamed Geotechnical Engineering Office (GEO) in 1991) in 1977, there was very limited geotechnical control of slope formation in both the private and public sectors. The stability of many old man-made slopes is therefore in doubt.

Since 1976, the Government has embarked on a long-term programme, known as the Landslip Preventive Measures (LPM) Programme, to deal with substandard government and private man-made slopes. Under the LPM Programme, batches of man-made slopes formed before the establishment of GEO (referred to as 'old slopes') are selected for study in a priority order in accordance with a risk-based ranking system. This system takes account of the relative landslide risk posed to the community (i.e. the relative likelihood of fatalities caused by slope failures).

Acceleration of the LPM Programme

Since the late 1970's, about $4.4 billion has been spent on studies and upgrading works on old slopes under the LPM Programme.

In 1991, streamlined procedures were introduced to boost the output of slope studies. A programme was commenced in 1992 to use private sector resources again to improve the progress of the LPM Programme.

As part of the implementation of the recommendations of the Slope Safety Review Report issued by the Works Bureau and endorsed by the Legislative Council in 1995, the GEO received increased resources to further accelerate the LPM Programme. On 1 April 1995, the GEO launched the 5-year Accelerated LPM Project to upgrade about 900 Government slopes and to carry out safety-screening studies on about 1,500 private slopes. This project primarily dealt with the high-priority slopes registered in the original Slope Catalogue, which was compiled in 1977-78. By the year 2000, about 3,500 high-priority slopes had been dealt with under the LPM Programme. Based on quantitative risk assessment, it is estimated that the overall landslide risk posed to the community by old man-made slopes has been reduced by about 50% compared with the risk level in 1977.

As part of Government's long-term strategy to improve slope safety in Hong Kong, the 10-year Extended LPM Project was launched in 2000 on completion of the 5-year Accelerated LPM Project. This 10-year Extended LPM Project deals with old man-made slopes in the New Catalogue of Slopes which was compiled between 1994 and 1998. There are about 54,000 sizeable man-made slopes in Hong Kong registered in the current Government's Slope Catalogue, comprising :

(a) about 17,000 post-1977 slopes which have been designed and constructed to the required safety standards introduced since that time, and

(b) about 37,000 pre-1977 slopes, many of which do not meet the current safety standards.

In terms of ownership, there are about 37,000 government slopes and about 17,000 private slopes. The 10-year Extended LPM Project will further boost the level of LPM output in terms of upgrading of old slopes affecting developments and major roads.

The target annual output under the 10-year Extended LPM Project is to upgrade 250 substandard Government slopes and carry out safety-screening studies on 300 private slopes. This amounts to about five times the output before the commencement of the 5-year Accelerated LPM Project in 1995. It is also some 40% higher than that under the 5-year Accelerated LPM Project in terms of the number of Government slopes to be upgraded annually (see Figure 1). The annual expenditure on slope studies and upgrading works under the LPM Programme has reached a historic high of about $900 million (December 2000 prices) in the last two years (see Figure 2). Consultants are being employed in addition to deployment of in-house staff resources to undertake the 10-year Extended LPM Project. When the Project is completed in 2010, the overall landslide risk posed to the community by the old man-made slopes (excluding squatters) will have been further reduced to an estimated 25% of that prevailing in 1977 due to the outcome of LPM action alone. Other measures, such as slope upgrading works under development projects and preventive maintenance works, will further reduce the landslide risk in Hong Kong.

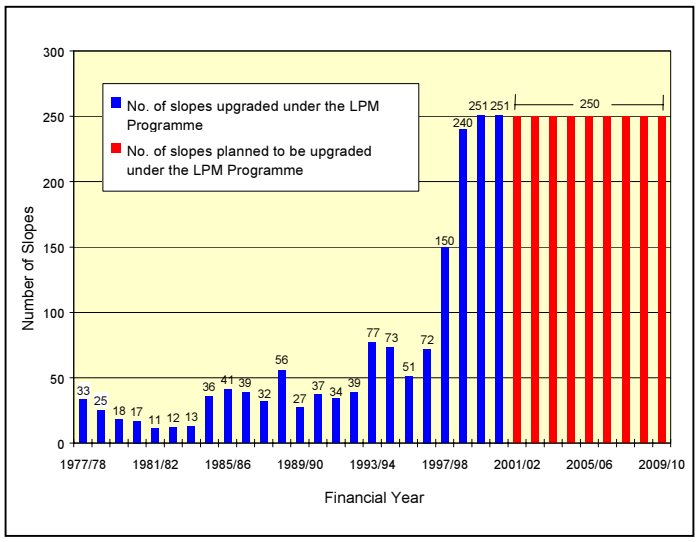

Figure 1 - Number of government slopes upgraded/ planned to be upgraded under the LPM Programme

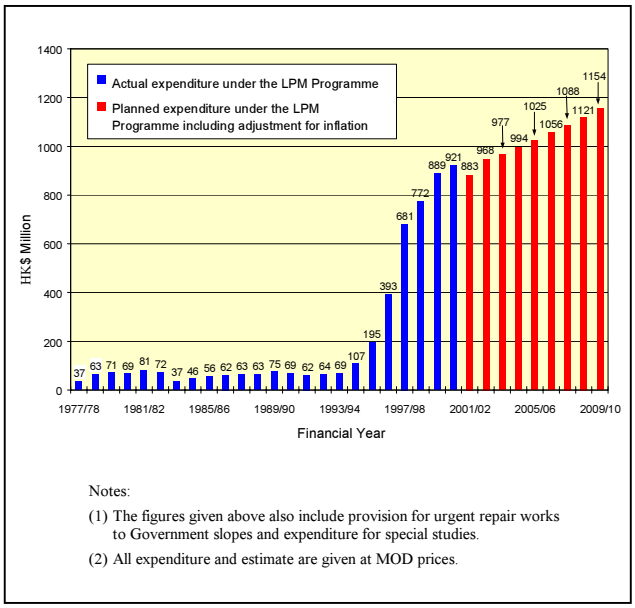

Figure 2 - Past and projected annual LPM expenditure

Selection of Slopes for Inclusion in the LPM Programme

The process of identifying the most deserving government and private slopes for detailed studies and/or upgrading works under the LPM Programme is known as 'LPM selection'. The effectiveness and efficiency of the selection process have a significant impact on the productivity and outcome of the LPM Programme in terms of maximising risk reduction in the shortest time possible. In order to cope with the increased output of the LPM Programme, the public's high expectation of slope safety, together with traffic and environmental constraints imposed on LPM works, a Business Process Re-engineering (BPR) project on LPM selection was undertaken by an in-house team of the GEO in 1999. The BPR project brought about drastic improvement in performance through a fundamental re-design of the process. Key changes made to the LPM selection process following the BPR Project included the development of an improved combined risk-based ranking system for selection of slopes, fast-tracking of the letting of consultancies, enhancement of management and updating of slope data, integrated action through the 'lot-by-lot' approach for private slopes and 'local area' approach on a geographical

basis for Government slopes, etc.

Slopes selected for action under the LPM Programme are referred to an inter-departmental committee, namely the Landslip Preventive Measures Committee (LPMC), for endorsement.

Dangerous Hillside Orders

Where prima facie evidence is established by a safety-screening study that a private slope is dangerous or liable to become dangerous, a statutory DH Order is served by the Buildings Department on the owners of the slope on the recommendation of the GEO. The Order requires the owners to arrange to carry out investigation and the necessary upgrading works to the slope. A DH Order may also be issued following a slope failure, or as a result of other stability concerns (e.g. observation of significant signs of distress) brought to the attention of the GEO. The substantial increase in the number of safety-screening studies carried out over the years is shown in Figure 3.

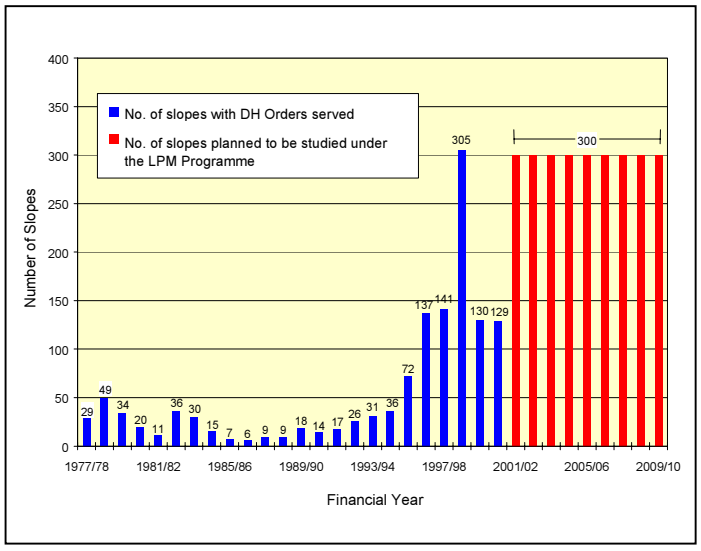

Figure 3 - DH Orders served by Buildings Department and planned safety-screening studies on private slopes under the LPM Programme

Upgrading Works to Government Slopes

Government slopes found to be below the required safety standards are recommended for upgrading works. These generally comprise large-scale engineering works to rectify the substandard slopes. The upgrading process involves careful assessment of the geological and groundwater conditions, likely modes of failure, detailed design and construction. Where appropriate, slope upgrading works may comprise prescriptive measures without the need for detailed ground investigations, laboratory testing and stability analyses.

For soil cut slopes, the commonly-adopted upgrading technique involves the use of soil nails. Construction of soil nails typically involves inserting a 25 mm or 32 mm diameter galvanised steel reinforcement bar into a 100 mm diameter drillhole formed to the designed length, followed by grouting up of the drillhole (see Figure 4). Raking drains may also be installed to control the build-up of groundwater pressure.

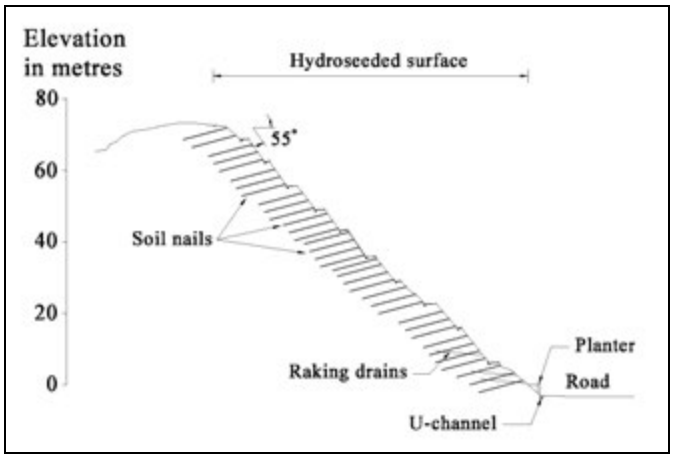

Figure 4 - Typical upgrading works for a soil cut slope

Other techniques used to stabilise soil cut slopes are cutting back to a shallower angle and supporting the slope with a retaining wall.

For loose fill slopes, the commonly-adopted upgrading technique involves recompaction of the top 3 m of fill to a dense state (see Figure 5).

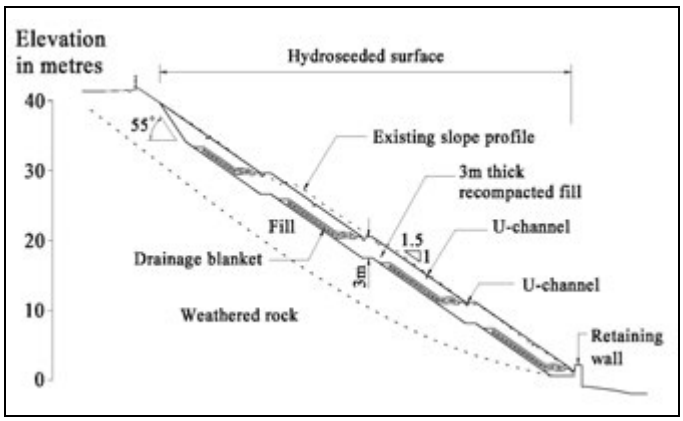

Figure 5 - Typical upgrading works for a fill slope

Since the necessary slope upgrading works are often close to buildings or busy roads, there are typically considerable constraints associated with tight working space, difficult access, the need for temporary closure of carriageways and/or footpaths, the need to minimise disturbance due to noise, dust, etc., safety of personnel working on steep slopes, concurrent active working sites that are scattered over different locations, etc.

Construction Site Safety

Site safety is particularly important in the course of LPM works on steeply-sloping ground to rectify potentially unstable slopes close to developments. In addition to ensuring the safety of the public and minimising disturbance to the community during the works, special attention is paid to the safety of the construction workers. A number of improvement initiatives have been introduced since 1997, such as closer monitoring of site safety matters, promoting safety awareness of all project personnel and strengthening control on LPM contractors and encouraging designers to specify construction methods that pose the least hazards whenever possible. As a result, the overall accident rate of LPM contracts has been substantially reduced and has remained at a low level, which is now well below the threshold figure (i.e. a maximum accident rate of 1.5 per 100,000 man-hours) set by the Works Bureau, see Figure 6.

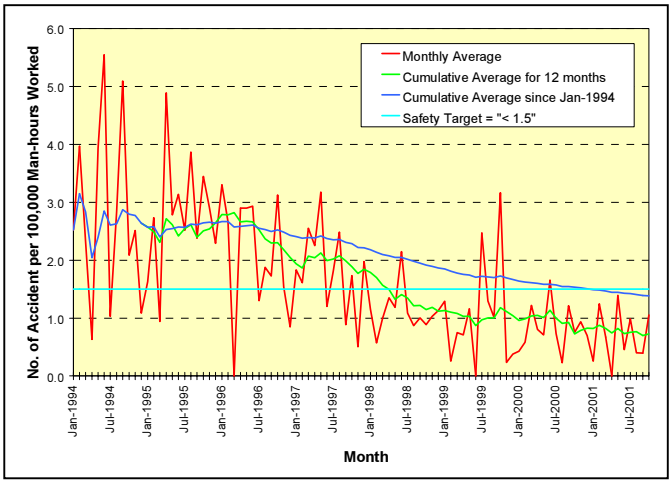

Figure 6 - Summary of accident statistics on LPM contracts since January 1994

The above provisions are proving to be effective in reducing accidents in LPM works sites. Nevertheless, the GEO will continue its efforts to achieve an even higher site safety standard in all LPM contracts.

Appearance of Slopes

It is Government's policy to make the appearance of engineered slopes as natural as possible, blending them with their surroundings and minimising their visual impact on the built environment. The GEO has made major efforts over the years to enhance the aesthetic aspects of slopes upgraded under the LPM Programme. In addition to slope appearance, due attention is also paid to ecological and sustainability aspects as well as tree preservation. Specialist landscape architects are engaged to provide professional advice on landscape treatment and bioengineering measures to blend the slopes upgraded under the LPM Programme into their surroundings.

Opportunities are taken during upgrading of existing Government slopes under the LPM Programme to provide a vegetation cover whenever practicable. The successful use of soil nailing as a means of stabilising soil cut slopes, rather than cutting them back, means that the existing slope profile can often

be maintained, thereby reducing the amount of vegetation clearance on the natural hillside above the man-made slope to be stabilized.

Shotcrete is used on slopes only after other techniques have been explored and found not practical or inadequate on safety grounds. Where the use of a hard surface cover is unavoidable, special measures are taken to improve its appearance wherever practicable, e.g. retaining existing trees using tree rings, incorporating planters, creepers or graphic design, colouring or painting, or a combination of the above.

Several bioengineering techniques which have been used successfully elsewhere are being assessed by the GEO for use on steep cut slopes with due regard to safety, cost and long-term maintenance requirements. Not all the successful techniques are applicable to Hong Kong because the slopes here are generally steep, and the climate and soil conditions may be quite different from that where the techniques have been used. Site trials are being carried out to assess the applicability of some techniques for the local climatic, topographic and soil conditions, and their performance is being monitored and evaluated.

Some typical photographs showing the appearance of slopes before and after LPM works are shown in Plates 1 to 4 to illustrate the enhancement in slope aesthetics as well as slope safety.

In September 2000, the GEO published new technical guidelines on landscape treatment and bio-engineering for man-made slopes and retaining walls to assist engineers in the design and construction of slope works (see Figure 7). The Publication has won the Grand Award in the "Outstanding Green Project Awards 2000" organized by the Leisure and Cultural Services Department in association with the Hong Kong Institute of Landscape Architects and the Society of Horticulture, Hong Kong.

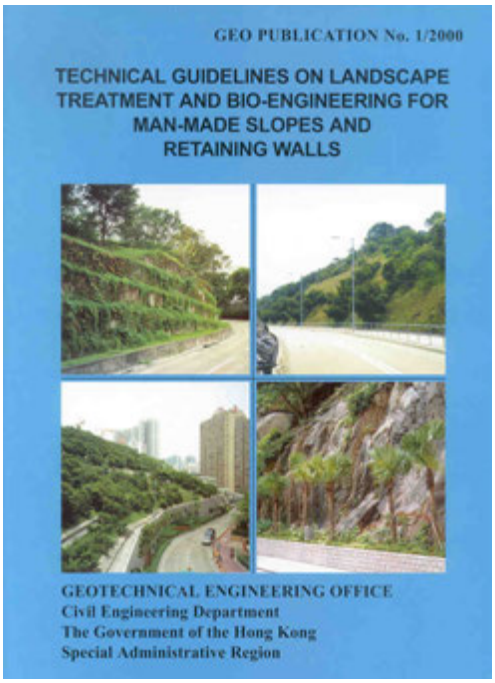

Figure 7 - Technical guidelines on landscape treatment and bio-engineering for slopes

Quality Assurance

In the quest for much higher productivity under the LPM Programme pursuant to the community's expectations, the GEO has been particularly conscious of the importance of maintaining and where possible enhancing the level of quality achieved in the design and works. The GEO has been proactive on this front and in 1997 implementation of the LPM Programme became the first process in the Civil Engineering Department to receive ISO 9001 certification. Since then, the GEO has maintained a continuous improvement culture and sought to update the Quality Manuals regularly in light of new technical and administrative developments as well as lessons learnt from landslide investigations.

Regular external audits are being carried out by the certification body to assess the effectiveness of the LPM quality system. In addition, the following internal audits are carried out with a view to improving performance and sustaining the continuous improvement efforts:

(a) Compliance Audits – these are conducted at regular intervals with respect to the various activities of the LPM process to ensure compliance with the documented procedures.

(b) Technical Audits – these are conducted on LPM works contracts to ensure compliance with the contract administration system.

(c) Consultancy Audits – these are conducted on LPM consultancy agreements to ensure compliance with the consultant management system.

(d) Construction Site Safety Audits – these are conducted during the construction of LPM works to ensure compliance with statutory requirements and assess the adequacy of the safety measures.

(e) Auditing for Prevention of Substandard Works – these are conducted during the critical stages of LPM works to audit site operations and quality control procedures with a view to averting non-conformances with respect to the specifications.

In addition to the above, the GEO carries out second party audits on selected critical aspects of the work of its consultants and contractors from time to time.

The GEO is committed to converting its existing certified Quality Management System to meet the ISO 9001 (Year 2000 version) and ISO 14001 requirements by the end of 2003.

Plate 1 - Appearance of a cut slope along Clear Water Bay Road before and after LPM works

Plate 2 - Appearance of a cut slope along Tai Po Road before and after LPM works

Plate 3 - Appearance of a fill slope in Homantin before and after LPM works

Plate 4 - Appearance of a retaining wall in the Mid-levels before and after LPM works