REVIEW OF LANDSLIDES IN 2004

GEO REPORT No. 202

A.F.H. Ng, T.H.H. Hui & H.W. Sun

GEOTECHNICAL ENGINEERING OFFICE

CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT

THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION

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This report was originally produced in October 2005 as GEO Landslide Study Report No. LSR 10/2005

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First published, January 2007

Prepared by:

Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon,
Hong Kong.

PREFACE

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. The GEO Reports can be downloaded from the website of the Civil Engineering and Development Department (http://www.cedd.gov.hk) on the Internet. Printed copies are also available for some GEO Reports. For printed copies, a charge is made to cover the cost of printing.

The Geotechnical Engineering Office also produces documents specifically for publication. These include guidance documents and results of comprehensive reviews. These publications and the printed GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the second last page of this report.

R.K.S. Chan
Head, Geotechnical Engineering Office
January 2007

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FOREWORD

This report presents the findings of a detailed diagnosis of landslides in 2004 that were reported to the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department. It serves to review the performance of the Government's slope safety system and identify areas for improvement in order to further enhance the slope engineering practice in Hong Kong.

The review was carried out by Mr A.F.H.Ng, Mr T.H.H. Hui, and Dr H.W. Sun of the Landslip Preventive Measures Division 1 under the supervision of Mr K.K.S. Ho. Assistance was provided by the GEO's landslide investigation consultants, Fugro Scott Wilson Joint Venture and Maunsell Geotechnical Services Limited.

R.K.S. Chan
Head of the Geotechnical Engineering Office

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ABSTRACT

This report presents the findings of a diagnostic review of landslides in 2004 that were reported to the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department. The review forms part of GEO's systematic landslide investigation programme, which was introduced following the 23 July 1994 Kwun Lung Lau landslide. The aims of this report are to review the performance of the Government's slope safety system and identify areas for improvement in order to further enhance the slope engineering practice in Hong Kong.

Altogether 69 genuine landslides were reported to the Government in 2004. All the available landslide data were examined and four landslide incidents were selected for follow-up studies under the systematic landslide investigation programme. These studies provided information and insight into the types and mechanisms of landslides, and facilitated the identification of areas deserving attention and improvement.

Based on the landslide data in 2004, there was no major landslides (viz. failure volume of 50 m^3 or above) on engineered man-made slopes that have been accepted under the slope safety system. The annual failure rate of minor landslides (viz. failure volume of less than 50 m^3) on engineered man-made slopes is about 0.03% in terms of number of slopes (i.e. the number of landslides relative to the total number of slopes in this category).

Overall, about 99.97% of the engineered man-made slopes performed satisfactorily without occurrence of landslides in 2004.

Recommendations for further improvement of the slope safety system and the slope engineering practice in Hong Kong are given in this report.

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1. INTRODUCTION

This report presents the findings of a diagnostic review of landslides in 2004 that were reported to the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department (CEDD). The review forms part of the GEO's systematic landslide investigation (LI) programme, which was introduced following the 23 July 1994 Kwun Lung Lau landslide. The LI programme has two principal objectives, as follows:

(a) identify, through studies of landslides, slopes that are affected by inherent instability problems so that appropriate follow-up actions can be taken for integrated slope assessment and upgrading works, and

(b) review the performance of Government's slope safety system and identify improvement to the slope engineering practice.

Selected significant landslides were identified for in-depth studies to identify lessons learnt together with the necessary follow-up actions. The findings of the studies are presented in a series of Landslide Study Reports. The present diagnostic review examines all the available landslide data, including the findings of the individual landslide studies, in order to review the performance of the Government's slope safety system and identify areas that deserve attention and improvement. The review has been carried out by the Landslip Preventive Measures Division 1 of the GEO, with assistance provided by the GEO's LI consultants, Fugro Scott Wilson Joint Venture and Maunsell Geotechnical Services Limited respectively.

Based on the review, improvement measures are proposed to further enhance the Government's slope safety system and the slope engineering practice in Hong Kong.

2. RAINFALL AND LANDSLIDES IN 2004

The factual information and the relevant statistics on rainfall and the reported landslides in 2004 were documented by Ng & Hui (2005). In 2004, the annual rainfall recorded at the Hong Kong Observatory (HKO)'s principal raingauge at Tsim Sha Tsui was 1,739 mm, which is about 21% lower than the mean rainfall of 2,214 mm recorded between 1961 and 1990, and it was the 17th driest year in Hong Kong since records began at 1884. Two Landslip Warnings were issued between 30 March 2004 and 21 September 2004.

Altogether 69 genuine landslides, discounting non-landslide incidents such as tree falls, were identified to have occurred in 2004 out of a total of 74 reported incidents. There was one major failure (i.e. failure volume of $\geq$50 m^3), which amounts to about 1.5% of the number of genuine landslides.

The range of different facilities affected by the landslides is summarised in Table 1. The consequences of the landslides, which have been classified in accordance with the type of failure, are summarised in Table 2. Table 3 shows the distribution of the different facility groups that were affected by the major landslides. The distribution of landslides as classified

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by the type of failure is given in Table 4.

The information of all the reported landslides has been uploaded to the GEO's computerised Slope Information System (SIS), which is accessible by the general public through computer terminals in the GEO. All the data on reported landslides were examined and additional information was collated by the LI consultants to assist in the selection of deserving cases for follow-up studies. In 2004, eleven incidents were selected for follow-up studies.

The individual landslide studies provided valuable information and insight into the types and mechanisms of landslides. The findings of the landslide studies have been documented and the reports are lodged in the Civil Engineering Library. A summary of the findings of the investigations of significant landslides is presented in the Hong Kong Slope Safety Website (http://hkss.cedd.gov.hk/hkss/eng/studies/lic/index.htm). Following the completion of each of the landslide studies, the key lessons learnt are identified and recommendations are made on the necessary site-specific, or more general, follow-up actions.

The rainfall in 2004 is much below average and the corresponding number of landslides was low. A more direct measure of the severity of a rainstorm in terms of specific consequences is the number of landslides that it is liable to cause. This is reflected by the Landslide Potential Index (LPI), which indicates the relative severity of a rainstorm in comparison with the most severe rainstorm in the past 20 years in terms of the number of landslides that the rainstorm could lead to, taking into account the rainfall characteristics as well as the spatial distribution of the rainstorms and the slope population. The maximum LPI for the most severe rainstorm in 2004 was unity, as compared to an LPI of 10 for rainstorm that led to the 23 July 1994 fatal landslide at Kwun Lung Lau. This reaffirms the fact that the small number of landslides reported in 2004 was simply a direct consequence of the rainstorm characteristics, whereby both the intensity and the locations of the rainstorms relative to the slope population were not conducive to potentially trigger a large number of landslides.

3. OVERALL DIAGNOSTIC REVIEW OF LANDSLIDES

3.1 Scope of the Review

The overall diagnostic review of all the available landslide data in 2004 provided a global picture of the performance of the different types of slopes in Hong Kong and facilitated the identification of specific areas that deserve attention.

The review has focused on the following aspects:

(a) coverage of the New Catalogue of Slopes,

(b) annual failure rates of different types of registered slopes, and

(c) diagnosis of landslides on slopes with geotechnical engineering input and, where relevant, geotechnical submissions that have been accepted under the slope safety system (hereinafter referred to as engineered slopes).

3.2 Coverage of the New Catalogue of Slopes

3.2.1 General

Sizeable man-made slopes and retaining walls, including those compiled under the GEO's project entitled 'Systematic Identification and Registration of Slopes in the Territory' (SIRST) and completed in September 1998, together with features newly formed or identified after 1998, are registered in the New Catalogue of Slopes. The methodology adopted in the identification of potentially registerable features under the SIRST project (which was done primarily based on Aerial Photograph Interpretation (API) and review of existing topographic plans), together with the criteria for registration of sizeable man-made slope features in the New Catalogue of Slopes, is given in GEO Circular No. 15.

3.2.2 Diagnosis

Of the 69 genuine landslides, 40 occurred on registered slope features. A breakdown of the other 29 incidents is given in Figure 1.

Of these 29 incidents, 11 involved small man-made slope features and 15 involved natural terrain, all of which do not satisfy the criteria for registration in the New Catalogue of Slopes. One of the other incidents involved a rock cut within an active quarry site where works were in progress at the time of failure and hence it was not yet ready for registration. The remaining two incidents involved features that satisfy the slope registration criteria but were not registered in the New Catalogue of Slopes at the time of failure (Figure 1).

3.2.3 Discussion

The above diagnosis indicates that the number of registerable slopes that were yet to be included in the New Catalogue of Slopes at the time of failure was less than 3% of the number of genuine landslides in 2004. None of the two incidents involved a major failure or any significant consequence such as building evacuation or road closure. Both of these involved only small cuts (about 5 m) affecting minor footpaths in remote areas.

The two slope features of concern have been registered in the New Catalogue of Slopes following the landslides.

3.3 Annual Failure Rates of Registered Slopes

3.3.1 General

Based on the landslide data and a review of the status of the corresponding slopes, the average failure rate of registered slopes can be assessed in terms of the different types of slopes of different ages, i.e. pre-1977 (viz. old slopes formed or substantially modified before 1977 when the Geotechnical Control Office, (renamed GEO in 1991) was established), or

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post-1977 (viz. formed or substantially modified after 1977).

The status of a slope can be distinguished in terms of whether or not it has been engineered in the past (i.e., with geotechnical engineering input). Engineered slopes include the following:

(a) slopes formed after 1977 that were designed, checked and accepted under the slope safety system as being up to the required geotechnical standards,

(b) slopes formed before 1977 that were subsequently assessed, checked and accepted under the slope safety system as being up to the required geotechnical standards,

(c) slopes formed before 1977 that were subsequently upgraded, checked and accepted under the slope safety system as being up to the required geotechnical standards, and

(d) slopes with Type 3 prescriptive measures carried out under a quality assurance system that satisfies the requirements of ETWB TCW No. 13/2005 (whereby the checking by the GEO of the design of the Type 3 prescriptive measures is waived).

The types of slope features considered in the present diagnosis include soil cuts, rock cuts, fill slopes and retaining walls.

The scale of a landslide is classified as follows:

(a) minor failure (i.e. failure volume of <50 m^3), and

(b) major failure (i.e. failure volume ≥ 50 m^3).

In the present context, the failure volume refers to the total volume of detached material and the volume of any deformed material that remains on the slope (which may, or may not, have displaced significantly).

The distribution of the scale of failures of the genuine landslides for different classes of slopes is summarised in Table 5.

3.3.2 <u>Diagnosis</u>

Of the 69 genuine landslides reported in 2004, a total of 40 landslide incidents (about 58%) affected 39 registered slopes (i.e. one of the slopes had multiple landslide incidents). Of these 40 landslide incidents, none was a major failure.

Approximate estimates of the number of engineered and non-engineered slope features have been made by reference to the classification assigned under the 'Systematic

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Identification of Features in the Territory' (SIFT) project and desk study findings regarding whether the slope features have gone through the slope safety system. The estimates of the number of engineered and non-engineered slopes based on reference to SIFT data are subject to some uncertainty as the SIFT class of a slope is assessed primarily using aerial photograph interpretation. Further information on the scope and limitations of the SIFT project is given by Wong & Ho (1999).

Six of the 69 genuine landslides (about 9%) affected engineered slopes, none of which was a major failure.

Based on the 2004 landslide data and a detailed review of the status of the slopes involved in the landslides, the annual failure rates of the different types of registered slopes have been calculated (Table 6). These calculated failure rates are not particularly sensitive to the assumptions made about the total numbers of different types of slopes, given the likely order of uncertainty involved. It should be noted that the calculated failure rates do not necessarily correspond to long-term average values because of the limited observation period. Notwithstanding this, these annual failure rates derived from a systematic review of all the landslide data over the year will provide useful insight into the performance of the slope safety system.

3.3.3 Discussion

The failure rates of engineered and non-engineered slopes have been calculated using three approaches.

The first approach involves assessing the failure rate on a slope number basis, i.e. the failure frequency is taken to correspond to the number of landslides divided by the total number of slopes of a certain status (viz. a given slope type that is engineered or non-engineered). In this regard, the failure rate of different slope categories and the performance of the slope safety system are related to the slope population as registered in the Slope Catalogue.

The second approach involves assessing the failure rate in terms of the surface area of landslides as divided by the total surface area of all slopes of the corresponding status.

The third approach involves assessing the landslide rate in terms of the number of landslides divided by the total surface area of slopes of the corresponding status. Relating the failure rate to the area of slopes, as opposed to just the number of slopes, would take into consideration the fact that a large slope is more susceptible to 'defects' than a small slope. In view of a possible marked difference between the surface areas of different slopes, it would be relevant to also consider slope surface areas in the calculation of failure rates of registered slopes.

Based on the data in 2004, the annual failure rates for all reported landslides correspond to 0.7×10^{-3} (number of landslides/number of registered slopes), 22.1×10^{-6} (total surface area of landslides/total surface area of registered slopes), and 0.7×10^{-6} (number of landslides/total surface area of registered slopes in square metres) respectively, using the three different approaches as described above.

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Comparisons of the annual failure rates of engineered slopes with that of non-engineered slopes are given in Section 3.4.2 below. It should be noted that the calculated failure rates for the different types of registered slopes based on the 2004 landslide data could be affected by factors such as the actual rainfall characteristics and the prevailing slope maintenance condition.

3.4 Diagnosis of Landslides on Engineered Slopes

3.4.1 General

A review of the 2004 landslides indicates that some of the incidents involved failure of engineered slopes. A meaningful diagnosis of landslides on engineered slopes requires detailed information about the nature and probable causes of the failures, together with the status and development history of the subject slopes. The present assessment is based on the detailed information obtained from the follow-up landslide studies.

Of the six landslides that occurred on engineered slopes, four were upgraded in the 1980's and two were upgraded in the 1990's (see Table 7). For the present purposes, slope features that were not accepted under the slope safety system (e.g. no geotechnical submissions made to the GEO for checking or submissions with outstanding GEO comments) are not considered to be engineered slopes. In 2004, one of the landslides involved slope features with outstanding GEO comments on the geotechnical submissions, which were not resolved by the designer, and hence it was not taken to have involved an engineered slope.

Engineered slopes with geotechnical submissions accepted under the slope safety system are classified in accordance with the following (see Table 8):

(a) whether the slope was formed after 1977 or whether it was an existing feature previously subjected to upgrading works or demonstrated by stability assessment as being up to the required geotechnical standards,

(b) the mechanism under which stability assessments or slope upgrading works were carried out (e.g. LPM Programme, private or Government development projects, works by private owners or default works by Government following the issue of Dangerous Hillside Orders),

(c) whether detailed geotechnical design calculations were carried out,

(d) whether site-specific ground investigation and laboratory testing were carried out for the stability assessment and design of slope upgrading works,

(e) whether the stability assessment or the design of slope upgrading works was checked and accepted by the GEO, or whether there were any outstanding GEO comments on the geotechnical submissions that were not satisfactorily

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resolved by the party concerned, and

(f) whether the slope was upgraded to meet current standards using prescriptive measures under an adequate quality system satisfying the requirements of ETWB TCW No. 13/2005 with the checking by the GEO waived.

A summary of the pertinent findings of the follow-up landslide studies is given in Table 9.

3.4.2 Overall Diagnosis

The breakdown of the six landslides that occurred on engineered slopes in 2004 with respect to the slope type and the scale of failure is shown in Table 10. All of these involved minor failures (i.e. <50 m^3), with a maximum failure volume of only about 5 m^3.

The annual failure rates for the 2004 landslide data on a slope number basis, unit slope surface area basis and the number of landslides per slope surface area basis respectively, are summarised in Table 11 for different categories of engineered slopes.

On a slope number basis, the failure rate of engineered slopes is about three times less than that of non-engineered slopes, whereas on a unit area basis, the failure rate of engineered slopes is some 29 times less than that of non-engineered slopes. In terms of the number of landslides as divided by the slope surface area, the corresponding failure rate of engineered slopes is about 10 times less than that of non-engineered slopes.

Of the six engineered slopes that failed in 2004, three were previously included in the Landslip Preventive Measures (LPM) Programme (see Table 12). The corresponding annual failure rates for slopes previously included in the LPM Programme are summarised in Table 13.

It may be noted from the above diagnosis that for 2004, the annual failure rate of LPM slopes for all landslides was apparently higher than the corresponding figure for engineered slopes (both on a slope number basis and in terms of number of landslide per unit slope area). On a unit area basis, however, the failure rate of LPM slope was comparable to that of engineered slopes. These could be related partly to the fact that the LPM Programme is focused on tackling more difficult and sizeable slopes with complex ground conditions. Caution needs to be exercised because the numbers being compared are small and they may not be statistically significant. Hence, the diagnosis should be taken as indicative only.

The target annual success rates (where ‘success rate’ = 1 - ‘failure rate’) for engineered slopes pledged by the GEO are 99.8% and 99.5% against major failures and minor failures respectively, as defined in terms of slope numbers. In 2004, the actual corresponding annual success rates were 100% and 99.97% respectively. The pledged targets were therefore satisfactorily achieved.

The trend of the annual success rates of engineered slopes from 1997 to 2004 is summarised in Table 14.

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3.5 Key Observations

3.5.1 Severity of Rainstorms that Triggered Landslides

Of the six rain-induced landslides that affected engineered slopes, three (involving minor rockfalls) had sufficiently reliable information to assess the timing and severity of the rainstorms preceding the failures (Table 9). All the three cases involved rainstorms which were less severe than that experienced in the past based on data from automatic raingauges installed in the vicinity of the subject slopes in the mid-1980's.

For the above three failures at rock cuts, progressive deterioration of the slope condition due to inadequate maintenance probably played a key role, as there were no obvious changes in environmental conditions of the slopes. Slope deterioration could take the form of progressive opening up of the adversely orientated rock joints due to root action associated with unplanned vegetation. As a result, subsequent rockfalls could be caused by rainstorms that are not particularly severe.

3.5.2 Landslides on Engineered Slopes

3.5.2.1 General

In 2004, six landslides occurred on engineered slopes (Table 9), comprising two soil cuts, three rock cuts and one fill slope. The maintenance responsibility for five of these slopes rested with Government whereas the other is under private ownership.

3.5.2.2 Soil Cuts

Two minor landslides occurred on engineered soil cut slopes with vegetated covers, one of which was upgraded using soil nails.

One of these was upgraded in 2002 by cutting back to 45° followed by installation of soil nails at 2 m centres. The slope comprised a vegetated cover, which replaced a shotcrete cover. The landslide involved a shallow failure of saprolite between soil nail heads during moderate rainfall. The landslide was probably primarily caused by concentrated surface runoff resulting from the blockage of a catchpit at the slope crest, which led to the wetting up of the ground mass and the local detachment. Similar minor failures within the active zones of soil nailed vegetated cut slopes have occurred in recent years. This calls for attention to the possibility of such failures, which are not explicitly considered in the current design methodology.

In the other case (engineered in the late 1990's) which comprises a 45° steep vegetated soil cut above a caisson retaining wall, bursting of a pressurised water main above the slope crest resulted in washout failure of the slope as well as internal erosion.

3.5.2.3 Rock Cuts

The three rockfall incidents affected engineered rock cuts that were accepted under the

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slope safety system in the 1980's (2 nos.) and in 1990 (1 no.) respectively. A combination of local adverse joints, water ingress and progressive deterioration of the slope condition probably played a key role in the failures. In addition, unplanned and undesirable vegetation due to lack of maintenance leading to root jacking action on the potentially unstable rock blocks was a key contributory factor to the failures.

Similar rockfalls have occurred from engineered rock cuts in previous years. One key factor is tree root growth, which can result in progressive deterioration of the slope condition and make it more vulnerable to water ingress.

The minor failures, once again, highlighted the difficulty of guarding against local and minor detachments with confidence. In practice, the risk of small detachments from rock cuts may be mitigated by means of a suitable protective rock mesh (or a ditch at the toe where space permits) as an integral element of the design. In this case, the detachment strictly should not be counted as a failure in the context of the assessment of failure rates of slopes, since it meets the design intent and does not impact on the affected facilities. The above approach may be incorporated as part of the upgrading works design, or provided to an existing slope as a preventive maintenance measure during routine maintenance or following the recommendations of Engineer Inspections.

3.5.2.4 Fill Slopes

Notable signs of distress and surface erosion were observed on an engineered fill slope, which was upgraded under the LPM Programme in 1999. Details of the investigation are given in FSWJV (2005a). The subject slope is located across a broad drainage valley at the confluence of four drainage lines. It comprises the construction of a toe retaining wall and the placement of 3 m thick compacted fill over the pre-existing old loose fill. The site setting is such that a perched water table is liable to develop in the loose fill above the relatively shallow rockhead due to subsurface seepage during heavy rainfall. Additional water ingress into the loose fill was also possible through leakage from the dilapidated cross-road culvert that was connected to the slope surface drainage system. The old loose fill under an increased overburden pressure was probably more vulnerable to ground settlement in response to wetting up and build-up of groundwater pressure, which in turn probably led to the distress observed on the comparative more 'rigid' compacted fill cap. This potential problem of post-construction ground movement was highlighted in GEO (2004). As regards the washout failure, this was found to be a recurring problem which was associated with overspilling from a stepped channel due to inadequate detailing of the drainage connections. A review of areas for improvement in the design and detailing of slope surface drainage is given by Hui & Sun (2005).

Distress was also noted on another compacted fill slope (with no detachment of material), which was upgraded under the LPM Programme in the late 1970's. The works comprised the construction of an 8 m (maximum) layer of compacted soil fill within the lower half of the slope within a valley, and a 3 m thick recompacted fill cap (which overlies a thick layer of old loose fill) was placed within the upper half of the slope. The hydrogeological setting of the slope is vulnerable to the build-up of groundwater pressure, especially at the lower end of the old fill body at about the mid-slope location in the event of water ingress into the more permeable loose fill beneath the recompacted fill cap. Details of the investigation

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are given in FSWJV (2005b). One of the key observations was that the adverse hydrogeological condition involving concentrated subsurface groundwater flow in a valley setting was probably exacerbated by the relatively low discharge capacity of the subsurface drainage provisions. This points to the need to review whether more robust subsurface drainage provisions are warranted for the 3 m fill recompaction approach, especially for upgrading loose fill slopes in an infilled valley with a sizeable catchment and/or a high groundwater level.

3.5.3 Landslides on Natural Hillsides and Disturbed Terrain

A total of 16 failures on hillsides (one of which involved a registered disturbed terrain feature) were reported in 2004, one of which involved major failure.

A detailed diagnosis of these 16 cases suggests that nine may be classified as natural hillside failures (i.e. the failures affected natural hillsides which have not been modified by human activities, such as cutting, filling, cultivation, etc.). The other seven involved hillsides that have been locally modified or disturbed by human activities but the man-made elements did not play a significant contributory role in these failures.

An overall review of the landslide incidents occurring on hillsides between 2000 and 2004 indicates that some of the failures (>100 incidents) affected sloping terrain located within the 'Development Line' (King, 1997). This marks a notional boundary between developed areas and natural terrain for the purposes of compiling the Natural Terrain Landslide Inventory (NTLI) in 1997 based on high-altitude aerial photographs, which only covered landslides on hillsides outside the 'Development Line'. Failures from hillsides within the 'Development Line' are liable to affect developed areas. In the assessment of known hazards on hillsides that may require systematic follow-up action on a prioritized basis, it would be important to take account of hillside failures located both within and outside the 'Development Line'.

The GEO is currently compiling an enhanced NTLI, which involves the use of low-altitude aerial photographs to cover hillsides for the whole of Hong Kong. This will greatly enhance the completeness of the inventory. It would also be appropriate to make reference to all reported hillside failures affecting developments as it is possible that some of these may not necessarily be picked up by the aerial photographs (shadow effect due to adjacent buildings, landslides not obvious by the time the aerial photographs were taken, etc.).

3.5.4 Landslides with Inadequate Maintenance Diagnosed as a Key Contributory Factor to Failure

All the 40 reported landslide incidents involving registered man-made slope features were reviewed to assess whether inadequate maintenance was likely to have been a major contributory factor in the failures. Reference has been made to the records of emergency inspections by the GEO or other Government departments, inspections of selected landslides by the LI consultants, together with the findings of follow-up landslide studies.

Inadequate slope maintenance was assessed to be a major contributory factor in four of

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the 40 incidents (i.e. 10%).

All the above four incidents affected Government slopes (two of which were covered with chunam surfacing and two of which were engineered slopes, one with stone pitching and the other of bare surface). However, extreme caution needs to be exercised because the numbers involved are small (as the rainfalls in 2004 were not severe) and hence they are not statistically significant (Tables 15 and 16). The above diagnosis should therefore be taken as indicative only.

The above re-affirms the importance of regular slope maintenance and serves as a reminder that even an engineered slope that meets the required safety standards is liable to fail due to lack of maintenance.

4. PROPOSED IMPROVEMENT INITIATIVES

Improvement initiatives were proposed by Hui et al (2004) following the diagnostic review of the landslides in 2003. The progress of the follow-up actions is summarised in Table 17.

Based on the present review, the following improvement initiatives are proposed:

(a) carry out a review of reported landslides on soil-nailed slopes to examine if there is a need for improved detailing against shallow failures (see Section 3.5.2.2),

(b) carry out a review of the need for improved subsurface drainage provisions in compacted fill slopes, especially for sites with an adverse hydrogeological setting (see Section 3.5.2.4), and

(c) Identify historical landslides that occurred on hillsides within or near the 'development lines' (see Section 3.5.3).

5. CONCLUSIONS

Based on the overall diagnostic landslide review presented in this report, the following observations are made with respect to the performance of the Government's slope safety system:

(a) No major landslides were reported on engineered slopes in 2004.

(b) The annual failure rate of minor landslides on engineered slopes, on a slope number basis, was 0.03% in 2004. The pledged annual success rates of 99.8% and 99.5% of engineered slopes in preventing major and minor landslides, respectively, were met.

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(c) More than 99.95% of the engineered slopes performed satisfactorily without the occurrence of any landslides in 2004.

A number of initiatives have been proposed, as detailed in Section 4 of the report, with a view to further improving the slope engineering practice and enhancing the slope safety system in Hong Kong.

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Table 1 - Number of Landslides Affecting Different Facilities

Affected Facility	Hong Kong Island	Kowloon	New Territories and Outlying Islands	All
Squatter Dwellings	0 (0)	1 (0)	5 (0)	6 (0)
Buildings	0 (0)	1 (0)	3 (0)	4 (0)
Roads	3 (0)	1 (0)	2 (0)	6 (0)
Transportation Facilities (railways, tramways, LRT, etc.)	0 (0)	0 (0)	0 (0)	0 (0)
Pedestrian Pavements/Footways	2 (0)	0 (0)	0 (0)	2 (0)
Minor Footpaths/Access	4 (0)	0 (0)	10 (0)	14 (0)
Construction Sites	1 (0)	1 (0)	0 (0)	2 (0)
Open Areas	4 (0)	3 (0)	13 (1)	20 (1)
Catchwaters	0 (0)	0 (0)	1 (0)	1 (0)
Others (e.g. carparks, parks, playgrounds, gardens, backyards, etc.)	3 (0)	1 (0)	10 (0)	14 (0)

Legend:
13(1) Thirteen landslides of which one was sizeable failure

Notes: (1) A given landslide may affect more than one key type of facility.
(2) Incidents which were not genuine landslides have been excluded.

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Table 2 - Landslide Consequence Related to Type of Slope Failure

Type of Failure		No. of Squatter Dwellings Evacuated		No. of Blocks, Houses or Flats Evacuated or Partially Closed	No. of Closure			Deaths	Injuries
		Permanent	Temporary		Roads	Pedestrian Pavements	Footpaths, Back Lanes, Private Access		
Fill Slope		0	0	0	0	0	0	0	0
Cut Slope	Soil	0	1 (7)	1	0	0	1	0	0
	Soil/Rock	0	0	0	0	0	0	0	0
	Rock	0	0	0	1	0	0	0	0
Retaining Wall		0	0	0	1	0	0	0	0
Natural Hillside		0	2 (2)	0	0	0	1	0	0
Registered Disturbed Terrain		0	0	0	0	0	0	0	0

Legend:
1 (7) Number of squatter dwellings evacuated with the number of tolerated squatter structures evacuated shown in blanket

Notes: (1) Asquatter dwelling is defined as a place of residence that contains one or more “tolerated squatter structures”, i.e. structures built for domestic purpose or non-domestic purpose and registered in the 1982 Housing Department’s Squatter Structure Survey.
(2) A failure may give rise to more than one key type of consequence.

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Table 3 - Distribution of Facility Groups Affected by Sizeable Landslides

	Facility Group Affected by Sizeable Landslides (Group No.)						
	1a	1b	2a	2b	3	4	5
All Major Landslides	0	0	0	0	0	0	1
Major Landslides on Man-made Slope	0	0	0	0	0	0	0
Major Landslides on Natural Hillside	0	0	0	0	0	0	1

Notes: (1) Facility groups are classified in accordance with that adopted for the New Priority Classification Systems (Wong, 1998).
(2) A given landslide may affect more than one key type of facility.

Table 4 - Number of Landslides as Classified by Type of Slope Failure

Type of Failure		No.	Percentage (%)
Fill Slope		3 (0)	4.3
Cut Slope	Soil	27 (0)	39.1
	Soil/Rock	16 (0)	23.2
	Rock	5 (0)	7.3
Retaining Wall		2 (0)	2.9
Natural Hillside		15 (1)	21.7
Registered Disturbed Terrain		1 (0)	1.5
Total		69 (1)	100

Legend:
15 (1) Fifteen landslides of which one was sizeable failure

Notes: (1) Where a landslide involved more than one type of failure, the predominant type of failure has been assumed in the above classification.
(2) Incidents which were not genuine landslides have been excluded.

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Table 5 - Breakdown of Scale of Failures for Different Classes of Slopes

	Number of Minor Failures (<50 m³)	Number of Major Failures (50 to 500 m³)	Number of Massive Failures (>500 m³)	
Registered Man-made Slopes	40	0	0	Σ = 40
Small Unregisterable Man-made Slopes	11 (1)	0	0	Σ = 9
Registerable Man-made Slopes Not Yet Registered at Time of Failure	3 (2)	0	0	Σ = 5
Natural Hillside	14	1	0	Σ = 15
	Σ = 68	Σ = 1	Σ = 0	Σ = 69

Notes: (1) One minor rockfall occurred at a temporary stockpile of rock blocks/soil in an active construction site. The stockpile was ubsequently cleared following the failure.

(2) One minor failure occurred on a cut slope under construction within a quarry site, which will be registered after completion.

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Table 6 - Annual Failure Rates of Registered Man-made Slope Features Based on Landslides Reported in 2004

		Non-Engineered Slopes			Engineered Slopes		
		Fill/Retaining Wall	Soil/Rock Cut	Overall(1)	Fill/Retaining Wall	Soil/Rock Cut	Overall
Slopes Involved in Landslides in 2004	Number	1	32	33	1	5	6
	Surface Area of Landslides (m^2)	33	400	433	2	25	27
Slopes Involved in Sizeable Landslides in 2004	Number	0	0	0	0	0	0
	Surface Area of Landslides (m^2)	0	0	0	0	0	0
Slopes Involved in Minor Landslides in 2004	Number	1	32	33	1	5	6
	Surface Area of Landslides (m^2)	33	400	433	2	25	27
Total Number of Registered Slopes		11,700	21,900	33,600	9,900	11,500	21,400
Total Surface Area of Registered Slopes (m^2)		6,594,000	12,059,000	18,653,000	11,794,000	23,427,000	35,221,000
Annual Failure Rates (All Landslides Considered)	On a Slope Number Basis	0.01 %	0.15 %	0.1 %	0.01 %	0.04 %	0.03 %
	On a Unit Slope Surface Area Basis	0.50×10^{-3} %	3.32×10^{-3} %	2.32×10^{-3} %	0.02×10^{-3} %	0.11×10^{-3} %	0.08×10^{-3} %
	Number of Landslides Divided by Slope Surface Area (no./m^2)	0.15×10^{-6}	2.65×10^{-6}	1.77×10^{-6}	0.08×10^{-6}	0.21×10^{-6}	0.17×10^{-6}
Annual Failure Rates (Sizeable Landslides Only)	On a Slope Number Basis	0 %	0 %	0 %	0 %	0%	0 %
	On a Unit Slope Surface Area Basis	0 %	0 %	0 %	0 %	0%	0 %
	Number of Landslides Divided by Slope Surface Area (no./m^2)	0	0	0	0	0	0

Note: (1) Registered Disturbed Terrain features are excluded from this calculation.

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Table 7 - Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 1 of 3)

1. Slopes Upgraded Under the LPM Programme

Slope No.	Incident No.	Location	Volume (m³)	Type of Slope	Remarks
7SW-C/C265	2004/04/0003	No. 67 Hoi Pa San Tsuen, Kwok Shui Road, Tsuen Wan	0.005 (rockfall)	Soil/Rock Cut	LPM works completed in 1988.
15NE-B/FR34	2004/04/0006	Downslope side of Shek O Road	Sign of distress	Fill/ Retaining Wall	LPM works completed in 1999.
11NE-C/C41	2004/05/0024	Service lane behind No. 37 Wan Hon Street, Kwun Tong	0.15 (rockfall)	Soil/Rock Cut	LPM works completed in 1990.

2 Slopes Assessed under the LPM Programme with No Upgrading Works Required

Nil

3. Slopes Assessed by Studies in the Late 1970's to mid-1980's with No Upgrading Works/Further Study Required

Nil

4. Slopes Assessed by Government Departments and Checked by GEO with No Upgrading Works Required

Nil

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Table 7 - Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 2 of 3)

5. Slopes Assessed by Private Owners and Checked by GEO with No Upgrading Works Required

Nil.

6. Slopes Formed or Upgraded by Government Departments and Checked by GEO

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
11SW-B/C51	2004/04/0002	Signal Hill Garden behind Minden Avenue, Tsim Sha Tsui	0.015 (rockfall)	Soil/Rock Cut	Geotechnical design on the subject slope was checked and accepted by the GCO in 1981.
11NE-D/CR15	2004/11/0068	Below Sau Fung Street, Sau Mau Ping	5	Soil Cut	Geotechnical design on the subject slope was checked and accepted by the GCO in mid-1980s.

7. Slopes Formed or Upgraded by Private Owners and Checked by GEO

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
11NE-B/C778	2004/05/0022	Mok Tse Che Chuen, Sai Kung	2	Soil Cut	Geotechnical design on the subject slope was checked and accepted by the GCO in 1989.

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Table 7 - Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 3 of 3)

8. Slopes Upgraded Following Service of DH Orders and Checked by GEO

Nil.

9. Slopes Assessed as Not Requiring Upgrading Works But with Outstanding GEO Comments

Nil.

10. Slopes Assessed as Requiring Upgrading Works But with Outstanding GEO Comments

Nil.

Notes: (1) Slopes under Categories 1 to 8 are classified as engineered slopes.
(2) Slopes under Categories 9 and 10 are post-1978 features but are not taken as engineered slopes.

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Table 8 - Classification of Engineered Slopes

Feature Type	Classification
Post-1978 Features (i.e. formed or upgraded after 1978)	1
Newly Formed	1N
Upgraded by LPM	1A
Upgraded by Other Government Departments	1B
Upgraded by Private Owners	1C
Upgraded following issue of DH Orders	1D
Pre-1978 Features (i.e. formed before 1978 and subsequently assessed under the slope safety system)	2
Assessed by LPM Stage 2 or Stage 3 Studies	2A
Assessed by Other Government Departments	2B
Assessed by Private Owners	2C
Assessed by Old Studies (e.g. Planning Division Stage 1 Study, Binnie & Partners Phase II Study, Existing Slopes Division Stage 1 Study)	2D

Note: The classification may be extended where possible by adding S, T, U, Y or N which are defined as follows:

S = detailed design calculations based on site-specific ground investigation and laboratory testing

T = detailed design calculations without site-specific ground investigation and laboratory testing

U = no detailed design calculations

Y = upgrading works/assessments were audited and accepted by the GEO

N = no evidence that the works/assessments were audited and accepted by the GEO

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Table 9 - Summary of Key Findings of Follow-up Landslide Studies

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relict Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Poor Condition of Maintenance	GEO Checking		Unauthorized Construction	Volume of Failure (m³)		Remarks
				Recorded	More from API	Recorded	More from API	G/W	Material Strength	Others #			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
Time unknown Slope below Shek O Road near Lan Nai Wan (15NE-B/FR34) (DS)	Engineered (Slope upgraded under LPM Programme in June 1999) (1ASY)	Not assessed	Y	N	N	N	N	N	N	N	Mod	N	Y	N	N	0	Signs of distress	Signs of slope distress in the form of local tension cracking, damage to concrete maintenance stairway and localised cracking and displacement of concrete drainage channels on the slope were observed in April 2004. Severe surface erosion occurred at the lower southern corner of the slope. The distress was probably a result of stress-induced and wetting induced settlement of the existing old fill/colluvium underlying the 3 m thick compacted fill cap. Additional water ingress through the dilapidated concrete in the cross-road culvert would have contributed to a rise in the groundwater. The recurring problem of surface erosion in the southern corner of the slope is caused by uncontrolled overspilling from a 750 mm stepped channel during rainstorms, which is probably due to poor detailing.
10.5.2004 Mok Tse Che Road, Sai Kung (11NE-B/C542) (DS)	Not engineered (Slope upgrading works not yet completed)	First rainstorm after upgrading works	N	N	N	N/A	N/A	N/A	N/A	N/A	N/A	Min.	N/A	N/A	N	1	0	The minor landslide involved a shallow failure of near-surface material between soil nail heads in a vegetated 65° steep portion of a soil cut slope. The failure was probably triggered by intense short-duration rainfall, which resulted in direct infiltration leading to the wetting up of the ground and loss of suction and hence shear strength. Other contributory factors include concentrated surface runoff and infiltration at the local low point, blockage of a catchpit at the slope crest and the absent of a crest drainage

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Table 9 - Summary of Key Findings of Follow-up Landslide Studies

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relict Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Poor Condition of Maintenance	GEO Checking		Unauthorized Construction	Volume of Failure (m³)		Remarks
				Recorded	More from API	Recorded	More from API	G/W	Material Strength	Others #			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
																		channel. The slope portion concerned was proposed to be upgraded by means of prescriptive soil nails with a vegetated cover protected by erosion control mat and wire mesh netting, together with a crest drainage channel. Post landslide inspection revealed that installation of wire mesh netting and construction of crest drainage channel had yet been carried out.
31.8.2004 Anderson Road Quarry, Kwun Tong (Within an active quarry rehabilitation site) (DS)	Not engineered (Slope formation works not yet completed at the time of failure)	N	N	N	N	N/A	N/A	N	N	N	Po	N	Y	Y	N	6	0	The minor landslide involved shallow failure of saprolite in between soil nails heads on a 55^o soil/rock cut slope during moderate rainfall. The landslide was triggered by rainfall, with adverse site settings (e.g. presence of a local rockhead depression and adversely orientated relict joints at the source area) are the key contributory factors to the landslide. The remedial works of a previous washout failure above the source area of the landslide, which comprised sand bags and no-fine concrete, would have provided another potential source of concentrated water ingress into the upslope area.

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Table 9 - Summary of Key Findings of Follow-up Landslide Studies

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relict Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Poor Condition of Maintenance	GEO Checking		Unauthorized Construction	Volume of Failure (m³)		Remarks
				Recorded	More from API	Recorded	More from API	G/W	Material Strength	Others #			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
31.3.2004 Service lane behind No. 37 Wan Hon Street, Kwun Tong (11NE-C/C41) (LR)	Engineered (Slope upgraded under LPM Programme in 1990) (1ASY)	N	Y	N	Not done	N	Not done	N	N	N	N	Sig.	Y	N	N	0.15	0	The minor rockfall occurred on a sub-vertical rock face of a 65^{o} steep rock cut slope during moderate rainfall. The detachment was rain-induced and was probably caused by water ingress into dilated sub-vertical rock joint, resulting in possible build-up of local cleft water pressure. Progressive deterioration of the rock slope and root jacking action of undesirable trees were the probable key contributory factors to the rockfall.
2.4.2004 Signal Hill Garden behind Minden Avenue, Tsim Sha Tsui (11SW-B/C51) (LR)	Engineered (Geotechnical submission checked by GCO in 1981) (1BY)	N	Y	N	Not done	N	Not done	N	N	N	N	Sig.	Y	N	N	0.2	0	The minor rockfall that occurred on the rock portion of a soil/rock cut slope was probably triggered by rainfall. The chunam cover on the slope surface was in dilapidated condition and the growth of undesirable vegetation along rock joints might have resulted in jacking action on rock blocks. Progressive deterioration of the slope condition associated with lack of slope maintenance probably played a key role in the rockfall.
2.4.2004 No. 67 Hoi Pa San Tsuen, Kwok Shui Road, Tsuen Wan (7SW-C/C265) (LR)	Engineered (Slope upgraded under LPM Programme in 1988) (1ASY)	N	Y	N	Not done	N	Not done	N	N	N	N	Sig.	Y	N	N	0.005	0	The minor rockfall occurred on a steep (65^{o}) rock portion of a soil/rock cut slope during moderate rainfall. The detachment may have been the result of progressive deterioration and lack of maintenance as indicated by the presence of undesirable vegetation at close proximity to the source of rockfall.

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Table 9 - Summary of Key Findings of Follow-up Landslide Studies

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relict Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Poor Condition of Maintenance	GEO Checking		Unauthorized Construction	Volume of Failure (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	G/W	Material Strength	Others #			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
8.5.2004 Near Mok Tse Che Chuen, Sai Kung (11NE-B/C778) (LR)	Engineered (Geotechnical submission checked by GCO in 1989) (1CSY)	N	Y	N	Not done	N	Not done	N	N	N	N	Sig.	Y	N	N	2	0	The minor landslide involved shallow failure of saprolite on a 45° steep soil cut slope during moderate rainfall. The landslide was probably caused by blockage of a catchpit at the slope crest, which resulted in concentrated surface runoff towards the landslide site leading to wetting up of the ground and loss of suction.
23.11.2004 Sau Fung Street, Sau Mau Ping (11NE-D/CR15) (LR)	Engineered (Slope upgraded by HD in the mid-1980s and modified in late 1990s) (1BY)	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	5	0	The incident involved the bursting of a 375 mm diameter pressurised, asbestos cement, saltwater main above the crest of an engineered slope feature. The concentrated water flow had caused severe erosion to a localised surface fill layer. Copious amounts of muddy water completely flooded the playground and ground floor of a school below.

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Table 9 - Summary of Key Findings of Follow-up Landslide Studies

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relict Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Poor Condition of Maintenance	GEO Checking		Unauthorized Construction	Volume of Failure (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	G/W	Material Strength	Others #			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
Time unknown Tseung Kwan O Chinese Permanent Cemetery (Natural hillside adjoining three registered fill slopes) (LR)	Not engineered (Failure involved unauthorised fill slopes)	Not done	N	N	N	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Po	350	0	The incident involved a major washout scar on three adjoining fill slopes which were constructed between 1997 and 2000 on unallocated government land with no authorisation by the Lands Department and no geotechnical submission to the Buildings Department. The failure was probably related to erosion caused by uncontrolled concentrated surface water flow as a result of water overtopping a shallow, unreinforced concrete lined channel.

Legend: Y = Yes; N = No; Po = Possible; Sig = Significant contribution; Mod = Moderate contribution; Min = Minor contribution; Little = Little contribution; (DS) = Detailed Study; (LR) = Landslide Review; (FN) = File Note

Notes:

(1) Massive failure denotes incident with failure volume (detached + deformed volume) >500 m^3.
Major failure denotes incident with failure volume between 50 m^3 and 500 m^3.
Minor failure denotes incident with failure volume <50 m^3.

(2) * denotes classification of slope status in accordance with Table 8 of this report.

(3) # denotes other deficiency in design/assessment, including poor detailing, inappropriate geological model, incorrect slope stability analysis, inadequate drainage provisions, etc.

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Table 10 - Breakdown of Landslides on Engineered Slopes

	Soil Cut Slope	Rock Cut Slope	Fill Slope	Retaining Wall	
All Landslides	2	3	1	0	∑ = 6 (100%)
Massive Failure (>500 m^3)	0	0	0	0	∑ = 0 (0%)
Major Failure (50 to 500 m^3)	0	0	0	0	∑ = 0 (0%)
Minor Failure (<50 m^3)	2	3	1	0	∑ = 6 (100%)

Table 11 - Breakdown of Annual Failure Rates on Engineered and Non-Engineered Slopes

	Failure Rate on a Slope Number Basis (Number of Landslides Divided by Total Number of Slopes)	Failure Rate on a Unit Area Basis (Surface Area of Landslides Divided by Total Slope Surface Area)	Failure Rate in Terms of Number of Landslides Divided by Total Slope Surface Area (no./m^2)
Registered Slopes with No Geotechnical Input (All Landslides Considered)	0.1 %	2.32×10^{-3} %	1.77×10^{-6}
Engineered Slopes Processed by the Slope Safety System (All Landslides Considered)	0.03%	0.08×10^{-3} %	0.17×10^{-6}
Registered Slopes with No Geotechnical Input (Sizeable Landslides Only)	0 %	0 %	0
Engineered Slopes Processed by the Slope Safety System (Sizeable Landslides Only)	0 %	0 %	0
Registered Slopes with No Geotechnical Input (Minor Landslides Only)	0.1 %	2.32×10^{-3} %	1.77×10^{-6}
Engineered Slopes Processed by the Slope Safety System (Minor Landslides Only)	0.03 %	0.08×10^{-3} %	0.17×10^{-6}

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Table 12 - Breakdown of Landslides on Slopes Previously Treated under the LPM Programme

	Soil Cut Slope	Rock Cut Slope	Fill Slope	Retaining Wall	
All Landslides	0	2	1	0	$\sum = 3$
Massive Failure (>500 m^3)	0	0	0	0	$\sum = 0$
Major Failure (50 to 500 m^3)	0	0	0	0	$\sum = 0$
Minor Failure (<50 m^3)	0	2	1	0	$\sum = 3$

Table 13 - Breakdown of Annual Failure Rates on Slopes Previously Treated under the LPM Programme

	Failure Rate on a Slope Number Basis (Number of Landslides Divided by Total Number of Slopes)	Failure Rate on a Unit Area Basis (Surface Area of Landslides Divided by Total Slope Surface Area)	Failure Rate in Terms of Number of Landslides Divided by Total Slope Surface Area (no./m^2)
Slopes Treated under LPM Programme (All Landslides Considered)	0.125 %	0.06×10^{-3} %	0.71×10^{-6}
Slopes Treated under LPM Programme (Sizeable Landslides Only)	0 %	0 %	0
Slopes Treated under LPM Programme (Minor Landslides Only)	0.125 %	0.06×10^{-3} %	0.71×10^{-6}

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Table 14 - Annual Success Rate of Engineered Slopes from 1997 to 2004

	Annual Success Rate on a Slope Number Basis, % (Number of Landslides Divided by Total Number of Slopes)							
	1997	1998	1999	2000	2001	2002	2003	2004
Engineered Slopes Processed by the Slope Safety System (Sizeable Landslides Only)	99.97	99.97	99.97	99.98	99.98	100	99.99	100
Engineered Slopes Processed by the Slope Safety System (Minor Landslides Only)	99.88	99.92	99.92	99.91	99.93	99.95	99.95	99.97

Table 15 - Breakdown of Key Contributory Factors in Landslides on Engineered Unsupported Soil Cut Slopes

	All Landslides (∑ = 1 No.)	Local Minor Failures (∑ = 1 No.)	Sizeable Failures (∑ = 0 No.)
Adverse Groundwater	0 (0%)	0 (0%)	0 (0%)
Adverse Geological Material	0 (0%)	0 (0%)	0 (0%)
Inadequate Slope Maintenance	1 (100%)	1 (100%)	0 (0%)
Note: A given landslide may be associated with more than one key contributory factors to the failure.			

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Table 16 - Summary of Annual Rainfall Recorded by the HKO at Tsim Sha Tsui and Number of Genuine Landslides Between 1997 and 2004

Year	Annual Rainfall at Tsim Sha Tsui (mm)	Number of Genuine Landslides
1997	3,343	559
1998	2,567	228
1999	2,129	402
2000	2,752	322
2001	3,092	214
2002	2,490	138
2003	1,942	201
2004	1,739	69

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Table 17 - Progress of Follow-up Actions on the Improvement Measures Recommended in the Review of 2003 Landslides

Recommended Improvement Measures	Progress
1. Carry out an overall review of recent landslides where inadequate surface drainage provisions were key contributory factors to the failures to identify areas for improvement.	Review completed. The findings of the review and areas requiring attention has been documented. The draft report has been circulated for comments and will be finalised in due course.
2. Carry out an overall review of recent landslides associated with bursting or leakage of water-carrying services to identify areas for improvement.	Review completed. The findings of the review and areas requiring attention has been documented as LSR 7/2005 published by the GEO.
3. Carry out API using low-level aerial photographs covering selected hillsides affecting the urban areas of Hong Kong to enhance the Natural Terrain Landslide Inventory	The exercise has been completed.
4. Review the current procedure and guidance in respect of follow-up actions on private slopes with signs of distress to identify areas for improvement.	The review has been completed and an improved procedure was promulgated.

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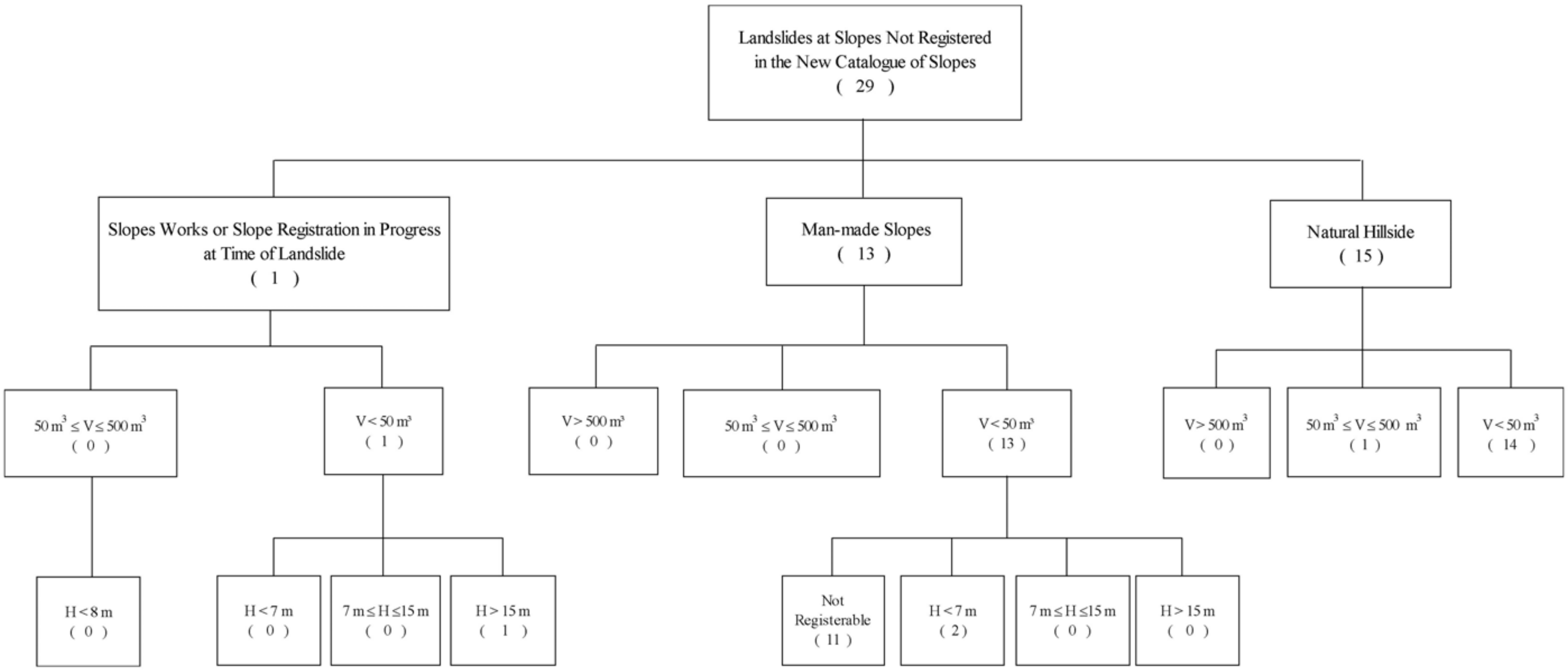

Legend:

V	Failure volume	H	Slope height in m	(2)	Number of cases = 2

Notes: (1) "Not Registerable" refers to cases involving slopes that do not satisfy the feature height criteria for registration in the New Catalogue of Slopes

(2) All Registerable slope features were registered in the New Catalogue of Slopes following the failures.

Figure 1 - Breakdown of Landslides at Unregistered Slopes in 2004

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GEO PUBLICATIONS AND ORDERING INFORMATION
土力工程處刊物及訂購資料

A selected list of major GEO publications is given in the next page. An up-to-date full list of GEO publications can be found at the CEDD Website http://www.cedd.gov.hk on the Internet under "Publications". Abstracts for the documents can also be found at the same website. Technical Guidance Notes are published on the CEDD Website from time to time to provide updates to GEO publications prior to their next revision.

部份土力工程處的主要刊物目錄刊載於下頁。而詳盡及最新的土力工程處刊物目錄，則登載於土木工程拓展署的互聯網網頁 http://www.cedd.gov.hk 的"刊物"版面之內。刊物的摘要及更新刊物內容的工程技術指引，亦可在這個網址找到。

Copies of GEO publications (except maps and other publications which are free of charge) can be purchased either by:

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土力工程處
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MAJOR GEOTECHNICAL ENGINEERING OFFICE PUBLICATIONS
土力工程處之主要刊物

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 300 p. (English Version), (Reprinted, 2000).

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1	Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2000).
Geoguide 2	Guide to Site Investigation (1987), 359 p. (Reprinted, 2000).
Geoguide 3	Guide to Rock and Soil Descriptions (1988), 186 p. (Reprinted, 2000).
Geoguide 4	Guide to Cavern Engineering (1992), 148 p. (Reprinted, 1998).
Geoguide 5	Guide to Slope Maintenance, 3rd Edition (2003), 132 p. (English Version).
岩土指南第五冊	斜坡維修指南，第三版(2003)，120頁(中文版)。
Geoguide 6	Guide to Reinforced Fill Structure and Slope Design (2002), 236 p.

GEOSPECS

Geospec 1	Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997).
Geospec 3	Model Specification for Soil Testing (2001), 340 p.

GEO PUBLICATIONS

GCO Publication No. 1/90	Review of Design Methods for Excavations (1990), 187 p. (Reprinted, 2002).
GEO Publication No. 1/93	Review of Granular and Geotextile Filters (1993), 141 p.
GEO Publication No. 1/2000	Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (2000), 146 p.
GEO Publication No. 1/2006	Foundation Design and Construction (2006), 376 p.

GEOLOGICAL PUBLICATIONS

The Quaternary Geology of Hong Kong, by J.A. Fyfe, R. Shaw, S.D.G. Campbell, K.W. Lai & P.A. Kirk (2000), 210 p. plus 6 maps.

The Pre-Quaternary Geology of Hong Kong, by R.J. Sewell, S.D.G. Campbell, C.J.N. Fletcher, K.W. Lai & P.A. Kirk (2000), 181 p. plus 4 maps.

TECHNICAL GUIDANCE NOTES

TGN 1	Technical Guidance Documents

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