REVIEW OF 1997 AND 1998 LANDSLIDES

GEO REPORT No. 107

H.N. Wong & K.K.S. Ho

GEOTECHNICAL ENGINEERING OFFICE
CIVIL ENGINEERING DEPARTMENT
THE GOVERNMENT OF THE HONG KONG
SPECIAL ADMINISTRATIVE REGION

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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. A charge is made to cover the cost of printing.

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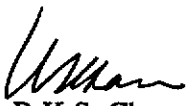

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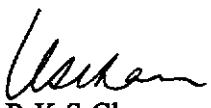
December 2000

FOREWORD

This report presents the findings of a detailed review of landslides that occurred in 1997 and 1998. It serves to audit the performance of Government's slope safety system and identify improvement to current slope engineering practice in Hong Kong.

The review was carried out by the Landslip Investigation Division of the Geotechnical Engineering Office with assistance provided by the 1997 and 1998 landslide investigation consultants.



R K S Chan

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ABSTRACT

This review aimed to audit the performance of Government's slope safety system and identify improvement to current slope engineering practice. It was carried out by the Geotechnical Engineering Office (GEO) of the Civil Engineering Department, as part of the landslide investigation initiative introduced following the 1994 Kwun Lung Lau landslide.

Nearly 800 landslides occurred in 1997 and 1998, all of which were reviewed. A total of 72 landslide incidents were selected for further study. These studies provided information and insight on the types and mechanisms of landslides in Hong Kong and permit diagnosis of areas requiring attention.

Based on the landslide data in 1997 and 1998, the average annual defect rate in terms of major failures (i.e. failure volume of 50 m^3 or above) at slopes that were processed by the slope safety system as being up to the required geotechnical standards is about 0.03%. These include slopes that were previously assessed, designed or upgraded to meet the required geotechnical standards. The corresponding average annual defect rate, based on the landslide data in 1997 and 1998, for slopes dealt with by the Landslip Preventive Measures (LPM) Programme is about 0.075%.

The average annual success rate against major failures on slopes processed by the slope safety system is greater than 99.9% for landslides in 1997 and 1998. Given that 1997 and 1998 were wetter than normal, the actual long-term annual success rate of the slope safety system will be greater than that assessed for 1997 and 1998.

Further improvement in the performance of the slope safety system can be achieved through measures to reduce non-compliances with the stipulated procedures and standards, adoption of more robust and reliable slope works, and enhancement of current slope engineering practice.

Recommendations for improving the performance of the slope safety system are given in the report.

CONTENTS

1. INTRODUCTION

This report presents the findings of a detailed review of landslides that occurred in 1997 and 1998. The review forms part of the Geotechnical Engineering Office (GEO)'s systematic landslide investigation (LI) initiative which was introduced following the 1994 Kwun Lung Lau landslide. This new initiative, which commenced in 1997, has two principal objectives:

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

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

Individual landslides were selected for study to identify lessons learnt and the necessary follow-up actions. This review examines all the landslide data and information from individual landslide studies to assess the overall performance of the slope safety system and identify areas requiring attention. The review has been carried out by the Landslip Investigation Division of the GEO, with assistance provided by the 1997 and 1998 LI consultants.

Arising from this review, recommendations on improvement to slope engineering practice in Hong Kong are made.

2. STUDIES OF INDIVIDUAL LANDSLIDES

A total of 559 and 228 'genuine' landslides (i.e. discounting non-landslide incidents, such as tree falls, flooding, etc.) was identified to have occurred in 1997 and 1998 respectively, making a sum total of 787 landslides in these two years (including those reported to the GEO and those identified separately by the LI consultants). The numbers of sizeable failures (i.e. with volume equal to or exceeding 50 m^3) that occurred in 1997 and 1998 are 60 and 26 respectively.

All the landslides were reviewed and additional data were collated to assess which incidents might warrant further study. Altogether 72 landslide incidents in 1997 and 1998 were selected for study. There are three types of landslide studies, namely:

(a) 'forensic study' of fatal or serious landslides (i.e. a study with the highest rigour of proof which can be presented as evidence in legal proceedings),

(b) 'detailed study' of significant landslides (i.e. an in-depth study of the history of the slope and causes of the failure), and

(c) 'initial study' of selected landslides (i.e. a study that focuses on certain aspects of the incident without the need for comprehensive documentation of all the details pertaining to the site and technical causes of the failure).

These individual landslide studies provided insight and valuable information on the types and mechanisms of landslides in Hong Kong, together with the necessary follow-up actions arising from each incident. The findings of the studies are documented in a series of Landslide Study Reports. Following each study, the key lessons learnt are identified and recommendations on site-specific and/or general follow-up actions are made, and action parties are agreed with GEO's senior management to implement the recommendations.

3. OVERALL LANDSLIDE REVIEW

3.1 Scope of Review

The review of the overall landslide data in 1997 and 1998 provided a global picture of the performance of the different types of slopes in Hong Kong and allowed a diagnosis of specific areas requiring attention.

The overall review has focused on the following key aspects:

(a) coverage of the New Catalogue of Slopes,

(b) failure rates of different types of catalogued slopes, and

(c) diagnosis of landslides on catalogued slopes which were previously processed by the slope safety system as being up to the required geotechnical standards.

3.2 Coverage of the New Catalogue of Slopes

3.2.1 General

All sizeable man-made slopes and retaining walls should be registered in the New Catalogue of Slopes, compiled under the 'Systematic Identification and Registration of Slopes in the Territory' (SIRST) project which was completed in September 1998. The criteria for features requiring registration are as follows:

(a) cut slopes, including any associated retaining walls, and retaining walls greater than 3 m high,

(b) fill slopes, including any associated retaining walls, greater than 5 m high,

(c) fill slopes, including any associated retaining walls, less than 5 m high, in Consequence-to-life Category 1 or 2, and

(d) disturbed terrain, which comprises a series of composite cut and/or fill slopes where the ground surface has been disturbed, the natural slope gradient is greater than 15° and although the individual slopes do not meet the height criteria for registration, the total height does meet the criteria for registration.

3.2.2 Diagnosis

In terms of the overall landslide data, about 37% (i.e. 296 out of 787) of the landslide incidents occurred on unregistered slope features at the time of their failure. A breakdown of these incidents is given in Figure 1.

Of these incidents, 85 cases involved small man-made slopes that do not satisfy the slope registration criteria, and 105 cases involved natural hillsides which will not be registered.

A total of 103 incidents involved registerable man-made slope features which were yet to be registered at the time of failure. Of the 103 incidents, four cases involved major failures. These affected an abandoned quarry, a squatter hut and two village access roads respectively.

The distribution of the volume of failure is summarised in Table 1.

3.2.3 Discussion

The coverage of the New Catalogue of Slopes has been assessed by reference to actual landslides which serves to give an indication of the scale of this aspect.

The diagnosis shows that the number of registerable slopes not yet identified by the SIRST project at the time of failures corresponds to a rate of about 13% for landslides in 1997 and 1998. The vast majority of these cases involved slope features of less than 7 m high and that there is a mechanism in place since November 1996 to arrange for subsequent registration of the concerned slope features following landslide incidents. None of the failures at such unregistered slope features in 1997 and 1998 resulted in serious consequences.

3.3 Failure Rates of Catalogued Slopes

3.3.1 General

The failure rates of the different types of slopes could be significantly affected by rainfall. Given that both 1997 and 1998 were wetter than average, the corresponding calculated failure rates will be on the high side compared to that for an average year.

The rates of landslides on catalogued slopes have been diagnosed in terms of the different types of slopes of different ages, viz. pre-1977 (i.e. formed or substantially modified before 1977), or post-1977 (i.e. formed or substantially modified after 1977).

The status of a slope has been distinguished as whether or not it has been processed by Government's slope safety system as being up to the required geotechnical standards. Slopes that were processed by the slope safety system as being up to the required geotechnical standards include the following:

(a) slopes formed after 1977 that are designed, and checked by the GEO as necessary, to the required geotechnical standards,

(b) slopes formed before 1977 that are subsequently assessed, and checked by the GEO as necessary, as being up to the required geotechnical standards, and

(c) slopes formed before 1977 that are subsequently upgraded, and checked by the GEO as necessary, to the required geotechnical standards.

The types of slope failures considered in the diagnosis are as follows:

(a) soil cut,

(b) rock cut, and

(c) fill slope/retaining wall.

The classification of the scale of failure is as follows:

(a) minor (failure volume < 50 m^3),

(b) major (failure volume of 50 to 500 m^3), and

(c) massive (failure volume > 500 m^3).

In the context of this review, failure volume refers to the sum total of volume of detached material and volume of any deformed material (which remains on the slope and has not displaced significantly).

3.3.2 Diagnosis

Of the 787 landslide incidents in 1997 and 1998, 491 occurred on catalogued slopes. Of these 491 landslides, 60 were sizeable (i.e. major or massive) failures.

Of the 491 landslides on catalogued slopes, 42 slopes were assessed to be features that were processed by the slope safety system as being up to the required geotechnical standards (see Section 3.4.1 below). The number of pre-1977 and post-1977 slopes in the New Catalogue of Slopes may be established approximately from the 'Systematic Identification of Features in the Territory' (SIFT) project (i.e. SIFT Classes A, B1 and C1 correspond to pre-1978 slopes, and SIFT Classes B2 and C2 correspond to post-1978 slopes). The SIFT

project, which forms part of the SIRST project, aims to search systematically for sizeable man-made slopes not previously registered in the 1977/78 Catalogue of Slopes and to update information on slopes already registered, based on studies of aerial photographs.

It should be noted that the SIFT project has adopted a slightly different 'cut-off' date of 1978 (i.e. 30.6.1978) as opposed to 1977. However, the differences in terms of the actual number of pre-1977 and post-1977 slopes assessed using the SIFT classes are not great. For the present review, a total of 37,000 pre-1977 slopes and 17,000 post-1977 slopes has been considered on the basis of the available data in the New Catalogue of Slopes.

The number of slopes which have been processed by the slope safety system as being up to the required geotechnical standards is less certain. The landslide data indicate that some of the post-1977 slopes could actually be not previously processed as being up to the required geotechnical standards because of absence of geotechnical design input and/or GEO checking (22 cases belong to this category in 1997 and 1998, see Section 3.5.7 below). However, some of the pre-1977 slopes could have been processed to be up to the required geotechnical standards bearing in mind past Stability Assessments may not have been identified or that upgrading works carried out may not necessarily have been picked up when the New Catalogue of Slopes was compiled.

Overall, it is considered reasonable as a starting point to make the broad assumption that the total number of pre-1977 slopes equate to the number of slopes that have not been processed as being up to the required geotechnical standards. A similar assumption is made for the relationship between post-1977 and slopes that have been processed as being up to the required geotechnical standards, for the purposes of calculating the overall failure rates of slopes based on the global landslide data.

Based on the above assumptions and the landslide data in 1997 and 1998, the assessed annual failure rates for different types of catalogued slopes are summarised in Table 2. The calculated failure rates are not sensitive to the assumptions made about the number of different slope types, given the likely order of uncertainty involved.

3.3.3 Discussion

Overall, the total number of landslides in 1997 and 1998 at registered slopes corresponds to an average annual failure rate of about 0.47% of features registered in the New Catalogue of Slopes.

R&D work is being carried out to see whether a methodology can be developed to correlate slope failure rate with rainfall.

3.4 Diagnosis of Landslides on Catalogued Slopes with Past Geotechnical Engineering Input

3.4.1 General

A review of the 1997 and 1998 landslides indicates that some of the incidents involved failure of slopes which have received input from a geotechnical engineer and been through the slope safety system. A meaningful diagnosis of this calls for detailed information on the

nature and causes of the landslides, together with the status and development history of the concerned slopes. The present assessment has been based on information from landslide studies, as well as a review of selected landslides where a follow-up study has not been carried out.

The list of slopes that have received input from a geotechnical engineer and been through the slope safety system is given in Table 3. A total of 42 incidents involved slopes which were processed by the slope safety system as being up to the required geotechnical standards, whilst three incidents involved slopes that had past input from a geotechnical engineer but they had not been accepted by the GEO checking system at the time of slope failure (i.e. there were major outstanding GEO comments). There are also a total of 22 incidents which involved post-1977 slopes but these cases could not be taken as having been processed to be up to the required geotechnical standards (see Section 3.5.7 below). Pertinent information on selected slopes is summarised in Table 4.

Slopes that were previously processed by the slope safety system as being up to the required geotechnical standards had sufficient information to permit a diagnosis of failures on this class of slopes. The status of these slopes has been assigned following the classification system shown in Table 5 which consider the following aspects:

(a) whether the slope was a newly-formed feature, or an existing feature which was previously subjected to upgrading works or Stability Assessments as being up to the required geotechnical standards,

(b) the mechanism under which slope upgrading works or Stability Assessments were carried out (e.g. via the LPM Programme, private owners, Government Departments or defaulted Dangerous Hillside Orders),

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

(d) whether site-specific ground investigation and laboratory testing was carried out, and

(e) whether the slope design or Stability Assessment was checked and accepted by the slope safety system, and whether there are outstanding GEO's comments on the submissions that were not satisfactorily addressed by the designers.

3.4.2 Diagnosis

The breakdown of the 42 incidents at slopes processed as being up to the required geotechnical standards with respect to the types of slopes (e.g. fill, soil cut or rock cut) and scale of failure is given in Table 6. It can be seen from Table 6 that 74% of these cases (i.e. 31 cases) involved minor failures whereas 17% involved massive failures.

Based on the 1997 and 1998 landslide data, the average failure rates for different classes of slopes can be deduced. It should be noted that the deduced failure rates are not necessarily the long-term average values given the uncertainties associated with the relatively short period of observation and that 1997 and 1998 were wetter than normal.

In terms of 1997 and 1998, the average annual failure rates are summarised as follows (see also Table 2):

(a) catalogued slopes not processed by the slope safety system as being up to the required geotechnical standards (all landslides) = 0.61%

(b) catalogued slopes processed by the slope safety system as being up to the required geotechnical standards (all landslides) = 0.12%,

(c) catalogued slopes not processed by the slope safety system as being up to the required geotechnical standards (major and massive landslides) = 0.064%, and

(d) catalogued slopes processed by the slope safety system as being up to the required geotechnical standards (major and massive landslides) = 0.032%.

Thus, the likelihood of failure of slopes processed by the slope safety system as being up to the required geotechnical standards is, on average, about five times less than that of slopes that had not been processed by the slope safety system as being up to the required geotechnical standards. In terms of sizeable landslides (i.e. major and massive failures), the likelihood of failure of slopes processed by the slope safety system as being up to the required geotechnical standards is, on average, about half of that for slopes that had not been processed by the slope safety system as being up to the required geotechnical standards.

It should be noted that the figure of 0.064% is the average value for major and massive failures on the 37,000 slopes not processed by the slope safety system as being up to the required geotechnical standards. However, many of the slopes are of relatively small size and the chance of a sizeable failure on these slopes is very small. Hence, the actual rate of sizeable failure on the more vulnerable population of slopes (i.e. slopes of relatively large size) will be much greater than 0.064%.

Of the 42 slopes processed by the slope safety system as being up to the required geotechnical standards, 15 were previously dealt with by the LPM Programme, three of which subsequently involved sizeable failures. The breakdown of landslides involving LPM slopes is shown in Table 7.

Given that about 2,000 slopes had been dealt with by the LPM Programme by the end of 1997, the average annual failure rates, based on 1997 and 1998 landslide data, are as follows:

(a) LPM slopes (all landslides) = 0.375%, and

(b) LPM slopes (major & massive landslides) = 0.075%.

It may be noted from the above diagnosis that in 1997 and 1998, the average failure rates of LPM slopes are higher than the average failure rate of slopes processed by the slope safety system as being up to the required geotechnical standards. This could partly be related to the fact that the LPM Programme tends to tackle more difficult sites involving large slopes, usually with complex ground conditions. However, caution needs to be exercised because small numbers are being compared particularly in the case of sizeable failures and the above should only be taken as indicative only.

The above diagnosis highlights the need to improve current slope engineering practice in order to further reduce the failure rate of slopes processed by the slope safety system as being up to the required geotechnical standards. There is currently insufficient data in the database to compare the relative failure rates of slopes formed or upgraded during different periods. The design process and practice in the early years of setting up the slope safety system may not have been sufficiently robust and could have resulted in premature 'sign-off' of slopes as being up to the required geotechnical standards. Given this and the possibility of deterioration of the overall slope condition, slopes processed in the early years, particularly those formed in the period 1977 to 1979, constitute a target group of slopes that deserves attention. This is now considered in the selection of slopes for action under the LPM Programme.

Analysis of the 1997 and 1998 landslide data has identified a total of 22 'post-1977' slopes which cannot be regarded as having been processed by the slope safety system as being up to the required geotechnical standards (Table 3). These comprise:

(a) three slopes with major outstanding GEO comments that had not been resolved by the designers, and

(b) 19 slopes with no evidence of design submission to GEO for checking, three of which were unauthorized constructions.

Of the three slopes in item (a) above, two involved a massive failure. Of the three unauthorized constructions in item (b) above, one involved a massive failure and the other two involved major failures.

For the slopes under category (b) above, the post-1977 status of 14 out of the 19 slopes was deduced from aerial photographs and, as such, some of them could have involved slope modification works comprising urgent repairs to landslides, which should not be regarded as being up to the required geotechnical standards in terms of long-term stability. There is a need to pick up these cases for follow-up action during the review of past stability assessment as part of the Engineer Inspection (EI) for maintenance.

3.5 Technical Assessment

3.5.1 Slope Deformation without Full Detachment of Debris

The large majority of landslides in Hong Kong are shallow failures and reportedly occur with little or no prior warning at or around peak rainfall intensity. However, the 1997

and 1998 landslide data have shown that some of the instabilities involved slope deformation, as evidenced by signs of distress, such as extensive tension cracking, without complete detachment of the unstable mass from the slip surface. The localised detachment that occurred from part of the unstable mass could involve a volume of detached material ranging from a small to significant scale. A proportion of these cases is characterised by deep-seated movement of a large volume of material in a deeply-weathered profile, although the same phenomenon has also been observed on fill slopes. Some of the cases have also exhibited signs of prolonged slope movement.

Altogether there are a total of 17 known cases (i.e. 2.1% of the total number of landslides of 787) involving significant slope deformation without complete detachment, of which five had major local detachment (i.e. about 6% of all the major and massive failures in 1997 and 1998) and the remaining 12 cases involved minor detachment (i.e. 1.7% of all the minor failures).

Of the 17 cases, at least six had observable evidence of slope deformation occurring for some time (e.g. several months or years), with deterioration of the unstable ground mass being a key contributory factor to the failure.

Seven of the 17 cases involved slopes processed by the slope safety system as being up to the required geotechnical standards (i.e. 17% of the total number of failures involving slopes previously processed as being up to the required geotechnical standards), whereas the other ten cases involved slopes not previously processed by the slope safety system as being up to the required geotechnical standards (i.e. 1.3% of the total number of failures not involving slopes in the former class). Six of the 17 cases involved fill slopes and 11 involved soil cut slopes. There were no data for rock cut slopes.

Based on the available data, the classes of slope failures that are more likely to exhibit such characteristics of incomplete detachment of deformed material are summarised below:

(a) incidents with major failures (viz. detachments) appear to be more likely to involve some deformed ground remaining on the slope compared to cases with minor detachments (by a factor of about 3.5),

(b) where a landslide occurs at a slope that has been processed as being up to the required geotechnical standards, then the chance that the landslide involves incomplete detachment of deformed material is higher than that if it occurs at a slope that has not been processed as being up to the required geotechnical standards (by a factor of about 13), and

(c) failure of fill slopes appear to be more likely to involve some deformed ground remaining on the slope compared to soil cut slopes (by a factor of about 1.8, but the relatively small sample size of fill slope failures should be noted).

The practical significance of the above observations are as follows:

(a) care should be taken in confirming the absence of signs of distress or slope deformation during landslide and maintenance inspections, and

(b) slopes with prior significant movements are liable to deteriorate as any unstable ground mass continues to open up without full detachment (e.g. during a severe rainstorm) and could fail in subsequent less severe rainstorms, giving rise to landslides that are a 'surprise' in that the slopes apparently survived more severe rainstorms. Given continued deterioration, slope instability may change from a 'ductile' mode to a 'brittle' detachment mode, particularly where there is water ingress into ground which has opened up significantly.

It should be qualified that the above sample of 17 cases was somewhat biased in that incidents with deformed volumes being significantly greater than the detached volumes tend to get selected for study. As a result, the estimated proportion of cases involving incomplete detachment is on the low side, since cases involving deformed volumes that are comparable to the detached volumes were not selected for study.

3.5.2 Severity of Rainstorms that Triggered Landslides

Of the 1997 and 1998 failures involving slopes processed by the slope safety system as being up to the required geotechnical standards, 18 incidents had sufficient information on the severity of the rainstorm that triggered the landslide (Table 4). Altogether 11 of the 18 incidents occurred during unprecedented rainstorms, whilst the remaining seven cases failed during rainstorms which were less severe than those experienced in the past according to automatic raingauges installed since about the mid-1980's.

For the above latter category of 'surprise' failures, deterioration of the slope condition may have played a role in those cases where there were no obvious changes in environmental factors and where contribution from inadequate slope maintenance was judged to be probably minimal. Another possible reason could be slope deformation caused by previous severe rainstorms which could have resulted in cracking and opening up of the ground, with subsequent failures occurring in less severe rainstorms.

The above diagnosis suggests that the proposition that the continued stability of an existing slope may be proven by having been tested by past rainstorms should be treated with extreme caution. Before one could confidently count on past performance regarding the margin of safety for long-term stability, there is a need to consider factors such as slope deterioration, deformation and possible changes in environmental factors.

3.5.3 Landslides at Slopes with Past Instability

Of the four massive landslides at soil cut slopes previously processed as being up to the required geotechnical standards, three (i.e. Ching Cheung Road, Ville de Cascade and Pak

Kong) had relict massive failures. Of the 11 massive landslides at 'pre-GEO' catalogued soil cut slopes, two (i.e. Shing Mun Tunnel Road and Fei Ngo Shan) had relict massive failures. Thus, there is a significant percentage of massive landslides on soil cut slopes with relict massive failures.

Of the above five (i.e. 3 + 2) massive landslides, information from documentary records on the past large-scale failures varied in detail but more details on the history of failures could be observed in aerial photographs, either as the only source of reference or to provide useful supplementary information.

Of the 42 slopes processed by the slope safety system as being up to the required geotechnical standards, a total of 29 cases contained information on whether the slope had subsequently suffered instability. Altogether 18 of these 29 cases have previously failed after being processed as being up to the required geotechnical standards, two of which were major failures and 16 were minor failures. Of these 18 cases, information on the previous failures for seven of them was obtained from aerial photographs only but there were no other documentary records of such instabilities.

The above diagnosis has reinforced the following key messages:

(a) consideration of past instability, particularly relict massive landslides, is important in slope assessment and design,

(b) a detailed API can provide useful information about past slope performance that cannot otherwise be obtained from documentary records, and

(c) consideration of past slope performance is important in EI because this will assist to pick up cases with inherent design or construction defects and facilitate review of the adequacy of past stability assessment.

3.5.4 Landslides at Fill Slopes Previously Processed As Being up to the Required Geotechnical Standards

A total of five fill slopes previously processed as being up to the required geotechnical standards (Table 4) has been studied in sufficient detail to provide some insight on the principal causes of failure. Of the five cases, two (one of which was massive) involved poor detailing, two involved non-compliance with standards (i.e. slopes not constructed in accordance with the design requirements) and one massive failure involved leaky water-carrying services. There are generally less uncertainties with respect to groundwater and materials in fill slopes that were processed by the slope safety system as being up to the required geotechnical standards than in cut slopes of the same status formed in natural materials, provided the fill slopes have been properly detailed and constructed.

To further reduce the rate of failure at fill slopes processed by the slope safety system as being up to the required geotechnical standards would call for improvement in detailing and construction control.

3.5.5 Landslides at Rock Cut Slopes Previously Processed As Being up to the Required Geotechnical Standards

All the 12 rock cut slopes under the above category involved failure volume of less than 50 m^3, nine of which had a failure volume of less than 3 m^3. The instabilities were generally caused by local groundwater and local adverse or open jointing in the rock mass which may not have been adequately considered in the design. Also, rock slopes can be vulnerable to local deterioration, bearing in mind most rock slopes are not provided with a surface cover.

The occurrence of minor failures arising from local adverse groundwater regimes and defects in the rock mass, possibly exacerbated by deterioration, is very difficult to confidently guard against in design assessment. It should be noted that in the case of rock cut slopes, small dislodgement could potentially result in more serious consequences compared to a similar failure at a soil cut or fill slope. This points to the need for improved detailing and protective measures in the design, such as rock debris traps, meshing, toe barriers, buffer zones, etc. to cater for such localised detachments.

3.5.6 Landslides at Soil Cut Slopes Previously Processed As Being up to the Required Geotechnical Standards

Of the 25 landslides at soil cut slopes previously processed as being up to the required geotechnical standards, 18 were studied in sufficient detail to enable a diagnosis of the problems involved.

Of the 18 cases, the breakdown of key contributory factors to the failures is as follows:

(a) 13 cases involved more adverse groundwater conditions than that allowed for in the design,

(b) 5 cases involved more adverse geological material than that allowed for in the design, and

(c) 7 cases involved inadequate slope maintenance.

A detailed breakdown of the key contributory factors together with the mode and scale of failure is shown in Table 8. It can be seen from Table 8 that inadequate slope maintenance was a key factor for small failures.

Of the 13 cases with groundwater problems, at least 8 (i.e. 62%) involved subsurface seepage and possible perching within the near-surface materials resulting from direct infiltration through the slope face or slope crest area. Transient elevated groundwater pressure may build up at the interface of colluvium and insitu material, at the soil/rock interface, or within a relict-jointed weathering profile where groundwater flow is significantly affected by the infilled discontinuities. The other five cases with groundwater problems involved development of cleft water pressures in open joints, or the build-up of groundwater levels at depth within the body of the slope, as a result of subsurface drainage concentration, such as streamcourse or variations in the rockhead profile.

As can be seen from Table 4, 13 out of 18 landslides (i.e. about 70%) on soil cut slopes processed as being up to the required geotechnical standards involved localised failures that were controlled mainly by the local geological and groundwater conditions. This gives an indication of the 'defect' rate (about 0.15%) associated with such localised failures given the current state-of-practice in Hong Kong. The data emphasize the need for improved detailing and protective measures in order to further reduce the failure rate.

The other 30% of the landslides at soil cut slopes previously processed as being up to the required geotechnical standards involving major or massive failures occurred at difficult sites with complex geology and/or groundwater conditions. A preliminary appraisal of the landslide data points to a number of possible indicators of potentially difficult sites, including:

(a) sites with relict massive or major failures (particularly in the case of cut slopes),

(b) evidence of high groundwater, or high level seepages, associated with drainage valleys, subsurface drainage concentration (e.g. depression in rockhead profile), dyke or persistent infilled subvertical discontinuities),

(c) planar geological features (such as joints, faults, bedding, foliation, planar soil-rock interface), especially where they are dipping out of the slope, laterally persistent, showing evidence of previous movement, associated with zones of weak materials such as kaolin, and affecting groundwater flow,

(d) evidence of signs of distress, such as significant slope deformation without complete detachment which may or may not have occurred for some time,

(e) slopes with a history of failure after being processed by the slope safety system as being up to the required geotechnical standards,

(f) complex groundwater conditions with a significant storm response or delayed response, and

(g) large cuttings in a deep weathering profile.

It is noteworthy that none of the failures of slopes previously processed as being up to the required geotechnical standards involved soil nailed slopes. This highlights the usefulness of more robust and reliable solutions, such as soil nails as opposed to cutting back, which would be less sensitive to local variations in ground conditions and better able to cope with unforeseen adverse ground conditions. It would be prudent to continue to review the performance of soil-nailed slopes to confirm their satisfactory performance.

The above diagnosis indicates that the vast majority of the slopes previously processed as being up to the required geotechnical standards performed satisfactorily in 1997 and 1998.

To further reduce the failure rate, particularly in respect of sizeable failures at difficult sites, would call for enhanced geological input, more robust slope design solutions and improved slope engineering practice.

3.5.7 Landslides at Post-1977 Slopes Which Have Not Been Processed As Being up to the Required Geotechnical Standards

An effective system of geotechnical control was introduced in 1977 following the establishment of the GEO. In principle, the status of post-1977 slopes should be such that they are up to the required geotechnical standards. However, the 1997 and 1998 landslide data have revealed that this is not necessarily the case in practice.

Of the 22 cases involving landslides at post-1977 slopes that cannot be taken to have been processed by the slope safety system as being up to the required geotechnical standards, a total of six had major or massive failures. Of these six cases, three involved unauthorized fill slopes or retaining walls, and the other three involved soil cut slopes, of which two had major outstanding GEO comments and the other one involved a New Territories Exempted House (NTEH) built after 1977 and before geotechnical control of sizeable NTEH slopes was implemented in 1987.

Discounting the three illegal slope features and the case involving an NTEH slope mentioned above, among the other 18 cases of post-1977 slopes, two had no design submissions made to the GEO, and three had major outstanding GEO comments (two of which subsequently had massive failures). The remaining 13 landslides involved cases either with no design input confirmed (three cases), or possibly no design input at all (10 cases).

Of the nine cases with either major outstanding GEO comments or no evidence of design input (including the three unauthorized constructions), six of them involved Government slopes.

It is of interest to note that one of the incidents which was classified as a slope processed by the slope safety system as being up to the required geotechnical standards (i.e. with geotechnical design input and checking by the GEO) involved slope works that did not comply with the approved drawings (i.e. failure occurred at a portion of slope which was not cut back as per the approved design). This deficiency came to light as a result of the landslide study.

It should be noted that these post-1977 slopes will not necessarily get selected for inclusion into the LPM Programme because there are no New Priority Classification System (NPCS) scores for priority ranking. In this regard, EI serves an important role in identifying such cases with deficiencies, through the review of past Stability Assessments, to determine the appropriate follow-up actions. It is therefore essential that EI's are carried out in a sufficiently rigorous manner in order to serve the intended purposes.

4. PROPOSED IMPROVEMENT MEASURES

4.1 Technical Improvement Measures

The following technical improvement measures are proposed:

(a) To develop and promote the use of improved detailing and protective measures (e.g. improved surface protection system and drainage provisions, barriers, buffer zones, etc.) in slope works in order to reduce the risk of localised failures.

(b) To enhance the reliability of slope assessment and improvement works by attending to the following:

(i) A comprehensive API report should be prepared to establish the history and nature of any past failures that may affect the slope feature. Past slope performance must be duly taken into account in the design of ground investigation and slope improvement works, and in Stability Assessments.

(ii) In assessing the design option to be adopted, the reliability and the robust nature of the design scheme should be considered, taking into account sensitivity of the option to the uncertainties involved. This assessment should be included as part of the design documentation.

(iii) The findings of verification of the design geological model during slope works should be incorporated as part of the as-built records. These, together with a schedule of key geotechnical design assumptions, should be included in the Maintenance Manual for future reference.

(iv) A post-construction review of the adequacy of design assumptions and slope performance should be carried out by the designer during the Contract Maintenance Period.

4.2 Administrative Improvement Measures

The following administrative improvement measures are proposed:

(a) To review the need for, and practicality of, introducing a slope certification system in the public works checking process.

(b) To improve the practice of EI by Government Departments via the following:

(i) The model EI brief should be expanded to include additional guidance and more stringent requirements to ensure that they are carried out in a suitably rigorous manner:

- completing a checklist on background information search to establish the full history of the slope, including past studies and Stability Assessments,

- updating key slope data (e.g. details of repair works carried out to landslides, details of preventive maintenance works carried out, unregistered slopes that satisfy the registration criteria, unauthorized geotechnical constructions, key information on slope feature as contained in the Catalogue for Slopes, etc.),

- review of adequacy of past Stability Assessments, including checking the compliance of the constructed works with the design,

(ii) An out-of-turn EI should be carried out in case of occurrence of landslides and report of significant signs of distress or new or increased seepage.

(iii) Introduce a procedure to facilitate timely feedback of relevant EI findings to update the Slope Information System (e.g. slope data, consequence category, Stability Assessments carried out, etc.).

(c) To examine the practicality of extending the scope of GEO's Maintenance Audit to include technical audit of the quality of EI procured by Government Departments.

5. CONCLUSIONS

Based on a detailed review of the landslides in 1997 and 1998, the following conclusions are made in respect of the performance of Government's slope safety system:

(a) The average annual 'defect' rate of major failures of slopes processed by the slope safety system as being up to the required geotechnical standards is about 0.03% for landslides in 1997 and 1998. The average annual 'defect' rate of major failures of slopes dealt with by the LPM Programme is about 0.075%.

(b) The annual success rate of slopes processed by the slope safety system as being up to the required geotechnical standards against major failures is more than 99.9% for landslides in 1997 and 1998. Given that 1997 and 1998 were wetter than normal, the actual long-term annual success rate of the slope safety system will be greater than that assessed for 1997 and 1998.

(c) Slopes processed by the slope safety system in the early years form a target group that deserves attention. This is because of the possibility of slope deterioration and the need to review whether more reliable and robust design schemes which have been developed in recent years are warranted. Such schemes (e.g. soil nails) have proved to be less sensitive to local variations in ground conditions and better able to cope with unforeseen adverse ground conditions than the traditional approach of cutting back the slopes without the use of support measures.

(d) Improvement in the performance of the slope safety system can be achieved through measures to reduce non-compliances with the stipulated procedures and standards, increased reliability of slope works and enhancement of current slope engineering practice. Areas requiring attention, and recommendations for improving the performance of the slope safety system, are summarised in Table 9.

LIST OF TABLES

Table 1 - Breakdown of Scale of Failure at Different Classes of Slopes

	No. of Minor Failure ($< 50\ m^3$)	No. of Major Failure (50 to $500\ m^3$)	No. of Massive Failure ($> 500\ m^3$)	
Registered man-made slopes	431	39	21	$\Sigma = 491$
Small unregisterable man-made slopes	85	0	0	$\Sigma = 85$
Registerable man-made slopes not registered at time of landslide	99	7	0	$\Sigma = 106$
Natural hillside	86	12	7	$\Sigma = 105$
	$\Sigma = 701$	$\Sigma = 58$	$\Sigma = 28$	

Table 2 - Annual Failure Rates of Catalogued Slopes Based on 1997 and 1998 Landslides

	Slopes Not Processed by the Slope Safety System As Being up to the Required Geotechnical Standards			Slopes Processed by the Slope Safety System As Being up to the Required Geotechnical Standards		
	Fill/Retaining Wall	Soil/Rock Cut	Overall	Fill/Retaining Wall	Soil/Rock Cut	Overall
Number of landslides in 1997 and 1998	46	403	449	5	37	42
Number of minor landslides in 1997 and 1998	34	368	402	2	29	31
Number of slopes	12,566	24,434	37,000	8,217	8,783	17,000
Average Annual Failure Rates (all landslides)	0.18%	0.82%	0.61%	0.03%	0.21%	0.12%

Table 3 - Landslip Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System As Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 1 of 5)

1. Slopes Upgraded under LPM

Slope No.	Incident No.	Location	Remarks
11NW-A/C55	MW97/7/70	Ching Cheung Road	88/89 LPM Programme
11NW-A/F16	MW98/6/4	Lai Yiu Estate	Works completed in Feb 1998. Failure during maintenance period.
11NE-D/F10	Report of seepage from slope	Hiu Kwong Street	LPM works completed in 1979. Signs of distress and significant seepage observed at slope.
7NW-B/C372 (formerly 7NW-B/CR27)	ME97/8/3	Kam Shan Terrace	LPM works completed in 1993
11NW-A/C78	MW97/6/21	Kwai Chung Road	LPM works completed in 1987
11NW-A/C79	MW97/5/6	Kwai Chung Road	LPM works completed in 1987
6SW-D/C282 (formerly 6SW-D/C9)	MW97/8/11	Hong Fai Road	LPM works completed in 1990
7SW-C/C300	MW97/12/2	Lo Wai Public School	LPM works completed in 1988
11SE-D/C49	HK97/5/4	Wan Tsui Road	LPM works completed in 1984
11NW-A/C56	Incident in 1997 - No Incident Report	Ching Cheung Road	LPM works completed in 1992
11NW-A/C56	MW98/6/5	Ching Cheung Road	LPM works completed in 1992
11SE-B/C87	HK98/9/1	A Kung Ngam Road	LPM works completed in 1985
7SW-C/C263	MW98/9/2	Ham Tin Tsuen	LPM works completed in 1987

2. Slopes Assessed by LPM and No Upgrading Works Required

Slope No.	Incident No.	Location	Remarks
11SW-C/C202	HK98/6/1	Mount Davies Road	Advisory Letter issued in 1989 and complied with by owner.
11SE-A/C15	HK97/3/1	King's Road below 39A Tin Hau Temple Road	The portion that failed was assessed by LPM Stage 3 study in 1986 as being up to the required geotechnical standards.

Table 3 - Landslip Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System As Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 2 of 5)

3. Slopes Assessed by Old Studies (e.g. Planning Division Stage 1 Study, B&P Phase II Study, etc.) and No Upgrading Works or Further Study Required

Slope No.	Incident No.	Location	Remarks
11SW-A/C718	Incident in 1998 (volume 10 m^3)	Kennedy Town Service Reservoir	B&P Phase IID found FOS > 1.4.
11NE-A/C21	K98/6/13	Fung Wong Reservoir	Failure occurred in the part of slope concluded to be up to standard. Remaining parts of slope which did not fail were upgraded under LPM.
11SW-B/CR183	HK98/6/7	Bowen Road	Planning Division Stage 1 Study

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

Slope No.	Incident No.	Location	Remarks
7NE-C/C95	ME97/7/1	Lai Ping Road	This is a special case - upgrading proposals by consultants (approved by GEO in 1997) did not address the deep-seated instability mode that occurred.
11NW-B/C37	MW98/6/10	United Christian College, Tong Yam Street	B&P Phase IID Study recommended upgrading works. Independent assessment by GEO District Division in 1984 concluded slope was up to standard.

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

Slope No.	Incident No.	Location	Remarks
11NW-A/R6 & 11NW-A/R12	MW97/6/30	Behind 2 & 3 Chung Shan Terrace	Assessed to be adequately stable and approved by GEO in 1993.

Table 3 - Landslip Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System As Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 3 of 5)

6. Post-1977 Slopes Formed or Upgraded by Government Departments, and Checked by GEO

Slope No.	Incident No.	Location	Remarks
8SW-C/C3	ME97/7/6	Hong Tsuen Road, Sai Kung	Slope formed in late 1970's and approved in 1982.
8SW-C/CR17 (formerly 8SW-C/C175)	ME97/7/15	Pak Kong Water Treatment Plant	Slope upgraded in 1995/6 following study of failure of newly-formed slope by Professor Vaughan.
7SW-B/C123	ME97/7/42	Shatin College	Slope modified in late 1970/early 1980 and accepted by GEO in 1983.
Slope works completed at time of failure. Slope being registered.	MW98/5/2	Junction of Ting Kau Bridge and Tuen Mun Road	Slope works completed in 1996. Failure occurred during maintenance period. In-principle check by GEO and detailed checking by Independent Checking Engineer.
11NW-A/C150	MW97/6/31	Lai King Hill Road	Modified as part of road project and submission approved by GEO in 1986.
11SW-D/CR227	HK98/5/2	Hong Kong Stadium	Failure in area which was not cut back in accordance with the approved design.
7SW-D/C235	MW97/6/60	King Tin Court, Tai Wai	Design submission approved by GEO in early 1980's.
7SW-D/C235	MW98/6/7	King Tin Court, Tai Wai	Ditto
11SW-D/C1840 (formerly 11SW-D/C126)	HK97/8/15	48 Deep Water Bay Road	Design submission approved by GEO in early 1980's.
11NW-A/C7	MW97/6/41	Lai Cho Road	Design submission approved by GEO in mid-1980's.
11NW-A/C152	MW98/10/2	Ha Kwai Chung Tsuen Resite Village	Design submission approved by GEO in 1987.
11NE-C/C191	K98/6/3	Choi Ha Road	Design by Advisory Division for HyD and approved by District Division in 1991.
Slope works completed at time of failure. Slope being registered.	K98/4/1	Po Lam Road	Design submission relating to reinforced fill embankments checked by GEO in 1994/5.

Table 3 - Landslip Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System As Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 4 of 5)

7. Post-1977 Slopes Formed or Upgraded by Private Owners, and Checked by GEO

Slope No.	Incident No.	Location	Remarks
11NW-A/CR261	MW97/6/20	Chung Shan Terrace	Upgrading works approved by GEO in 1988.
6SE-D/C304	MW98/6/9	Sunny Villa, Castle Peak Road	Slope formation works approved by GEO in 1979.
6SE-D/C301	MW97/5/7	Hanley Villa, Yau Kom Tau	Slope formation works approved by GEO in 1989.
7NE-D/F99	ME97/8/16	Li Po Chun United World College	New slope formation approved by GEO in 1995.
7NE-C/C106	ME97/7/29	KCRC, near University Station	Upgraded in 1991 following detailed study in 1987. No submission made to GEO for checking. Planning Division Stage 1 study deleted in 1988 as a result of the above study.
11NE-A/C69	K97/8/1	St Joseph Anglo Primary School	Assessed to be adequately stable and approved by GEO in mid-1980s.
11SE-A/C179	HK97/8/4	121 Quarry Bay Street	Works carried out by owners as required by Advisory Letter were designed by consultants and accepted by GCB.
11SE-A/CR43	HK98/7/3	Tin Hau Temple Road	DHO served in 1983 and upgrading proposals approved by GEO in 1984.

8. Pre-1977 Slopes Assessed and No Upgrading Works Required, with Outstanding District Comments

Nil

9. Post-1977 Slopes with Outstanding GEO Comments on Geotechnical Submissions

Slope No.	Incident No.	Location	Remarks
7SW-D/C292	MW97/7/66	Shing Mun Tunnel Road	Slope formed by HyD in 1989/1990.
Slope works completed at time of failure. Slope being registered.	MW98/6/11	Tai Po Road near Chek On Estate	Active road project site - slope formed in 1996/7.
13NE-A/C132	MW98/6/1 & MW98/6/2	South Lantau Road	Slope formed by HyD in late 1970's/early 1980's.

Table 3 - Landslip Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System As Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 5 of 5)

10. Post-1977 Slopes with No Evidence of Design Submission and GEO Checking

Slope No.	Incident No.	Location	Remarks
7SW-B/R50 & 7SW-B/R51	ME97/7/5	Tao Fung Shan	Illegal construction of retaining walls in the late 1980's.
11NE-D/F284	ME98/6/10	Au Tau Village Road	Illegal dumping of fill between 1976 and 1991.
5SE-D/F17	MW98/6/12	PFA fill slope, Siu Lang Shui	Illegal dumping of PFA fill by a STT in the 1980's and 1990's.
7SE-A/CR375	No Incident Report	Ha Wo Che	Slope formed between 1981 and 1983. No geotechnical submission made because feature was considered by DLO to be an NT exempted structure.
11NW-B/C339	MW97/6/13	Tai Po Road near Kowloon Reservoir	Slope modified between 1986 & 1988 as part of road project.
7SE-D/C215	ME97/6/7	Venice Villa, Ho Chung	Formed as part of housing development in 1988 (limited submission made after construction but no evidence of formal approval by GEO).
3SW-D/C149	ME97/12/2	Sha Lo Tung, Tai Po	SIFT indicates formation between 1978 and 1980, and enlarged again in 1984.
7SW-D/C23	MW97/7/89	Lower Shing Mun Road, Shatin	SIFT indicates construction between 1980 and 1984.
7SW-D/C565	MW97/6/59	Lion Rock Tunnel Road	SIFT indicates construction between 1977 and 1981. Slope was not included in submission made by HyD after construction.
7SW-D/C247	MW97/8/5	Chik Wan Road, Tai Wai	SIFT indicates construction between 1978 and 1980.
3NE-C/C118	ME97/7/96	Luk Keng Road	SIFT indicates modification between 1986 and 1996.
7NW-B/CR418	ME97/8/8	House 204A, Pan Chung, Tai Po	SIFT indicates construction of retaining wall in 1977-1982.
11NE-D/C515	ME97/5/17	Yau Yue Wan Village, Tseung Kwan O	SIFT indicates construction in progress in 1986.
11SE-D/C285	HK97/8/3	Shau Kei Wan Fire Station	Feature formed in 1985. Information on design submission and checking could not be located.
7NW-B/C177	ME97/7/87	Ting Kok Road	SIFT indicates construction between 1981 and 1984.
12NW-C/C96	ME97/8/15	Clear Water Bay Road	SIFT indicates periodic modification until 1984. Surface: Bare Slope Surface
7NW-B/C242	ME98/6/38	Wun Yin Ha Tsuen, Tai Po	SIFT indicates slope formed in 1988-1989.
8SW-B/C152	ME98/6/77	Wong Keng Tei, Sai Kung	SIFT indicates slope constructed between 1988 and 1991.
9SW-D/C139	MW98/7/3	Sham Wat Road	Road upgraded in 1987 but no clear evidence of sign-off by GEO.

Notes: (1) Slopes in categories 1 to 8 are classified as features processed by the slope safety system as being up to the required geotechnical standards.

(2) Slopes in categories 9 and 10 are post-1977 slopes that cannot be taken as having been processed by the slope safety system as being up to the required geotechnical standards.

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 1 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
7.7.1997 Ching Cheung Road (LS)	Processed as being up to required standards (1: LPM upgraded for 5yr) (1ASY)	Y	N	Y	Y	Y (Minor)	N	Sig	0	0	Minor	N	N	Y	N	500	4,700	Massive failure (soil cut) Surface: Vegetation
17.7.1997 Ching Cheung Road (LS)		N	Y													700	4,000	Further detachment from deformed ground (soil cut) Surface: Vegetation
3.8.1997 Ching Cheung Road (LS)		N	Y													2,000	2,000	
2.7.1997 KCRC University Station (LS)	Processed as being up to required standards (10: KCRC upgraded for 6 yr) (1NTN)	N (2-3 yr)	Po	N	N	N	Y (Minor)	Sig	Minor	0	0	N	N	N (not explicitly required)	N	30	0	Local minor failure (soil cut) Surface: Chunam Cover
2.7.1997 Tao Fung Shan (B) (LS)	Post-1977 (10: illegal-formed for 7 yr) (1NUN)	N (32 yr)	N	N	N	N	N	N/A	N/A	Sig (no formal design)	Minor	N/A	N	N	Y	400	0	Major failure (fill slope and retaining wall). Unauthorized formation without formal design. Surface: Chunam Cover & Vegetation

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 2 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
9.6.1998 Tai Po Road near Chek On Estate (LS)	Post-1977 (9: HyD development formed for 0.5 yr) (1NSN)	N (10 yr; 1st wet season)	N	N	N (slope newly formed)	N	N (slope newly formed)	Mod	Sig	0	0	N	Major	Y	N	5	1,400	Massive failure (soil cut) Surface: Hydroseeding
8.5.1997 Wonderland Villas (LS)	Processed as being up to required standards hillside (5: Private assessed for 13 yr) (2CSY)	Y (12 yr; worst since gauge installed in 1978)	Po	N	N	N	N (minor at adjacent hillside)	Sig	0	0	0	N	N	Y	N	80	0	Local major failure (hillside) Surface: Natural Dense Vegetation
27.4.1998 Po Lam Road Platform (LS)	Processed as being up to required standards (6: HD development formed for 1.5 yr) (1NSY)	N (< 1 yr; 1st wet season)	N	N	N	N	N	0	0	0	0	Y	N	Y	N	20	0	Works non-conforming to design (fill slope). Detailed check by Independent Checking Engineer. Surface: Stone-pitching
4.6.1997 Lai Cho Road (LS)	Processed as being up to required standards (6: NTDD upgraded for 9 yr) (1BSY)	Y (51 yr)	N	N	N	N	N	Sig	Minor	0	0	N	N	Y	N	33	0	Local minor failure (soil cut) Surface: Vegetation
3.8.1997 St Joseph Anglo Chinese School, Ngau Tau Kok (LS)	Processed as being up to required standards (7: Private upgraded 12 yr) (1CSY)	N (1-2 yr)	Po	N	N	N	N (past failure may be inferred from field inspection)	0	Sig (old scar)	0	Mod	N	N	Y	N	25	0	Local minor failure (soil cut) Surface: Rubble Stone Facing

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 3 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
8.5.1997 Kwai Chung Road (A) (LS)	Processed as being up to required standards (1: LPM upgraded for 10 yr) (1ATY)	Y (40 yr)	Po	N	N	N	N	Mod	Sig	0	0	N	N	Y	N	23	0	Local minor failure (rock cut) Surface: Bare Rock Surface
8.5.1999 Kwai Chung Road (B) (LS)	Processed as being up to required standards (1: LPM upgraded for 10 yr) (1ATY)	Y (40 yr)	Po	N	N	N	N	Mod	Sig	0	0	N	N	Y	N	15	0	Local minor failure (rock cut) Surface: Bare Rock Surface
3.7.1997 Hong Tsuen Road (LS)	Processed as being up to required standards (6: NTDI assessed for 14 yr) (1NSY)	Y (46 yr)	N	N	N	Y (erosion)	Y (extensive surface erosion)	Sig	Mod	0	0	N	N	Y	N	250	0	Major failure (soil cut) Surface: Vegetation
4.6.1997 Chung Shan Terrace (A) (LS)	Processed as being up to required standards (5: Private assessed for 4 yr) (2CSY)	Y (41 yr)	N	N	N	Y (minor at adjoining slope)	N	Sig	0	0	Mod	N	N	Y	N	14 (3 nos.)	0	Local minor failures (soil cut) Surface: Vegetation

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 4 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
4.6.1997 Chung Shan Terrace (B) (LS)	Processed as being up to required standards (7: Private upgraded for 5 yr) (1CSY)	Y (51 yr)	N	N	N	Y (minor)	N	Sig	0	0	Min	N	N	Y	N	85	0	Local major failure (soil cut) Surface: Vegetation
2.7.1997 Li Po Chun United World College (B) (LS)	Processed as being up to required standards (7: Private development formed for 2 yr) (1NSY)	Y (18-30 yr; 2nd wet season)	N	N	N	N	N	0	0	Mod (poor surface drainage detailing)	0	? (possible loose fill)	N	Y	N	25	0	Shallow slip but cover fairly large area (fill slope). Surface: Hydroseeding
2.7.1997 Shing Mun Tunnel Road (LS)	Post-1977 (9: HyD development formed for 8 yr) (1NSN)	Y (38 yr)	N	N	Y	Y	N	Sig	?	0	0	N	Major	Y	N	10	2,000 ???	Massive failure (soil cut) Surface: Vegetation
3.7.1997 Ha Wo Che (LS)	Post-1977 (10: Private development formed for 14 yr) (1NUN)	Y (120 yr)	Y (deformed in a storm on 1.7.1997)	N	N	N	N	N/A	N/A	Sig (no formal design)	0	N	N	N (NT exempted house)	N	60	0	Major failure (soil cut). NT exempted house slope without formal design. Slope deformed for at least 2 days before full detachment. Surface: Chunam Cover

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 5 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
3.7.1997 Ville de Cascade (LS)	Processed as being up to required standards (6: NTDD upgraded for 15 yr) (1BSY)	Y (132-151 yr)	Y	N	Y	Y (minor)	Y	Sig	Minor	0	0	N	N	Y	N	15	2,500-10,000	Massive failure (soil cut) Surface: Vegetation
24.5.1998 Hong Kong Stadium (LS)	Processed as being up to required standards (6: ArchSD upgraded for 4 yr) (1BSY)	N (5 yr; not worst rain)	Po	N	N	Y (minor)	Y	0	Mod	0	Mod	Y (slope not cut back as per approved design)	N	Y	N	5	0	Local minor failure (soil cut) Surface: Chunam Cover
9.6.1998 Lai Yiu Bus Terminal (IS)	Processed as being up to required standards (1: LPM upgraded; failed during maintenance period) (1ASY)	N (Not assessed; 1st wet season)	N	N	N	N	N (newly formed)	0	0	Minor (inadequate subsurface drainage provision)	0	Y (loose fill)	N	Y	N	20 ??	###	Massive failure (fill slope) Surface: Hydroseeding
9.4.1998 Hiu Kwong Street (LS)	Processed as being up to required standards (1: Old LPM upgraded for 21 yr) (1ASY)	N (little rain)	Y	N	N	Y (major)	N	0	0	Mod (cap susceptable to settlement)	0	N	N	Y	N	0	###	Massive failure (fill slope). Triggered by leaky water-carrying services. Surface: Sprayed Concrete

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 6 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
17.9.1998 A Kung Ngan Road (IS)	Processed as being up to required standards (1: LPM upgraded for 13 yr) (1ATY)	N (little rain)	Po	N	N	Y (minor)	N	Sig	0	?	0	N	N	Y	N	< 1	0	Local minor failure (rock cut). LPM upgrading works not extensive. Surface: Unplanned Vegetation
2.7.1997 Lai Ping Road (LS)	Processed as being up to required standards (4: post-1977 slope; NTDD assessed and found no problem of deep failure) (1NSY)	Y (1,000 yr)	Y	N	N	Y (major)	Y	Sig	?	Sig (tension cracking not considered in design)	0	N	N	Y	N	4,000	100,000	Massive failure (soil cut and hillside over crest) NTDD assessment in 1996 found inadequate FOS against shallow failure. Surface: Bare Slope Surface
9.6.1998 Fung Wong Reservoir (LS)	Processed as being up to required standards (3: Old study assessed for 12 yr) (2DTY)	N (8 yr)	Po	N	N	N	Y (minor)	Mod	Mod	0	Minor	N	N	Y	N	120	0	Local major failure (soil cut). Planning Stage 1 Study. Surface: Sprayed Concrete
4.7.1997 Pak Kong (LR)	Processed as being up to required standards (6: WSD development formed for 6 yr and upgraded for 1 yr) (1NSY)	Y (Not assessed; 1st wet season after upgrading)	N	Y (in 1992 after slope formation)	N	N	N	Sig	? (Minor)	0	0	N	N	Y	N	0	10,000	Massive failure (soil cut) Surface: Hydroseeding

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 7 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
9.6.1998 Sunny Villa (LS)	Processed as being up to required standards (7: private development formed for 16 yr) (1NSY)	N (5 yr)	?	N	N	N	N	Sig	Minor	0	Minor	N	N	Y	N	200	0	Local major failure (soil cut) Surface: Bare Slope Surface
9.6.1998 Au Tau Village Road (LS)	Post-1977 (10: illegal-formed for 7-22 yr) (1NUN)	Y (18 yr)	Po	N	N	N	N	N/A	N/A	Sig (no formal design)	0	N/A (loose fill)	N	N	Y	170	0	Major failure (fill slope). Illegally formed. Surface: Unplanned Vegetation
9.6.1998 PFA fill slope, Siu Lang Shui (LS)	Post-1977 (10: illegal-formed for 2 yr) (1NUN)	N (6 yr; 2nd wet season only)	N	N	N	N	Y (erosion)	N/A	N/A	Sig (no formal design)	0	N/A (loose fill)	N	N	Y	1,000	500	Massive failure (fill slope). Illegally formed. Surface: Bare Slope Surface
3.7.1997 Kam Shan Terrace (IS)	Processed as being up to required standards (1: LPM upgraded for 4 yr). (1ASY)	Not assessed (time of failure not known)	N	N	Y	Y	N	?	0	?	Sig	N	N	Y	N	2	0	Local minor failure (soil cut: washout) Another 7 m^3 landslide on part of slope not upgraded under LPM. Surface: Vegetation
12.8.1997 Hong Fai Road (A & B) (IS)	Processed as being up to required standards (1: LPM upgraded for 7 yr) (1ASY)	Not assessed (time of failure not known)	N (erosion)	N	Not assessed	N	Not assessed	Mod	Mod	?	Minor	N	N	Y	N	18 & 12	0	Local minor failures, 2 nos. (soil cut) Surface: Sprayed Concrete

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 8 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
31.12.1997 Lo Wai Public School (LR + CCRR)	Processed as being up to required standards (1: LPM upgraded for 9 yr) (1ASY)	Not assessed (time of failure not known)	Po	N	Not assessed	?	Not assessed	Sig	?	0	Mod	?	N	Y	N	##	0	Local minor failure (soil cut) Surface: Vegetation
10.5.1997 Wan Tsui Road (LR)	Processed as being up to required standards (1: LPM upgraded for 13 yr) (1ATY)	Not assessed										N	N	Y	N	< 1	0	Local minor failure (rock cut) History of failure after LPM works. Surface: Bare Rock Surface
August 1997 Ching Cheung Road at Slope No. 11NW-A/C56 (LR)	Processed as being up to required standards (1: LPM upgraded for 5 yr) (1ASY)	Not assessed (time of failure not known)	N	Y	?	?	N	?	?	0	Mod	N	N	Y	N	15	0	Local minor failure (soil cut) Surface: Vegetation
9.6.1998 Ching Cheung Road at Slope No. 11NW-A/C56 (LR)	Processed as being up to required standards (1: LPM upgraded for 5 yr) (1ASY)	Not assessed (time of failure not known)	N	Y	?	?	N	0	0	0	Mod	N	N	Y	N	< 1	0	Local minor failure (soil cut) Surface: Bare Slope Surface

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 9 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
1998 Ham Tin Tsuen (LR)	Processed as being up to required standards (1: LPM upgraded for 12 yr) (1ASY)	Not assessed									Minor	N	N	Y	N	< 1	0	Local minor failure (rock cut) Surface: Unplanned Vegetation
10.7.1997 Kennedy Town Police Quarters (IS)	Pre-1977 (2: LPM assessed for 7 yr; inadequate FOS for minor failure on soil cut; not upgraded due to low consequence) (N/A)	Not assessed (time of failure not known)	N	N	Not assessed	N	Not assessed	N/A	N/A	Substan-dard (pre-1977)	Mod	N	N/A	N/A	N	1	0	Local minor failure (pre-1977 soil-rock cut). Rock cut found to be stable in past LPM assessment. Surface: Bare Rock Surface
25.8.1997 Building Contractors' Association School, Tin Hau Temple Road (IS)	Pre-1977 (2: LPM assessed for 7 yr; found to have inadequate FOS but DH Order not recommended due to low consequence) (N/A)	Not assessed (Time of failure not known)	N	N	Not assessed	Y (minor)	Not assessed	N/A	N/A	Substan-dard (pre-1977)	Mod	N	N/A	N/A	N	10	0	Local minor failure (pre-1977 soil cut). Advisory letter issued in 1990 after LPM assessment. Boulder stabilization and minor works carried out but not on the landslide portion. Surface: Chunam Cover

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 10 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
August 1997 Po Tung Road, Sai Kung	Pre-1977 (2: LPM assessed for 7 yr; FOS inadequate and Advisory letter issued) (N/A)	Not assessed											N	Y	N	10	0	Local minor failure (soil cut). FOS assessed by S2 Study as between 1.1and 1.2. Surface: Chunam Cover
8.5.1997 Between Pope Paul VI College and Shek Pai Street (IS)	Processed as being up to required standards (2: LPM assessed for 4 yr) (2ASY)	Not assessed (time of failure not known)	N	N	Not assessed	N	Not assessed	N/A	N/A	N/A	Mod	N	N	Y	N	0 (not genuine landslide)	0	Local water seepage and erosion from slope (soil cut). Advisory letter served after LPM assessment and works complied with in 1995. Assessed by ArchSD in 1996; further study recommended. Surface: Chunam Cover
30.5.1998 Mount Davies Road (IS)	Processed as being up to required standards (2: LPM assessed for 10 yr; works required by Advisory letter carried out by private owners) (1CTY)	Not assessed	N	N	N	Y (minor found after the 1998 landslide)	N	Mod	?	? (works on rock cut not extensive)	Mod	N	N	Y	N	3	0	Local minor failure (rock cut). S2 Study concluded adequate FOS for soil portion. Minor works on rock portion recommended by Advisory letter. Surface: Sprayed Concrete

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 11 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
9.6.1998 Bowen Road on 11SW-B/CR183 (LR)	Processed as being up to required standards (3: Old study assessed for 12 yr) (2DTY)	N (not severe rain)	N	N	N	N	N	?	?	?	Mod	N	N	Y	N	< 1	0	Local minor failure (rock cut) Planning Stage 1 Study Surface: Unplanned Vegetation
9.6.1998 United Christian College, Tong Yam Street (LR)	Processed as being up to required standards (3: Old study case; GEO checked in 1984) (1DTY -special)	Not assessed	N	N	Not assessed	N	Not assessed	?	?	?	?	N	N	Y	N	10	0	Local minor failure (soil cut) B&P Phase IID Study recommended upgrading works. GEO District assessment in 1984 concluded that the slope was up to standard. Surface: Chunam Cover
June 1998 Kennedy Town Service Reservoir (LR)	Processed as being up to required standards (3: Old study assessed for 16 yr) (1DTY)	Not assessed	N	N	Not assessed	N	Not assessed	?	?	?	Mod	N	N	Y	N	10	0	Local minor failure (rock cut) B&P Phase IID Study. Surface: Unplanned Vegetation
4.5.1998 Junction of Ting Kau Bridge and Tuen Mun Road (LS)	Processed as being up to required standards (6: HyD development formed for < 1 yr) (1NSY)	N (2-5 yr; 1st wet season)	N	N	N	N	N	Mod	0	Sig (detailing problem)	0	? (fill compaction)	N	Y	N	500	800	Massive failure (fill slope) Detailed check by ICE. Surface: Hydroseeding

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 12 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
4.6.1997 Lai King Hill Road (LR)	Processed as being up to required standards (6: HyD development formed for 11 yr) (1NTY)	?	N									N	N	Y	N	20	0	Local minor failure (soil cut). Erosion/wash-out failure. Surface: Chunam Cover
4.6.1997 King Tin Court (LR)	Processed as being up to required standards (6: TDD development formed for 16 yr) (1NSY)	?	N								Mod	N	N	Y	N	2	0	Local minor failure (soil cut) Surface: Vegetation
9.6.1998 King Tin Court (IS)	Processed as being up to required standards (6: TDD development formed for ## yr) (1NSY)	?	N								Mod	N	N	Y	N	2	0	Local minor failure (soil cut) Surface: Unplanned Vegetation
4.3.1997 King's Road below 39A Tin Hau Temple Road (LR)	Processed as being up to required standards (6: HyD development upgraded for 6 yr) (1BTY)	?	Not assessed								?	N	N	Y	N	< 1	0	Local minor failure (rock cut) Very minor. Surface: Bare Rock Surface

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 13 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
22.10.1998 Ha Kwai Chung Tsuen Resite Village (LR)	Processed as being up to required standards (6: TDD development upgraded for 10 yr) (1BSY)	?	Not assessed								?	N	N	Y	N	< 1	0	Local minor failure (rock cut) Surface: Sprayed Concrete
9.6.1998 Choi Ha Road (IS)	Processed as being up to required standards (6: HyD development formed for 6 yr) (1NSY)	?	N	N	N	Y (minor)	Not assessed	?	Mod (fill)	?	Mod	N	N	Y	N	15	0	Local minor failure (soil cut). Designed by GEO Advisory Division. Surface: Vegetation
8.5.1997 Hanley Villa, Yau Kom Tau (IS)	Processed as being up to required standards (7: private development formed for 8 yr) (1NSY)	?	N	N	Not assessed	Y (minor)	Not assessed	? (mod)	? (minor)	0	Mod	N	N	Y	N	4	0	Local minor failure (soil cut). Works suggested in Advisory letter issued after 1996 landslide not carried out. Surface: Vegetation
5.7.1998 Tin Hau Temple Road (LR)	Processed as being up to required standards (7: private upgraded for 14 yr) (1CSY)	?	Not assessed								?	N	N	Y	N	< 1	0	Local minor failure (rock cut) Upgraded following DH Order arising from Old Study (North Point Area Study) Surface: Sprayed Concrete

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 14 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
6.6.1998 South Lantau Road (LR)	Post-1977 (7: HyD formed for 15 yr) (1NSN)	?	N	N	?	Y (minor)	Not assessed				Minor	N	Major	Y	N	10	0	Local minor failure (soil cut). History of minor failures after slope formation. Surface: Bare Slope Surface
4.6.1997 Tai Po Road near Kowloon Reservoir (IS)	Post-1977 (10: HyD development for 9 yr; not sure if checked by GEO) (1NTN)	?	N	N	Not assessed	N	Not assessed	0	0	Mod (surface water concent-ration)	Mod	N	N	N (no record of GEO checking found)	N	7	0	Local minor failure (soil cut). Surface: Vegetation
4.6.1997 Mai Luen Industrial Building, Kwai Chung (IS)	Post-1977 (10: Default upgraded at southern part of slope for 12 yr; not sure if the landslide part was also upgraded ??)	?	N	N	Not assessed	Y (minor)	Not assessed	?	?	0	Mod	N	N	N (no record of checking of default works can be found)	N	30	0	Local minor failure (soil cut). Slope status not certain; not known if there was previous engineering input. Surface: Vegetation
23.6.1997 Lion Rock Tunnel Road (IS)	Post-1977 (10: HyD development formed for about 17 yr) (1NUN)	Not assessed (time of failure not known)	N	N	Not assessed	N	Not assessed	N/A	N/A	Sig (no formal design)	Mod	N	N	N (not submitted to GEO for checking)	N	5	0	Local minor failure (soil cut). No formal design. Surface: Bare Slope Surface
3.8.1997 Tai Chow House, Quarry Bay (IS)	Processed as being up to required standards (7: private upgraded for 20 yr) (1CTY)	?	N	N	Not assessed	Y (minor)	Not assessed	Mod	Mod	0	Mod	N	N	Y	N	2	0	Local minor failure (rock cut) Upgrading works designed and checked in 1977. Surface: Bare Rock Surface

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 15 of 15)

Landslide	Slope Status (Classification)*	Worst Rain	Deterioration	Massive Relict Failure		Failure after Slope Formed/Modified		Deficiency in Design/Assessment			Inadequate Maintenance	Works Deficiency	GEO Checking		Unauthorized Construction	Failed Volume (m^3)		Remarks
				Recorded	More From API	Recorded	More From API	GW	Mat. Strength	General			Outstanding GEO Comment Not Resolved	Submitted to GEO for Checking		Detached	Deformed	
22.8.1997 Deep Water Bay Road, Shousan Hill (IS)	Processed as being up to required standards (7: private development for 14 yr) (1NTY)	?	N	N	Not assessed	N	Not assessed	?	?	?	Mod	N	N	N	N	2	0	Local minor failure (soil cut). Surface: Bare Slope Surface

Legend:

Y = Yes
N = No
Po = Possible
? = Not known
Mod = Moderate contribution
Minor = Minor contribution
LS = Landslide study
IS = Initial study
0 = Little contribution
LR = Landslide review
Sig = Significant contribution
N/A= Not applicable
Massive failure = failure volume (detached + deformed) above 500 m^3
Major failure = failure volume between 50 m^3 and 500 m^3
Minor failure = failure volume less than 50 m^3
* denotes classification of slope status in accordance with Table 5

Table 5 - Classification of Slope Features

Feature Type	Classification
Post-1977 Features (Formed or upgraded after 1977)	1
Newly Formed	1N
Upgraded by LPM	1A
Upgraded by Other Government Departments	1B
Upgraded by Private Owners	1C
Upgraded by default of DH Orders.	1D
Pre-1977 Features (Formed before 1977 and subsequently assessed as being up to the required geotechnical standards)	2
Assessed by LPM Stages 2 or 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

Notes: The classification may be extended where possible by adding S, T, U, Y or N 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 checked and accepted by the GEO

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

Table 6 - Breakdown of 1997 and 1998 Landslides at Slopes Processed As Being up to the Required Geotechnical Standards

	Soil Cut	Rock Cut	Fill	Retaining Wall	
All landslides	25	12	5	0	$\Sigma = 42$
Massive failure (> 500 m^3)	4	0	3	0	$\Sigma = 7$ (17%)
Major failure (50 to 500 m^3)	4	0	0	0	$\Sigma = 4$ (9%)
Minor failure (< 50 m^3)	17	12[see note]	2	0	$\Sigma = 31$ (74%)
Note: Of the 12 rock cut slope failures, nine cases involved a failure volume of less than 3 m^3 (seven of which had a failure volume of less than 1 m^3).					

Table 7 - Breakdown of 1997 and 1998 Landslides at LPM Slopes

	Soil Cut	Rock Cut	Fill	Retaining Wall
All landslides	6	7	2	0
Massive failure (> 500 m^3)	1	0	2	0
Major failure (50 to 500 m^3)	0	0	0	0
Minor failure (< 50 m^3)	5	7	0	0

Table 8 - Breakdown of Key Contributory Factors to Failures at Soil Cut Slopes Processed As Being up to the Required Geotechnical Standards

	All landslides (Σ = 18 no.)	Local Minor Failures (Σ = 10 no.)	Massive or Major Failures (Σ = 8 no.)
Adverse Groundwater	13 (72%)	5 (50%)	8 (100%)
Adverse Material	5 (28%)	3 (30%)	2 (25%)
Inadequate Slope Maintenance	7 (39%)	7 (70%)	0

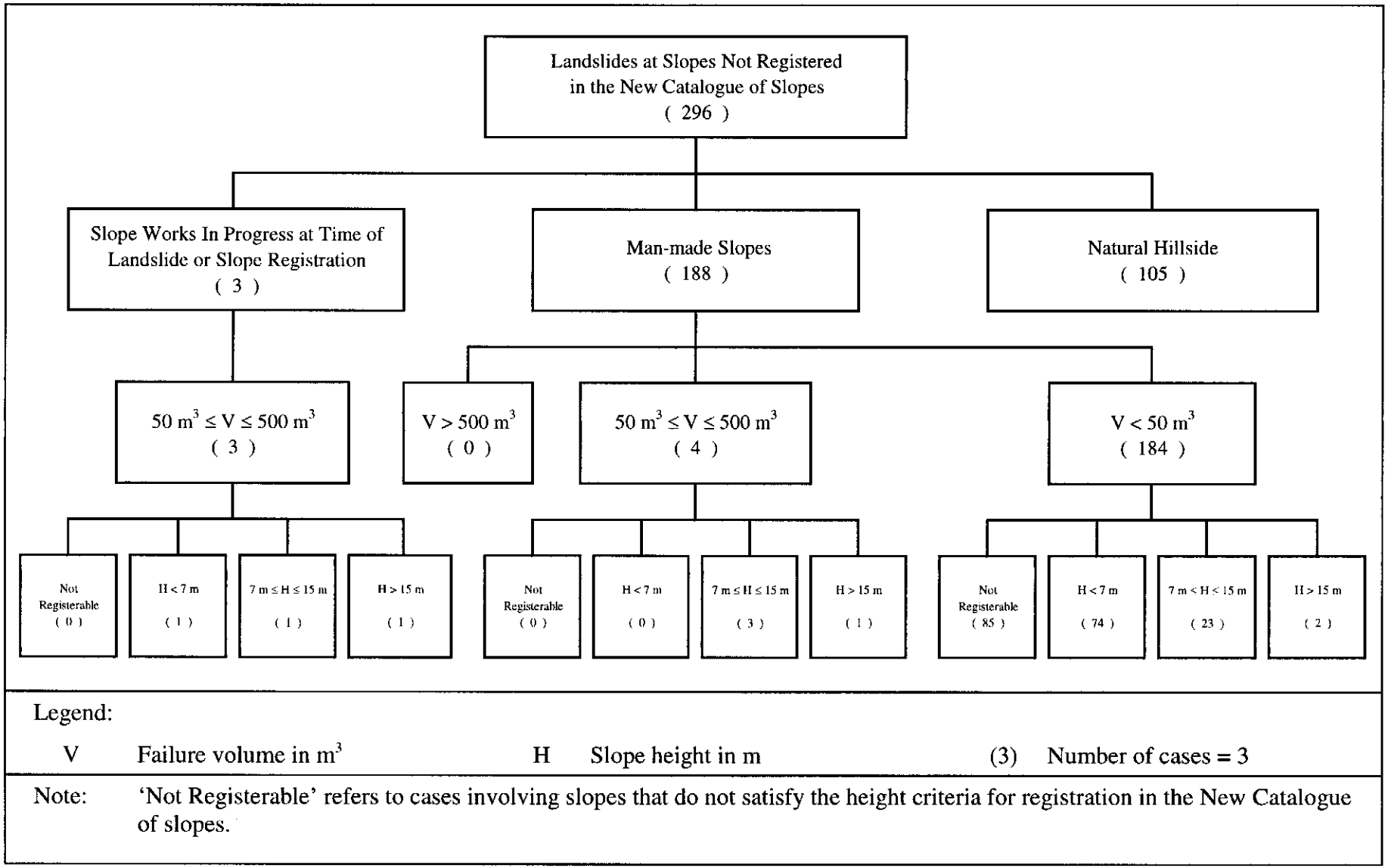
Table 9 - Summary of Areas Requiring Attention and Recommended Improvement Measures (sheet 1 of 2)

Areas Requiring Attention	Recommended Improvement Measures
• A significant number of minor failures occurred at slopes processed by the slope safety system as being up to the required geotechnical standards. • Some sizeable failures occurred at slopes processed by the slope safety system as being up to the required geotechnical standards. • Failures occurred at unauthorized constructions • Failures occurred at registerable man-made slope features that were yet to be registered. • Failures occurred at post-1977 slopes with major outstanding GEO comments. • Failures occurred at post-1977 slopes with no design input and/or no geotechnical submission for checking by GEO. • Some slope failures involved deformed material not fully detaching from the slip surface and remaining on the slope, hence giving rise to the hazard of possible further failures at less severe rainfall than that which caused the initial failure. Some slopes exhibit signs of distress before failure.	1. Develop and promote improved detailing and protective measures in slope improvement works to reduce the risk of localised failures. 2. Enhance reliability of slope assessment and improvement works by attending to the following aspects: (a) Carry out a comprehensive API and take due account of past instability in slope assessments, (b) Consider reliability of the design scheme in option assessment for slope improvement works, (c) Incorporate the findings of verification of the design geological model during slope works as part of the as-built records for inclusion in slope maintenance manuals, and (d) Require designers to review slope performance and adequacy of design assumptions during the Contract Maintenance Period. 3. Review the need for, and practicality of, introducing a slope certification system in the public works checking process. 4. Upgrade the practice of EI by: (a) Expanding the model EI Brief to require the completion of a checklist on background information in order to establish the history and status of the slope, prompt updating of key slope data (e.g. details of repair works carried out to landslides, details of preventive maintenance works carried out, unregistered slopes that satisfy the registration

Table 9 - Summary of Areas Requiring Attention and Recommended Improvement Measures (sheet 2 of 2)

Areas Requiring Attention	Recommended Improvement Measures
	criteria, unauthorized geotechnical constructions, key information on slope features as contained in the Catalogue of Slopes, etc.), and assessment of compliance of past slope works with the design as far as possible as part of the review of past Stability Assessments, (b) Requiring an out-of-turn EI following landslides or report of significant signs of distress, or new or increased seepage, (c) Introducing a procedure to facilitate timely feedback of relevant EI findings to update the Slope Information System, and (d) Examining the practicality of extending the scope of GEO's Maintenance Audit to include technical audit of the quality of EI procured by Government Departments.

LIST OF FIGURES



Legend:

V Failure volume in m^3 H Slope height in m (3) Number of cases = 3

Note: 'Not Registerable' refers to cases involving slopes that do not satisfy the height criteria for registration in the New Catalogue of slopes.

Figure 1 - Breakdown of Landslides at Unregistered Slopes in 1997 and 1998