Highway Slope Manual

Geotechnical Engineering Office
Civil Engineering and Development Department
The Government of the Hong Kong
Special Administrative Region

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This Highway Slope Manual is a continuously updated version incorporating amendments issued since the Highway Slope Manual was published. The continuously updated version is released in e-format only on the CEDD website. This Highway Slope Manual is to be cited as "GEO (2017). Highway Slope Manual (Continuously Updated E-Version released on 7 September 2017). Geotechnical Engineering Office, Civil Engineering and Development Department, HKSAR Government, 116 p."

Foreword

The purpose of this Manual is to recommend a standard of good practice on slope engineering that is specific for the planning, investigation, design and construction of projects in Hong Kong that involve highway slopes and for their maintenance. This Manual covers principles only and refers to published information including GEO publications. Readers should consult these and other up-to-date information for more detailed coverage of specific subjects.

The preparation of the Manual is under the overall direction of a Steering Committee (SC) and carried out by a Working Group (WG). The membership of the SC and WG is given on the next page. The Highways Department, the Hong Kong Institution of Engineers (both Civil and Geotechnical Divisions) and the Institution of Highways and Transportation (Hong Kong Branch) are represented on the SC and the WG. The Hong Kong Automobile Association, which is the largest organisation representing the interests of the road users, is also represented on the SC.

Various other parties have contributed to the preparation of the Manual. These include Atkins China Ltd on Chapter 2, Urbis Ltd on Chapter 6 and also Halcrow China Ltd on Chapter 7.

To ensure that the Manual would be considered as a consensus document in Hong Kong, draft versions of the Manual were widely circulated to interested parties both locally and abroad for comment. Many useful comments from individuals and organisations were received. The comments received have been taken into account in finalising the Manual. All contributions are gratefully acknowledged.

As with other GEO guidance documents, this document gives guidance on good engineering practice, and its recommendations are not intended to be mandatory. It is recognised that practitioners may wish to use alternative methods to those recommended herein. Practitioners are encouraged to comment at any time to the Geotechnical Engineering Office on the contents of this Manual, so that improvements can be made to future editions.

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Head, Geotechnical Engineering Office
November 2000

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1 Introduction

1.1 Purpose and Scope

The purpose of this Manual is to recommend a standard of good practice on slope engineering that is specific for the planning, investigation, design and construction of projects in Hong Kong that involve highway slopes and for their maintenance.

In the context of this Manual, highway (or roadside) slopes are taken to include all types of man-made slope features (viz. cut slopes, fill slopes and retaining walls) and man-made features on natural terrain (e.g. boulder fences and check dams), the failure of which could affect a road. Reference is also made in relevant Sections of the Manual to natural terrain hazards that could affect a highway where appropriate.

Highway slope owners are taken to mean not only the owners but also the parties who are responsible for the maintenance of the highway slopes. Road owners are taken to mean owners of a road. The term “geotechnical engineer” is taken to mean a professionally qualified person with an adequate level of experience in geotechnical engineering for the tasks required to be carried out. A suitable qualification is Registered Professional Engineer (Geotechnical), information on which can be obtained from the Engineers Registration Board of Hong Kong.

While the guidance given in this Manual is written with public roads in mind, the principles are also applicable to private roads and railways.

The document is aimed at qualified professional engineers who are conversant with the relevant engineering principles and tools. It covers general principles and the standard of care required, but does not contain detailed procedures and methods. It guides the readers to other published documents including Geotechnical Engineering Office (GEO) publications, where such details may be found.

Landfill slopes and foundations for embankments on soft ground, which require special consideration, are not covered in this Manual and readers should refer to relevant literature on these subjects.

1.2 Problems with Highway Slopes in Hong Kong

The annual total number of reported landslides affecting roads during the period 1984 to 1998 ranges from 33 (in 1984) to 490 (in 1993) with an average of 166. These involved mainly man-made slope features. Some of these landslides resulted in fatalities, e.g. the landslides at Kennedy Road (Chan et al, 1996), Castle Peak Road (Chan et al, 1996), Fei Tsui Road (GEO, 1996a) and Shum Wan Road (GEO, 1996b). Others caused serious disruption to the traffic and the community, e.g. the rockfall during the Tuen Mun Highway widening works in 1995 which involved a fatality (Wong, 1997) and the landslide at Ching Cheung Road in 1997 (Halcrow, 1998). Table 1.1 and Plates 1.1 to 1.3 give examples of highway slope incidents in recent years which have resulted in fatalities and injuries. Plate 1.4 is an example of a slope failure which caused the complete closure of a major road for a long period.

Despite the fact that on average more than 300 natural terrain landslides occur every year (Evans et al, 1998), they have not been of great consequence to highways, as so far they have mainly occurred in relatively remote areas. However, new development, re-development and highway projects have continued to extend into areas close to steep natural terrain, thereby increasing the landslide risk. There have in fact been 'near miss' cases involving landslides on natural terrain (Evans et al, 1998; Franks, 1998; King, 1997). On 4 and 5 November 1993, Lantau Island was subjected to a severe rainstorm, resulting in over 800 natural terrain landslides there, some of which affected roads (Wong et al, 1997a; Wong et al, 1998b). Plates 1.5 to 1.7 show some of the natural terrain landslides in recent years. Plate 1.8 shows a highway located close to steep natural terrain.

Table 1.1 Highway Slope Incidents in Recent Years Involving Fatalities and Injuries

Year	GEO Incident No. and Reference	Location	Estimated Volume of Landslide Debris (m^3)	Fatality	Injury
92	HK92/5/38 (Chan et al, 1996)	Slope beneath Wah Yan College, Kennedy Road.	500	1	0
93	MW93/6/14 (Chan et al, 1996)	A bus shelter at Cheung Shan Estate.	50	1	4
94	MW94/8/3 (Chan et al, 1996)	Castle Peak Road, Tsing Lung Tau near Lightpost FA1221-7G.	300	1	0
95	HK95/8/43 (GEO, 1996a)	No. 30 Fei Tsui Road (Baptist Church), Chai Wan.	14 000	1	0
95	HK95/8/49 (GEO, 1996b)	Shum Wan Road, Aberdeen.	26 000	2	5
95	MW95/8/21 (Wong, 1997)	Road widening project site near Siu Lam, Tuen Mun Highway.	6	1	1
97	MW97/7/10 (Halcrow, 1999a)	Lido Beach, Castle Peak Road, Ting Kau.	750	0	6

Note: Cases involving only very minor injuries (e.g. persons suffering simply from shock or persons discharged soon after receiving minor treatments at a hospital) have not been included in this Table.

Note:	A car travelling along Kennedy Road was hit by the landslide debris and the driver was killed.

Plate 1.1 Landslide at Kennedy Road in May 1992 (Chan et al, 1996)

Note:	A public light bus was hit by the landslide debris and pushed down an embankment onto the beach below the road. Three persons were trapped inside the bus, and a man on board was killed.

Plate 1.2 Landslide at Castle Peak Road in August 1994 (Chan et al, 1996)

Note:	A 15-tonne rock block was dislodged from a cut slope alongside Tuen Mun Highway near Siu Lam during excavation. A van hit the rock, resulting in one fatality and one injury.

Plate 1.3 Rockfall during the Tuen Mun Highway Widening Works in August 1995 (Wong, 1997)

Note:	The landslide resulted in the closure of the road for more than three weeks.

Plate 1.4 Landslide at Ching Cheung Road in August 1997 (Halcrow, 1998)

Plate 1.5 Large Channelised Debris Flow on Natural Terrain in Tsing Shan, near Tuen Mun, in September 1990 (King, 1996)

Note: The landslide debris reached the adjacent KCRC railway track.

Plate 1.6 Open-slope Debris Avalanche on Natural Terrain in Ma Liu Shui in July 1997 (Lam, 1999)

Note: The landslide debris reached the cycle track at the toe.

Plate 1.7 Open-slope Debris Avalanche on Natural Terrain in Ma On Shan in July 1997 (Halcrow, 1999b)

Plate 1.8 Steep Natural Terrain along the North Lantau Expressway near Tung Chung

1.3 Highway Slope Management System

To ensure that the safety of slopes is adequately managed and their stability maintained, road owners should set up appropriate slope management systems commensurate with the number of slopes and the size of the slope-related problems (e.g. the potential risk to life and property and the socio-economic impact associated with disruption to traffic in the event of landslides) that they have to manage. A range of options is illustrated in Figure 1.1.

The Highways Department (HyD) of the Hong Kong Special Administrative Region (SAR), being responsible for the maintenance of a large number of highway slopes in Hong Kong, has established a comprehensive slope management system. A brief description of HyD's system is given in Appendix A.

Apart from HyD, there are others who are responsible for the maintenance of roadside slopes. These include the Agriculture, Fisheries and Conservation Department, Architectural Services Department, Drainage Services Department, Hospital Authority, Housing Authority, Water Supplies Department, Kowloon-Canton Railway Corporation, Mass Transit Railway Corporation, universities and private parties. An appropriate slope management system should be set up by each party. In some cases, e.g. a private lot with only a few slopes affecting a lightly used road, a simple slope management system may be adequate.

Highway Slope Management System(1)

	Slope Information System	Slope Maintenance and Upgrading System	Emergency System
Key Components of the Systems	Inventory of slopes(2) Slope location plans Slope catalogue(3) As-built records of slopes and slope works Location plans and details of services especially water-carrying services that could affect or be affected by slopes Records of past landslides	Slope Maintenance Plan/Maintenance Manuals System for upgrading of substandard slopes Qualified and experienced personnel for carrying out maintenance inspections Adequate resources for carrying out the required maintenance works Slope maintenance inspection and works records	Emergency procedures Procedures to allow early identification and inspection of serious landslide incidents Staff on standby 24 hours to report or receive reports on landslide incidents and to arrange inspection of landslides Qualified and experienced personnel for carrying out landslide inspections Resources available for carrying out urgent repairs
Road Owners with a Large Number of Highway Slopes to Maintain	Computerised slope inventory and database for managing the slope information	A detailed Slope Maintenance Plan/Maintenance Manuals supplemented with a set of circulars/guidance notes/ instructions A long-term strategy for selecting substandard slopes for upgrading A dedicated team of staff and a term contractor for carrying out routine maintenance inspections and works One or more consultants engaged to undertake the Engineer Inspections (EIs) for different packages of slopes Computerised system to manage slope maintenance inspection and works records	A detailed Emergency Manual supplemented with a set of circulars/guidance notes/instructions An emergency controller to assign priority for the inspection of serious landslide incidents A dedicated team of staff on call 24 hours a day to report or receive reports on landslide incidents A term contractor engaged for carrying out urgent repairs Geotechnical engineers or consultants engaged to undertake the landslide inspections
Road Owners with Only a Few Highway Slopes to Maintain	Slope information kept in the form of paper file records	A few instructions to document the maintenance system Upgrading of substandard slopes based on the recommendations of the EIs or as ordered by the Building Authority An in-house experienced technical staff or a contractor/property management agent engaged for carrying out routine maintenance inspections and works A geotechnical engineer professionally qualified in Hong Kong engaged to undertake the EIs Slope maintenance inspection and works records kept on paper files	A few instructions to document the emergency system A designated person to report landslides to the Police or GEO who would arrange inspection and urgent repair works, where required

Notes: (1) This Figure aims to illustrate the range of options which road owners with a large number of highway slopes and those with a small number to maintain can adopt, in order to have a good slope management system. Road owners with other slopes to maintain can also adopt the appropriate option to suit their circumstances.

(2) The inventory of slopes should include not only slopes maintained by the road owners but also those owned or maintained by other parties, the failure of which could affect their roads.

(3) This should include information such as slope type, slope geometry and boundary, type of surface protection, signs of seepage and movement and time of observation, and reference to previous study/investigation reports and facilities affected.

Figure 1.1 Range of Options for Highway Slope Management System

2 Planning of Highway Projects

2.1 General

In planning new highway and road improvement projects, geotechnical aspects should be considered together with other requirements in the early stages of the planning process. The preferred route alignment and the associated optimum design options along the route should be selected based on a balanced evaluation of the cost-effectiveness of the possible alternatives taking into account all factors, including geotechnical requirements.

Reference should be made to Chapter 8 of the Hong Kong Planning Standards and Guidelines (Planning Department, 1991) for guidance on the standards for planning land requirements for highways. The Transport Planning and Design Manual (Transport Department, 1984) and the Project Administration Handbook (PAH) for Civil Engineering Works (Government of Hong Kong, 1992) contain useful information on planning and design of transport infrastructure and planning of civil engineering project respectively. Reference should be made to Chapter 3 of this Manual for guidance on site investigation for planning of highway projects.

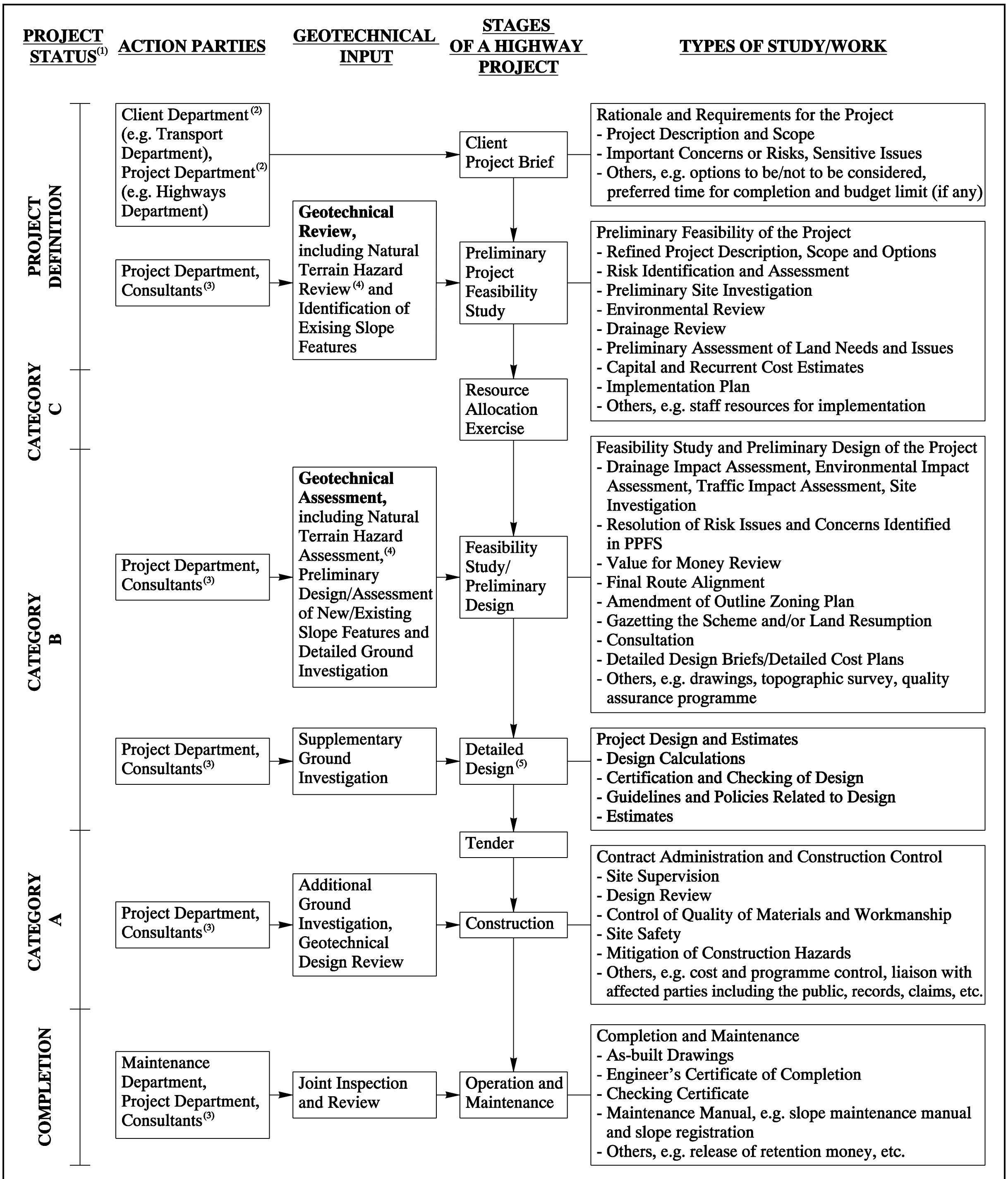
2.2 Planning of Highway Projects

2.2.1 Planning of New Highway Projects

Planning of a new highway is an iterative process which involves transport, highway, environmental and geotechnical professionals. The process starts with the transport/highway professionals putting forward possible route corridors through which a number of different route alignments are to be examined. Geotechnical input should be introduced at this stage to avoid areas with significant geotechnical hazards, where this is possible, and to select an appropriate route alignment with optimum design options. Great benefits can be achieved through a review of geotechnical aspects at this early stage of the planning process.

Geotechnical input for the planning of highway projects should initially consist of a Geotechnical Review (GR) (see Section 2.3). If necessary, a Geotechnical Assessment (GA) should also be carried out (see Section 2.4). The GR/GA should provide the relevant information for determining the scope, land-take, cost and time requirements for the investigation, design, construction and maintenance of the geotechnical works and hazard mitigation measures. For Government projects, the project office should arrange to carry out the GR at the Preliminary Project Feasibility Study (PPFS) Stage and the GA, if necessary, at the Feasibility Study (FS)/Preliminary Design (PD) Stage as illustrated in Figure 2.1.

The project proponent should engage a geotechnical engineer to take charge of the GR/GA. Such work demands a lot of judgement based on limited information. For this reason, the geotechnical engineer needs to be a very experienced practitioner. He should scrutinise all information collected and carry out the review/assessment personally; and should maintain a close liaison with the highway planning personnel throughout the planning process to provide timely geotechnical advice and recommendations for the completion of the PPFS and FS/PD. He should also carefully estimate and recommend to the client the geotechnical personnel requirements to be provided for the various stages of the project, including the requirement to have a competent and experienced team leader to oversee the



Notes:
(1) The projects in the Public Works Programme of the Hong Kong Special Administrative Region are given a category status (e.g. A, B or C), each of which constitutes authority to proceed with a specific stage or value of work (Government of Hong Kong, 1992).
(2) The GEO may assist the Client/Project Department in preparing the Client Project Brief.
(3) The GEO may assist the Project Department in these tasks instead of consultants.
(4) Guidance on Natural Terrain Hazard Review and Natural Terrain Hazard Assessment is given in GEO Special Project Report No. SPR 5/2000 (Ng et al, 2000).
(5) For major highway projects designed by consultants, funds for detailed design could be secured by upgrading part of the project to Category A.

Figure 2.1 Geotechnical Input at Various Stages of a Highway Project in the Public Works Programme

investigation and design, and to scrutinize the quality of the geotechnical works at key stages.

2.2.2 Planning of Road Improvement Projects

The scope of a road improvement project can vary widely, ranging from upgrading of a road class (e.g. from a district distributor to a primary distributor), to local improvements of a road's alignment (e.g. widening). In a road improvement project, existing slopes should be upgraded to a standard commensurate with the consequence category rating of the improved road. It may also be beneficial to upgrade adjacent substandard slopes to take advantage of the economy of scale and closure for road works. Guidelines for including slope upgrading and landslide mitigation works as part of a road improvement project are given in Table 2.1.

For road improvement projects involving the re-alignment of an existing road to follow a new route, the guidance given in Section 2.2.1 regarding the carrying out of a GR/GA during the project planning stage is also relevant. It is particularly important that the scope of the geotechnical works and hazard mitigation measures is not underestimated for such projects.

As compared with a new highway, planning of a road upgrading or re-alignment project is generally more constrained by the existing road alignment, structures and land use, services and utilities and the surrounding topography. The need to maintain traffic flow during construction is also an important constraint. The selection of appropriate route alignment and/or design options should take into account these constraints.

2.3 Geotechnical Review

The objective of a Geotechnical Review (GR) is to identify and assess the impacts of significant geotechnical hazards and critical geotechnical issues that could influence the feasibility of a highway project. The geotechnical activities in a GR are illustrated in Figure 2.2. A model brief for carrying out a GR is given in Appendix B.

In a GR, geotechnical hazards and issues are considered in a general manner as the time available for the review is usually limited especially where a number of possible route corridors/alignments are to be examined. The review should be based mainly on available information collected from a desk study including an aerial photograph interpretation. The locations of existing slope features and new geotechnical features likely to be formed should be determined. A walkover survey should also be carried out to confirm the presence, nature and severity of hazards from the key natural terrain and man-made geotechnical features identified in the desk study. The potential impacts of the geotechnical hazards along the possible route corridors/alignments should be assessed. Examples of the geotechnical hazards that need to be considered are given in Table 2.2. Where natural terrain hazards are identified, a Natural Terrain Hazard Review (NTHR) should be carried out. Examples of some common natural terrain landslide hazards posed to a highway are illustrated in Figure 2.3. Guidance on Natural Terrain Hazard Review is given in GEO Special Project Report No. SPR 5/2000 (Ng et al, 2000).

Where significant geotechnical hazards are identified, in particular natural terrain hazards, the GR should include a careful assessment to determine whether an adjustment of a route corridor/alignment and/or provision of appropriate mitigation measures are warranted.

If alternative route corridors/alignments are to be considered, the assessment should include, where possible, a ranking of the alternatives taking into account the possible impacts of the geotechnical hazards and the likely costs of mitigation measures required. This geotechnical ranking, with appropriate weighting, could form the basis for a balanced

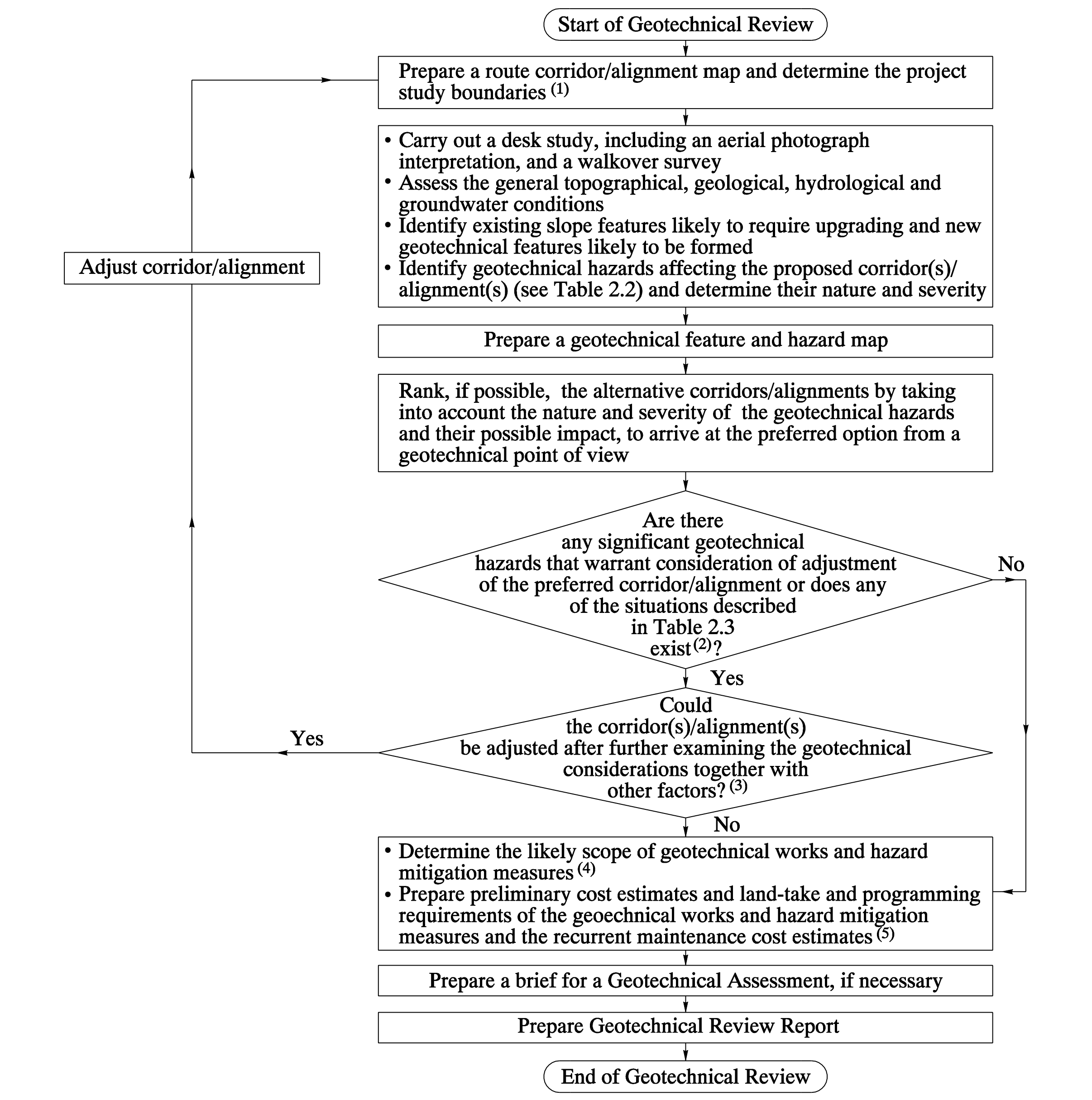
Table 2.1 Guidelines for Including Slope Upgrading and Landslide Mitigation Works as Part of a Road Improvement Project

Geotechnical Considerations	For Road Improvements Which Will Result in an Increase in Landslide Risk[2] (e.g. upgrading of road class and road widening)	For Road Improvements Which Will Not Result in any Increase in Landslide Risk[2] (e.g. road re-surfacing and road drainage improvement)
(a) Existing substandard man-made slope features[1] and natural terrain which could be affected by the road improvement works	Assess the effects of the works on the slope features and on natural terrain, and include any necessary upgrading or mitigation works as part of the project.	
(b) Existing substandard man-made slope features[1] along the road or nearby which could affect the road project in the event of a failure	Include the upgrading of existing substandard man-made slope features as part of the project.	Include the upgrading of existing substandard man-made slope features as part of the project where (i) the deferral of the upgrading works would pose unacceptable risk to the public, or (ii) the cost and time required for such upgrading works do not exceed 30% of the project estimate.
(c) Existing substandard man-made slope features[1] along the road or nearby which would not affect the road project in the event of a failure	Include the upgrading of existing substandard man-made slope features as part of the project where (i) the deferral of the upgrading works would pose unacceptable risk to the public, or (ii) the cost and time required for such upgrading works do not exceed 30% of the project estimate.	No need to include upgrading of these features in the project. However, where immediate and obvious signs of danger are identified, immediate risk mitigation measures (e.g. road closure) or urgent repairs should be carried out as appropriate. Permanent stabilisation, drainage or defensive works should be carried out as early as possible, either as part of the project or separately.
(d) Landslides and boulder/rock falls from natural terrain which could affect the road project	Assess the impacts from such hazards and implement mitigation measures. See Table 2.2 for natural terrain hazards to be considered.	No need to consider such hazards in the project. However, where immediate and obvious signs of danger are identified, immediate risk mitigation measures (e.g. road closure) or urgent repairs should be carried out as appropriate. Permanent stabilisation, drainage or defensive works should be carried out as early as possible, either as part of the project or separately.

Notes:
(1) The considerations should also cover any existing slope drainage and associated road drainage and water-carrying services that could affect or be affected by the slope features.

(2) A road improvement project will result in an increase in landslide risk if there will be an increase in the consequence to life or economic consequence in the event of a slope failure, e.g. due to an increase in traffic volume, on completion of the improvement of the road.

(3) For works which require land resumption, the timing of land availability should be considered. The design of the slope upgrading and landslide mitigation works should avoid having to resume land as far as possible.



Notes: (1) Possible route corridors, different route alignments and the project study boundaries should be jointly developed by a multi-disciplinary team of professionals including a geotechnical engineer. This should take into account all constraints (see Note (3) below) known to the team at this stage.

(2) A recommendation should be made by the geotechnical engineer to the multi-disciplinary team of professionals.

(3) This should be examined by the multi-disciplinary team of professionals. Other factors to be reviewed include public needs, transportation requirements, availability and resumption of land, town planning requirements, highway and structural engineering requirements, environmental (including landscape, visual and ecological), drainage and traffic impacts, etc. Consideration should be given to the costs of any land resumption required for the preferred corridor/alignment.

(4) Consideration should be given to the uncertainties of the vertical route alignment.

(5) The capital cost estimates should allow for planning and supervision of ground investigation, stability assessment and design of upgrading works for existing slopes, and design and supervision of construction of the geotechnical works and hazard mitigation measures by geotechnical engineers. The uncertainties in land-take, cost and time required should also be estimated, as input to the financial and programming risk analyses for the project.

Figure 2.2 Geotechnical Activities in a Geotechnical Review

Table 2.2 Geotechnical Hazards That Need to be Considered for a Highway Project

Existing man-made slope features that could affect or be affected by the project	All substandard features the failure of which could affect the route or could be caused by the works. All features which are up to standard but could be affected by the works (e.g. due to installation of buried water-carrying services, changes in surface and subsurface water flow regime and lateral loads that will be imposed by new highway structures).
Man-made slope features that will be formed along the route	All cut slopes, fill slopes and retaining walls, with particular attention drawn to those to be formed in difficult ground, e.g. steep hillside, adverse geological conditions such as presence of dykes, faults and other weak zones, and adverse surface water or groundwater conditions.
Natural terrain landslide hazards	All natural terrain landslide hazards, including debris avalanches, debris slides, channelised/non-channelised debris flows, boulder/rock falls, gully and other forms of erosion and deep-seated ground movements (see Figure 2.3), which could affect the route or could be caused by the works. Guidance on natural terrain hazard review and natural terrain hazard assessment is given by Ng et al (2000).
Other geotechnical hazards	All other hazards, including the presence of soft ground and karstic areas.
Hazards associated with the geotechnical works	All hazards associated with construction of the geotechnical works, e.g. rock blasting near sensitive receivers, open or supported excavations including those for cut and cover tunnel construction and temporary diversion of surface water, traffic diversion and/or road closure to mitigate the hazards during construction.

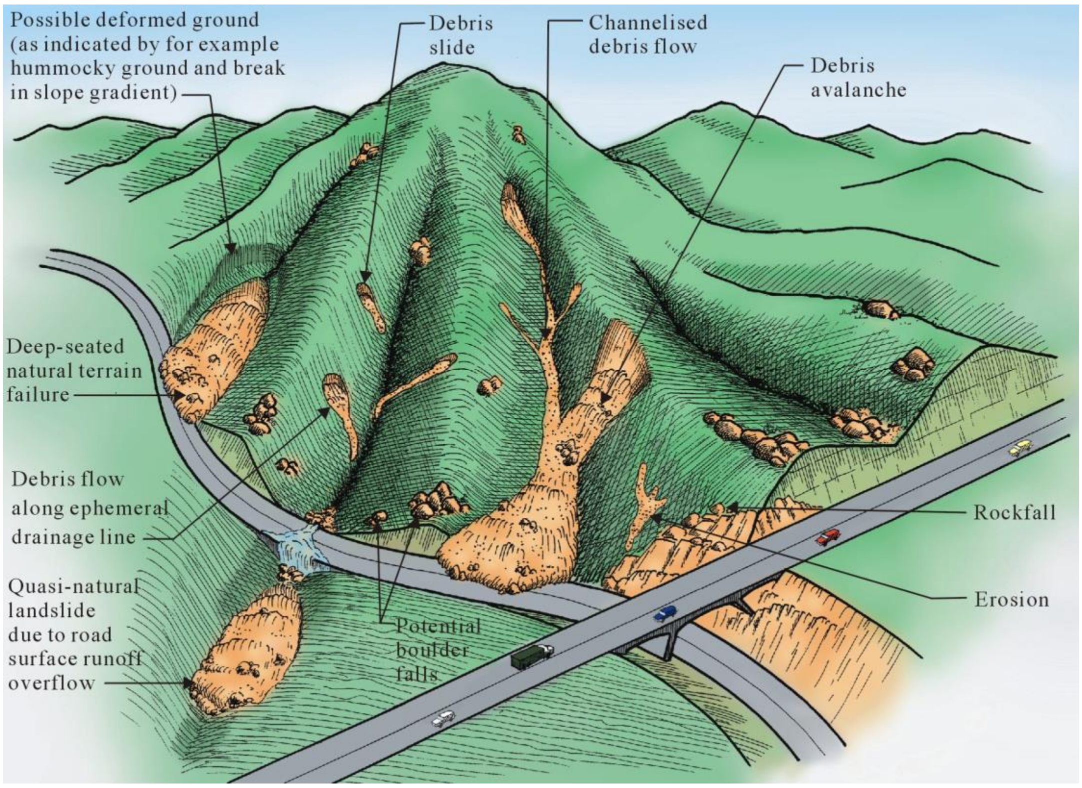


Figure 2.3 Natural Terrain Landslide Hazards Posed to a Highway

evaluation of the geotechnical factors with other factors such as land-take, environmental, drainage and traffic impacts, etc., in an overall assessment of alternative route corridors/alignments.

A preliminary estimate of the costs, programming and geotechnical personnel requirements for the investigation, design and construction of the likely geotechnical works and hazard mitigation measures, and of the recurrent maintenance costs, should be made in the GR as input to the PPFS.

As a general guide, if any of the situations given in Table 2.3 is found to exist, then a GA should be recommended to be carried out.

Table 2.3 Guidelines on When a Geotechnical Assessment Should be Carried Out for a Highway Project

(a)	Where the highway route passes through areas which could be affected by natural terrain landslide hazards (see Table 2.2 and Figure 2.3). Reference should be made to the criterion below[2]: Where there is natural terrain outside the highway, but within the same catchment, that is at an angular elevation of 20° or more from the highway <u>and</u> where there is ground sloping at more than 15° within 50 m horizontally upslope of the edge of the highway. (Further guidance on use of this criterion and determination of the need for further assessment of natural terrain hazards is given by Ng et al (2000)).
(b)	Where the highway route passes through steep terrain the stability of which could be influenced by the engineering works associated with the project. Reference should be made to the criterion below[2]: Where the maximum gradient across the project study boundaries (or any 50 m long strip of land within the study boundary), at right angles to the alignment of the highway, is greater than 15°.
(c)	Where existing slope features are present within the project study boundary or just outside but which could affect or be affected by the proposed highway project. Reference should be made to the criterion below: Where any slope steeper than 30° or a retaining wall, or a combination of the two, with a height greater than 6 m exists within the project study boundary or within 6 m of the boundary.
(d)	Where the highway route traverses areas of soft ground or karstic areas.
(e)	Where there is a likelihood that hazards associated with the construction of the geotechnical works exist (e.g. blasting near sensitive receivers and open or supported excavations exceeding 6 m deep).

Notes:
(1) The project proponent should consult a geotechnical engineer in applying the above guidelines.
(2) 1:5 000 scale topographical maps should be used in applying the criterion.

2.4 Geotechnical Assessment

The objective of a Geotechnical Assessment (GA) is to assess in detail the impacts of the geotechnical hazards and critical geotechnical issues that could influence the design of a highway project, confirm the project feasibility and identify the best option to be taken through to detailed design. The geotechnical activities in a GA are similar to those of a GR except that these are carried out in greater detail. Also, ground investigation works, where considered necessary, would be carried out. The GA should determine more accurately than in the GR the scope of the geotechnical works and hazard mitigation measures, the land-take, costs, programming and geotechnical personnel requirements for investigation, design, construction and maintenance of the chosen route alignment/design option. A model brief for carrying out a GA is given in Appendix C.

GAs should be conducted to different degrees of detail depending on the scale of the potential geotechnical risk and the uncertainties involved, and the feasibility of re-aligning the highway route or adopting an alternative design option later to avoid the risk.

Where natural terrain hazards which could affect a proposed highway project are identified, a Natural Terrain Hazard Assessment (NTHA) (Ng et al, 2000) should be carried out and a mitigation strategy developed as part of the GA. In some situations, even minor earthworks can have a significant impact on the stability of natural terrain. Where the highway or its works are likely to affect the stability of steep natural terrain, the effects should also be assessed and any necessary mitigation measures put in place. Particular attention should be given to assessing whether the natural terrain contains relict structures indicative of slope movements in the past (see Section 3.4.2). Such structures can have a significant influence on the stability of the natural terrain particularly if the highway project is likely to result in changes to ground and/or groundwater conditions.

In assessing the natural terrain hazard mitigation strategy, the provision of buffer zones or catch ditches along the highway should be considered where space permits. However, this solution is often not practicable and other mitigation measures such as constructing the highway on an elevated structure or embankment or provision of defensive works (e.g. barriers, canopies and rock sheds) may be considered. Landslide debris deposition basins, deflection berms or restraining structures at the mouth of drainage lines should also be considered where the possibility of channelised debris flows is identified. In some cases, check dams constructed upstream may be a cost-effective solution for the mitigation of channelised debris flows. Reference should be made to relevant literature for information on this subject (e.g. Franks & Woods, 1997; Lo, 2000). The GA should determine the scope of the mitigation works.

Where a boulder field is identified, there can be great uncertainties in the scope of works, which needs to be accurately assessed before and during construction. Where new cuttings are to be made in a corestone bearing rock mass, there can be great uncertainties associated with the costs and time for excavation. Attention should also be paid to implementing suitable control and safety precaution during rock excavation (see Section 7.3). Appropriate contingencies should be allowed for boulder/rock removal and boulder stabilisation in the works contract in terms of costs and programming.

The formation of high cuts and fill embankments along highways (e.g. > 30 m) should be avoided as far as possible, as these are not only visually obtrusive, they can be difficult and expensive to maintain. Where any high unsupported cuts cannot be avoided after exploring the possibility of adjusting the route alignment and adopting design options such as cut and cover tunnels and elevated structures, design solutions more robust than unsupported cuts such as soil nailing should be considered.

Where a rock cut is required to be formed or re-profiled, especially a high one, the design process should commence at the early stage of the project (e.g. at the Feasibility Study/Preliminary Design stage (see Figure 2.1)). Relevant information should be collected as part of the Geotechnical Assessment (GA) for the preliminary design of the rock slope profile including any berms and/or catch ditch needed (see Section 4.4), and of the likely stabilisation/protective measures. Ground investigation works, if considered necessary, should be carried out. Any special requirements (e.g. landscape/aesthetics, maintenance, land-take and traffic), if dictated by the overall design geometry and constraints, should be identified and specified in the GA, so that they can be adequately addressed in an integrated manner at or before the subsequent design and construction stages. The likely excavation methods and procedures that can satisfy all requirements should be identified, and any significant construction management issues should be highlighted.

Traffic disruption may affect critical facilities which are of social or economic importance, e.g. hospital, fire station, airport, power station, container port and the nearby major roads. Serious traffic disruption could result in significant socio-economic loss to the community. Where road closure is necessary for construction of the geotechnical works or hazard mitigation measures, it may be necessary to carry out a traffic impact assessment at the GA stage for the construction scenarios anticipated. In situations where loss of essential services and/or social disruption are judged to be unacceptable, provision should be made in the works contract for traffic impact mitigation measures to be implemented during construction. This could include minimising closure to not more than a few sections of the road at the same time, limiting the closure length, period of closure, as well as distance between closures, or providing alternative access to the facilities during periods of road closures. Good co-ordination of construction activities to minimise idling time could also reduce the road closure period. The requirements of the relevant authorities should be identified (Highways Department, 1995).

The GA should address the contractual and construction management issues related to the geotechnical works and hazard mitigation measures. The possible impact of contract strategy on the quality of the geotechnical works and hazard mitigation measures should be considered at the early stage of the project. Where a Design & Build form of contract is intended to be used for a highway project with a significant proportion of geotechnical works, in particular where the payment is to be on a lump sum basis, adequate site investigation should be carried out to ensure that there is sufficient information to define beyond any reasonable doubt the scope of the geotechnical works and hazard mitigation measures under the contract. The contract should specify requirements for construction supervision and design review, geotechnical checking, auditing and control testing to ensure quality of the works and construction site safety (see Section 7.2). The use of Design and Build form of contract would not be appropriate if the scope of the geotechnical works and hazard mitigation measures could not be clearly defined for whatever reasons prior to the award of the contract. Reference should be made to Works Bureau Technical Circular No. 31/99 (Works Bureau, 1999a) for guidance.

3 Site Investigation

3.1 General

Guidance on the standards of good practice for site investigation is given in Geoguide 2 (GCO, 1987). Geoguide 3 (GCO, 1988) describes good practice for the description of rocks and soils for engineering purposes in Hong Kong.

For a road project, site investigation frequently extends beyond the design stage, for example, to verify critical geotechnical design assumptions during construction or to support review of performance of slopes during maintenance.

Allowance should be made in the project programme and cost estimates for carrying out site investigation at different stages. The amount of ground investigation works required depends on the amount of existing information available, the complexity of the ground and the scope of works involved in the road project. For even small road projects, the time required from the resolution of land matters, access and application for permission to carry out the ground investigation (e.g. road excavation permit) to the completion of ground investigation reports may range from 4 to 9 months. Extra time will also be needed where a traffic impact assessment is required (see Section 3.3). The cost of ground investigation works (including laboratory testing) to provide information for design is normally at least 2% to 3% of the project estimate. It can be much higher if difficult ground conditions are encountered or if the project comprises mainly slope works, e.g. road improvement projects. Sufficient funds should also be provided to engage an adequate number of experienced site supervisory personnel to supervise the ground investigation works (see Section 3.4.1).

3.2 New Road Projects

Site investigation for a new road project should be carried out in stages. Information from the successive stages can be used to adjust project details to account for the ground conditions encountered and to revise the investigation works and methods to obtain the most relevant and reliable information. For fast track projects for which there is insufficient time to carry out multi-stage ground investigations before tendering, and for Design and Build projects, a comprehensive ground investigation should be carried out to reduce uncertainties in the design as far as possible.

At the preliminary project feasibility study stage, generally only an indicative route corridor or possible alignments traversing a broad band of terrain are given. A Geotechnical Review (GR) is usually required (see Sections 2.2.1 and 2.3). A desk study of the existing information available is the most cost-effective approach of site investigation at this stage. The potential uses of different types of information collected for the desk study are briefly described in Table 3.1. Some of the information available may be of questionable quality (e.g. very old ground investigation and construction records). Particular care should be taken to avoid over reliance on such information in drawing critical conclusions. A site reconnaissance/walkover survey should be carried out at selected locations along the routes under investigation, to confirm and supplement the information collected during the desk study. Such reconnaissance work is very valuable. It takes relatively little time to carry out, and it allows a rapid evaluation of the scale of the hazards for comparison of various route options.

Table 3.1 Potential Uses of Different Types of Information to be Collected at Desk Study Stage for a Highway Project

Types of Information	Potential Uses
Topographical maps and plans	1:5 000 maps are useful for initial screening of key topographical constraints and hydrological and hydrogeological features along the highway route and within the project study boundary and nearby. Larger scale maps, e.g. 1:1 000 maps, are useful for examining individual slope features.
Hong Kong Geological Survey geological maps and memoirs and Geotechnical Area Studies Programme (GASP) Reports	Information on the geology and structure (e.g. faults) and engineering geological information within the project study boundary and nearby can be found from relevant geological maps, memoirs and GASP Reports.
Data in the Slope Information System (SIS) and data from the Slope Maintenance Responsibility Information System (SMRIS) maintained by the Lands Department	These are useful for locating sizeable existing man-made slope features within the project study boundary and nearby. The SMRIS data can provide information on land and slope ownership status. Lease and engineering conditions can be obtained from the Lands Department, if required.
Past landslide data and study reports	The Annual Rainfall and Landslides Reports and the Landslide Study Reports together with the lessons learnt give useful information on and insights into the types of problems that need to be solved for slope features within the highway project study boundary and nearby.
Ground investigation and laboratory test data	These can provide subsurface geological and geotechnical information, including the groundwater conditions and soil and rock joint shear strength data.
Aerial photographs	These can provide information on site history and geomorphology. For example, the presence of any old fills left on the downhill side of an existing road when it was formed, and their extent, time of placement, and histories of past failures, if any, can be assessed using available photographs. Photolineaments which are often the surface expressions of geological structures such as faults can also be identified. Furthermore, the aerial photographs can be used to assess whether there have been significant past movements/signs of distress at areas of natural terrain, and whether drainage/stream courses, boulders and other hazards are present and could affect the highway project.
Natural Terrain Landslide Inventory (NTLI), Boulder Field Inventory and landslide database of the GEO	These can provide information on large-scale natural terrain landslides and boulder falls, and landslides associated with man-made slope features within the project study boundary and nearby.
Slope construction and Engineer Inspection for Maintenance records	These can provide an indication on the standard of construction (e.g. degree of compaction of fill embankments) and information obtained during maintenance of existing man-made slope features. Record photographs can sometimes show the ground conditions of highway slopes to different degrees of detail.
Services and utilities information	Information on the locations of such features and their age and maintenance (e.g. records of leakage and bursts for water-carrying services) is useful for highway slope design and stability assessment.

Note: Reference should be made to Appendices A and B of Geoguide 2 (GCO, 1987) for additional guidance.

Where a Geotechnical Assessment (GA) is needed (see Sections 2.2.1 and 2.4), further site investigation should be carried out and be part of the Feasibility Study/Preliminary Design stage of the highway project. The main aim of such site investigation is to determine more accurately the nature and severity of all geotechnical hazards affecting the project. It should include a more detailed aerial photograph interpretation and walkover survey/mapping along the proposed route to ascertain the nature, location and geometry of the existing and potential hazard features and any signs of distress or movement of the ground (see Section 3.4.2).

Simple ground investigation works, such as dynamic probing, trial pits and trenches, and slope surface stripping, are cost effective for collecting data. Remote sensing techniques and geophysical methods are also cost-effective for collecting information where the project study area is large, but the results should be interpreted using logs from ground investigation drillholes and trial pits, for data control purposes. Examples of geophysical methods include seismic and resistivity surveys. Reference may be made to the Transportation Research Board (1996) and World Road Association (PIARC) (1997) for a discussion on the latest developments in these areas. In some cases, it may be necessary to sink drillholes, carry out field tests and install suitable instruments for monitoring purposes.

Any ground investigation works required in the GA should be carried out as early as possible. Such works should be planned to provide sufficient information to formulate the geological, groundwater and surface water models for the detailed design of the slope features, geotechnical works and hazard mitigation measures. Data obtained from ground investigation during detailed design are seldom fully used because they are not available in time. Therefore, ground investigation should only be carried out in the detailed design stage where it is essential to fill data gaps.

In the ground investigation, soil and rock samples should be recovered for detailed examination and checking for adverse features such as weak zones (see Section 3.4.3) and, where necessary, laboratory testing. Detailed engineering geological mapping of the geotechnical features along the chosen route should proceed as part of the ground investigation. It should provide detailed descriptions of the exposed materials, including any discontinuities, relict structures and their nature, persistence and orientations, at natural terrain or man-made slope features. Observations of possible adverse topographical features (e.g. drainage valley with colluvial/alluvial deposit and local depression above a slope), surface water distribution and seepage points should also be recorded. These observations and other ground investigation information should be examined together carefully, to develop the geotechnical hazard models taking into account the hazards that could affect or could be introduced by the road project during construction and in the long term. The data needs for resolving key issues in the design of slope features, geotechnical works and hazard mitigation measures (e.g. stability, land-take, construction, etc.) should be satisfied as far as possible.

In the mapping of discontinuities, special emphasis should be given to identifying adverse geological features and dilated rock joints or open joints with infill or sediment, which could indicate progressive slope deterioration and/or adverse groundwater conditions. The key characteristics of these adverse geological features should be adequately mapped. In addition, care must be taken to ensure that apparently minor, but kinematically significant joint sets or individual joints are not overlooked (Evans & Irfan, 1991). However, sample of joint measurements should be representative of the overall picture, in order to avoid collection of large quantities of measurements that may have little relevance to stability assessment.

[Amd HSM/01/2017]

Large-scale rock slope failures have occurred involving laterally persistent discontinuities such as sheeting joints. The waviness of a sheeting joint could involve local steepening of the joint dip angle behind the slope face, which can be difficult to detect in practice (HCL, 2001). [Amd HSM/01/2017]

Site-specific laboratory tests may be carried out to characterise the operational joint shear strength where considered necessary, with consideration given to the roughness and persistence of the joint, influence of any weak infill, etc. (Hencher, 1981). [Amd HSM/01/2017]

At the construction stage, additional ground investigation will be required in areas where critical information is incomplete for verification of the assumptions made in the geotechnical design or slope stability assessment, e.g. due to access or time constraints. In cases where the level of the soil/rock interface is critical, such as in designing new rock slopes, it is worthwhile to carry out proof drilling at close centres (say 15 to 20 m) to confirm the rockhead level and the associated weathering profiles prior to cutting the slopes above. This should be considered if, for example, there are tight land constraints at the crest of the slope, or features such as dykes or fracture zones are present in the rock which may lead to very variable rockhead levels. Pre-drilling is also needed to determine the founding level of retaining walls. Installation/replacement of piezometers may be required to provide further groundwater information. Guidance on geotechnical design review during construction is given in Section 7.4.

Groundwater information is particularly important for the design and stability assessment of geotechnical works for a highway project. A search should be carried out, preferably at preliminary project feasibility study stage, to locate data from existing piezometers and raingauges along the route, both within the project study boundary and nearby. This should be followed by a walkover survey along the route to identify locations and record the amount of seepage from existing slopes. The information collected should be examined together with the existing groundwater data to review the need for further investigation, taking into account the new slopes to be formed along the highway. If required, monitoring should be carried out at existing piezometers and additional piezometers should be installed to fill the data gaps.

Any groundwater monitoring required should be carried out as early as possible after the decision is made to proceed with the project. Data should be collected for a sufficiently long period for the assessment of groundwater levels and their possible changes in response to rainfall and highway construction effects, for the design and stability assessment of new and existing slope features respectively. If verification of the assumed groundwater levels is needed, e.g. where it is critical to the design and stability assessment, arrangement should be made under the construction contract to continue the monitoring into the construction stage and afterwards. Any requirement for additional piezometers to be installed during construction should be included in the contract.

The control of surface water is also extremely important. Particular attention should be given to identifying surface water flow paths and evaluating their possible effects on the new and existing slopes in the highway project. Reference should be made to Section 5.2 for guidance on the provision of slope drainage and associated road drainage.

3.3 Road Improvement Projects

For road improvement projects, similar principles as for site investigation of new road projects apply, especially where new slopes are to be formed by cutting into the natural terrain or existing slopes. Special attention should be paid to ensure the safety of road users and the investigation personnel (Works Branch, 1995a), that disruption to traffic is minimal and that road drainage and roadside services are not adversely affected.

Where possible, all ground investigation works should be carried out away from the road carriageway and pedestrian footpaths so that the minimum horizontal clearances from the carriageway as given in the Transport Planning and Design Manual Volume 2 Chapter 3 (Transport Department, 1984) and an accessible width of 1 600 mm of footway can be maintained.

Very often, space or access is limited and the above requirements cannot be met at all locations along the road. In such situations, consideration should be given to adopting suitable techniques that can allow some of the investigation works to be carried out on or above the slope, e.g. using lightweight platforms and equipment erected from above, so that closure of the road is not required at these locations.

Prior to the start of ground investigation works, traffic impact assessments (TIAs) may have to be carried out where road or pedestrian traffic will be affected. Reference should be made to Guidance Note No. RD/GN/021 issued by the Highways Department (1995) on this. Where a TIA is required, adequate time should be allowed for in the ground investigation programme. Depending on the site conditions, it may take 6 to 8 weeks or more to carry out the TIA and obtain the necessary permission to commence the ground investigation works on site.

3.4 Other Considerations for Road Projects

3.4.1 General

Ground investigation works such as drillholes for a road project are often carried out concurrently at widely spaced locations. In putting together the investigation requirements, a programme supplemented with a layout plan should be prepared showing the locations and nature of works that are to be carried out concurrently, so that adequate site supervisory personnel can be assigned. This should be done taking into account the actual site conditions ascertained from a walkover survey along the route.

At locations where re-routing and/or ducting of any existing services near highway slope features are likely to be required, the locations of the services should be confirmed by inspection pits during ground investigation. Such locations should be surveyed and documented. This information is important to facilitate both design and construction, in particular to minimize the need for re-design during the contract.

3.4.2 Areas with Signs of Distress or with Known or Suspected Ground Movement/Deformation

In situations where new high cuttings are to be excavated in sloping terrain, whether in soil or rock, a central issue is whether the natural ground is inherently stable, or whether it contains relict structures caused by slope movements in the past. Many significant landslides on roads were “second time slides”. Therefore, where a proposed route traverses areas with signs of distress, or areas with known or suspected past ground movement/deformation, as identified by aerial photograph interpretation, a detailed study should be carried out to provide data for the assessment of the stability of the terrain and its possible impact on the route.

Low altitude aerial photographs and data on past landslides could provide information for assessing whether there has been progressive development of a ground failure involving significant ground deformation (Sun & Campbell, 1999). A site walkover survey should be carried out to collect information on the nature of the distress and/or ground movement/deformation together with geomorphological and engineering geological mapping. Where required, conventional surveying should also be carried out to provide ground movement monitoring and control data at carefully selected locations. In some cases, it may be worthwhile to sink drillholes and install instrumentation such as piezometers and inclinometers to provide subsurface hydrogeological and deformation information to aid interpretation. Where necessary, suitable investigations and tests should be carried out to determine the mass shear strength of the deformed ground for the purpose of slope stability assessment and design. General guidance on slope instability recognition, surface observation, geological mapping, etc., is given in Chapters 8 and 9 of TRB Special Report 247 (Transportation Research Board, 1996).

3.4.3 Geological Features Adverse to Stability of Cut Slopes

The presence of adversely oriented clay seams and clay-filled joints in a weathered rock mass (Plates 3.1 and 3.2) can contribute to the failure of highway cut slopes, e.g. the cut slope failure at Fei Tsui Road (GEO, 1996a). Other geological features such as adversely located fault zones or major joint sets, weak or impermeable materials, pre-existing shear surfaces, preferential flow paths and internal erosion pipes, can also affect slope stability. They should be specifically checked for when investigating existing cut slopes, as well as after any new cut faces are formed along the road during construction.

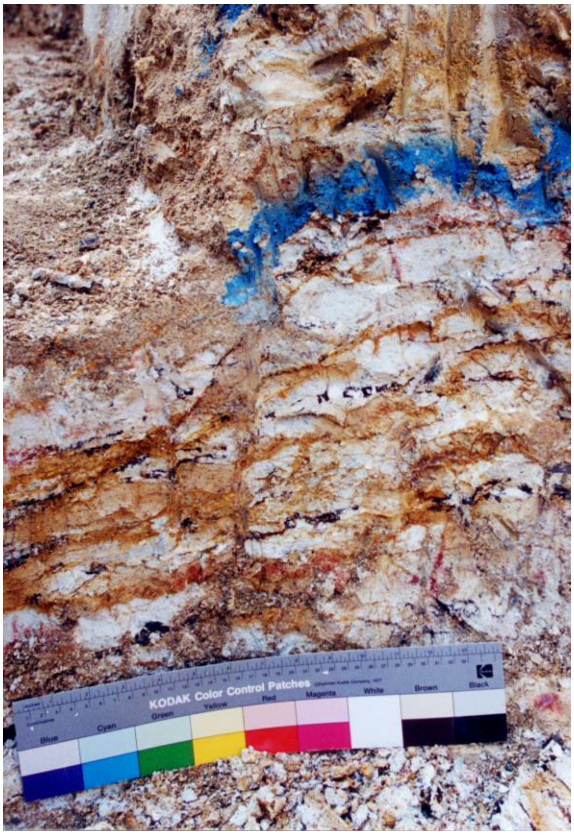


Plate 3.1 Fei Tsui Road Landslide Which Occurred in August 1995 (GEO, 1996a)

Plate 3.2 Kaolinite-rich Altered Tuff Exposed at the Fei Tsui Road Landslide

4 Design of Slopes and Retaining Walls

4.1 General

General guidance on the geotechnical design and stability assessment of slopes and retaining walls is given in the references as shown in Table 4.1. This Chapter provides additional guidance relevant to highway slopes. Guidance on drainage provisions, water-carrying services, design review during construction, maintenance and landscaping, which are an integral part of slope design and stability assessment, is given in other chapters in this Manual. The designer should familiarise himself with the contents of the Geotechnical Assessment (GA) Report before commencing the detailed design. If a GA is not required to be conducted, the contents of the Geotechnical Review Report and the general guidance given in Section 2.4 may still be relevant and should be borne in mind.

Table 4.1 General Guidance on the Geotechnical Design/Stability Assessment of Slopes and Retaining Walls

General Guidance	References
Design and stability assessment of new and existing slopes, and existing gravity retaining walls	Geotechnical Manual for Slopes (GCO, 1984); Works Bureau Technical Circular (WBTC) No. 13/99 (Works Bureau, 1999b)
Design of new retaining walls	Geoguide 1 (GEO, 1993)
Prescriptive measures for cut slopes and retaining walls	GEO Report No. 56 (Wong et al, 1999)
Stability assessment of old masonry walls	GEO Circular No. 6/96 (GEO, 1996c)
Design and construction of rock slopes	Geotechnical Manual for Slopes (GCO, 1984); Rockfall Hazard Mitigation Methods (FHWA, 1994); Parts 3 and 4, Landslides: Investigation and Mitigation (Transportation Research Board, 1996)
Design of reinforced fill structures	Geospec 2 (GCO, 1989)
Design of reinforced fill slopes	GEO Report No. 34 (Wong, 1993)
Design of embedded retaining walls for deep excavations	GCO Publication No. 1/90 (GCO, 1990)
Assessment of natural terrain	Geotechnical Manual for Slopes (GCO, 1984); GEO Special Project Report No. SPR 5/2000 (Ng et al, 2000)
Slope detailing (i.e. surface protection measures and drainage provisions)	Geotechnical Manual for Slopes (GCO, 1984); GEO Report No. 56 (Wong et al, 1999); CED Standard Drawings (CED, 1991); HyD Standard Drawings (Highways Department, 1998)

4.2 Consequence Category of Highway Slopes

In determining the consequence category of a highway slope in the event of a landslide, the designer should exercise professional judgement in assessing factors such as possible mechanism and scale of failure, proximity of the road to the slope, the likely travel distance of landslide debris, and the nature of the highway. Examples of consequence-to-life categories and economic consequence categories of highway slopes directly affecting a road are given in Tables 4.2 and 4.3 respectively.

Table 4.2 Consequence-to-life Categories of Highway Slopes

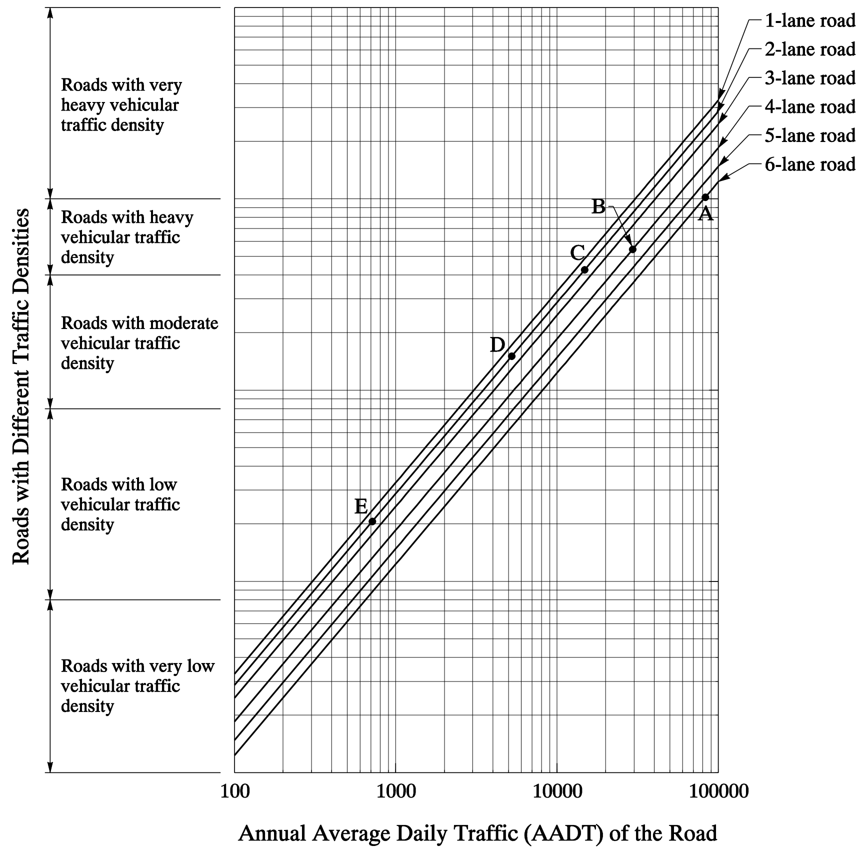
Examples	Consequence-to-life Category		
	1	2	3
Slopes affecting roads with very heavy vehicular traffic density	✓		
Slopes affecting roads with moderate to heavy vehicular traffic density		✓	
Slopes affecting roads with very low to low vehicular traffic density			✓

Notes:
(1) The above examples are for guidance only.
(2) Reference may be made to the nomograph in Figure 4.1.
(3) Where a highway slope also affects other facilities (e.g. buildings), the highest consequence category should be adopted for the slope.

Table 4.3 Economic Consequence Categories of Highway Slopes

Examples	Economic Consequence Category		
	A	B	C
Slopes affecting expressways, urban or rural trunk roads, primary distributors or roads of strategic importance (e.g. North Lantau Expressway, Tuen Mun Highway, Ching Cheung Road, etc.) and mass transportation facilities (e.g. MTR and KCR)	✓		
Slopes affecting district or local distributors, rural roads types (A) and (B) which are not sole accesses		✓	
Slopes affecting rural feeder roads and small roads not classified by Transport Department, which are not sole accesses			✓

Notes:
(1) The above examples are for guidance only.
(2) In assessing the economic consequence in the event of road blockage or closure due to a landslide, due regard should be given to factors such as:
(a) whether the road is a sole access which has implications on the accessibility of emergency vehicles such as fire engines and ambulances,
(b) the consequence to the facilities served by the access, and
(c) impact on alternative transportation routes and essential services.



Legend:

- A Princess Margaret Road (from Wylie Road to Pui Ching Road)
- B Pokfulam Road (from Pokfield Road to Mount Davies Road)
- C Castle Peak Road (from Sham Tseng to Siu Lam)
- D Borrett Road
- E Shouson Hill Road West

Notes:

(1) The above nomograph corresponds to a reference landslide (i.e. 50 m^3 in volume) directly affecting roads with different vehicular traffic densities (see Wong et al (1997b) for details).

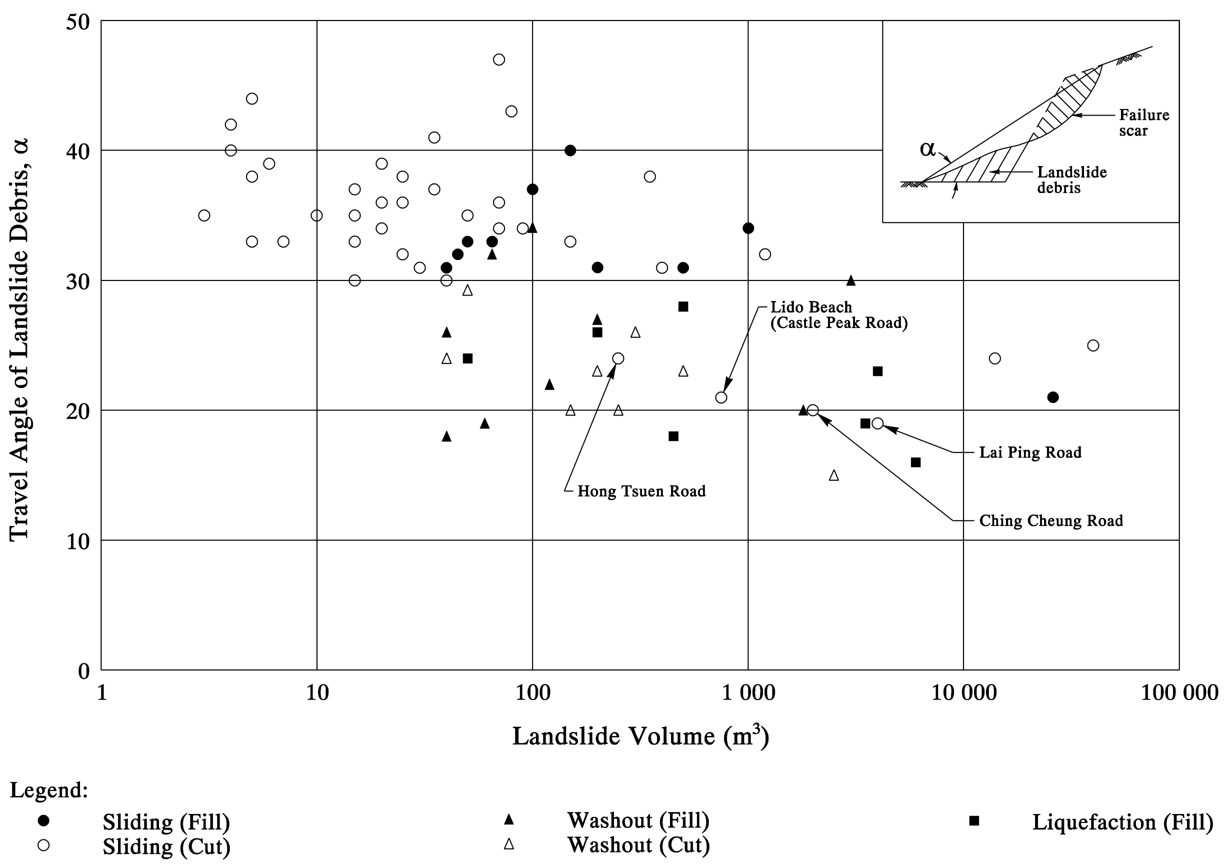
(2) Information on actual AADT is given in the Annual Traffic Census and Statistics published by the Transport Department. Design AADT values are given in the Transport Planning and Design Manual (Transport Department, 1984).

(3) The design AADT, the expected AADT or the actual AADT, whichever is the highest, should be considered. The AADT used should be documented in the Maintenance Manual to facilitate review in future Engineer Inspections for Maintenance (GEO, 1998a).

(4) A to E are examples based on 1999 traffic census data (Transport Department, 2000).

Figure 4.1 Relationship between Roads with Different Traffic Density, AADT and Number of Road Lanes

Where the road lies beyond the expected influence zone of a landslide, the consequence categories as given in Table 4.2 may be downgraded as appropriate. Reference may be made to Figure 4.2 and WBTC No. 13/99 (Works Bureau, 1999b) for further guidance on this.



Notes:

(1) This Figure is based on Wong et al (1997b) and GEO internal data. Discussion on different slope failure mechanisms is given by Wong et al (1998a).

(2) The mobility of landslide debris is dependent on the mechanism and volume of failure (Wong & Ho, 1996).

(3) The travel angle for typical rain-induced landslides involving small to medium-scale failure (viz. landslide volume < 2 000 m³) generally ranges from 30° to 40°, but it could be lower for unfavourable site settings.

(4) For landslides involving static liquefaction of loose fill or wash-out action, the travel angle reduces to 15° to 30°.

(5) The high mobility of the four cut slope failures highlighted, viz. at Castle Peak Road (Halcrow, 1999a), Ching Cheung Road (Halcrow, 1998), Hong Tsuen Road (Halcrow, 1999c) and Lai Ping Road (Sun & Campbell, 1999), is related to the specific site settings.

Figure 4.2 Data on Debris Mobility for Different Mechanism and Scale of Landslides Involving Cut and Fill Slopes in Hong Kong

4.3 Factors of Safety

The recommended minimum factors of safety for design of new highway slopes and stability assessment of existing highway slopes are given in Tables 4.4 and 4.5 respectively.

For a failed or distressed slope feature, the cause of the failure or distress must be specifically identified and taken into account in the design of the remedial works. The designer should decide on the minimum factors of safety to be adopted for the remedial works design (i.e. to consider whether to design in accordance with Table 4.4 or 4.5), taking into account the findings of the failure investigation and the degree of uncertainties involved.

Table 4.4 Recommended Minimum Factors of Safety for the Design of New Highway Slopes for a 10-year Return Period Rainfall

Economic Consequence Category	Consequence-to-life Category		
	1	2	3
A	1.4	1.4	1.4
B	1.4	1.2	1.2
C	1.4	1.2	> 1.0

Notes:

(1) In addition to a minimum factor of safety of 1.4 for groundwater conditions resulting from a 10-year return period rainfall, a slope of Consequence-to-life Category 1 should have a factor of safety of at least 1.1 for the predicted worst credible groundwater conditions.

(2) The factors of safety given in this Table are recommended minimum values in general. Designers should assess if higher factors of safety are warranted in particular situations in respect of loss of life and economic loss (i.e. considering the cost-benefit in designing a highway slope to a higher factor of safety). For particularly vulnerable situations (e.g. sizeable slopes affecting heavily-used facilities with potential major knock-on effects such as landslide debris causing derailment of high-speed trains), a higher factor of safety will be warranted to ensure a sufficiently low level of risk. In such cases, the designer may consider it prudent and useful to also undertake supplementary quantitative risk assessment (Cruden & Fell, 1997) to evaluate the risk and examine the necessary mitigation works.

(3) The choice of factors of safety against economic loss is a decision that must be made by the owner upon the advice of the designer. In advising the owners, the designer should decide for himself the severity of the economic consequence and should balance the potential economic consequence in the event of a failure against the increased construction costs required to achieve a higher factor of safety.

(4) The reliability and robustness of the slope works should be considered, taking into account the sensitivity of performance of the slope works to the uncertainties involved.

(5) Adequate detailing and protective measures should be provided in the design (e.g. improved surface protection systems and drainage provisions, barriers, debris traps, buffer zones, etc.) to reduce the risk of local failures.

(6) The geotechnical parameters to be used in conjunction with the above minimum factors of safety should be the selected values determined by the designer based on ‘best estimate’ parameters following the guidance given in Geoguide 1 (GEO, 1993).

(7) Representative geological models and proper geotechnical characterisation are important for appropriate zoning of the slope-forming material. The relevant design parameters should be determined taking into account the variability in the ground profile.

(8) Some guidance on the assessment of the design groundwater conditions and the worst credible groundwater conditions is given in GCO (1984) and GEO (1993) respectively.

Table 4.5 Recommended Minimum Factors of Safety for the Stability Assessment of / Design of Remedial or Preventive Works to Existing Highway Slopes

Consequence-to-life Category	1	2	3
Recommended Minimum Factor of Safety for a 10-year Return Period Rainfall	1.2	1.1	> 1.0

Note: The conditions to be satisfied for a slope to be regarded as an 'existing slope' for stability assessment and design purposes are stipulated in GCO (1984). In most instances, it is likely to be difficult to fulfill all the necessary conditions because of the scarcity and inadequate quality of the available information and the uncertainty associated with possible adverse changes in the site setting at or in the vicinity of the slope. For these reasons, the guidance on minimum factors of safety given in Table 4.4 should apply in general, except in the rare situation where the designer is confident to use this Table after a rigorous assessment of comprehensive and sufficiently reliable information (see also Works Bureau, 1999b).

4.4 New Rock Cut Slopes

General guidance on the design of rock cut slopes along highways, including stabilisation and rockfall control, is given in Federal Highway Administration (1994) and Transportation Research Board (1996). The design process should include consideration of stability, rockfall hazards, drainage, aesthetics/landscape aspects, land-take, method of excavation, construction safety, maintenance requirements, etc., in an integrated manner.

The practice of relying on conventional stereographic projections and generalised assumptions about joint strength, groundwater, block size, etc. may not be adequate to cater for local weaknesses in the rock mass. Local variations in the slope surface profile that could make minor instabilities kinematically feasible may not be identified if generalised assumptions about the slope profile are made in stereographic analysis. In addition, where a slope has a plan curvature and the presence of an undulating joint set is evident, some localised, potentially unstable, rock blocks may not be reflected in the stereoplots (Hui, 2006). Where appropriate, sensitivity analysis should be carried out to allow for local variations in the slope surface profile. [Amd HSM/01/2017]

Caution should be exercised to avoid over-reliance on simple statistical computer programs because kinematic analysis using joint sets derived from a contoured stereoplot may obscure the variability of discontinuity orientations. With the use of statistical computer programs, the significance of some of the infrequent but critical joints may be missed. Designers should be involved in the site mapping and examine the original uncontoured joint data to critically appraise the results of stereographic analysis. [Amd HSM/01/2017]

Large-scale engineering geological drawings and marked-up transparent overlays to photographs showing all salient features of the rock mass, including locations and extent of potentially unstable blocks and areas of seepage as well as dimensioned locations, extent and details of the proposed support and drainage measures should be prepared. [Amd HSM/01/2017]

The majority of engineered rock cut slope failures in Hong Kong involve minor rockfalls due to local adverse groundwater regimes, root wedging and/or loose or unstable blocks. The latter may be associated with the presence of weaker, more weathered and/or closely jointed rock within a generally strong rock mass, which can be especially vulnerable to deterioration. Such minor rockfalls can be difficult to guard against in design. Although the chance of direct impact by a small rockfall is not high, the consequence in the event of direct impact could be serious given the nature of the material. A pragmatic approach is to provide suitable protective and mitigation measures such as rock mesh netting, rockfall fence, rock trap or rock ditch, rockfall barrier or buffer zone (where space permits) in order to mitigate the consequence and hence reduce the risk of minor rockfalls. In this regard, minor rockfalls successfully retained by these mitigation measures as intended should not be regarded as a failure. [Amd HSM/01/2017]

Specific unstable blocks and seepage locations should be dealt with by means of appropriate local support and drainage measures. However, in the case of a heavily jointed or intensely fractured rock mass, patterned rock dowelling in conjunction with prescriptive subsurface drainage measures and rock mesh netting could be an appropriate solution (MGSL, 2002). Adequate number of fixing pins should be provided to ensure that rock mesh netting closely follows the rock slope profile as far as practical, particularly along the edge of the rock mesh netting on rugged rock surface to prevent any potential loose blocks from falling out from the opening between the netting and the rock surface (Lee et al, 2014). Where potentially unstable blocks exceed the maximum size that rock mesh netting could retain, other appropriate methods (e.g. stabilisation, removal, etc.) should be considered (Hui, 2006). The identification of the weaker parts of the rock mass and seepage locations requiring works can only be specified in detail once the rock face is exposed during construction. A hard cover, such as shotcrete, to the entire rock face is generally not necessary and should be avoided on aesthetic grounds. However, the provision of a hard cover (e.g. stone pitching) together with subsurface drainage measures to local patches of weaker rock mass to limit infiltration and deterioration may be justified from slope stability point of view, subject to appropriate landscape treatment.

[Amd HSM/01/2017]

General guidance on the use of prescriptive concrete buttresses for rock cut slopes is given in Section 5.6 of the Prescriptive Measures for Man-made Slopes and Retaining Walls (GEO, 2009). However, the use of prescriptive concrete buttresses should only be confined to the treatment of small local overhangs or rock blocks. Detailed stability assessment and structural design of reinforced concrete buttresses should be carried out when they are used to stabilize sizeable unstable rock blocks. [Amd HSM/01/2017]

The nature of rock cuts dictates that the design can only be finalised and the extent of stabilisation works ascertained following detailed mapping after the rock face is excavated. Notwithstanding this, all available information including ground investigation and geological mapping data should be used to determine the initial profile of a rock cut. General principles and key considerations relating to the development of engineering geological models are given in Section 3 of the Engineering Geological Practice in Hong Kong (GEO, 2007).

[Amd HSM/01/2017]

As only a small amount of water is needed to fill up rock joints and lead to high cleft water pressure, extreme caution should be exercised in assessing the design groundwater condition. Sufficient subsurface drainage provisions should be prescribed in order to minimise the uncertainty and sensitivity associated with groundwater response in rock slopes.

[Amd HSM/01/2017]

The designer should assess at an early stage the need for the provision of berms and/or catch ditches taking into account all relevant requirements, constraints and available ground information (see Section 2.4). Table 4.6 summarises the key factors that need to be considered in the design of new rock slopes along highways, with particular reference to the provision of berms or catch ditches. [Amd HSM/01/2017]

Table 4.6 Key Factors to be Considered in the Design of New Rock Cut Slopes along Highways (Sheet 1 of 2)

Factors	Considerations
Stability	• The overall cut slope profile (viz. slope angle and possible use of berms) should be determined to ensure stability, taking into account geological features and characteristics of discontinuities in the rock mass, groundwater condition, etc. Major geological features such as adversely dipping persistent discontinuities, sheeting joints, weak weathered seams, fault zones, etc., should be given special attention in the investigation and design of rock cuts. • The practice of relying on generalised assumptions about strength of discontinuities and groundwater may not adequately cater for local weak zones in the rock mass. The rock face should be mapped in detail by experienced personnel. Pitfalls in the practical use of stereographic projection techniques are highlighted by Hencher (1985). • Berms should be provided between batters of significantly different gradients associated with different degrees of weathering. • Berms are generally not necessary in ‘massive rock’(1) from a stability point of view.
Rockfall Hazards	• Where berms are provided, possible ‘ski-jump’ effect of rockfall should be assessed as appropriate. • Berms, if provided, should be as wide as possible (preferably at least 3 m) in order to contain small rockfalls. • Consideration should be given to providing measures on berms (e.g. rock fence, planter box, etc.) to contain small rockfalls. • For a large rock slope, the potential risk of rockfall hazards can be difficult to mitigate with a high degree of confidence. Where practicable, a catch ditch should be provided along the toe of the rock cut to contain potential rockfalls.
Drainage	• Unless the designer considers that there is no potential for surface erosion, drainage channels (e.g. along berms) should be provided. • Berm drainage channels would reduce the velocity and volume of runoff on the slope surface, with consequent reduction of erosion and infiltration.
Aesthetics/ Landscape Aspects	• Where berms are provided, they should be of a sufficient width (preferably at least 3 m) for incorporating landscape works. Suitable measures should be provided to mitigate the possible adverse effects of root growth on slope stability (e.g. by providing a concrete blinding layer at the base of the planter box).

Table 4.6 Key Factors to be Considered in the Design of New Rock Cut Slopes along Highways (Sheet 2 of 2)

Factors	Considerations
Land-take	• A rock slope without berms would minimise land-take. • The option of providing a catch ditch/buffer zone and/or rockfall barrier at road level to mitigate rockfall hazards may not necessarily take up a lot more space than provision of berms on the slope.
Construction	• The construction process (e.g. blasting) is liable to weaken the rock mass, particularly at berm locations if these are provided for in the design. Controlled blasting techniques (e.g. pre-splitting) should be employed to minimise damage.
Maintenance	• Aspects of maintenance inspections and works, including provision of safe access, should be considered and agreed with the maintenance party during the design stage. • Many rock slopes in Hong Kong require regular maintenance (e.g. unplanned vegetation, local deterioration, etc.). Berms can facilitate access for maintenance inspections and works. If berms are not provided, adequate working space at road level should be allowed for as far as possible. • Where berms are provided to allow access for maintenance inspections and works, they should be as wide as practicable for this purpose (preferably at least 3 m). Adequate access to the berms should also be provided to ensure a safe working environment. • Access for maintenance can be difficult and expensive for slopes that are in excess of about 15 m in height but with no berms.
Note:	‘Massive rock’ is defined as a widely-jointed (spacing over 600 mm) rock mass having no unfavourably oriented discontinuities or other defects.

5 Drainage and Water-carrying Services

5.1 General

Slope drainage, road drainage and water-carrying services should be engineered in an integrated manner to ensure that water is channelled safely without impairing ground stability.

General guidance on the provision of subsurface drainage measures and design of slope surface drainage is given in Chapters 4 and 8 respectively of the Geotechnical Manual for Slopes (GCO, 1984). Guidance on prescriptive surface and subsurface drainage measures applicable to existing slopes is given in GEO Report No. 56 (Wong et al, 1999). Methods for the design of road drainage and road pavement subsoil drainage are covered in Road Note 6 "Road Pavement Drainage" (Highways Department, 1994) and Road Note 8 "Subsoil Drainage for Road Pavement" (Highways Department, 2000) respectively. Guidance on the planning, design and management of stormwater drainage systems and facilities is given in the Stormwater Drainage Manual (Drainage Services Department, 2000).

Leakage of water from buried water-carrying services (including sewers, stormwater drains and watermains) can trigger large-scale landslides. The fatal landslide which occurred in 1994 at Kwun Lung Lau (GEO, 1994) is a well documented example. Reference should be made to Section 9.7 of the Geotechnical Manual for Slope (GCO, 1984), Section 6.2.4 of Chapter 7 of the Hong Kong Planning Standards and Guidelines (Planning Department, 1994) and the Code of Practice on Inspection & Maintenance of Water Carrying Services Affecting Slopes (Works Branch, 1996) for guidance on the standards of good practice to prevent leakage from water-carrying services affecting the stability of slopes.

5.2 Slope Drainage and Associated Road Drainage

5.2.1 General Considerations

Unless the highway slope drainage and associated road drainage systems are properly designed and maintained, surface runoff will overflow onto and channelise along roads. If this surface runoff is not drained in time, water may overflow onto the downhill area and trigger serious landslides (Plates 5.1 and 5.2).

Landslides can occur at a road section where:

(a) the upslope drainage or the associated road drainage is partially or fully blocked or has an inadequate design capacity; during rainstorms, the road section will collect a large volume of surface runoff from uphill areas, which may discharge onto the downhill slope, and

(b) the slope below the road onto which the surface water may overflow is a substandard man-made feature, or steep natural terrain of marginal stability, or ground susceptible to erosion or washout by concentrated surface water flow.

Plate 5.1 Surface Runoff Channelising along a Road

Plate 5.2 Shum Wan Road Landslide in August 1995 (GEO, 1996b)

Table 5.1 gives examples of locations which satisfy criteria (a) and (b) above. If the failure of the ground at these locations involves slopes in the Consequence-to-life Category 1 or Economic Consequence Category A (see Section 4.2), then the road section is a 'critical' location in terms of impact of drainage on slope stability.

Table 5.1 Examples of Locations Which May be Considered as 'Critical' with Regard to the Impact of Drainage on Stability of Highway Slopes

(a)	Road sections similar to that at Nam Long Shan Road as in the Shum Wan Road landslide in 1995 (i.e. a long and sloping road with adjacent large uphill slopes which can intercept and collect a large volume of surface runoff and discharge it onto the downhill slopes in the event that nearby catchpits, drainage channels or road drainage components are blocked during heavy rain).
(b)	Road sections traversed by drainage culverts/pipes draining large catchment areas uphill, the blockage of which or the blockage of the nearby stormwater inlets could lead to severe flooding and adversely affect the stability of slopes in the adjacent area.
(c)	Road sections affected by slopes below a catchwater which could be subject to overflowing due to blockage of the catchwater, e.g. by landslide debris.
(d)	Sag points of roads susceptible to large runoff from adjacent road surfaces and slopes which could be discharged onto downhill slopes.
(e)	Road bends supported by downhill slopes.
(f)	Road sections with significant superelevation and large cambering (e.g. greater than 5%) which may lead to overflowing across the carriageway and onto the downhill slopes.

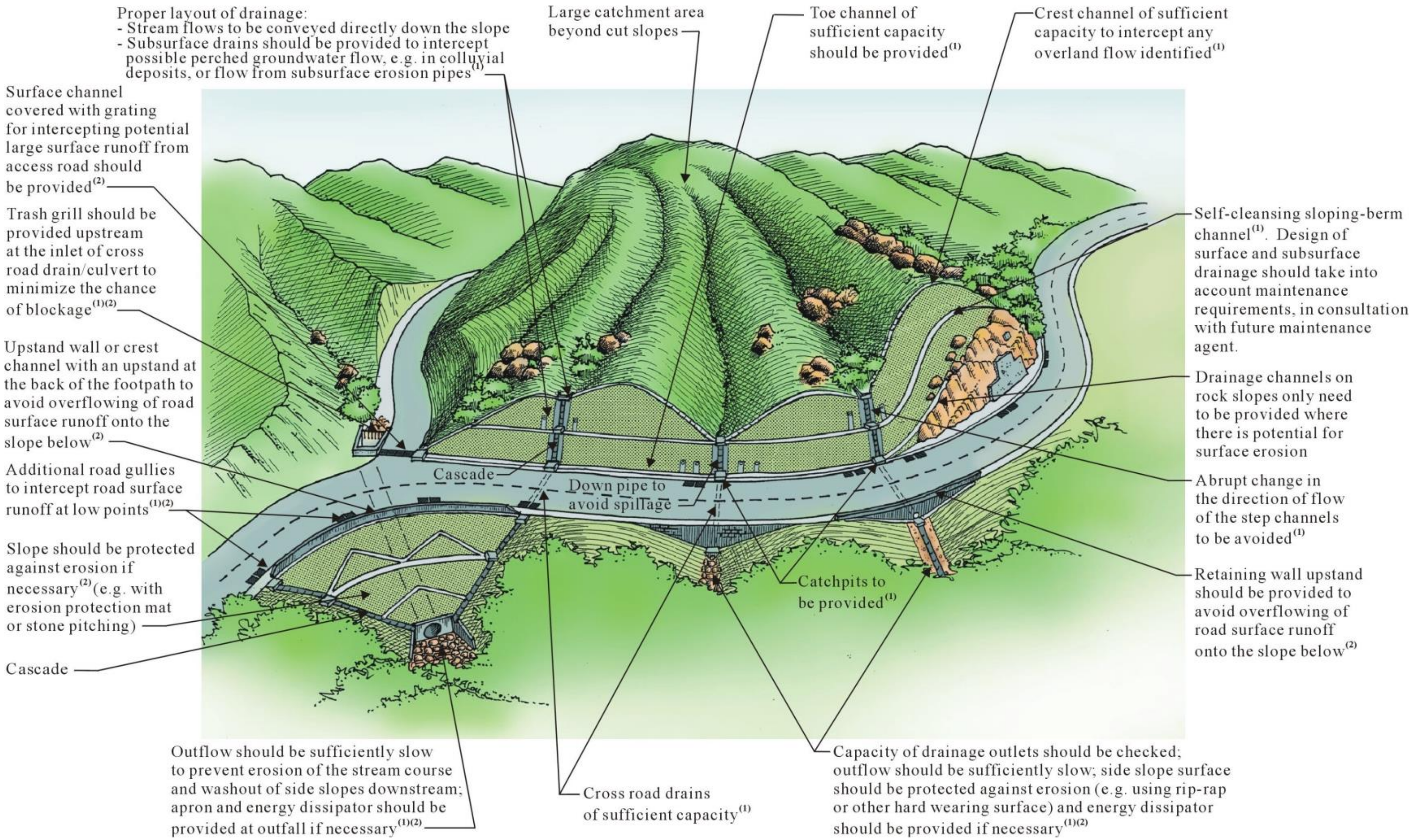
Note: The examples of locations given in this Table should be considered as 'critical' if the failure of the ground at these locations involves slopes in the Consequence-to-life Category 1 or Economic Consequence Category A.

5.2.2 Design of New Drainage Works

Highway slope drainage systems should be designed based on a two hundred-year return period rainstorm (GCO, 1984).

The discharge of surface runoff from a slope and groundwater from any subsurface drainage measures directly onto a road should be avoided as far as possible. Surface runoff along a road should also be collected and discharged properly. In cases where surface runoff is carried across the original catchment boundaries, the impact of additional discharge into existing watercourses and drainage systems should be considered and accounted for (Works Branch, 1995b).

In the design, critical road sections should be identified (Section 5.2.1). Figure 5.1 and Plate 5.3 show examples of methods of handling surface water at critical locations along a road and examples of highway slope drainage and associated road drainage measures.



Notes: (1) Examples of good practice in the design of slope drainage and associated road drainage measures for a new road.

(2) Possible drainage improvement works for an existing road.

Figure 5.1 Examples of Methods of Handling Surface Water at Critical Locations along a Road

(a) Trash Grill at Inlet of Cross Road Drain to Minimise Chance of Blockage

(b) Cascade with Cover to Carry Water Down a Steep Rock Slope

(c) Cross Road Drain and Hard Wearing and Impermeable Slope Surface on the Downhill Side of a Road

(d) Roadside Channel with Grating Covers to Intercept Road Surface Runoff

Plate 5.3 Examples of Highway Slope Drainage and Associated Road Drainage Details

Design detailing of slope drainage and associated road drainage measures should be given particular attention, especially at critical locations. Also, the drainage design should incorporate details which require minimal maintenance. Recommended details of slope drainage and associated road drainage are available in standard drawings (Civil Engineering Department, 1991; Highways Department, 1998).

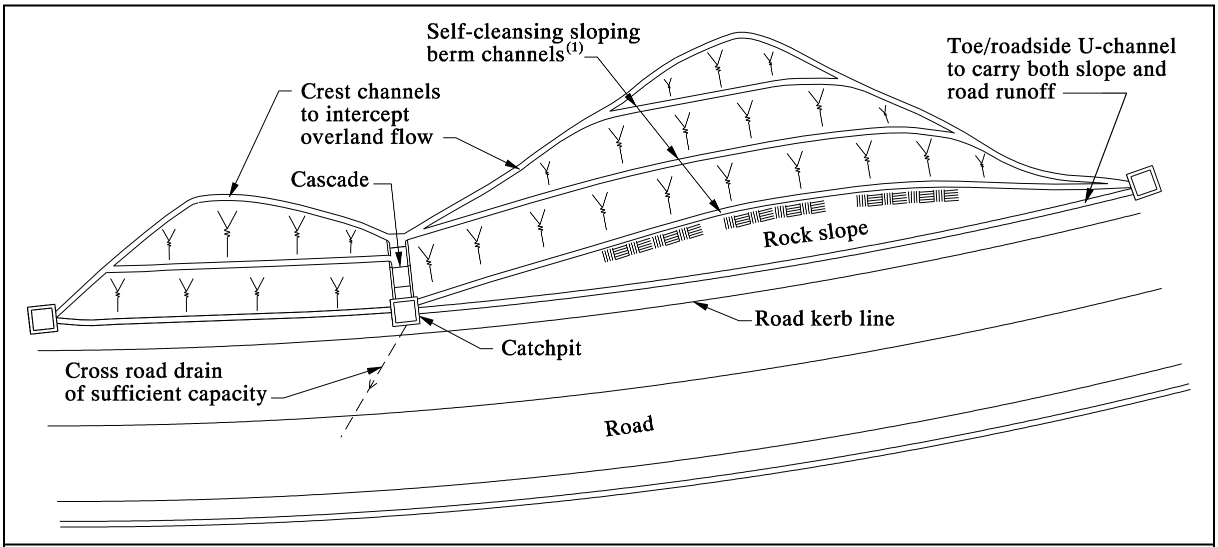
A well-designed surface drainage layout for highway slopes (Figure 5.2), comprising berm channels that drain runoff onto the peripheral down-the-slope channels, would minimise the provision of stepped channels on a slope face. The velocity of the flow in slope drainage channels should be within an appropriate range (see Section 8.3 of GCO, 1984).

Cascades, with cover where necessary, and properly designed catchpits at the bottom, should be used on steep soil/rock slopes to carry water safely down the slope with minimum risk of overspill or excessive splash. They are much more effective at controlling velocity of water than stepped channels, and are preferred especially for channels larger than 400 mm wide. Guidance on the design methodology of cascades is given by Essery & Horner (CIRIA, 1978). In some situations, down pipes may be used, but appropriate detailing of the inlet is required to avoid large volumes of debris from entering the pipe and provision should be made for maintenance to clear blockages if required. Recommended details are available in standard drawings (Civil Engineering Department, 1991).

At critical locations, gullies and buried drainage facilities including pipes and cross road drains/culverts should be generously provided. The capacity to be provided should take into account the possible consequences of overflow that may arise in exceptionally heavy rainstorms or if there is partial blockage. The headwater level at the inlets of cross road drains/culverts should also be checked, taking into account the outlet head/flow conditions, to ensure that water will not overflow onto the road level in the case of these drainage facilities being partially blocked (with say only 50% of the design capacity remaining). Guidance on the hydraulics and design of cross road drains/culverts is given in various design manuals (e.g. Drainage Services Department, 2000; Federal Highway Administration, 1985; Texas Highway Department, 1962).

The containment of the road surface runoff within the limits of the road carriageway should be enhanced at critical locations. This can be achieved, for example, by the provision of an upstand wall or by the provision of channels with an upstand along the crest of the downhill slopes (see Figure 5.3), to contain and divert any surface runoff overflow to an appropriate discharge point. As an additional contingency measure, the slopes on the downhill side of the road may be provided with a robust surface protection (e.g. vegetation established using an erosion protection mat or stone pitching) to enhance their erosion resistance. Under no circumstances should the slopes be used as a runoff surface to cater for surface water overflow from the road above.

For roadside drainage, roadside channels with removable, perforated covers may be used as they are easy to maintain and do not become blocked so easily as buried drainage pipe systems with gullies at wide spacings. They can collect runoff from uphill slopes as well as from the carriageway and can also form a continuous cut-off to prevent surface runoff from overflowing onto the downhill area (see Figure 5.3). Where they are provided, attention should be given to the design detailing and construction aspects so that they do not obstruct the subsoil drainage flow in the pavement sub-base.



Note:	(1)	The decision to select the 'sloping berm' option should be made by the designer after careful consideration of the site conditions and other factors (e.g. maintenance, land-take and ease of construction).

Figure 5.2 Berm Channels for a Highway Cut Slope

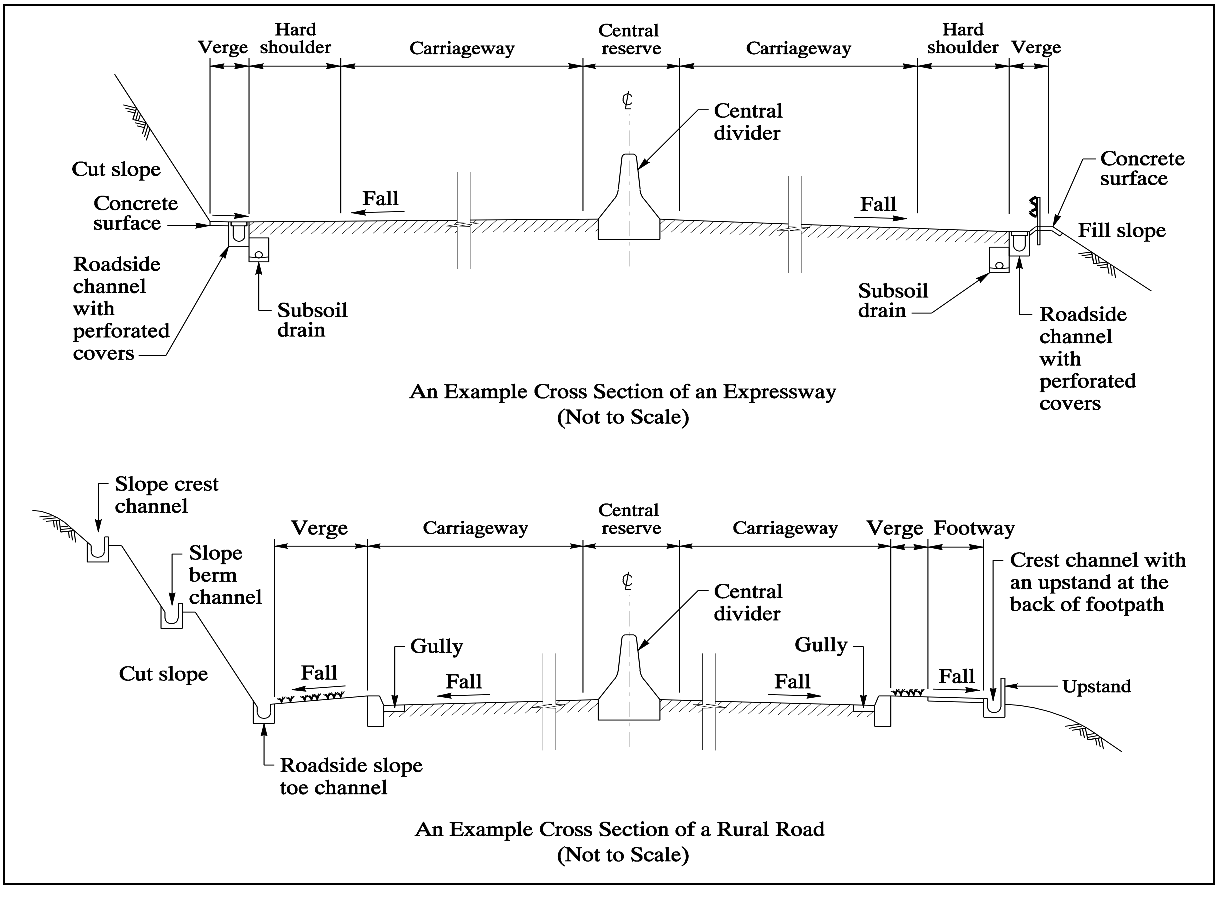


Figure 5.3 Examples of Roadside Channels

5.2.3 Drainage Improvement Works

For existing roads, critical locations should be identified and any road drainage improvement works needed should be carried out in a priority order based on the consequence-to-life and socio-economic consequences should slope failure occur (Figure 5.1). Where opportunities arise, the necessary improvement works should be carried out as part of a road improvement (e.g. widening or upgrading) project or a new project nearby (see Section 2.2.2), or as part of the slope preventive maintenance programme (see Section 8.3).

Any road drainage improvement works required should be carried out to meet the current standards. The maintenance requirements of the improvement works should be documented in a maintenance manual. The adequacy of the works should be reviewed by reference to the maintenance inspections made, including those on the slopes nearby. Further drainage improvement works should be carried out if found necessary.

5.3 Water-carrying Services

When designing a new road, opportunity should be taken to locate buried services well away from the crest of slopes. As a general rule, buried services should not be placed in a slope nearer to the crest of the slope than a horizontal distance equal to its vertical height. For road or slope improvement works, the same rule should also be applied to re-route the existing buried services away from the slopes, where practicable. In cases where the siting of new buried services or the relocation of existing buried services outside the crest area is impractical, mitigation measures for minimising the impact of water leakage on slope stability as detailed in the Code of Practice on Inspection & Maintenance of Water Carrying Services Affecting Slopes (Works Branch, 1996) should be adopted.

General guidance on trench excavation on or above highway slopes (e.g. for services and utilities) and the precautions to be taken for excavation during the wet season are given in Chapter 9.4 of the Geotechnical Manual for Slopes (GCO, 1984). Before any trench excavation at or close to the toe of highway slopes is carried out, an assessment should be made of the effects of the proposed works on slope stability. Where necessary, the extent of excavation should be limited and adequate slope support/stabilisation works should be put in place.

Special attention should be given to locations where permeable fill is present beneath the road surface (e.g. uncompacted fill bodies and granular sub-base) as such material can convey water over long distances, with the resulting risk of affecting the stability of slopes far away from the location of the leaking buried services.

6 Landscape Aspects

6.1 General

The design of a slope should not only take into account the stability, cost and maintenance requirements but should also consider the aesthetic aspects of the slope (Works Branch, 1993). The aesthetic design should aim to complement the landscape and visual character of the areas along the road and to improve the overall visual quality of its setting. The designer should consider the need for advice from landscape architects, both at the design stage and during construction. Such advice is particularly important at locations of high visual sensitivity.

In general, to achieve a balanced slope design that will satisfy both the engineering and aesthetic requirements, geotechnical engineers and landscape architects should work together as a team from inception of the project to develop an integrated solution. Integration of landscape considerations within the various stages of the planning, slope design, construction and maintenance processes is illustrated in Figure 6.1 and discussed below. Conflicts may arise between the engineering and landscape requirements. In such cases, safety considerations should take precedence.

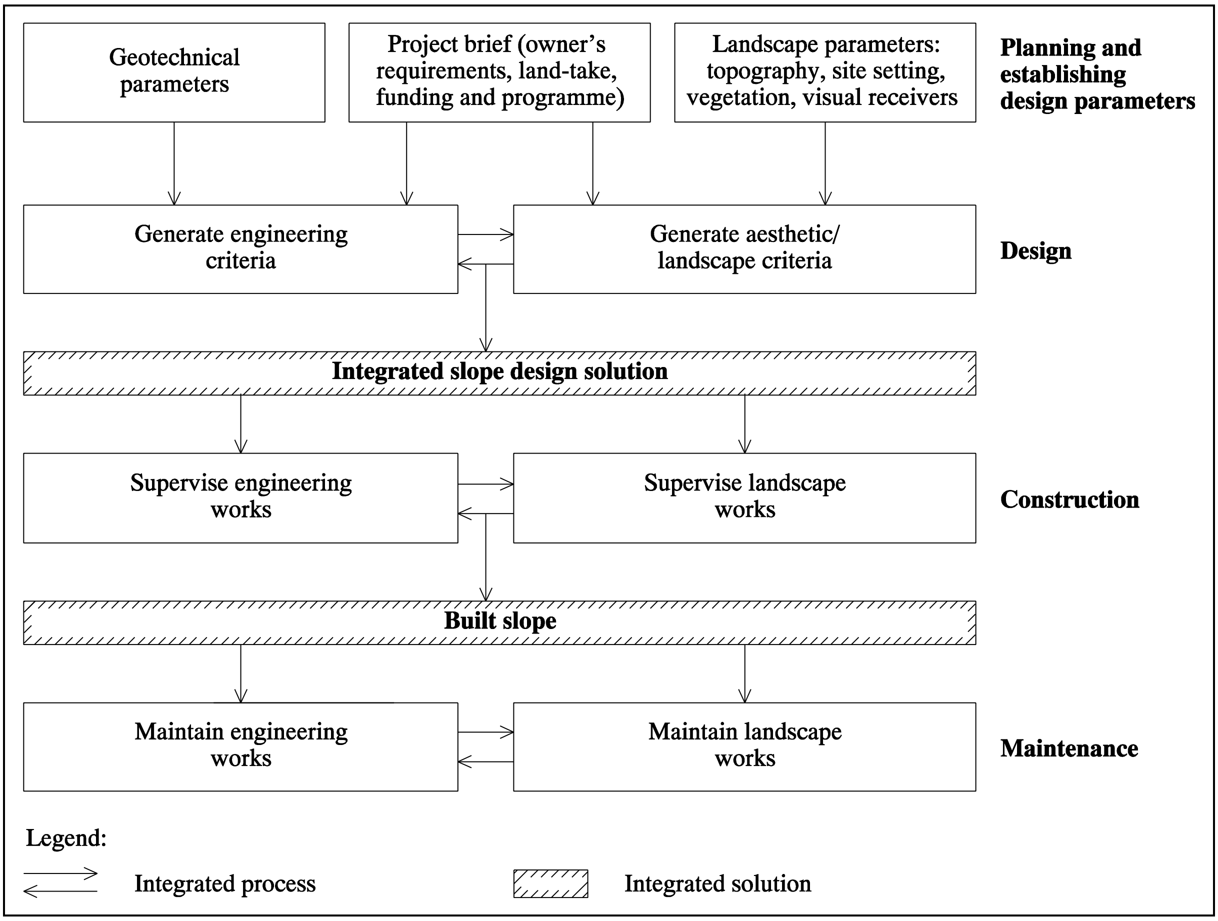


Figure 6.1 Integration of Geotechnical and Landscape Design into the Slope Design, Construction and Maintenance Processes

For the control of visual impact of new slopes, the use of sprayed concrete or other hard surface on slopes should only be considered as a last resort and only after other techniques have been explored and found not practical. This principle should also be adopted for both preventive maintenance and upgrading works to existing slopes.

Detailed guidance on landscape treatment and bio-engineering techniques for man-made slopes and retaining walls is presented in GEO Publication No. 1/2011 (GEO, 2011). [Amd HSM/01/2017]

6.2 Planning of Landscape Works

For new road or road improvement projects involving slope works, it is necessary to consider landscape, visual and ecological impact issues as part of the planning process. For major projects, a landscape, visual and ecological impact assessment should be part of the statutory Environmental Impact Assessment (Environmental Protection Department, 1997 and 1998). This will require the input of landscape architects at various stages of the project and due allowance should be made for programming and funding arrangements.

The resources to be allocated to the landscape/visual design of a roadside slope should be proportional to the visual sensitivity of the location. As a guide, the provision for landscape works should be around 10% but could be up to 20% of the cost estimate for the slope works for very sensitive locations.

6.3 Design Considerations

6.3.1 General

In planning new highway and road improvement projects, areas of high aesthetic value should be avoided and, where unavoidable, every effort must be made to minimise the overall impact and to preserve the balance of every aspect of the environment. Existing landscape features, e.g. trees and rock outcrops, should be retained where possible.

It is important that the engineering and landscape solutions are not developed in isolation from each other, but as part of an integrated process. The aesthetic design solution of a slope should take account of the specific local environmental characteristics and setting (e.g. colouring, micro-climate and vegetation types). Even if two slopes at different locations have similar geotechnical characteristics, the aesthetic considerations may be quite different. For example, attention should be given to the colours in the surrounding landscape as well as textures of vegetation and rock which might be complemented in the final design (Department of Transport, 1992).

Slopes in urban or urban fringe areas demand solutions that are different from those appropriate to rural, rural fringe or Country Park areas. Consideration should be given to adopting solutions that provide opportunity to enhance the environment with vegetation.

Where vegetation is to be established on a slope, the planting design should as far as practicable seek to promote the development of ecologically balanced plant communities, preferably using native species in the area, with a view to supporting wildlife as well as to achieving a self-sustainable landscape with minimal maintenance requirements.

The basic considerations of good aesthetic design are summarized below. Further guidance is given in GEO (2000).

(1) ***Unity and Coherence.*** Solutions that involve simple combinations of materials and features, in a regular rhythm or pattern which blend into the surrounding landscape are generally well received by viewers. An example of good practice is shown in Plate 6.1.

(2) ***Proportion and Scale.*** The design of a slope should take into account the principle of proportion; that is, the appropriateness of the size of one part of an object to that of another part. An example of good practice is shown in Plate 6.2.

(3) ***Pattern and Texture.*** Pattern creates visual interest and can reduce the apparent size of a slope by breaking it up visually. An example of a good solution is shown in Plate 6.3.

(4) ***Rhythm and Complexity.*** In landscapes where there are strong patterns and textures, simple, uniform slope treatments will tend to stand out and can be rather monotonous. An example of a good solution is shown in Plate 6.4.

(5) ***Colour and Albedo.*** Colours used on slopes should be chosen so that they respond to, and complement colours in the surrounding landscape (Plate 6.5). ‘Albedo’, or reflectivity should be avoided so that slopes can blend into the landscape rather than stand out. For this reason, sprayed concrete slopes with no landscape treatment should be avoided.

6.3.2 Aesthetics of Highway Slope Design

Whilst the basic aesthetic slope design principles are common to slopes found in any location, roadside slopes have certain characteristics which are specific to the highway environment.

Roadside slopes tend to have strong linear characteristics corresponding to the linear character of highways themselves. In the roadside environment, hard, engineered lines that look unnatural when seen in the wider landscape setting (e.g. those arising from the long and linear features of a roadside slope) should be avoided. This should be done ideally by rounding off the edges of the roadside slopes (Civil Engineering Department, 1991) and by the use of curves instead of straight edges or planes for forming and blending roadside slopes into their surroundings. An example of good practice is shown in Plate 6.6.

Note: Planting at the toe, top of retaining wall and soil slope above successfully creates a unified appearance to the whole slope and blends it into the surrounding landscape.

Plate 6.1 Unity and Coherence

Note: The creative use of a series of small terraces reduces the apparent size and scale of the slope and allows the introduction of valuable greenery into the road corridor.

Plate 6.2 Proportion and Scale

Note: A good solution which employs techniques in a co-ordinated manner, resulting in a composition that has both a good pattern and texture.

Plate 6.3 Pattern and Texture Plate

Note: A good solution which uses two scales of ribbing to provide sufficient complexity, together with a wave pattern detail, creating a uniform rhythm.

Plate 6.4 Rhythm and Complexity

Note: The red-oxide colour of the sprayed concrete slope could be a 'complementary' colour to the greens elsewhere in the landscape providing a better 'fit' with the surroundings.

Plate 6.5 Colour and Albedo

Note: A good solution to the problems of linear roadside slopes where straight lines and linear cut slopes have been avoided.

Plate 6.6 Rounding off Edges

Roadside slopes may also be distinguished from other types of slope by virtue of the fact that they are often spatially constrained. This may mean that re-profiling of existing roadside slopes is not always possible and the landscape works must fit the existing slope form. Where a road verge or a footpath at the toe of a roadside slope is available, use of toe planters should be explored to obscure the bottom few metres of the slope and contribute to the greening of the roadside environment (Plate 6.7). Alternatively, planters on berms on the slopes can help to break up the towering effect of a slope. Reference should be made to Works Branch (1992) for guidance on the allocation of space for urban street trees.

Because of their linear characteristics, roadside slopes are likely to appear monotonous or boring. The principles of 'Pattern and Texture' and 'Rhythm and Complexity' identified above should be applied to create variety and interest in long roadside slopes. Plate 6.4 illustrates a good example of the creation of interest in an otherwise monotonous roadside wall.

Generally, roadside slopes have a high degree of visual exposure as they are not only seen by those who live and work around them but also by potentially thousands of people who travel on the roads each day. For this reason, it may be justifiable to expend a greater proportion of the budget of roadside slopes on aesthetic design, than in the case of slopes in other locations. Plate 6.8 shows a good example of the use of innovative landscape design in a prominent urban location.

Highways are environments with a strong functional characteristic and the aesthetic treatment of slopes should ensure that the normal functioning of the highway is not in any way impeded. In particular, the functional clearances of roadside features should meet minimum standards, as should features that define sight lines. Reference should be made to the Transport Planning and Design Manual Volume 2 Chapter 3 (Transport Department, 1984) on visibility and sight-line standards.

Designers should note that various Government Departments have set up Vetting Committees on Slope Appearance to control the use of sprayed concrete in slope works (Works Bureau, 2000). Also, the aesthetic design of retaining structures associated with the public highway system should be submitted to the Advisory Committee on the Appearance of Bridges and Associated Structures (ACABAS) for their vetting (Works Bureau, 1998b and 1998c).

Note: Even the smallest area can provide sufficient space to establish trees of significant size.

Plate 6.7 Toe Planters

Note: An example of a slope in a visually prominent roadside location where additional resources were made available to achieve an innovative aesthetic design solution.

Plate 6.8 Innovative Landscape Treatment

6.4 Maintenance Considerations

Maintenance responsibilities in and around the highway environment may involve maintenance parties from a number of different Government Departments. When designing roadside slopes, the designers should take note of the maintenance parties for the completed landscape works by referring to Works Branch (1994a) and should ideally consult these parties at design stage on the aspects of maintenance requirements.

The landscape design of roadside slopes should aim to reduce maintenance requirements (e.g. clearance of overgrown vegetation) to the absolute minimum. It should take into account the fact that space alongside a road is often limited and access to a roadside slope is often difficult. Consideration should be given by the designer to the provision of a safe access for watering in the early years of vegetation establishment and for inspecting the slope and landscape, and maintaining vegetation in the long term. Account should be taken in the landscape design of whether there is a suitable source of water nearby for initial watering purposes.

Where a vegetation cover is provided, careful management by the owner or his maintenance agent in the early years of vegetation establishment will help to ensure that the vegetation remains self-sustaining in the longer term. Long-term maintenance is fundamental to the success of vegetative treatments. The use of fast growing non-native, pioneer tree species to promote the establishment of other native plants, carries with it the need to remove these plants entirely some 5 to 8 years to avoid them becoming dominant.

Where vegetation cover has to be cleared to facilitate the inspection of the slope, provisions should be made for re-planting and regeneration of plant species. Other maintenance operations that should be undertaken on a regular basis include repair of large eroded vegetated areas on the slope and the general inspection of the health of plants. For further guidance on the maintenance of landscape works, reference should be made to GEO (1998a), GEO (2000), Highways Department (1996), SILTECH (1991), Urban Services Department (1992), Works Branch (1993) and Works Branch (1994b).

When slopes with a chunam or sprayed concrete cover require maintenance works, the opportunity should be taken to see if any part of the slope can be provided with a vegetation cover instead (Works Bureau, 2000).

7 Construction Control

7.1 General

The planning for construction control should be carried out at the design stage. The degree of control required will be dependent on the nature of the works, the consequence to life and socio-economic consequence in the event of a failure, the geological conditions and the contractual arrangement of the project. This Chapter provides guidance on construction control for slope works for road projects.

General guidance on construction for slopes and retaining walls and their construction control is given in Chapter 9 of the Geotechnical Manual for Slopes (GCO, 1984) and Chapters 3 and 9 of Geoguide 1 (GEO, 1993). Guidance on construction site safety management is given in the Construction Site Safety Manual (Works Branch, 1995a), Works Bureau (1998a) and Works Bureau (1999c). Guidance on procedures for road closure during construction is given in the Project Administration Handbook (PAH) Volume I Chapter 3 (Government of Hong Kong, 1992).

7.2 Supervision of Works

Site supervisory staff responsible for ensuring the quality of materials and workmanship under the works contract should include adequate geotechnical personnel for the supervision of the geotechnical works and hazard mitigation measures required. Guidance on the requirements for supervision and typical examples of suggested supervision packages for various types of geotechnical works are given in the PAH Volume III Chapter 7 Clause 4.3 (Government of Hong Kong, 1992). In determining the number of site supervisory staff to be provided, specific consideration should be given to the possibility of a number of construction activities occurring simultaneously along the length of the road. The duties and responsibilities of the various parties should be clearly defined.

Site inspections by geotechnical professionals responsible for independent checking of the slope design should be carried out at critical stages of the works including site inspections to vet the design assumptions (and proposed design amendments as appropriate) based on the actual ground conditions encountered. [Amd HSM/01/2017]

Good communication should always be maintained between the designer of the geotechnical works and hazard mitigation measures and the site supervisory staff. Both parties should familiarise themselves with the contents of the Geotechnical Review Report, the Geotechnical Assessment Report (if available) and the geotechnical design reports, in addition to the drawings and specification. Frequent site visits and discussions with the site supervisory staff commensurate with the size and complexity of the project should be made by the designer. At the commencement of the contract, the site supervisory staff should be made aware of the critical construction activities, any additional ground investigation needed and the geotechnical design assumptions. Where the assumptions are not met or where information critical to the verification of design assumptions is revealed on site, the designer should be informed so that site inspections and any necessary design modifications can be made promptly (see Section 7.4). Both design verification and contract compliance testing requirements should be identified early. Arrangements should be put in place by the site supervisory staff shortly after commencement of the contract to ensure the security of the test samples and adequate and timely supervision of any field investigation, design verification and tests required. In some projects, e.g. those involving complex or large-scale rock excavations/slope works, there could be a need to have a professionally qualified and suitably experienced geotechnical engineer or a team of such engineers resident on site to supervise critical construction activities and undertake design review.

Filling operations for a highway project may have to be carried out simultaneously at a number of places at long distances apart. In these circumstances, careful planning should be made to ensure that adequate experienced site staff are available for supervising the placement and compaction of fill and drainage and filter materials, and for conducting any necessary compaction control supervision, arranging the sampling and testing, interpretation of test results and keeping traceable records.

During excavation for the construction of a road, overspill of soil and rock spoil onto the slopes below may occur. These materials can easily be obscured by existing natural vegetation or vegetation that subsequently grows on them. Depending on their locations and geometry, they may pose a hazard if they slide or liquefy in the event of heavy rain. Care should be taken to avoid such overspill or to ensure that such materials are removed at the earliest practicable time once they are identified.

Adequate temporary surface water drainage and slope surface protection should be provided for excavations or fill embankments, especially where large areas are opened up for the road construction in the wet season and there is a significant catchment channelling rainwater into the area (see Sections 9.3 and 9.4.5 of the Geotechnical Manual for Slopes (GCO, 1984)). Where the road crosses existing drainage/stream courses, temporary diversion of the surface water will be necessary during construction. The effect of the temporary flow on slope stability and existing drainage should be assessed.

An examination of the performance of the permanent surface water (slope and road) drainage provisions should be carried out during construction, taking into account the actual site and weather conditions encountered. Where necessary, improvement should be made in consultation with the designer, who should make a careful inspection to finalise the details.

Activities that could present a public safety hazard and the sensitive receivers should be identified. Where rock excavation or removal of spoil is to be carried out near an existing road and the potential consequence of falling debris is significant, adequate protective measures and/or any necessary road closure or traffic diversion should be implemented prior to the work. A survey of the condition of the nearby slopes and likely affected facilities should be conducted, with photographs and/or video taken of any visible signs of distress and structural defects, before the work commences. Where it is judged that the potential volume of falling rock cannot be adequately contained by the protective works, the contractor should be requested to modify his proposed working methods before the work can proceed. Contingency measures should be put in place to clear any fallen debris and repair the protective works quickly to allow the road to re-open within an acceptable period of time. In some situations, rockfall preventive works may have to be implemented in addition to protective measures. Where blasting is involved, the existing slopes alongside the road which may be affected by the blasting operation should be inspected prior to and after each blast and their stability conditions reviewed and certified by a geotechnical engineer prior to making arrangements for re-opening the road (Yeung, 1998). Further guidance on rock removal from slopes along roads is given in Section 7.3 below.

Monitoring installations for evaluation of construction effects on sensitive receivers (e.g. movement and vibration monitoring points) and for verification of design assumptions (e.g. piezometers) should be protected. These should be repaired/replaced where necessary if damaged by construction activities.

For major road projects, the Design and Build form of contract is sometimes used. For such contracts, the contractor should be required to engage an adequate number of qualified and experienced supervisory professionals and competent supporting technical personnel, especially for supervising potentially hazardous construction activities (e.g. blasting and rock excavation). The professionals in the contractor’s team responsible for carrying out inspections and assessments to ensure quality of the works and public safety during construction should be identified. Also, auditing of the contractor’s work against contract requirements, which is a particularly important activity, should be carefully arranged. This should be carried out by personnel independent of the contractor’s site supervisory team and appointed by the client directly, at critical stages of construction (Works Bureau, 1999d). Special control testing, including appointment of laboratories independent of the contractor to carry out the sampling and testing for the critical contract compliance tests (e.g. tests to check the adequacy of fill slope compaction), should also be arranged by the auditing team for the client.

Detailed as-built records should include large-scale engineering geological drawings (e.g. marked-up transparent overlays to photographs) depicting all the major geological features and dimensioned locations, extent and details of all support, drainage and mitigation measures. Photographic record of the exposed rock face should be made as part of the as-built record, especially where a surface cover (e.g. shotcrete to local weak zones or fibre-reinforced soil) is provided. [Amd HSM/01/2017]

7.3 Rock Removal from Slopes

7.3.1 Rock Breaking Methods

Rock breaking methods commonly used in Hong Kong are listed in Table 7.1. The choice of the methods is governed by rock strength and structure, groundwater conditions, safety, and environmental and socio-economic considerations. Fly rock from blasting, and falling rock blocks and debris from percussive excavation methods are common safety hazards. Debris falling onto roads can necessitate prolonged road closure with serious socio-economic implications. The rockfall during the Tuen Mun Highway widening works in 1995 is an illustrative case (Wong, 1997). This case also shows that the use of low energy methods of rock breaking cannot eliminate all problems since failure can occur along unknown geological defects. Apart from the fall of debris and rock fragments, dropping of tools and toppling of construction plant from roadside slopes can also pose a risk to road users.

Table 7.1 Commonly Used Methods of Rock Breaking

Type of Method	Method of Rock Breaking	Typical Energy Rating
Mechanical	Hand breaking by 'feathers and wedges' method	Low
	Digging and scraping with machines	Low
	Line drilling	Low
	Hydraulic hammers	Medium
	Hydraulic wedge breakers	Medium
Chemical	Expansive grout	Low
Blasting	Bulk blasting	High
	Presplitting/smooth wall blasting	High

Note: Typical considerations for rock breaking methods

- Spillage/dislodgement of loose material from the rock mass
- Failures due to unknown geological defects in the rock mass
- Rock mass instability induced by weight of construction plant and equipment
- Uncontrolled leakage of grout into open discontinuities or fractures
- Flyrock causing harm to life and property
- Overbreak of the rock mass
- Adverse effects of excessive ground vibration (e.g. due to blasting, drilling, hammering, etc.) on the rock mass
- Adverse effects of excessive gas pressure on the rock mass (Blastronics, 2000)
- Noise causing nuisance or harm

In the formation of new rock cuts involving substantial rock breaking using expanding agents, adequate measures need to be taken to prevent the uncontrolled flow of the expanding agents, which may adversely affect the stability of rock faces. Moreover, as expanding agents can continue to expand for at least several days, time-dependent deterioration in stability can occur where there is uncontrolled or unintended flow of the expanding agents into joints. [Amd HSM/01/2017]

Blasting is the most common method for bulk excavation in rock in Hong Kong. The most significant problems associated with blasting are flyrock, ground vibration and noise. Figure 7.1 summarises the common methods for the optimisation and control of blasting. Where a permanent rock face is to be formed, controlled blasting techniques should be adopted, where possible, to improve the stability of the rock face and to achieve a good slope surface finish. Reference should be made to Sections 9.4.2 and 9.4.3 of the Geotechnical Manual for Slopes (GCO, 1984) and Section 9.13 in FHWA (1994) for guidance. Methods for assessment of stability of slopes subjected to blasting vibration are given in GEO Report No. 15 (Wong & Pang, 1992).

OPTIMISATION AND CONTROL OF BLASTING

Good Blast Design and Control

- Assessment of previous blasting effects in similar ground conditions.
- Use of no-blast zones.
- Accurate positioning and drilling of blast holes.
- Use of controlled blasting (presplitting or smooth wall blasting) techniques.
- Carrying out blasting trials.
- Specifying blasting sequence.
- Specifying burden.
- Specifying stemming.
- Specifying allowable charge weight of explosives and limits on ground vibration and noise.
- Identifying sensitive receivers and specifying monitoring and on-going interpretation and review requirements.
- Use of experienced personnel for blast design and specification, and for assessment of blasting effects and monitoring, interpretation and review.

Recognition of Hazards

- Regular programme of inspection and mapping.
- Systematic rock mass characterisation.
- Identification and assessment of potential failure modes and block sizes.
- On-going risk assessment procedure.
- Provision of induction/awareness programme and safety training for site personnel.
- Use of experienced personnel for supervision and for undertaking the above tasks.

Prevention of Flyrock

- Optimum charging.
- Pre-blast condition survey of nearby facilities.
- Adequate front row burden.
- Accurate positioning/drilling of blast holes.
- Checking that stemming is sufficient.
- Use of flyrock matting, netting and cages.

Adequate Safety Provisions

- Use of buffer zones.
- Shelter for personnel close to the blast.
- Procedures for evacuation of people in affected areas.
- Road closure or traffic diversion and control.
- Containment and retention of potential rockfall.
- Pre-blast survey and stabilisation of adjacent rock mass if necessary.
- Post-blast checking of potential danger before returning to normal site control.

Figure 7.1 Common Methods for Optimisation and Control of Blasting

7.3.2 Safety Precautions

The main safety precautions that should be considered when rock excavation is to be carried out above and adjacent to a road are given in Table 7.2. Some of these precautions cannot be specified fully in advance in the contract documents because they are related to the working method to be used. The precautions are most effective when addressed at all stages of a project, as shown in Figure 7.2.

Table 7.2 Range of Safety Precautions for Rock Excavation Adjacent to Roads

(a) Provision of method statements detailing the proposed ways and means for excavating rock adjacent to the carriageway (which should be reviewed carefully by experienced engineers).

(b) Provision of road closure or traffic diversion arrangements during critical slope formation operations, e.g.
- mobilisation and demobilisation of construction plant and equipment on the slope,
- rock breaking and blasting,
- rock blocks and debris removal, and
- checking for suspected misfires of blasting.

(c) Provision of temporary rockfall containment and retention measures as appropriate, e.g. rock traps, berms, barriers, catch fences, free hanging mesh, etc.

(d) Stabilisation of potentially unstable boulders and rock exposures prior to access road formation or excavation, where necessary.

(e) Provision of no-blast zones close to carriageway and checking of blast hole locations and charge weights.

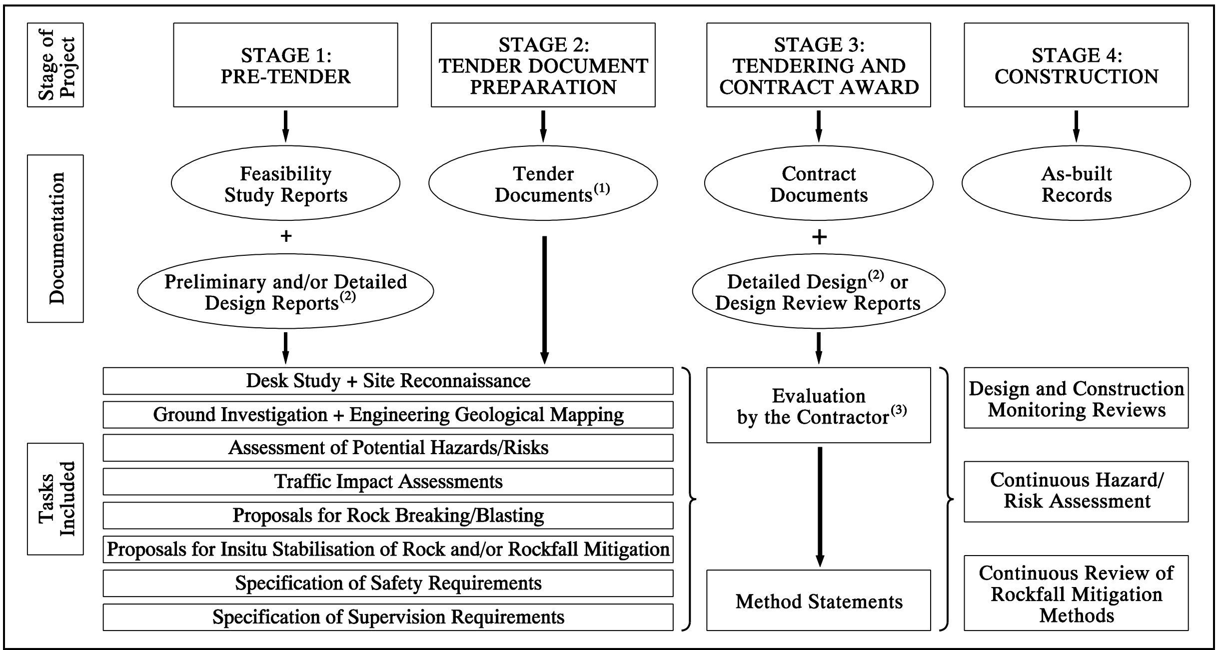
(f) Engaging persons who possess a valid Mine Blasting Certificate or are duly authorised by the Commissioner of Mines in accordance with the Mines (Safety) Regulations (Government of Hong Kong, 1986) to carry out blasting.

(g) Supervision of works by a geotechnical engineer and other suitably experienced personnel with clearly defined and stated responsibilities and authority to suspend all works.

(h) Carrying out inspection of excavated faces by a geotechnical engineer before making arrangements for re-opening the road.

(i) Independent checking of work procedures, geotechnical assumptions, adequacy of new geotechnical works and hazard mitigation measures and stability of existing slopes, including site checks by a geotechnical engineer and other suitably experienced personnel.

(j) Provision of induction/awareness programme on potential rockfall hazards and training in safety aspects of working adjacent to carriageway for site personnel who require them.



Notes: (1) The responsibility for the evaluation of rockfall and design of mitigation measures should be clearly specified. The levels of supervision, qualifications and experience of supervisory staff at different stages of construction should also be specified. All available geotechnical information, initial traffic impact assessment reports, risk assessment reports and information on contractual constraints which may affect the execution or progress of the works (e.g. traffic restrictions and access constraints) should be provided to the tenderers. Where existing slopes are to be modified, information on the extent and details of any existing engineering measures such as coverage and details of rock bolts and dowels installed on the slopes should also be provided.

(2) For Design and Build contracts, only preliminary design reports are prepared at the pre-tender stage and detailed design reports are prepared by the contractor at the contract award stage.

(3) Evaluation of hazard/risk and traffic impact assessment findings should be included.

Figure 7.2 Processes to Address Safety Concerns Arising from Rock Breaking above and adjacent to Roads at Various Stages of a Project

7.3.3 Rockfall Protection and Prevention

Given the uncertainties inherent in any excavation, it is unrealistic to assume that all potentially unstable rock blocks on slopes can be identified by inspection and stabilised using preventive methods alone (such as slope treatment which involves removal or in-situ stabilisation of potentially unstable blocks of rock). Therefore, protective methods (such as provision of rockfall protective barriers) should also be considered for controlling rockfalls.

Except in negligible risk situations, the evaluation of potential rockfall risk should include a comprehensive geotechnical investigation to assess the potential failure modes and the likely scale of rockfalls (sizes of rock blocks and kinetic energy). Rockfall trajectory analyses using computer simulations may be carried out to support decisions on appropriate risk mitigation options. Where such analyses are used, the uncertainties associated with the model and parameters should be borne in mind in interpreting the results of the simulations.

The type and capacity of any protective barrier to be provided and the requirements for any slope treatment prior to excavation would depend on the severity of the rockfall hazard posed to the carriageway (Figure 7.3).

If rockfall protective barriers or fences are required along the road, their location, height and capacity, in terms of the maximum kinetic energy that they can absorb, should be specified. The typical temporary protective fences used in Hong Kong (see Plate 7.1) often have energy-absorbing capacities of only about 10 kJ (equivalent to an approximately 1 m^3 rock block impacting at a velocity of about 3 m/s). Commercially available specialised rockfall fences (see Plate 7.2) have energy-absorbing capacities of up to 2 500 kJ, but even this value is still only equivalent to about 50% of the kinetic energy associated with the fatal 15-tonne rockfall that occurred during the Tuen Mun Highway widening works in 1995 (Wong, 1997).

Clearly, where there is a rockfall risk road closure is essential during critical stages of the works, even if rockfall fences are provided. It should be noted that rockfall fences deform towards the carriageway when absorbing rockfall energy. Capacities of specialised rockfall fences stated by their suppliers are related to certain amounts of deformation. Therefore, adequate clearance must be provided between the carriageway and the fence to allow for such potential deformation.

7.4 Geotechnical Design Review

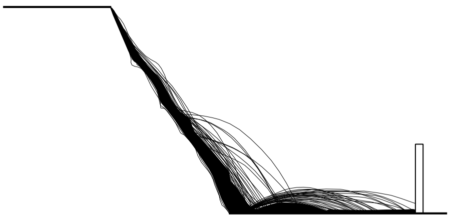
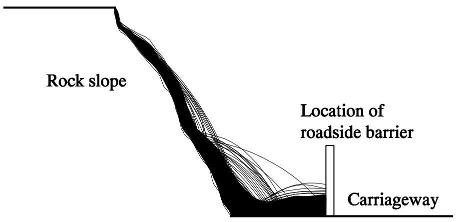
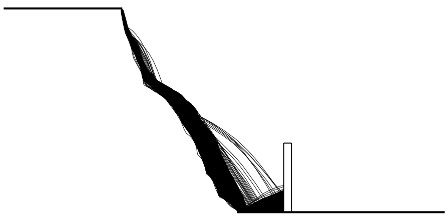
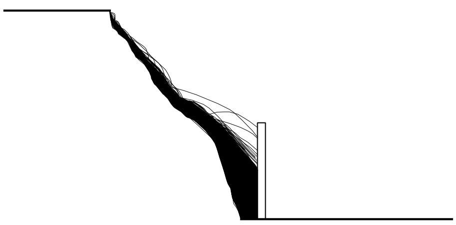
Assumptions critical to the design of any slope works (such as the geological and groundwater models) should be reviewed during construction by a geotechnical engineer who is familiar with the design. This is particularly important for a road project where the alignment may need to be adjusted at a very late stage and there is insufficient time to complete the necessary ground investigation before the works contract commences.

Often the best time to carry out the design review and to confirm the ground conditions at slope features is when the ground is exposed at various stages of excavation where extensive access scaffolding is available for mapping. For a road project, the examination of exposures should be carried out for all slopes in the same area, in an integrated manner. Attention should be given to assessing the influence of variations in rock mass weathering on the design (see Section 3.2 and Table 4.6). Provision should be made in the programme for the mapping and stability assessment of rock slopes, and for amending the design and construction details of the slope stabilisation and rockfall mitigation works.

[Amd HSM/01/2017]

Extra care should also be exercised in verifying the boundaries of different weathering grades of rocks, particularly when detailed mapping of the rock face has not been carried out at the design stage (FSWJV, 2006). Design reviews during construction call for input by geotechnical professionals with adequate engineering geological knowledge and local experience. [Amd HSM/01/2017]

The design review should take into account in particular the performance of the slope drainage and associated road drainage systems provided along the road and any seepage as observed in the rainstorms during construction (see Section 7.2). A review of the adequacy

	Results of Rockfall Trajectory Analyses	Protective Barrier Required	Required Slope Treatment Prior to Excavation
LOW ROCKFALL HAZARD 	No rocks reach roadside barrier.	Simple fence/barrier or concrete block barrier.	No significant requirements.
MODERATE ROCKFALL HAZARD 	No rocks reach barrier in full flight. Bouncing rocks impact barrier at less than 1 m height.	Low energy requirements of up to 100 kJ. Movable barrier with posts socketed in rock and netting.	Increasing demand for slope treatment or preventive works and protective measures to control the block size and quantity of rockfall prior to excavation, with provision for standby plant and measures to break up and clear debris, repair or replace protective fence/barrier, and to implement road closure during excavation.
HIGH ROCKFALL HAZARD 	Bouncing rocks impact barrier at less than 3 m height. Rocks in full flight impact barrier at less than 1 m height.	Moderate energy requirements of up to 250 kJ. Specialised rockfall fence with adequate energy-absorbing capacity.	
VERY HIGH ROCKFALL HAZARD 	Rocks in full flight impacting barrier at heights less than 5 m.	Requires high capacity energy-absorbing rockfall fence, up to a maximum available capacity of 2 500 kJ.	
EXTREME ROCKFALL HAZARD 	Rocks in full flight impacting barriers at heights of 5 m or more.	Requires rockfall fence of maximum available capacity of 2 500 kJ approx. The height of the barrier can become a critical consideration.	Extremely demanding requirements where it is not possible to close the road.

Note: This Figure gives examples only of the requirements for protective barriers and slope treatment prior to excavation for different results of rockfall trajectory analyses.

Figure 7.3 Examples of Requirements for Protective Barriers and Slope Treatment Based on Rockfall Trajectory Analyses

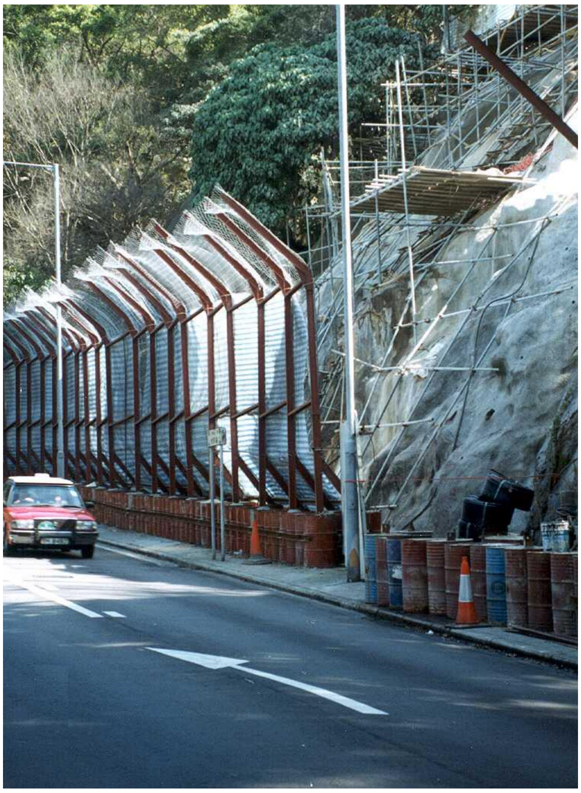


Plate 7.1 Typical Temporary Protective Fences in Hong Kong

Plate 7.2 Specialised Rockfall Fence

of the drainage layout and detailing should be conducted. Attention should also be given to reviewing the provision of surface water drainage to ensure adequate flow capacity and containment of flow within the road and the drainage channels provided during heavy rainstorms, both during and after construction.

The client should be advised to arrange auditing of construction activities and testing for critical items of the works. This should be carried out by professionals independent of the site supervisory team (Works Bureau, 1999d). Particular attention should be given to auditing the frequency and quality of the compaction control tests carried out for fill slopes (e.g. security of samples and selection of field test locations), especially those along a long stretch of highway embankment built over a drainage course, and assessing the adequacy of compaction.

An overall design review should be carried out towards the end of the contract prior to the issue of a certificate of completion. Where the assumptions cannot be fully verified during the contract period and it is not cost-effective nor practicable to extend the contract, the geotechnical engineer should include a recommendation in the Slope Maintenance Manual (see Section 8.2) to advise the owner to undertake further design reviews after the hand over of the works by the contractor.

8 Slope Maintenance and Upgrading

8.1 General

The recommended standards of good practice for slope maintenance are given in Geoguide 5 (GEO, 1998a), which should be followed by all slope owners including owners of highway slopes. General guidance on the inspection and maintenance of water-carrying services affecting slopes is given in the Code of Practice on Inspection & Maintenance of Water Carrying Services Affecting Slopes (Works Branch, 1996).

In order to reduce the risk of landslides, the Government of the Hong Kong SAR has a long-term strategy to upgrade substandard man-made slopes including highway slopes under a Landslip Preventive Measures (LPM) Programme (see Appendix D). However, owners with a large number of roadside slopes to maintain should also develop their own programme of upgrading substandard slopes to reduce the risk of landslides affecting their roads and the road users.

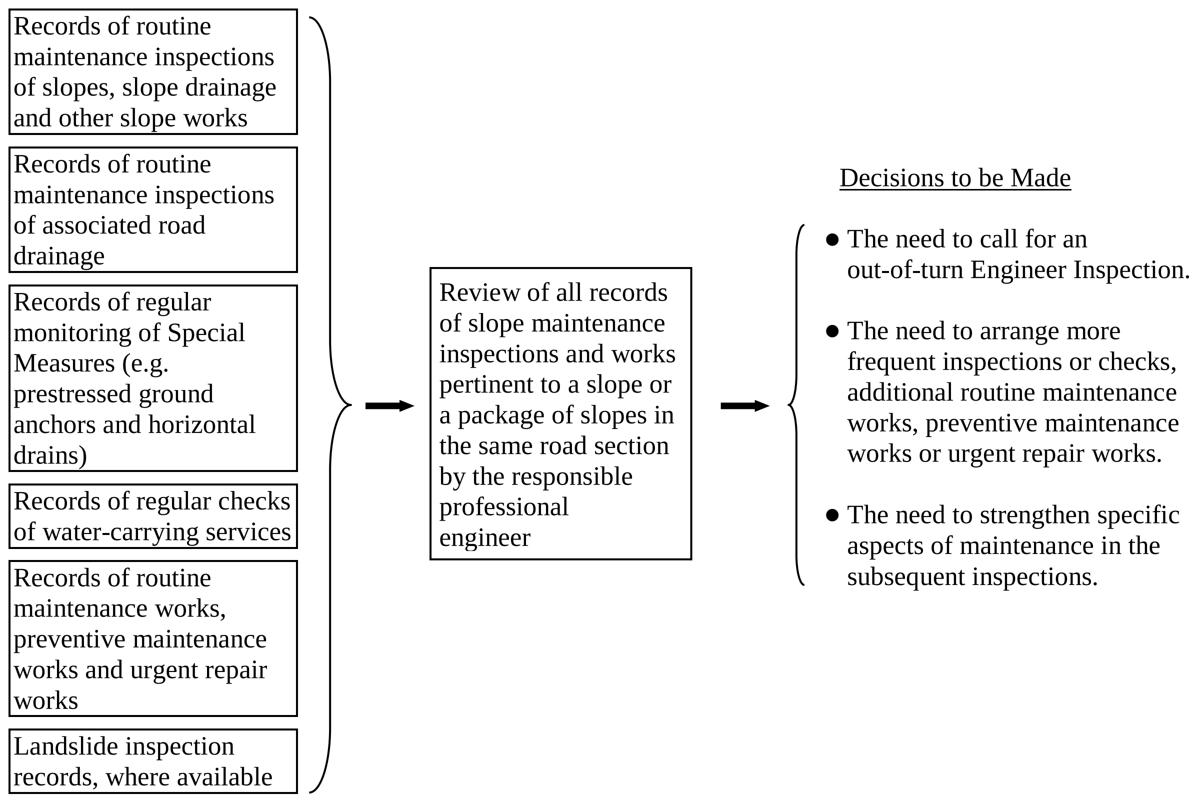
This Chapter supplements the guidance given in Geoguide 5 and provides guidance to highway slope owners for developing a maintenance and upgrading strategy and implementing slope maintenance and upgrading works. The maintenance responsibility of man-made slopes in Hong Kong is determined based on the principles given in WBTC No. 26/99 (Works Bureau, 1999e).

8.2 Slope Maintenance

Maintenance inspections for slopes include routine maintenance inspections, Engineer Inspections (EI) for Maintenance, regular monitoring of any Special Measures (e.g. prestressed ground anchors and horizontal drains) present, and regular checks of water-carrying services and road drainage that could affect the slopes. Routine maintenance works are usually required after maintenance inspections. Urgent repair works, preventive maintenance works or stability assessments may also have to be carried out depending on the outcome of the inspections.

In determining the frequency of routine maintenance inspection for highway slopes, consideration should be given to the potential consequence-to-life and the seriousness of the socio-economic consequence (e.g. possible major disruption to the community due to the need to close a trunk road) in the event of a slope failure. There may be benefits to increase the frequency of inspection to above the minimum levels as recommended in Geoguide 5 and in the Code of Practice on Inspection & Monitoring of Water Carrying Services Affecting Slopes, for slopes in the Consequence-to-life Category 1 or Economic Consequence Category A (see Section 4.2).

Where routine maintenance inspections of slopes, slope drainage and associated road drainage, monitoring of Special Measures and regular checks of water-carrying services are carried out by different maintenance teams or parties, a co-ordinated approach should be adopted. This should include a review of all records of maintenance inspections and works after a complete cycle of routine maintenance inspection by the professional engineer responsible for overseeing the maintenance of the slopes. The purpose of the integrated review is to examine all relevant records together to provide insightful information for making decisions on whether additional maintenance works or other actions are required to be carried out (Figure 8.1).



Notes:

(1) Routine maintenance inspections of the slopes, slope drainage and other slope works and any associated road drainage should preferably be carried out by the same maintenance team.

(2) For routine maintenance inspections and works on the same road section that are carried out by other parties, the owner should arrange to obtain where possible the inspection and works records from the relevant parties for the integrated review by the responsible professional engineer.

Figure 8.1 Co-ordinated Approach to Highway Slope Maintenance

Adequate and safe access should be provided to highway slopes for carrying out maintenance inspections and maintenance works. Such access should be extended to cover areas beyond the boundary of the slope where necessary (e.g. for inspection of any works on the natural slope beyond the crest of the man-made slope for which the maintenance responsibility has been assigned to the road owner). The access arrangement and design should ensure safety of the inspection and maintenance personnel and avoid disruption to the traffic, especially where access has to be made from a busy road. Where possible, a road shoulder or lay-by to facilitate safe access should be incorporated in the design of new roads and improvement of existing roads. For existing slopes, the adequacy of access for carrying out maintenance inspections should be reviewed as part of the Engineer Inspections and recommendations on any improvements necessary should be made.

The volume of soil/rock debris found during routine maintenance inspections along the road should be recorded together with its location. Particular note should be taken of any quantity of debris larger than that usually found at a particular location, accumulation of debris repeatedly found at the same location and any other abnormal observations (e.g. heavy seepage in the dry season). These observations must be reported promptly to the owner or party responsible for maintaining the slope. Where signs of distress (such as tension cracks, landslide scarps/scars, ground subsidence, bulging or distortion of any masonry wall supporting the road or settlement of the slope crest platform) are observed, advice should be sought from a geotechnical engineer on any necessary actions.

In maintaining a hard slope surface cover, sprayed concrete should not be applied over a defective cover. Also, the slope should be given a vegetation cover wherever possible (see Section 6.4).

The cost-effectiveness of the slope maintenance strategy and actions should be reviewed from time to time with due account taken of the slope upgrading and preventive maintenance initiatives (see Section 8.3).

8.3 Slope Upgrading and Preventive Maintenance

Where there is a large number of substandard slopes, the highway slope owner should develop a scheme for prioritising and selecting slopes for upgrading such that the landslide risk can be reduced cost-effectively and efficiently (see Figure 1.1). The scheme should be based on the relative risk of the slopes. Reference may be made to the New Priority Classification Systems (NPCS) for slopes and retaining walls developed by GEO (Wong, 1998) in devising a suitable scheme. Where appropriate, quantitative risk assessment techniques may be used to provide information for relative ranking of road sections for improvement taking into account landslide risk and traffic needs (ERM-HK Ltd, 1999).

Sometimes, it can be economical and also less disruptive to the local residents to package a number of slopes in an area and upgrade them simultaneously. The package may include some slopes which are of lower priority for upgrading in terms of landslide risk level, in order to avoid coming back to the same area to carry out the upgrading works later. The opportunity should also be taken to upgrade the road drainage system at the same time (see Section 5.2.3). The approach of packaging slopes should take into account the possible disruption to the traffic and safety to road users during construction. This is particularly important when the engineering works are to be carried out for a number of slopes at the same time along the same road section. Close liaison with relevant Government Departments (e.g. Police and Transport Department) should be maintained in planning and during the construction works.

In selecting slopes for upgrading, particular care should be taken to avoid omitting those slopes which have only been partly upgraded in the past. Some slopes deserve priority for upgrading, e.g. where repeated failures have occurred, or where there are recurrent maintenance problems at the slope. Slopes for which the stability has been assessed by previous studies, but the status as to whether the assumptions made in these studies are still valid and current safety standards are met is not clear should also be given appropriate attention.

In addition to the slope upgrading programme, the highway slope owner should develop a slope preventive maintenance programme integrated with it and taking into account the findings from routine maintenance inspections and Engineer Inspections for Maintenance. Information obtained from the maintenance inspections, e.g. changes in slope or road usage condition, should be reviewed to reassess the priority of the slope for upgrading or preventive maintenance under the integrated programme.

Warning signs should be erected at those roadside slopes that have been confirmed by stability assessments to be substandard and included in a slope upgrading or preventive maintenance programme (see Figure E2 in Appendix E).

9 Landslide Emergency Preparedness and Response

9.1 Emergency Preparedness

Road owners or their maintenance agents should have an adequate emergency system in place that would enable an organised and timely response to landslides that affect their roads (see Figure 1.1). They should be aware of the Hong Kong SAR Government's emergency system for responding to natural disasters including landslides. A brief introduction on this and the available sources of information are given in Appendix E.

During an emergency, it is essential to have accurate and timely information about the landslide sites and rainfall data (e.g. rainfall information via Hong Kong Observatory's website http://www.hko.gov.hk/) to ensure a speedy and appropriate response. Road owners or their maintenance agents should maintain and keep up-to-date an effective information system containing sufficient information on their slopes. The use of modern information and telecommunication technology can greatly facilitate retrieval and transmission of critical information during emergency operations.

Under the emergency system, the road owner or his maintenance agent should have maintenance staff on call 24 hours a day who can be mobilised at short notice throughout the year. Sufficient staff and contractor resources, as well as plant and equipment, should be available at times of emergency. The operation of the system should be documented with clear procedures (including when to seek advice from a geotechnical engineer), and the duties and responsibilities of all the personnel involved should be clearly defined. A contingency plan should be in place to deploy staff and resources, and to maintain effective communication with various Government Departments during extreme disaster events.

The emergency system should allow early identification and inspection of serious landslide incidents and enable urgent remedial actions to be taken to ensure public safety. Landslides affecting critical roads should be adequately and speedily dealt with as prolonged traffic disruption may have serious socio-economic consequences. There should be a designated authority for assigning resources and priority for inspection and urgent repairs, and for providing information to the media.

For road sections of strategic importance, including the sole access to critical facilities such as hospitals and fire stations, the road owners and/or relevant authorities should liaise with various Government Departments. They should have contingency plans in place to cover possible scenarios such as quick diversion of traffic, re-opening of the roads and restoration of the critical services. Such road sections and the critical facility owners should be pre-identified, and the contingency plans should be documented.

Adequate and suitable training should be provided to all staff who are involved in the system. In particular, staff who would be involved in landslide inspection should be given training on classification of the seriousness of the incident, the immediate actions to be taken, accurate reporting of factual information and answering media enquiries. Pre-wet season briefings and drills are particularly valuable, especially for new staff.

The emergency system should be reviewed after each wet season and, where possible, after each heavy rainstorm event which has resulted in a large number of landslides, so that improvements can be identified. Such reviews should include debriefing sessions for experience sharing by staff who have been mobilised. Records of landslide incidents, the consequences and the follow-up actions should be maintained. Such records should be taken into account in the periodic reviews of the emergency system.

9.2 Emergency Response

9.2.1 General

Guidance on precautionary measures to be taken during landslide inspection is given in the Safety Guide for Geotechnical Engineers Attending Landslip Incidents (GEO, 1999b) which, although written for geotechnical engineers, is equally useful for highway personnel who undertake landslide inspection. Guidance to geotechnical engineers on landslide inspection, urgent repair and the re-opening of roads after landslides is given in the GEO Emergency Manual (GEO, 1998b). A checklist of possible sources of danger and causes of slope failure for landslide inspection during emergency is given in Appendix F.

9.2.2 Landslide Inspection

Accurate assessment and reporting of the consequence or potential consequence of a landslide, and accurate reporting of its location and size are important for assigning the priority for inspection and follow-up action. Guidance on the classification of landslide incidents affecting roads is given in Table 9.1.

For “serious” landslide incidents, the road owner’s maintenance staff should seek geotechnical advice from a geotechnical engineer on any urgent repairs needed and/or the extent and duration of any road closure. After a joint inspection on site, the geotechnical engineer should discuss with the civil/highway engineer (or an equivalent level staff) from the maintenance team to confirm the details of the urgent repair works and any road closure required and the subsequent road re-opening criteria. Consultation channels between the advisory and action parties should then be agreed and maintained until the necessary repair works are completed and the road re-opened.

For “significant” landslide incidents, geotechnical advice on urgent repairs is normally required. The road owner’s maintenance staff should seek such advice from a geotechnical engineer. They should be present during the site inspection to discuss and agree on any follow-up actions.

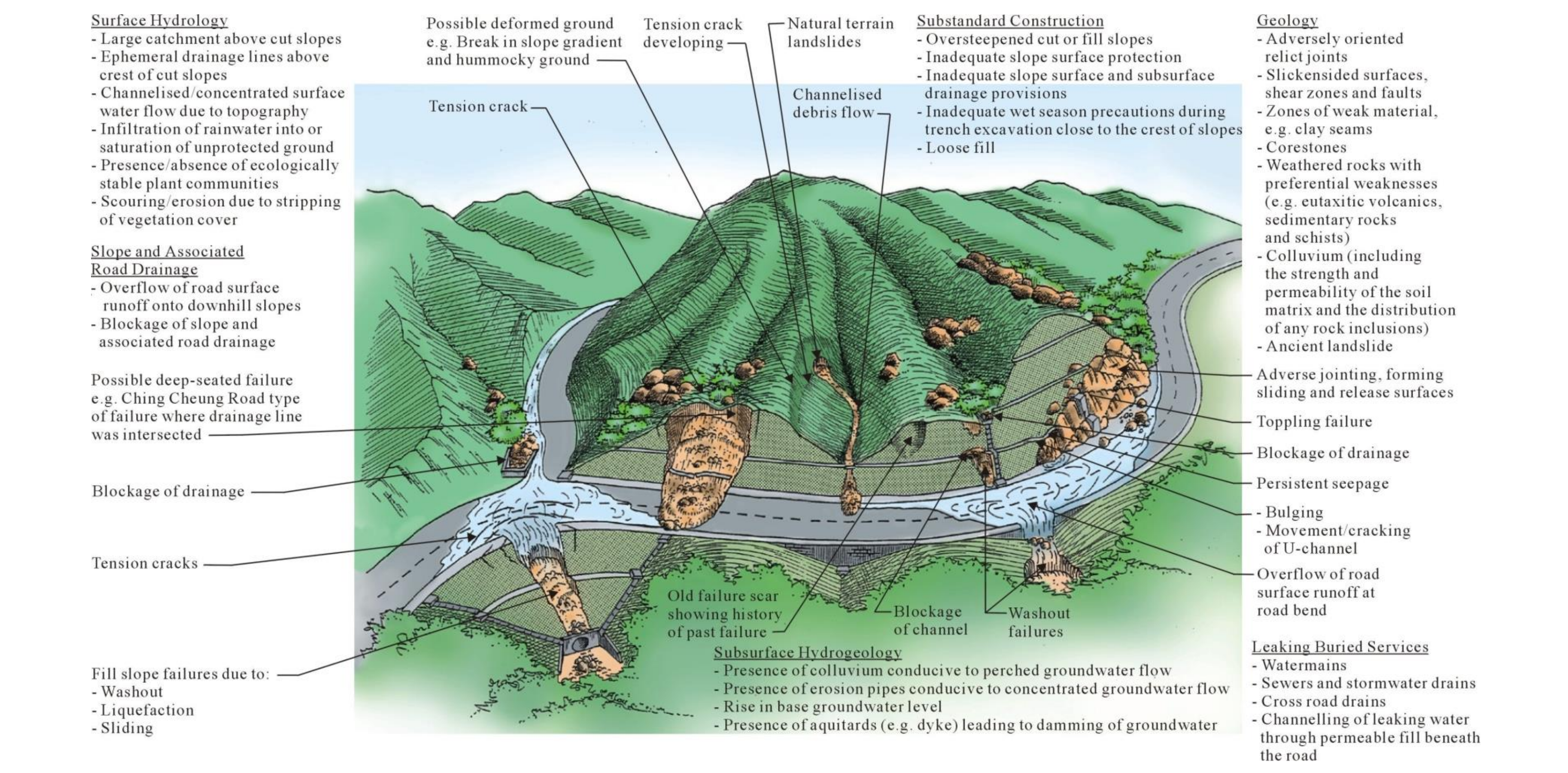
For “minor” landslide incidents, geotechnical advice is usually not required. The road owner’s maintenance staff should arrange for the necessary works to be carried out immediately (e.g. clearing of landslide debris, covering of failure scar by a secure, impermeable membrane and diversion of surface water away from the scar). If there are signs of continuing and significant seepage from the ground, the size of the failure is increasing, past failures are known or observed, or if there are any other geotechnical concerns, advice should be sought from a geotechnical engineer.

The factors that could have contributed to the slope failure should be carefully assessed during the landslide inspection, where site conditions permit. Figure 9.1 shows some of the common factors that may contribute to the failure of man-made slopes. In all cases, the road owner's maintenance staff with the assistance from the police should take immediate action (e.g. cordoning off the site) to safeguard the public prior to seeking the necessary geotechnical advice.

Table 9.1 Classification of Landslide Incidents Affecting Roads

Incident Classification	Examples	Landslide Inspection
Serious	(a) An incident affecting a road with casualties or suspected casualties.[1] (b) An incident which has resulted in closure of a Category A Economic Consequence facility (e.g. an expressway, a trunk road or a primary distributor such as North Lantau Expressway, Tuen Mun Highway, Ching Cheung Road, etc.[2]). (c) An incident which has resulted in closure of a sole access to critical services[3], e.g. hospitals, fire stations, etc. (d) An incident affecting a road which necessitates a major evacuation of affected buildings.	• Top priority should be assigned for inspection. • Road owner should mobilise a professional civil/highway engineer (or an equivalent level staff) from his maintenance team and the emergency contractor to attend the site inspection. • A geotechnical engineer (GE) should also be requested to inspect the site immediately.
Significant	An incident which is not minor but does not fall into the serious incident category.	• Lower priority than serious incidents[4]. • A GE should be requested to inspect the site in a priority order on the basis of consequence and other factors such as available resource, traffic and weather conditions, geographic locations, etc.
Minor	An incident with no immediate consequence, e.g. a small-scale landslide say < 10 m^3 affecting a rural road. For roads of a higher consequence category, the volume of debris should be less than 5 m^3 for the incident to be classified as minor.	• Lowest priority. • Road owner's maintenance staff to inspect the site first and seek geotechnical advice if necessary.

Notes:
(1) The Fire Services Department being called out for a rescue operation for a slope failure affecting a road may be an indication of a serious incident.
(2) A list of such roads (e.g. Red and Pink Routes) is maintained by the Transport Department and Highways Department.
(3) A list of such roads should be maintained by the road owners.
(4) Incidents liable to develop into serious incidents should be accorded priority for site inspection.



Notes:
(1) The factors listed above are not exhaustive.
(2) Where practicable, inspection of the failure scar should be made to assess the geological and groundwater conditions after the landslide debris has been cleared.
(3) Inspection should also be made from a vantage point in order to have an overall view of the failure site.
(4) The anticipated rainfall condition should be considered in making emergency recommendations.

Figure 9.1 Examples of Common Factors Contributing to Failure of Man-made Slopes

Landslide inspection should not be confined to the boundary of a failed man-made slope feature. Where safe access is possible, inspection should be extended to cover the ground beyond the crest of the slope, if considered necessary, as well as the road and its drainage provisions above or below the slope, to identify areas of distress including tension cracks. Some distressed slopes may exhibit progressive movement but rapid failure may be triggered by subsequent heavy rain infiltrating into the tension cracks. Therefore, any surface water flow paths leading to the failed area and any areas of observed tension cracks and the natural surface water catchment above them should be considered in determining the extent of any road closure and in giving other safety recommendations.

An important factor to be considered is the potential for surface water to overflow from a road surface onto the slopes below. All slope drainage and associated road drainage provisions in the vicinity of a slope failure should be inspected, and any blockages should be cleared and damage repaired as early as possible so as to minimise the chance of further slope failures. Road surface runoff should be diverted away from any open trenches/excavations along the road. This should be conducted in a manner that can avoid causing slope instabilities at locations away from the landslide scar.

In many cases, it may not be possible to inspect the failure in detail during the first visit, e.g. due to the focus on taking immediate actions to safeguard life and property and the prevailing weather conditions. It may be necessary to carry out subsequent visits to inspect the slope and the road. Viewing the site from a safe vantage point in daylight or from a helicopter and examination of available topographical maps, plans and good quality aerial photographs could help to determine the safe access and the strategy for a detailed inspection of the failure and the pertinent features along the road.

Repeated minor failures at a slope or at different slopes along a particular road section should be carefully assessed as these may be indicative of a major failure taking place, e.g. incidents that took place at Ching Cheung Road (Halcrow, 1998) and Lai Ping Road (Sun & Campbell, 1999). In this regard, reference may be made to the GEO landslide database (Chan et al, 1998).

For landslide incidents which have resulted in casualties or serious disruption to traffic, incidents at slopes which have previously been upgraded or designed to meet current safety standards, and for incidents at slopes with repeated failures, a detailed investigation/study should be carried out to establish the probable causes of the failure and identify any lessons learnt and necessary follow-up actions.

9.2.3 Road Closure

The geotechnical engineer in consultation with the road owner should review and recommend the extent and duration of any road closure. The risk of further failure, including failure of the areas in the vicinity of the landslide site, should be assessed and the extent of the road closure should cover doubtful areas if they are identified. The possibility of long runout distance/high mobility landslide debris should be considered (see, for example, the incident that took place at Castle Peak Road in 1997 (Halcrow, 1999a)). Some past landslide debris mobility data are given in Figure 4.2 (see Section 4.2). The road closure, if required, should be extended to cover any nearby pedestrian walkways likely to be affected.

Further site inspection and surveillance by the geotechnical engineer, and discussion with the personnel engaged to investigate the landslide (if any such investigation is carried out) may be necessary to confirm the assumed causes and trigger of the failure and to ensure that the extent and duration of road closure are adequate.

The decision as to whether a road should be closed or continued to be closed in the event of a landslide should be based entirely on public safety considerations. This should be made after a careful inspection and assessment of the site conditions, with due allowance made for the anticipated weather (in particular, rainfall) conditions after the landslide and other slope stability related factors. The highway engineer and maintenance staff engaged by the road owner should take charge of the overall situation regarding remedial and urgent repair works, with the advice of the geotechnical engineer. They should also initiate effective actions with other relevant parties on any road closure and the arrangements for any necessary traffic diversions, including liaison with the police and the transport authority. Close liaison between the geotechnical engineer and the highway engineer should be maintained in order that any follow-up actions for remedial and urgent repair works and re-opening of the road can be planned and implemented efficiently and effectively.

9.2.4 Urgent Repairs

Where there is significant impact on the road users' safety, urgent repair works should be arranged promptly by the road owner or his maintenance agent, who should ensure that a suitable contractor is engaged to carry out the work. Where necessary, geotechnical advice on urgent repair works needed to render a landslide area temporarily safe should be obtained from a geotechnical engineer. Safety of emergency workers should be considered when specifying urgent repair works. Effective communication should be maintained among the various parties involved in the inspection of the landslide, preparation of the specification and in supervision and acceptance of urgent repair works.

The type and extent of urgent repair works should be such that they can be completed quickly to enable the re-opening of the road safely (see Section 9.2.5) and as early as possible. For urgent repairs to soil cut slopes, the use of prescriptive measures as given in GEO Report No. 56 (Wong et al, 1999) is recommended. Where time and site conditions permit, the opportunity should be taken to carry out the repair works up to permanent work standards. Wherever practicable, the geotechnical engineer should be informed after the landslide debris on the road and slope has been cleared and before the slope surface is covered up, so that he can carry out a follow-up inspection to verify the assumptions made in specifying the works and amend the design of the works where necessary to take account of the ground conditions revealed.

Simple items of work such as removal of landslide debris, local slope trimming, surface protection and drainage diversion or improvement, etc., can be carried out by contractors with proven general civil engineering experience such as those on the Works Bureau list of approved contractors for site formation works or roads and drains. For more substantial slope remedial and stabilisation works, use of contractors with landslide preventive works experience, such as those on the Works Bureau list of approved specialist contractors in the landslip preventive works category, is recommended. As-built records of urgent repair works carried out should be prepared and these should be passed to the road owner or his maintenance agent for retention and reference. Such records should be checked by the supervising personnel to ensure that they accurately show the extent, the key dimensions and the details of the works.

Upon completion of the repair works for a failed slope, an inspection of the slope should be carried out by a geotechnical engineer as soon as practicable. The information obtained from the inspection together with the as-built records certified by the supervising personnel should be used to update the Maintenance Manual and to establish the need and the priority of the slope for further upgrading or preventive maintenance works (see Section 8.3).

9.2.5 Re-opening of Roads

In making a decision to re-open a road which has been closed due to landslides, public safety is the prime consideration and this should not be compromised for public convenience. The necessary urgent repair works that will allow the re-opening of a road should be checked for satisfactory completion by the professional engineer who is responsible for the works before the re-opening of the road. For serious landslide incidents, the advice of a geotechnical engineer should be sought on road re-opening. For all other cases, geotechnical advice should be sought if it is necessary to interpret geotechnical data before reaching a decision. Sufficient lead time should be allowed for any necessary inspection, monitoring survey and consultation to be made before re-opening the road, and for arrangements to be made to inform the public. This is especially important when re-opening of the road before the morning rush-hours is intended.

In some instances, there may be a need to re-open a road in the shortest possible time, e.g. for a sole access to a critical facility or for a busy road with grossly inadequate alternative routes. Prolonged road closure could lead to unacceptable consequences to the traffic and major disruption to the community. Where the repair works would take a long time to complete, partial closure of the road together with implementation of suitable risk mitigation measures may be considered. However, this should be adopted only when the risk of further slope failure can be judged to have been reduced to an acceptable level. A road may be re-opened under certain restrictive conditions (e.g. checking of a pre-determined rainfall intensity level not being exceeded or forecast not to be exceeded, surveillance to confirm no further development of heavy rainfall and deterioration of the observed signs of distress, and monitoring to confirm no trend of accelerating ground movements). In such cases, alert levels should be established and contingency plans, which should include follow-up risk mitigation actions by designated authorised personnel and the channels of communication, should be agreed by all the parties concerned and clearly documented.

Conditional re-opening of a road is not recommended as a general measure as there will be difficulties in implementing the measures effectively, in particular in forecasting the weather condition. Also, frequent closures and re-openings of a road can cause confusion to road users. Where a decision is made to have partial closure or conditional re-opening of a road, good communication between all parties concerned should be maintained in order that any difficulties that may arise can be resolved promptly.

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Note: * denotes copies of GEO Internal Reports are available for inspection in the Civil Engineering Library, Civil Engineering Department. Some of the GEO Internal Reports may be turned into GEO Publications in future. Readers are advised to check the latest list of GEO Publications at the CED website http://www.cedd.gov.hk/eng/publications/index.html on the Internet. [Amd HSM/01/2017]

Appendix A

The Slope Management System of the Highways Department of the Government of the Hong Kong SAR

The Slope Management System of the Highways Department of the Government of the Hong Kong SAR

The Highways Department (HyD) is responsible for the maintenance of most highway slopes in Hong Kong. A total of about 15 200 highway slope features were identified in the establishment of a Roadside Slope Inventory in 1997 by the HyD. About 12 500 of these features are under the HyD's maintenance responsibility, of which about 10 000 are sizeable features (c.f. a total of about 54 000 sizeable features registered in the New Slope Catalogue by GEO (Lam et al, 1998)).

The District and Maintenance Sections of the HyD engage maintenance term contractors to undertake all routine maintenance of their slopes, preventive maintenance and upgrading of substandard slopes using prescriptive measures, repairs to leaking drains and urgent repairs to failed slopes. Their staff also attend to slope failures affecting roads as part of the HyD's emergency service (see Appendix E).

A Geotechnical Advisory Unit (GAU) comprising professional geotechnical engineers was set up in the Headquarters of the HyD in 1998. It provides in-house geotechnical advice on slope maintenance, undertakes design of preventive maintenance and prescriptive measures for slopes, and co-ordinates and advises on matters related to slopes. It also co-ordinates the selection of substandard slopes maintained by the HyD for inclusion in the Landslip Preventive Measures (LPM) Programme managed by the GEO and the formulation of a slope improvement programme to be implemented by the HyD to supplement the LPM Programme.

A Slope Maintenance Committee, chaired by the Assistant Director/ Headquarters with representatives from the District and Maintenance Sections and GAU as members, was also set up in 1998. The Committee sets policy and establishes procedures for slope maintenance and improvement, including routine maintenance, preventive maintenance, and upgrading of slopes where appropriate. It also monitors the programme of maintenance actions and obtains and allocates resources for it.

The Landscape Unit of the HyD provides landscape advice on slope-related works.

The policy and procedures on slope maintenance and improvement, and the responsibilities of various parties involved in the HyD are documented in a Slope Maintenance Plan which is audited by the GEO.

Reference

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Appendix B

Model Brief for a Geotechnical Review

Model Brief for a Geotechnical Review

B.1 Objectives

The objective of the Geotechnical Review (GR) is to identify and assess the impacts of significant geotechnical hazards and critical geotechnical issues that could influence the feasibility of the highway project.

B.2 Scope

Plans on the proposed highway route corridor(s)/alignment(s) and the areas to be studied are attached. The GR shall be carried out as an integral part of the highway planning process. The professionally qualified person who is in charge of this Assignment shall maintain a close liaison with highway planning and engineering personnel at all times during the GR. The following tasks shall be carried out:

(a) Carry out a desk study which shall include the following:

(i) search for, obtain and study information relevant to the project from existing sources, including that from but not limited to the following sources:

- the Slope Information System (SIS),
- the Slope Maintenance Responsibility Information System (SMRIS),
- the Landslide Databases,
- the Natural Terrain Landslide Inventory (NTLI),
- the Boulder Inventory Maps,
- the Geotechnical Area Studies Programme (GASP),
- the Annual Hong Kong Rainfall and Landslides Reports,
- relevant landslide study reports,

(ii) study relevant past ground investigation records and geotechnical reports,

(iii) study the published geological maps and memoirs, and

(iv) study the most recent set of topographical maps and at least two sets of good quality aerial photographs, with one set to be relatively clear of vegetation (those from the years 1963 and 1964 are recommended) together with the most recent set covering the study area. Additional photographs shall also be studied to obtain relevant information for specific years where the desk study has identified that significant events, such as landslides and hillfires, have occurred.

(b) Carry out a walkover survey of the corridor(s)/alignment(s) and nearby, record key natural terrain and man-made geotechnical features, paying particular attention to recording any signs of ground instability and geotechnical hazards identified from the desk study, and confirm on site the nature and areal extent of the key geotechnical features and geotechnical hazards identified, and signs of seepage.

(c) Based on the work of (a) and (b) above:

(i) assess the general topographical, geological, hydrological and groundwater conditions along the existing and/or proposed highway corridor(s)/ alignment(s) and nearby, and refine the project study boundaries if necessary,

(ii) carry out a Natural Terrain Hazard Review (NTHR) for the highway project, in accordance with the guidelines issued by the Geotechnical Engineering Office, and

(iii) identify all existing man-made slope features and surface drainage systems along the proposed corridor(s)/alignment(s) and nearby that could affect or be affected by the proposed highway project.

(d) Carry out a preliminary assessment of the site conditions and the identified geotechnical hazards that could significantly impact on the cost and programming of the project, in particular:

(i) assess the impacts of the potential hazards from natural terrain (i.e. landslides and rock/boulder falls), determine the extent of the terrain that needs to be further assessed and if possible, outline the likely mitigation strategy required,

(ii) determine the need for formation and location of any new man-made slope features,

(iii) determine if a Geotechnical Assessment (GA) is required or not, and if so, prepare a brief for the GA with the objectives stated and the likely scope, duration and cost provided,

(iv) determine if a Natural Terrain Hazard Assessment (NTHA) is required or not and if so, prepare a brief with the objectives stated and the likely scope, duration and cost provided, and

(v) describe the objectives, assess the likely scope, duration and cost of subsequent phases of ground investigation (GI) works, and prepare a preliminary programme of the GI.

(e) Based on the work in (d) above:

(i) assess how the identified geotechnical features, hazards and constraints may affect the proposed highway corridor(s)/alignment(s) and liaise with the highway engineers on improvements to the corridor(s)/alignment(s), if necessary,

(ii) identify any specific contractual or construction management issues related to the likely geotechnical works and hazard mitigation measures (e.g. contract form, supervision, design review, traffic constraints and safety of road users, blasting control, access provision, etc.), and

(iii) provide preliminary estimates of the costs, programming and geotechnical personnel requirements for the investigation, design and construction of the geotechnical works and hazard mitigation measures and preliminary estimates of the recurrent maintenance requirements.

(f) For road improvement projects:

(i) determine the safety standard for all of the existing man-made slope features based on the anticipated use of the highway,

(ii) determine the date of construction of the features where possible and check records to determine whether there is documentary evidence to confirm if their stability is up to current safety standard, and

(iii) outline the necessary investigation and assessment of the stability and/or the likely landslide preventive works required to upgrade the features to the current safety standard.

(g) Based on the available information:

(i) rank the alternative corridors/alignments based on the magnitude of the geotechnical hazards present along each proposed corridor/alignment, and

(ii) recommend the appropriate rating to be used for the geotechnical factors in the overall highway corridor/alignment evaluation process.

B.3 Deliverables

The Consultants shall produce:

(a) A Geotechnical Review Report documenting the work done, the information examined, the findings and recommendations, and including schematic plans and cross sections at critical locations of the geotechnical works and hazard mitigation measures proposed for the project. The GR Report shall include:

(i) a Geotechnical Feature and Hazard Map at a scale of 1:1 000 or 1:5 000, showing the corridor(s)/alignment(s) considered and all catchments, the source and areal extent of all geotechnical hazards identified, the locations and details of all existing slope features including those to be upgraded and new slope features to be formed under the project and the principal drainage courses,

(ii) a brief for the Geotechnical Assessment, if required, including a recommendation on the study boundary requirements for a Natural Terrain Hazard Assessment where necessary, and a plan showing the scope of the ground investigation works to be undertaken in the subsequent stages of the project, with supporting justifications for the proposed works, and

(iii) a summary of the GR Report, including the estimated costs, duration and geotechnical personnel requirements of the GA where required, for inclusion in the Preliminary Project Feasibility Study Report.

(b) A Natural Terrain Hazard Review Report where a NTHR has been carried out.

B.4 Programme of Implementation

(a) The due date for commencement of the GR shall be ________________.

(b) A working programme, to be agreed with the Employer, shall be prepared within ________ weeks of the commencement of the GR.

(c) The due date for completion of the GR shall be ________________.

Notes: (1) An example of a programme for the GR of a highway project is given in Figure B1. The actual programme and milestones should dovetail those of the PPFS for the highway project.

(2) More than one team of geotechnical engineers and technical personnel may be needed and the programme may have to be adjusted, depending on the size of the study area and the number of alternatives to be considered.

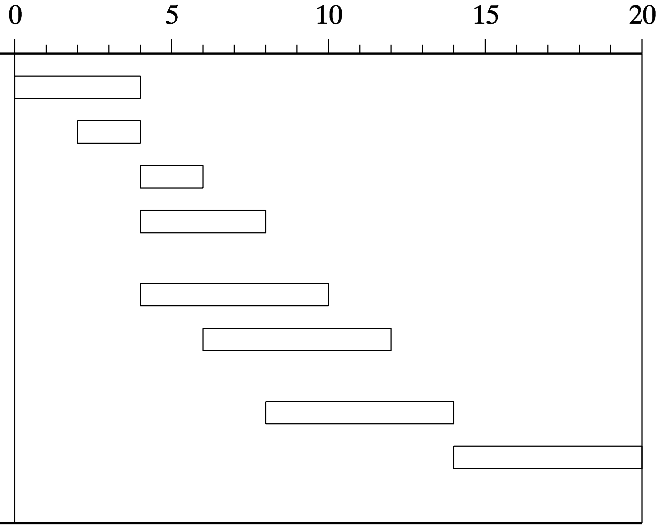
B.5 Geotechnical Personnel for the GR

The Consultants shall engage professionally qualified persons with an adequate level of experience in geotechnical engineering and/or engineering geology to carry out the work under this Assignment. A professionally qualified person with suitable local experience in geotechnical engineering shall be in charge of the Assignment. A suitable qualification is Registered Professional Engineer (Geotechnical). This person shall scrutinize the relevance, adequacy and quality of all information collected, carry out the site walkover survey and prepare the GR Report personally.

B.6 Information to be Provided by the Employer

The Consultants shall search for and obtain all relevant published and publicly available information. All other information held by the Employer and relevant to the GR will be provided to the Consultants free of charge.

Activities	Duration (weeks)
1. Desk Study	2 - 4
2. Aerial Photograph Interpretation	1 - 2
3. Walkover Survey	1 - 2
4. Geotechnical Feature and Hazard Map	2 - 4
5. Preliminary Assessment of Data	4 - 10
6. Optional Alternative Corridor/ Alignment Assessment	4 - 8
7. Draft Geotechnical Review Report	4 - 8
8. Circulate for Comment and Finalise Geotechnical Review Report	4 - 6



Note: The above programme for GR is prepared for a proposed new road project or a road improvement project based on the time normally available for a Preliminary Project Feasibility Study (PPFS).

Figure B1 Example of a Programme for the Geotechnical Review of a Highway Project

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Note: The items given in Section B.2 of this Model Brief for GR are for guidance only. The project engineer should modify the items of the Brief as appropriate, taking into account the need, scale and complexity of the project.

Appendix C

Model Brief for a Geotechnical Assessment

Model Brief for a Geotechnical Assessment

C.1 Objectives

The objective of the Geotechnical Assessment (GA) is to assess the impacts of the geotechnical hazards and critical geotechnical issues that could influence the design of the highway project, confirm the project feasibility and identify the best option to be taken through to detailed design. The GA shall determine more accurately than in the Geotechnical Review (GR) the scope of the geotechnical works and hazard mitigation measures, the land-take, cost and programming requirements for investigation, design, construction and maintenance of the geotechnical works.

C.2 Scope

The Preliminary Project Feasibility Study (PPFS) Report, the GR Report, and plans on the proposed highway route(s) and the areas to be studied in this GA are attached. The GA shall be carried out as an integral part of the highway planning process. The professionally qualified person who is in charge of this Assignment shall maintain a close liaison with highway planning and engineering personnel at all times during the GA. The following tasks shall be carried out:

(a) Review and update the information relevant to the project, including the following:

(i) information from the following sources including that from previous reports:

- the GR Report and Natural Terrain Hazard Review Report (if available),
- the Slope Information System (SIS),
- the Slope Maintenance Responsibility Information System (SMRIS),
- the Landslide Databases,
- the Natural Terrain Landslide Inventory (NTLI),
- the Boulder Inventory Maps,
- the Geotechnical Area Studies Programme (GASP),
- the Annual Hong Kong Rainfall and Landslides Reports,
- relevant landslide study reports,

(ii) relevant past site investigation records, geotechnical design reports and construction records,

(iii) published geological maps and memoirs,

(iv) relevant topographical maps, and

(v) relevant services and utilities records.

(b) Carry out a detailed Aerial Photograph Interpretation (API) for the proposed alignment(s) and nearby, which shall involve a study of all available aerial photographic records to:

  (i) establish the history of development along the route alignment(s),

  (ii) determine the nature, history and stability of man-made slopes, and

  (iii) establish landslide history of natural terrain as required to support a Natural Terrain Hazard Assessment if this is needed.

(c) Carry out a detailed walkover survey of the proposed alignment(s) and nearby to:

  (i) review and update the records presented in the GR Report on key natural terrain and man-made geotechnical features, signs of ground instability and geotechnical hazards, and

  (ii) undertake the geological, geomorphological and seepage mapping, and structural geological measurements.

(d) Critically review and revise, if necessary, the objectives and scope of the ground investigation (GI) works as recommended in the GR Report. Prepare a GI plan which shall contain the requirements of ground investigation works, including any field testing and laboratory testing, and groundwater and ground movement monitoring needed. Agree with the Employer the scope of the GI and the method of procurement.

(e) Procure or arrange to carry out and supervise the GI works together with the necessary topographical surveys, field testing, laboratory testing and monitoring works to determine the subsurface conditions (including confirmation of the locations of services and utilities) and the nature and areal extent of the geotechnical hazards.

(f) Carry out a Natural Terrain Hazard Assessment (NTHA) for the highway project, in accordance with the guidelines issued by the Geotechnical Engineering Office, and assess the need for hazard mitigation measures.

(g) Check records to determine whether there is documentary evidence to confirm if the stability of any existing man-made slope features is up to current safety standards. If such documentary evidence is inconclusive, assess the stability of those features or where practicable, recommend prescriptive measures to upgrade the features.

(h) Assess the effect of existing and new man-made slope features (e.g. those in the vicinity of natural terrain) on the stability of the natural terrain.

(i) Based on the work of (a) to (h) above:

(i) determine and update the general topographical, geological, hydrological and groundwater conditions along the existing and/or proposed highway alignment(s) and nearby, and confirm the project study boundaries,

(ii) confirm, and update if necessary, the information of existing man-made slope features and surface drainage systems along the proposed alignment(s) and nearby that could affect or be affected by the proposed highway project, and

(iii) assess how the identified geotechnical features, hazards and constraints may affect the proposed alignment(s) and liaise with the highway engineers on improvements to the alignment(s) and/or alternative design option(s), if necessary.

(j) Based on the work of (f) to (i) above:

(i) provide a preliminary design of the necessary geotechnical works and the types of measures that would mitigate against the identified geotechnical hazards. The recommendations shall cover any upgrading works to existing slope features and any new man-made slope features and hazard mitigation measures. The preliminary design shall be sufficient for costing and planning of supplementary GI to allow detailed design to proceed. It shall include preliminary design calculations as necessary and provide a description of the anticipated construction methods and sequence of the works,

(ii) prepare a brief for detailed design of the geotechnical works and hazard mitigation measures of the project, and

(iii) identify and assess any specific contractual or construction management issues related to the geotechnical works and hazard mitigation measures (e.g. contract form, supervision, additional GI needed during construction, design review, auditing, traffic constraints and safety of road users, blasting control, quality control testing, access provision, etc.).

(k) Provide estimates of the costs, programming and geotechnical personnel requirements for the investigation, design and construction of the geotechnical works and hazard mitigation measures and the recurrent maintenance requirements. Check the project feasibility by comparing these estimates with those in the PPFS Report.

(l) Prepare a programme for any supplementary GI works required to be carried out before or during the detailed design stage of the project with the objectives of the GI stated, the land matters to be resolved for the GI and the likely scope, duration and cost provided.

(m) Identify any statutory and consultative processes associated with the geotechnical works necessary to ensure the timely implementation of the project (e.g. geotechnical submission to the Geotechnical Engineering Office). If instructed by the Employer, make the submissions to obtain the necessary approval/acceptance.

(n) Based on the available information:

(i) rank the alternative alignments/design options based on the magnitude of the geotechnical hazards present along each proposed alignment and/or associated with each design option, and

(ii) recommend the appropriate rating to be used for the geotechnical factors in the overall highway alignment/design option evaluation process.

C.3 Deliverables

The Consultants shall produce:

(a) A Desk Study Report which shall document the information examined and work carried out in C.2(a) and C.2(b) above, with Geotechnical Information Unit (GIU) references where appropriate, and describe the geological setting of the preferred route. Where necessary, a ground investigation (GI) plan as stated in C.2(d) above shall also be prepared.

(b) A GI Review Report documenting the findings, interpretation and conclusions of the walkover survey carried out in C.2(c) above and the GI, including any field testing, laboratory testing and groundwater and other monitoring works carried out in C.2(e) above, making reference to any GI contractor and laboratory testing reports produced, and making recommendations on any supplementary GI works needed for detailed design or additional GI works required during construction.

(c) Topographical Survey Maps at a scale of 1:1 000.

(d) Engineering Geological Maps at a scale of 1:1 000 showing:

(i) the solid and superficial geology along the highway route,

(ii) the locations of exposures of soil and rock, annotated with key information about the nature of the materials,

(iii) areas of past instability, e.g. landslide scars, boulder/rock fall locations, annotated with key information about the nature of the instability,

(iv) drainage courses and information on any areas of seepage observed,

(v) existing man-made slope features, and

(vi) new slope features to be formed.

(e) A Natural Terrain Hazard Assessment (NTHA) Report where a NTHA has been carried out. The NTHA Report shall detail the work carried out, and the findings and recommendations of the NTHA as stated in C.2(f) above. The Report shall contain all necessary photographs, tables, figures and drawings, including cross sections, to adequately illustrate the reasoning given in the text of the Report. In particular, the Report shall contain the following key drawings:

(i) cross sections showing possible debris travel paths from the identified potential landslide source locations and boulder/rock fall locations along the route,

(ii) Landslide and Boulder/Rockfall Hazard Maps at a scale of 1:1 000 showing:

- principal drainage courses, and all catchments and subcatchments affecting the route,
- likely landslide sources,
- likely boulder/rock fall locations,
- debris flow paths from landslide sources with the likely limits of travel of debris,
- boulder/rock fall trajectories with the likely limits of travel of boulder/rock falls.

Larger scale drawings (e.g. 1:500 and 1:200) shall be provided if particular areas of natural terrain require amplification.

(f) A Geotechnical Assessment Report documenting the findings and recommendations of the work as stated in C.2(g) to C.2(n) above. The Report shall include plans and cross sections of preliminary design of the geotechnical works and hazard mitigation measures proposed for the project. It shall also highlight any matters in relation to the proposed geotechnical works and hazard mitigation measures, and diversion/ducting of services/utilities, that require further investigations or particular attention before or during the detailed design stage. The final Reports and Maps as stated in C.3(a) to C.3(e) above shall become the companion documents of the GA Report.

C.4 Programme of Implementation

(a) The due date for commencement of the GA shall be ________________.

(b) A working programme, to be agreed with the Employer, shall be prepared within _____ weeks of the commencement of the GA.

(c) The due date for completion of the GA shall be ________________.

Notes: (1) An example of a programme for the GA of a highway project is given in Figure C1. The actual programme and milestones should dovetail those of the highway project.

(2) More than one team of geotechnical engineers and technical personnel may be needed and the programme may have to be adjusted, depending on the size of the study area and the number of alternatives to be considered.

C.5 Geotechnical Personnel for the GA

The Consultants shall engage professionally qualified persons with an adequate level of experience in geotechnical engineering and/or engineering geology to carry out the work under this Assignment. A professionally qualified person with suitable local experience in geotechnical engineering shall be in charge of the Assignment. A suitable qualification is Registered Professional Engineer (Geotechnical). This person shall scrutinize the relevance, adequacy and quality of all information collected, carry out the site walkover survey and prepare the GA Report personally.

C.6 Information to be Provided by the Employer

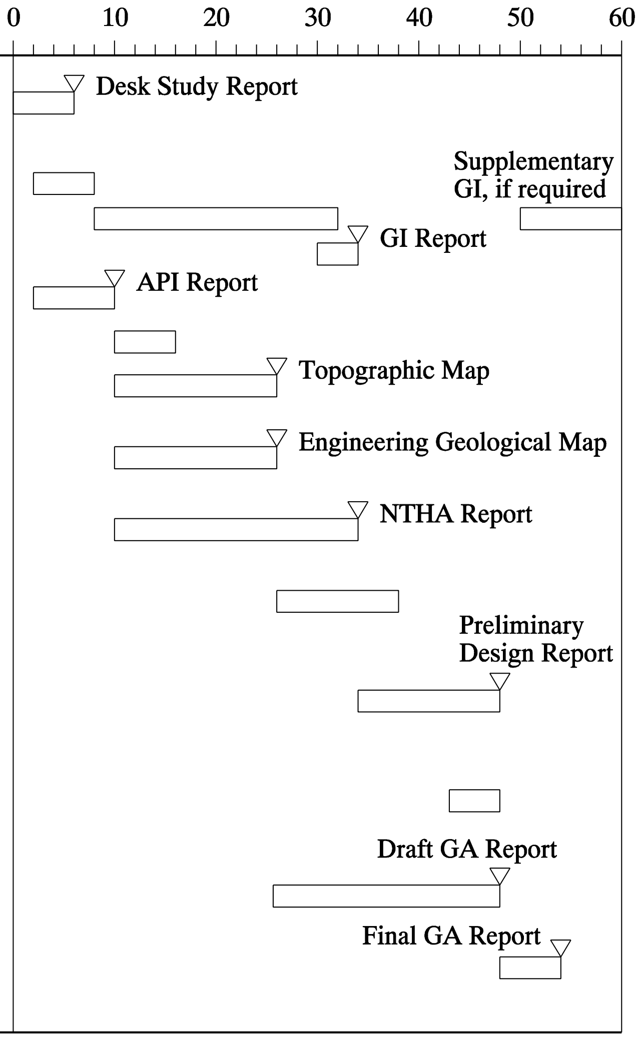
The Consultants shall search for and obtain all relevant published and publicly available information additional to those identified in the Geotechnical Report. All other information held by the Employer and relevant to the GA will be provided to the Consultants free of charge.

*   *   *   *   *

Notes: (1) The items given in Section C.2 of this Model Brief for GA are for guidance only. The project engineer should modify the items of the Brief as appropriate, taking into account the need, scale and complexity of the project.

(2) For Government highway projects, the guidelines given in the Project Administration Handbook Volume II Chapter 4 (Government of Hong Kong, 1992) should be followed in the preparation of the preliminary design of the geotechnical works and hazard mitigation measures as stated in C.2(j)(i) above. The preliminary design may be based on assumed parameters and information collected in the desk study and site reconnaissance, with appropriate sensitivity analyses carried out.

Activities	Duration (weeks)
1. Desk Study	2 - 6
2. Ground Investigation (GI)	
2.1 GI Plan	2 - 6
2.2 GI Works	16 - 24
2.3 GI Report	2 - 4
3. Aerial Photograph Interpretation	4 - 8
4. Walkover Survey	2 - 6
5. Topographic Survey, including vegetation clearance	8 - 16
6. Engineering Geological/ Geomorphological Mapping	8 - 16
7. Natural Terrain Hazard Assessment (NTHA), where required	12 - 24
8. Alternative Alignments and/or Design Options Assessment, where necessary	6 - 12
9. Preliminary Design of Geotechnical Works and Hazard Mitigation Measures, where required	8 - 14
10. Cost Estimates and Project Programming	4 - 6
11. Draft Geotechnical Assessment (GA) Report	18 - 26
12. Circulate for Comment and Finalise Geotechnical Assessment Report	4 - 6



Notes:

(1) The above programme for GA is prepared for a proposed new road approximately 1 km long, with a study area comprising approximately 40 hectares of natural terrain.

(2) The NTHA may be carried out separately.

(3) The programme for GI is indicative.

(4) Additional time may be required for checking land status and obtaining access permission for carrying out GI works.

Figure C1 Example of a Programme for the Geotechnical Assessment of a Highway Project

Appendix D

Landslip Preventive Measures Programme

Landslip Preventive Measures Programme

The Geotechnical Engineering Office (GEO) of the Civil Engineering Department (CED) of the Government of the Hong Kong SAR undertakes an on-going Landslip Preventive Measures (LPM) Programme to reduce the risk of landslides arising from old man-made slopes. Most of these slopes were formed prior to the introduction of SAR-wide geotechnical control in Hong Kong in 1977. They may not meet current standards of safety and could pose a hazard to life and property.

Under the LPM Programme, slopes that are of private maintenance responsibility are selected for safety-screening studies for assessing the need for serving Dangerous Hillside (DH) Orders under the Buildings Ordinance. Slopes that are of Government maintenance responsibility are selected for investigation and where necessary upgrading works carried out to bring them to current safety standards. The process of selecting slopes for action under the LPM Programme is known as 'LPM selection'. A risk-based ranking system, NPCS (Wong, 1998), has been set up to facilitate this process. For further information on the LPM process, reference should be made to GEO Information Note No. 9/99 (GEO, 1999).

In 1995, the Government undertook to speed up the LPM Programme by launching a 5-year Accelerated LPM Project. This Project deals principally with old man-made slopes registered in the 1977/78 Catalogue of Slopes. The old Slope Catalogue, compiled in 1977/78, registered about 10 000 man-made slopes that were in existence before 1977. The LPM selection work for this 5-year Accelerated LPM Project has been completed and about 900 Government slopes and 1 500 private slopes have been selected via the existing LPM selection process for action under this Project.

As part of the Government's commitment to further reduce the risk of landslides in Hong Kong, the GEO has started a 10-year Extended LPM Project following the completion of the 5-year Accelerated LPM Project in the year 2000. The 10-year Extended LPM Project will deal with slopes registered in the New Catalogue of Slopes, completed in 1998 and in which about 54 000 man-made slopes have been registered (Lam et al, 1998). Under this Project, a total of 2 500 Government slopes will be upgraded and safety-screening studies will be carried out on 3 000 private features by the year 2010. It is the Government's slope safety policy that all high consequence Government slopes which may affect major facilities including major roads will have been dealt with by 2010.

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Appendix E

Landslide Emergency System of the Government of the Hong Kong SAR

Landslide Emergency System of the Government of the Hong Kong SAR

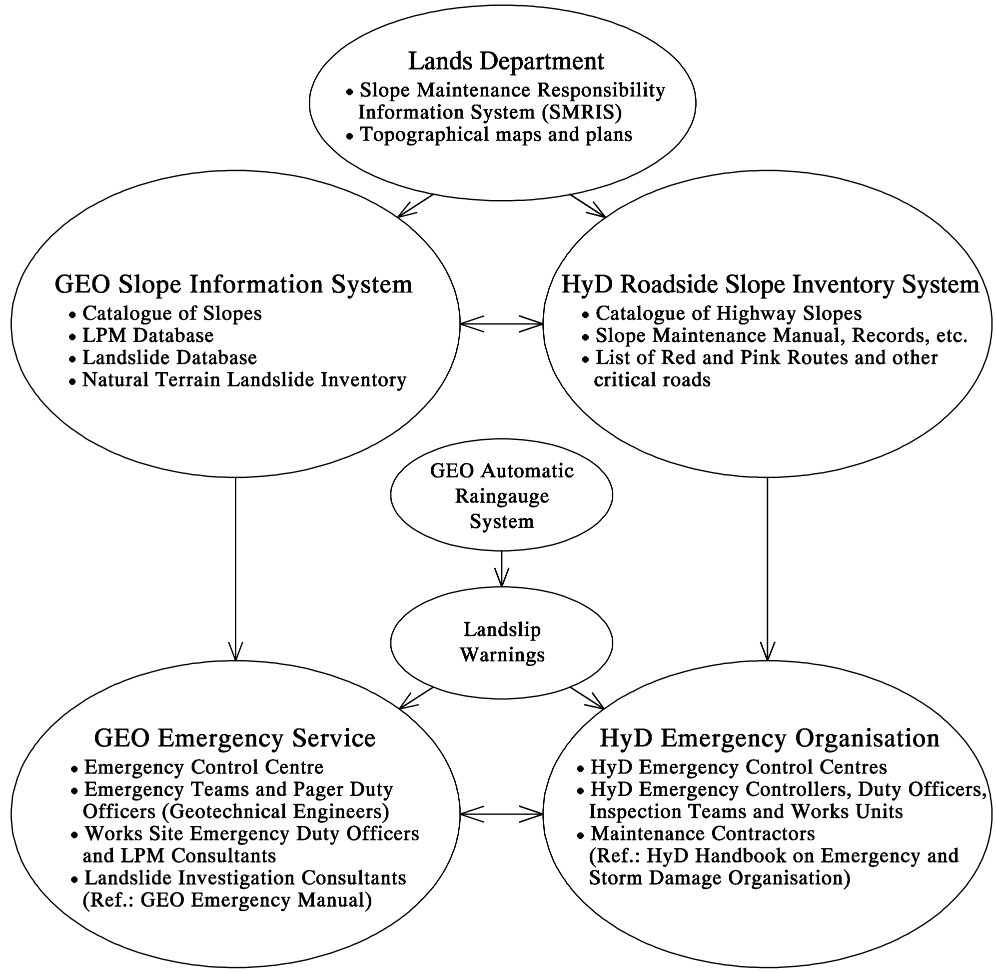
The Government of the Hong Kong SAR has an established emergency system for responding to natural disasters including landslides. Details of the system, including the activation of an Emergency Monitoring & Support Centre in the event of a major disaster, are contained in the Hong Kong Contingency Plan for Natural Disasters (Security Bureau, 1999). This Contingency Plan also summarises the responsibilities of the Government Bureaux and Departments involved.

The Geotechnical Engineering Office (GEO) of the Civil Engineering Department is responsible for issuing Landslip Warnings (in consultation with the Hong Kong Observatory) and advising other Government Departments on potential dangers due to landslides and measures to deal with them. The Highways Department (HyD) is responsible for, among others, the clearance of blockage and repair of damaged public roads caused by landslides, and also urgent repair of failed slopes affecting public roads.

To warn the public of the landslide risk during periods of heavy rainfall, the GEO operates a Landslip Warning System on the basis of recorded rainfall data and the latest weather information including short-term rainfall forecast from the Hong Kong Observatory. The GEO also maintains a 24-hour service to provide geotechnical advice to Government Departments on any emergency action to be taken in case of danger, real or suspected, arising from landslides. The operation of the GEO emergency system is documented in the GEO Emergency Manual (GEO, 1998). The HyD also operates Emergency Control Centres to deal with emergency on roads including that arising from landslides. Details of the HyD emergency system are contained in the Handbook on Emergency and Storm Damage Organisation (Highways Department, 1998). Responsibilities of Government Departments, major transport operators and agencies in handling an emergency where traffic and transport are seriously affected, are given in the Emergency Transport Arrangements document of the Transport Department (1999).

Figure E1 shows the relationship between the HyD and the GEO, and the emergency preparedness components for landslides affecting public roads. It also lists the sources of information that can be referred to during the emergency operations.

Complementary to the Government’s publicity campaign on personal precautionary measures during heavy rainstorms and Landslip Warnings, warning signs have been erected along roads with a history of landslides and at highway slopes that have been confirmed by stability assessments to be substandard and included in a slope upgrading or preventive maintenance programme. This will help to alert road users of the potential landslide risk along such roads. Display signs, which show not only the slope registration number, but also the name of the slope owner or the maintenance agent and telephone number of the contact person, have been displayed at suitable locations. These signs together with the SMRIS (Slope Maintenance Responsibility Information System) database on slope maintenance responsibility maintained by the Lands Department will greatly facilitate quick identification of slopes and slope owners and action parties at times of emergency. Examples of the slope display signs and warning signs are shown in Figure E2.



Landslide Emergency Preparedness Components

(1) Documented emergency organisation and operational procedures
(2) List of emergency contacts and telephone numbers
(3) List of emergency resources, details of emergency equipment and their mobilisation procedures
(4) Emergency traffic management procedures
(5) Emergency communication procedures between site staff and the emergency control centres, and liaison with other Government Departments
(6) Duties and responsibilities of emergency staff, consultants and contractors
(7) Guidance on landslide classification and priority for inspection
(8) Technical guidance on landslide inspection, road closure, urgent repair and road re-opening
(9) Staff training, drills and guidance for emergency personnel on site safety
(10) Review of emergency operation and debriefing
(11) Contingency plan for extreme landsliding events triggered by heavy rainfall
(12) Contingency plan for strategic roads and sole access to critical services
(13) Publicity campaign for personal precautionary measures during heavy rainfall and Landslip Warnings
(14) Slope Registration Number Plates
(15) Roadside Warning Signs along busy roads with past landsliding history and at slopes confirmed by stability assessments to be substandard and included in a slope upgrading or preventive maintenance programme
(16) Crisis Communication Centre and Crisis Manager

Figure E1 Emergency Preparedness Components for Landslides Affecting Public Roads

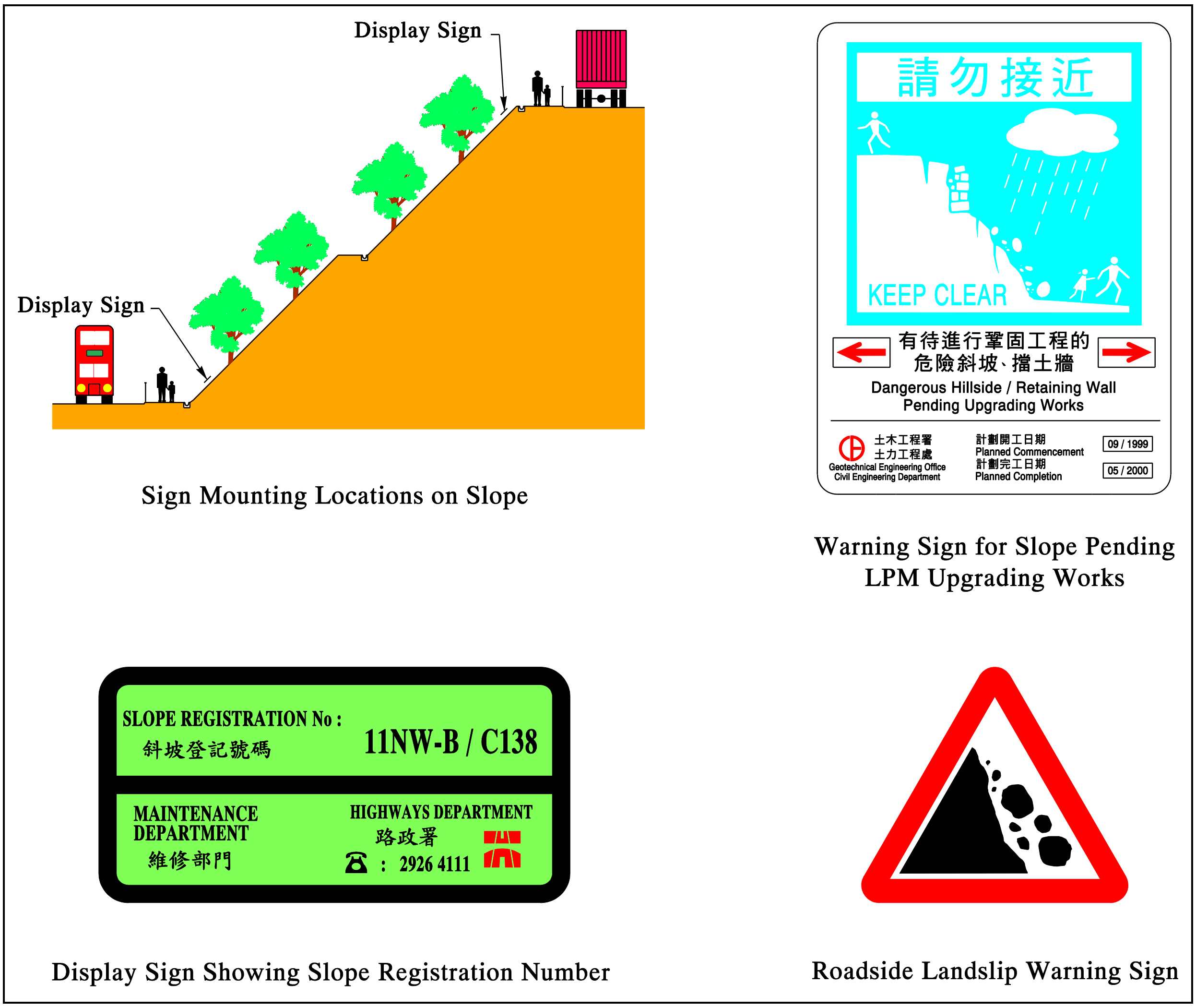


Figure E2 Examples of Display Signs for Slope Identification and Landslip Warning

References

Geotechnical Engineering Office (1998). *GEO Emergency Manual*. Geotechnical Engineering Office, Hong Kong. (Amended from time to time).

Highways Department (1998). *Handbook on Emergency and Storm Damage Organisation, Part I – Organisation and Procedures for the Three Regional Offices*. Highways Department, Hong Kong, 27 p.

Security Bureau (1999). *Hong Kong Contingency Plan for Natural Disasters (Including Those Arising from Severe Weather Conditions)*. Security Bureau, Government Secretariat, Hong Kong.

Transport Department (1999). *Emergency Transport Arrangements (Transport Department Technical Circular No. 3/99)*. Transport Department, Hong Kong, 41 p.

Appendix F

Site Check List for Landslide Inspections

Site Check List for Landslide Inspections

The site check list below may be used as a guide for landslide inspections during emergency, but it is by no means exhaustive. It includes the possible sources of danger and causes of failure which should be noted by the engineer in the course of his inspection.

(a) As water is normally the key element in triggering landslides, consider and look for the sources of water that are likely to adversely affect the situation and obtain the related information:

  (i) rainfall and the time of failure (for correlation with development of rainfall at the nearest raingauge),

  (ii) flooding and its timing,

  (iii) concentrated surface water flow, channelised flow or areas of water ponding above the slope or along the road,

  (iv) sewers and stormwater channels and drains, gullies, catchpits, cross road drains, etc., and their conditions,

  (v) buried or exposed fresh or salt water pipes along the road and their conditions,

  (vi) prominent water courses such as nullahs, natural drainage lines, etc., and their conditions, and

  (vii) diversion of flow due to blockage of natural drainage lines and seepages from slopes.

(b) Look for indications of ground movement such as displacement and/or cracking of:

  (i) paved ground, road kerbs and drainage channels,

  (ii) slope drainage channels, catchpits, and

  (iii) trees or other normally vertical features.

(c) Look at surface features for signs of distress:

  (i) tension cracks on the ground surface or road pavement,

  (ii) bulging of slopes or heave of ground or road,

  (iii) local depression of paved ground or road,

  (iv) subsidence of ground or road,

(v) excessive water seepage (indicative of high groundwater level or distressed services),

(vi) landslide debris, and

(vii) scouring or undercutting of the slope face, ground or road features by surface water.

(d) Check retaining walls including masonry type walls:

(i) tilt and horizontal misalignment,

(ii) settlement and undermining of foundations,

(iii) cracking (including broken tell-tales),

(iv) bulging,

(v) fallen debris or dislodgement of masonry blocks, and

(vi) excessive seepage and/or weephole flows.

(e) Look for other adverse features in the area where further deterioration may cause collapse:

(i) boulders/corestones (inadequate embedment),

(ii) open-jointed soil/rock faces,

(iii) leaning trees,

(iv) blocked slope or road drains,

(v) damaged slope surface protection,

(vi) pre-existing tension cracks,

(vii) old drainage lines,

(viii) recent changes to upslope or downslope environment (e.g. any resurfacing, demolition, site formation, utility installation, etc.) which could adversely affect the drainage characteristics of the area around the slope and road, and

(ix) material that has moved or been disturbed during the present landslide but has not yet detached from the slope.

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