土木工程拓展署
土力工程處
Geotechnical Engineering Office
Civil Engineering and
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香港的山泥傾瀉
LANDSLIDES IN HONG KONG

前言

教育局於2005年公布，三年新高中學制將於2009年9月在中四級實施。地理科是其中一個重點的選修科目。

新高中地理科課程是根據2005年教育局出版的一份文件和課程發展議會《高中課程指引》(2007)的建議而制訂。在此課程中，地理被視為一門學科讓學生可以從空間的角度了解自身所處的地球。

土木工程拓展署轄下的土力工程處應教育局的請求，在天然災害及地球科學兩個新高中地理科課程內容上製備了一份「教學支援教材套」。其中有關香港岩石及礦物的資料亦適用於部份化學科的課程。

「教學支援教材套」包括了14本小書冊、4張海報、3片光碟及其他一些補充資料。此教材套在香港的斜坡安全、山泥傾瀉、地質及地貌等課題上提供了合適及最新的資料並同時符合新高中地理科課程的水平。

土力工程處的「香港地質調查組」負責編寫有關香港地質及地貌方面的內容，而「斜坡安全部」則負責香港斜坡安全及山泥傾瀉的部份，「斜坡安全部」的同事亦負責整個項目的策劃與安排。我謹向各位參與這項工作的同事致謝。

我相信這教材套對各位負責新高中地理科目的老師在擬備教材時能提供合適的參考。此教材套亦給予有興趣於這些課題的廣大讀者一些有用的資料。

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Foreword

In 2005, the Education Bureau (EDB) announced that a three-year New Senior Secondary (NSS) curriculum would be implemented at Secondary 4 in September 2009. Geography is one of the elective subjects under the NSS curriculum.

The NSS curriculum has been developed on the basis of the recommendations made by an EDB document in 2005 and a Senior Secondary Curriculum Guide of 2007. Within the curriculum, geography is seen as a key educational discipline that provides students with a spatial understanding of the Earth on which we live and work.

At the request of the EDB, the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department have prepared support teaching materials for the NSS Geography curriculum under the topics of Natural Hazards and Earth Science. The materials written on rocks, minerals and ores in Hong Kong are also suitable for part of the Chemistry curriculum.

The "Teaching Support Materials Kit" consists of 14 booklets, 4 posters, 3 CDs and other supplementary information sheets. This teaching kit contains pertinent and up-to-date information on slope safety, landslides, geology and geomorphology in Hong Kong, written at a level that is suitable for the NSS Geography curriculum.

Hong Kong Geological Survey of GEO have compiled the teaching materials that describe the geology and geomorphology of Hong Kong. The Slope Safety Division of GEO have prepared the teaching materials on Hong Kong slope safety and landslides. Colleagues in the Slope Safety Division are also responsible for the overall planning and coordination of this project. Their contributions are gratefully acknowledged.

I am confident that, for years to come, secondary school geography teachers will find the kit invaluable for preparing their classroom teaching materials. The contents will also be of interest to the more general readers who may wish to learn more about these topics.

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December 2008

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Introduction

山泥傾瀉是香港最常見的天然災害之一，其破壞力非常大，同時造成不少傷亡。回顧香港過去百多年歷史，山泥傾瀉不時經常重現，斜坡安全已成為香港市民世世代代都要面對的問題。自1948年起，山泥傾瀉導致超過470人死亡(圖1)，可見山泥傾瀉問題的嚴重性。山泥傾瀉問題實質上是戰後市區發展的產物，大部份的死亡均為人造斜坡崩塌所導致(圖2)。大部份的山泥傾瀉是由降雨引發，所引發山泥傾瀉的數目，會因不同暴雨的特質而有異。

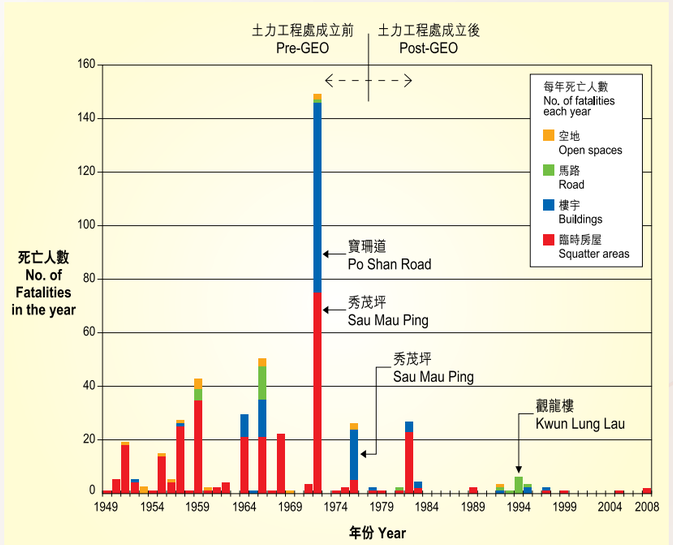


圖1. 山泥傾瀉導致的死亡人數。
Figure 1. Number of fatalities due to landslides.

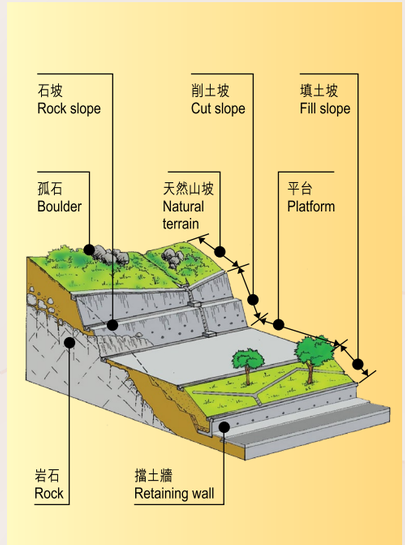


圖2. 斜坡的類別。
Figure 2. Types of slope.

Landslides are one of the most common natural hazards in Hong Kong. They are very destructive and usually result in extensive damage. Over the past century of Hong Kong's history, landslides have occurred regularly. Slope safety has become a problem that will continue to be faced by many generations to come. The scale of the landslide problem is indicated by the fact that landslides have been responsible for the death of more than 470 people since 1948 (Figure 1). The landslide problem is essentially the product of post-war urban growth, for most of these deaths resulted from the collapse of man-made slopes (Figure 2). The majority of landslides are caused by rainfall. While some past rainstorms have caused many landslides, others have caused relatively few.

山泥傾瀉簡史

土木工程拓展署轄下土力工程處於2005年出版了一本以香港山泥傾瀉為主題的書，名為《山崩土淹話今昔》(圖3)。書中照片數量超過二百多張，涵蓋時期由1889年至1999年。這本書應能滿足對歷史資料有所求的讀者。

圖3. 《山崩土淹話今昔》一書的封面。
Figure 3. The front cover of the book "When Hillsides Collapse - A century of landslides in Hong Kong".

在1949年至1977年(即土力工程處成立之前)之間，幾乎每年均發生致命的山泥傾瀉。尤其於1957、1959、1964、1966及1968年，每年平均有30人死於山泥傾瀉(圖1)。

1972及1976年發生了兩次暴雨災害，政府因此於1977年成立了土力工程處作為一個制訂斜坡政策的中心部門。香港歷史上最嚴重的山泥傾瀉發生於1972年6月18日。下午1時後不久，位於秀茂坪安置區發生山泥傾瀉(圖4)，一幅40米高的路堤邊坡倒塌，隨之而來的泥石摧毀了位於斜坡下面的臨時安置區，導致71人死亡及60人受傷。數小時後，香港島半山區寶珊道一處私人住宅區附近的山坡又發生另一重大山泥傾瀉，一座12層高的私人住宅大廈被急速傾瀉的山泥沖毀(圖5)，導致67人死亡及20人受傷。此山泥傾瀉成因的詳情，請參閱附錄A。

圖4. 1972年秀茂坪山泥傾瀉。
Figure 4. 1972 landslide in Sau Mau Ping.

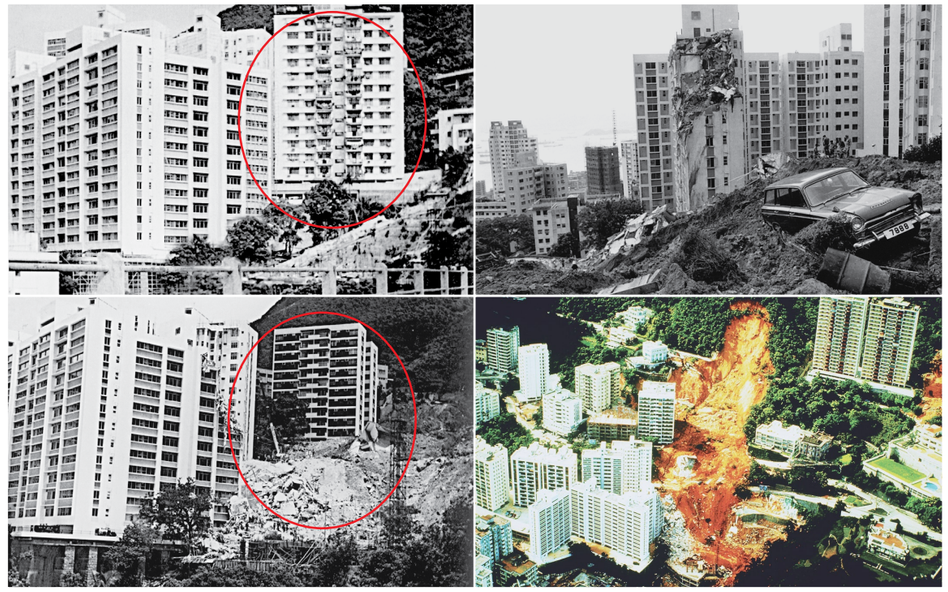


圖5. 1972 年寶珊道山泥傾瀉。
Figure 5. 1972 landslide in Po Shan Road.

A Brief History of Landslides

The Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department published a book in 2005 with Hong Kong landslides as the theme. The title of the book is "When Hillsides Collapse – A century of landslides in Hong Kong" (Figure 3). There are over 200 photographs in this book, illustrating the period from 1889 to 1999. Readers may refer to this book for more historical information.

Between the period 1949 and 1977 (*i.e.* before the establishment of the GEO), fatal landslides occurred nearly each year. Notably, in 1957, 1959, 1964, 1966 and 1968 where an average of 30 people died in each of these years due to landslides (Figure 1).

Two disastrous rainstorms occurred in 1972 and 1976 and a central slope policing body, the Geotechnical Engineering Office, was created in 1977. The two most destructive landslides in the recent history of Hong Kong took place on 18 June 1972. Shortly after 1 pm, a major landslide occurred in the Sau Mau Ping Resettlement Estate. The failure (Figure 4) involved the collapse of the side-slope of a 40m high road embankment constructed on sloping ground. The resulting flowslide destroyed many huts in a licensed temporary housing area, killing 71 people and injuring 60 others. Hours later, another major landslide occurred, in a private residential district on a steep hillside at Po Shan road in the Mid-levels area of Hong Kong Island. 67 people were killed and 20 injured when an occupied 12-storey private apartment building was demolished under the impact of an extremely rapid flowslide. The landslip (Figure 5) was initiated on the hillside above by the collapse of a steep cutting in a works site for a private building (see Appendix A for more details).

四年後，一個強烈風暴帶來暴雨，另一宗致命山泥傾瀉於1976年8月25日再次在秀茂坪區發生(圖6)。填土築成的公路邊坡倒塌，引致區內發生至少4次山泥傾瀉。其中三次演變為泥流。泥石大片滑下直至被大廈阻擋，地下的房間被山泥淹沒，眾多住客被困，導致18人死亡及24人重傷。

山泥傾瀉發生後，政府立即成立獨立調查小組(圖7)。此小組由海外土力專家組成，他們建議成立中央政策組織以監管香港斜坡的調查、設計、工程、監察及維修的整個過程。

土力工程處於1977年成立後，制定了有效的斜坡安全系統以減低山泥傾瀉的風險，並提升大眾對有關風險的危機意識(詳情請參閱「香港斜坡安全」一書)。

圖6. 1976年秀茂坪山泥傾瀉。
Figure 6. 1976 landslide in Sau Mau Ping.

表1是過去20年一些較為矚目的山泥傾瀉事件的一個簡單摘要。

Four years later, another destructive landslide occurred in the Sau Mau Ping again, on the morning of 25 August 1976, following heavy rainfall associated with a severe tropical storm (Figure 6). At least 4 landslides took place in the estate resulting from the collapse of the side-slopes of highway embankments formed of earth fill. Three of these turned into flowslides. The debris moved downwards as "a large sheet" until arrested by the building, the ground floor rooms of which were inundated by fluid mud, trapping many occupants; 18 people were killed and 24 seriously injured.

Immediately after the landslide, the Governor established an Independent Review Panel on Fill Slopes (Figure 7), comprised largely of overseas geotechnical experts, which recommended the creation of a central policing body to regulate the whole process of investigation, design, construction, monitoring and maintenance of slopes in Hong Kong.

圖7. 1976年秀茂坪山泥傾瀉獨立調查小組報告，其中建議成立中央監管部門。
Figure 7. Investigation report on the 1976 Sau Mau Ping landslides by an independent review panel. One of the recommendations was the creation of a central policy body to oversee slope problems in HK.

Since the establishment of the GEO in 1977, an effective slope safety system was devised to reduce the landslide risk and to address public attitudes to risk (see another booklet on "Hong Kong Slope Safety" for details).

Table 1 summarizes some notable landslides in Hong Kong during the past 20 years.

年份 Year	山泥傾瀉地點 Location of Landslide	死亡人數 No. of Fatalities	受影響設施 Affected Facilities	備註 Remarks
1990	青山 (圖8) Tsing Shan (Figure 8)	—	山麓 Hillside	有紀錄以來最大的天然山坡山泥傾瀉。 The biggest landslides occurring on natural terrain.
1992	碧瑤灣 (圖9) Baguio Villas (Figure 9)	2	樓宇 Buildings	一名小童及一名工程師罹難，多達1,500名居民須疏散。 A child and a government engineer were killed. More than 1500 residents were evacuated.
1993	象山邨 (圖10) Cheung Shan Estate (Figure 10)	1	巴士站 Bus stop	
1993	大嶼山 (圖11) Lantau Island (Figure 11)	—	山麓 Hillside	在11月發生約860宗天然山坡崩塌事件。 More than 860 natural terrain landslides in November.
1994	觀龍樓 (圖12) Kwun Lung Lau (Figure 12)	5	行人路 Pedestrian	
1994	青山公路 (圖13) Castle Peak Road (Figure 13)	1	馬路 Road	
1995	翡翠道 (圖14) Fei Tsui Road (Figure 14)	1	馬路 Road	
1995	深灣道 (圖15) Shum Wan Road (Figure 15)	2	船廠 Shipyard	
1995	屯門公路 (圖16) Tuen Mun Highway (Figure 16)	1	馬路 Road	建築地盤有大石塌下，並引至屯門公路大塞車。 Boulder fall from a construction site. Also caused a major traffic deadlock.
1997	九華徑 (圖17) Kau Wa Keng (Figure 17)	1	臨時房屋 Squatter areas	
1997	萬佛寺 (圖18) Ten Thousand Buddhas' Monastery (Figure 18)	1	小屋 Small hut	
1997	呈祥道 (圖19) Ching Cheung Road (Figure 19)	—	馬路 Road	呈祥道須封閉三星期。 Closure of a major highway for more than three weeks.
1999	深井新村 (圖20) Sham Tseng San Tsuen (Figure 20)	1	臨時房屋 Squatter areas	十三人受傷，天然山坡發生泥石流。 13 injuries. Debris flow from natural terrain.
1999	石硤尾邨 (圖21) Shek Kip Mei Estate (Figure 21)	—	樓宇 Buildings	永久疏散300戶家庭約700人。 Permanent evacuation of about 300 families and some 700 residents.
2005	芙蓉山村 (圖22) Fu Yung Shan Tsuen (Figure 22)	1	臨時房屋 Squatter areas	
2008	咖啡灣 (圖23) Cafeteria Beach (Figure 23)	2	小屋 Small hut	
2008	廣泛地區、特別是大嶼山 (圖24) Over the whole territory, especially in Lantau Island (Figure 24)	—	樓宇、馬路及山麓 Buildings, roads and hillsides	在六月份超過600宗人造斜坡及天然山坡崩塌事件。 > 600 landslides in June and most of them were natural terrain landslides.

表1. 香港過去20年一些較為矚目的山泥傾瀉事件。
Table 1. Notable landslides in Hong Kong in the past 20 years.

圖8. 1990年青山山泥傾瀉 (見表1)。
Figure 8. Landslide at Tsing Shan, 1990 (see Table 1).

圖9. 1992年碧瑤灣山泥傾瀉 (見表1)。
Figure 9. Landslide at Baguio Villas, 1992 (see Table 1).

圖10. 1993年象山邨山泥傾瀉 (見表1)。
Figure 10. Landslide at Cheung Shan Estate, 1993 (see Table 1).

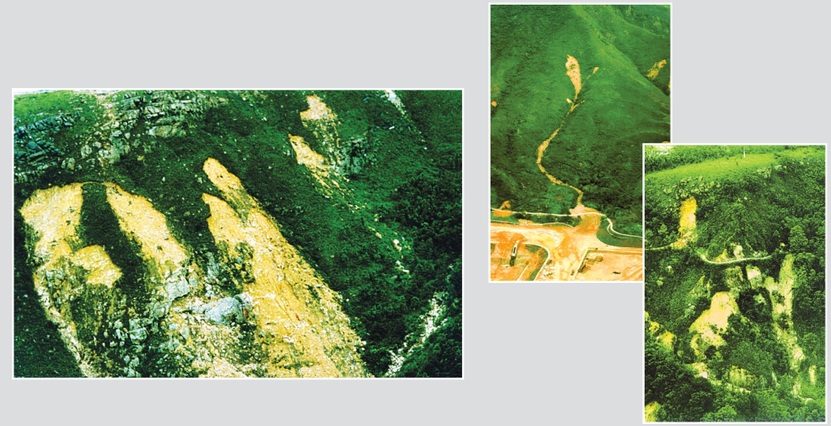


圖11. 1993年大嶼山山泥傾瀉 (見表1)。
Figure 11. Landslide in Lantau Island, 1993 (see Table 1).

圖12. 1994年觀龍樓山泥傾瀉 (見表1)。
Figure 12. Landslide at Kwun Lung Lau, 1994 (see Table 1).

圖13. 1994年青山公路山泥傾瀉 (見表1)。
Figure 13. Landslide at Castle Peak Road, 1994 (see Table 1).

圖14. 1995年翡翠道山泥傾瀉 (見表1)。
Figure 14. Landslide at Fei Tsui Road, 1995 (see Table 1).

圖15. 1995年深灣道山泥傾瀉 (見表1)。
Figure 15. Landslide at Shum Wan Road, 1995 (see Table 1).

圖16. 1995年屯門公路山泥傾瀉 (見表1)。
Figure 16. Landslide at Tuen Mun Highway, 1995 (see Table 1).

圖17. 1997年九華徑山泥傾瀉 (見表1)。
Figure 17. Landslide at Kau Wa Keng, 1997 (see Table 1).

圖18. 1997年萬佛寺山泥傾瀉 (見表1)。
Figure 18. Landslide at Ten Thousand Buddhas' Monastery, 1997 (see Table 1).

圖19. 1997年呈祥道山泥傾瀉 (見表1)。
Figure 19. Landslide at Ching Cheung Road, 1997 (see Table 1).

圖20. 1999年深井新村山泥傾瀉 (見表1)。
Figure 20. Landslide at Sham Tseng San Tsuen, 1999 (see Table 1).

圖21. 1999年石硤尾邨山泥傾瀉 (見表1)。
Figure 21. Landslide at Shek Kip Mei Estate, 1999 (see Table 1).

圖22. 2005年芙蓉山村山泥傾瀉 (見表1)。
Figure 22. Landslide at Fu Yung Shan Tsuen, 2005 (see Table 1).

圖23. 2008年咖啡灣山泥傾瀉 (見表1)。
Figure 23. Landslide at Cafeteria Beach, 2008 (see Table 1).

圖24. 2008年廣泛地區，特別是大嶼山山泥傾瀉 (見表1)。
Figure 24. Landslide over the whole territory, especially in Lantau Island (see Table 1).

在過去23年(1985-2008)共有22人死於山泥傾瀉。除了一宗有關在施工地盤的致命意外及另一宗有關執行緊急任務的工程師的事故之外，共有20名市民因暴雨而死亡。受影響的設施包括(圖25)：

- 寮屋區
- 行人路、巴士站等
- 靠近斜坡的道路；及
- 建築物內

其實，1985至2005年間受山泥傾瀉影響(不一定是致命的山泥傾瀉)的設施大致相同(圖26)。

在過去23年內，有百分之八十的意外死亡事故發生於以上設施(圖27)。而百分之九十四有關事故於山泥傾瀉警告(圖28)生效時發生。如公眾於暴雨期間按政府指引採取預防措施(圖29)，過去23年內百分之八十的山泥傾瀉死亡事故或可避免。

圖25. 容易受山泥傾瀉影響的設施。
Figure 25. Common facilities affected by landslides.

圖26. 1985至2005年間受山泥傾瀉影響的設施。
Figure 26. Facilities affected by landslides (1985-2005).

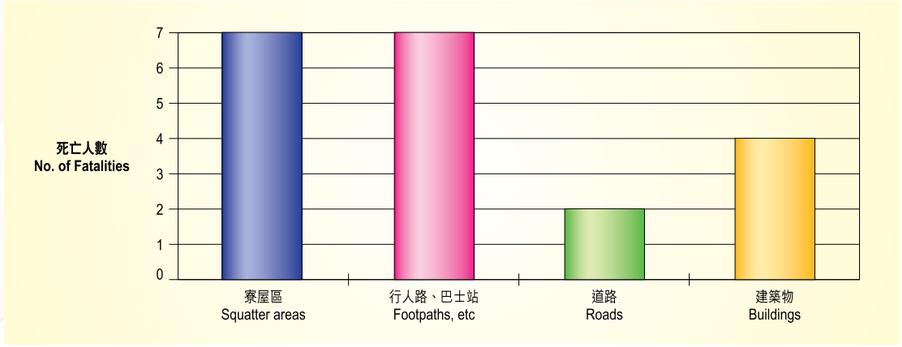


圖27. 1985至2007年山泥傾瀉導致的死亡人數分佈。
Figure 27. Distribution of landslide fatalities (1985-2007).

A total of 22 people were killed by landslides in last 23 years (1985-2008). Excluding one fatality related to active construction site and one related to an engineer carrying out emergency duty , a total of 20 members of public were killed during heavy rain. The affected facilities included (Figure 25):

- squatter areas
- on footpaths, bus shelters, etc.
- associated with driving along steep slope; and
- inside buildings

In fact, the facilities affected by landslides (not necessarily those fatal landslides) from 1985-2005 were similar (Figure 26).

80% of total fatalities in the last 23 years occurred in the above facilities (Figure 27). 94% of these fatalities occurred when Landslip Warning (Figure 28) was still in force. If the public had taken government's messages on precautionary measures during heavy rain seriously (Figure 29), 80% of the landslide fatalities in last 23 years might have been avoided.

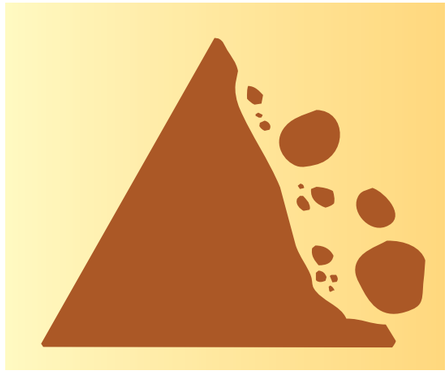


圖28. 山泥傾瀉警報訊號。
Figure 28. Landslip warning signal.

圖29. 市民於暴雨或山泥傾瀉警告生效期間應採取的預防措施。
Figure 29. Precautionary measures to be taken by the public during heavy rain or landslip warning is in force.

導致山泥傾瀉的成因

在香港，大部份發生的山泥傾瀉幅度較小(不足3米深)及規模較小。平均而言，約百分之九十崩塌的體積少於50立方米，而約百分之五十則少於10立方米。約百分之三的山泥傾瀉體積多於500立方米。

香港普遍的斜坡災害於表2按不同的斜坡種類、斜坡物質性質及快速崩塌形式而分類。圖2展示不同種類的斜坡，而圖31及32則說明崩塌形式。香港大部份崩塌發生於舊的削土坡。但亦有發生於舊的填土坡及擋土牆。近來，天然地形的山泥傾瀉有增加趨勢，例如大嶼山西部因2008年6月7日的暴雨(圖33)而發生了超過400宗山泥傾瀉。圖30顯示於2007年土力工程處接獲的山泥傾瀉種類。

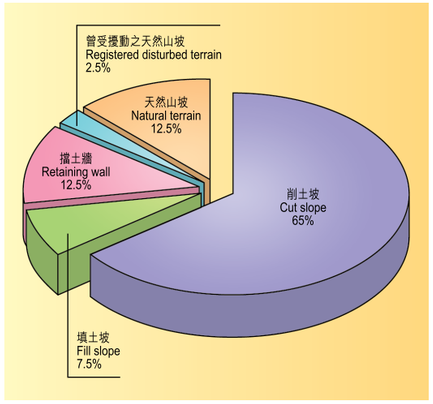


圖30. 2007年土力工程處接獲的山泥傾瀉種類。
Figure 30. Type of landslides reported to GEO in 2007.

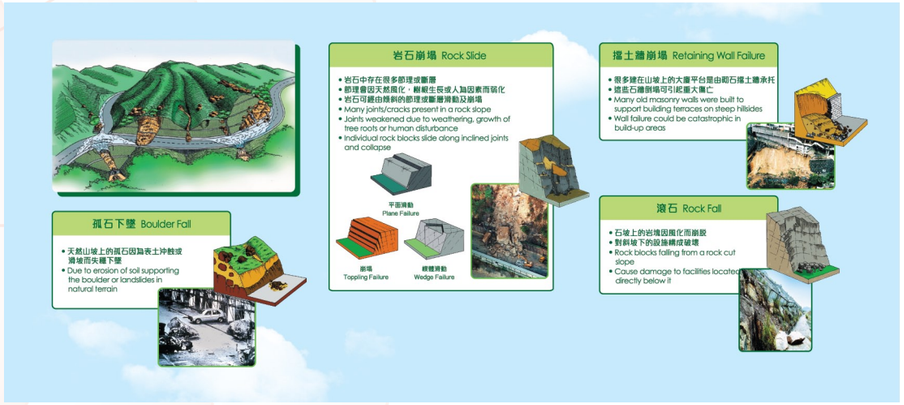


圖31. 常見的山泥傾瀉模式(非土坡)。
Figure 31. Common failure mechanism of landslides (non-soil slopes).

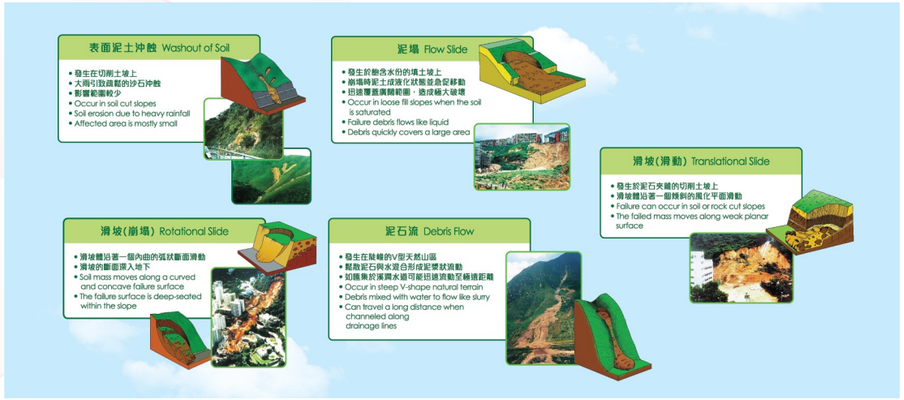


圖32. 常見的山泥傾瀉模式(土坡)。
Figure 32. Common failure mechanism of landslides (soil slopes).

Causes of Landslides

The majority of the landslides in Hong Kong are shallow (<3m deep) and of a small scale. On average, about 90% of the failures are less than 50m^3 in volume and about 50% are less than 10m^3 in volume. About 3% of the landslides are greater than 500m^3 in volume.

The common types of slope hazards in Hong Kong are summarized in Table 2 with respect to the different slope types, nature of slope-forming material and mechanisms of fast-moving failures. Figure 2 explains the different types of slope and Figures 31 and 32 illustrate the failure mechanisms. In Hong Kong, most of the failures occur on old cut slopes. However old fill slopes and retaining walls are also involved. Recently, number of natural terrain landslides shows an increasing trend, *e.g.* over 400 landslides occurred in western part of the Lantau Island as a consequence of the June 7, 2008 rainstorm (Figure 33). Type of landslides reported to GEO in 2007 is shown in Figure 30.

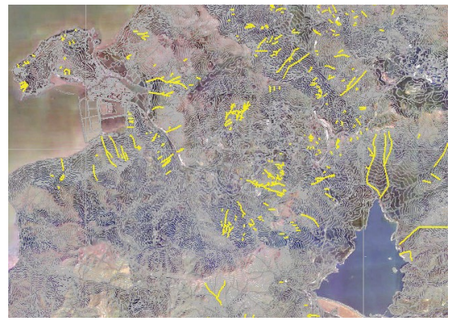


圖33. 2008年6月7日的暴雨導致在大嶼山西部超過400宗天然山坡倒塌(黃色線段)。
Figure 33. Over 400 natural terrain failures occurred in western part of the Lantau Island as a consequence of the June 7, 2008 rainstorm (yellow lines).

斜坡種類 Slope Type	崩塌形式 Failure Mechanism	闡釋 Description	
填土坡 (註1) Fill slope (note 1)	滑動 Sliding	沿剪切面或較薄的剪切區域滑動而分離的部份土體，剪切面可能是直的或彎曲的。	Detachment of part of the soil mass by way of sliding along a shearing surface or within a relatively thin shear zone, which may be straight or curvilinear.
	液化 Liquefaction	由鬆散土體形成的斜坡具有亞穩土壤結構，若斜坡在高飽和度及持續剪切力的狀態下，亞穩結構會突然崩塌，令土壤的抗剪強度顯著減弱，導致泥流形式的山泥傾瀉。這是「滑動」崩塌的特殊個案。	Sudden collapse of the metastable soil structure within a loose soil mass in the slope when it is subjected to a high degree of saturation under sustained shear stresses, resulting in a significant reduction in soil shear strength and leading to a flowslide type failure. This is a special case of "sliding" failure.
	沖蝕 Washout	部份土體因地面水流出的沖刷作用而分離。	Detachment of part of the soil mass induced by the scouring action of running surface water.
削土坡 Soil cut slope	滑動 Sliding	沿剪切面或在較窄的剪切帶內滑動而分離的部份土體。而風化土則亦有可能於削石坡出現崩塌的情況。	Detachment of part of the soil mass by way of sliding along a shearing surface or within a relatively narrow shear zone. For saprolitic soil, the failure mechanisms operating in rock cut slopes are also possible.
削石坡 Rock cut slope	滑動 Sliding	沿岩體平面或接近平面的裂縫滑動而分離的部份岩體，結合岩體的應力釋放面 。	Detachment of part of the rock mass by way of sliding along a planar or near-planar discontinuity in the rock mass in combination with a release surface.
	坍塌 Toppling	因直/橫不連續面構成的石塊底部旋轉而分離的石塊。	Detachment of blocks of rock by way of rotation about the base of rock blocks delineated by sub-vertical and sub-horizontal discontinuities.
	楔型崩塌 Wedge Failure	沿裂縫交叉點滑動而分離的石楔。	Detachment of wedges of rock by way of sliding along the intersection of sets of discontinuities.
	解開 Ravelling	從斜坡面分離的細小獨立碎石。	Detachment of small individual rock fragments from the slope face.
註 (1) : 這通常由風化花崗岩、風化火山岩、殘積土或坡積物的土壤填料組成，石填料並不包括在內。 Note (1) : This commonly comprises soil fill derived from decomposed granites, decomposed volcanics, residual soil or colluvium. Rock fill is not considered here.			

表2. 常見的山泥傾瀉模式。
Table 2. Common failure mechanism of landslides.

廣泛而言，山泥傾瀉主要有兩大成因：天然作用和人為作用。圖34簡單展示山泥傾瀉的一些常見天然因素，而圖35則闡釋一些常見的人為因素。

從專業角度來說，香港山泥傾瀉的一般普遍成因如表3所列。

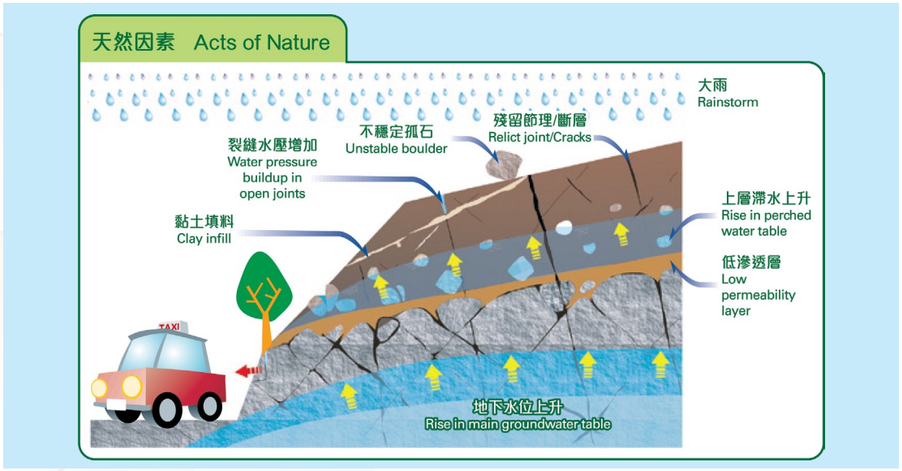


圖34. 導致山泥傾瀉的一些常見天然因素。
Figure 34. Some common natural causes of landslides.

Broadly speaking, there are two main causes of landslides: Acts of Nature and Acts of Mankind. Figure 34 shows some common natural causes of landslides in a simplified way while Figure 35 explains some common human causes.

More technically, the common generic contributory factors in landslides in Hong Kong are shown in Table 3.

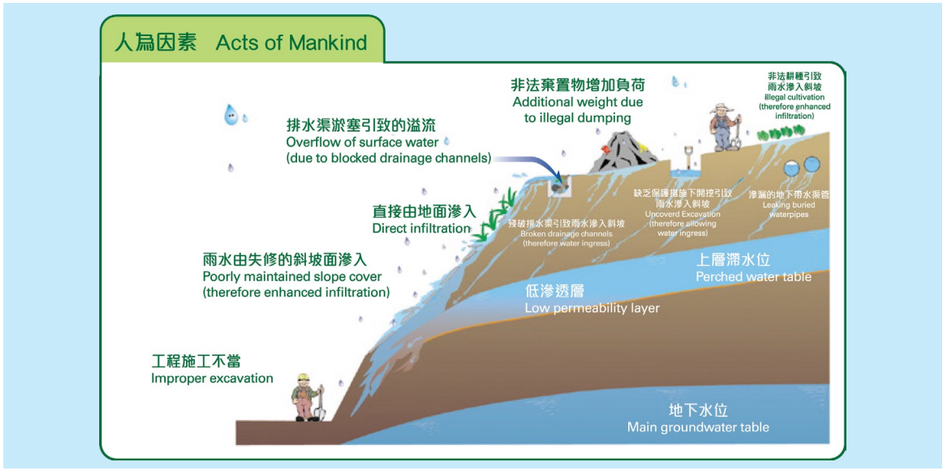


圖35. 導致山泥傾瀉的一些常見人為因素。
Figure 35. Some common human causes of landslides.

	一般成因 Generic Factors		相對發生頻率 Relative Degree of Occurrence
固有不利的地質弱點及不理想的水文地質制度 Inherent adverse geological weaknesses and unfavourable hydrogeological regime	不利的地質物質，如高度高嶺石化的花崗岩和火山岩、已風化的岩牆、火山岩組內的沉積層等。	Adverse geological materials, *e.g.* intensively kaolinised granites and volcanics, weathered dykes, sedimentary layers within volcanic formations, *etc.*	不普遍 Not common
	不利的地質裂縫如位置不利、廣泛、持續及填入黏土或粉砂的裂縫、先前存在的剪切面或區域、已形成並有擦痕面或被礦物或高嶺土厚厚覆蓋的裂縫。	Adverse geological discontinuities, *e.g.* adversely - orientated, extensive and persistent, clay or silt infilled discontinuities, pre-existing shear surfaces or zones, well-developed discontinuities that are slickensided or heavily coated with minerals or kaolinite.	不普遍 Not common
	水文地質環境有利於上層滯水位的發展，例如風化石被鬆散坡積物或填土的面層覆蓋。	Hydrogeological setting favourable to development of perched water level, *e.g.* a surface layer of loose colluvium or fill overlying weathered rock.	普遍 Common
	水文地質環境有利於高基層地下水位的發展。	Hydrogeological setting favourable to development of a high base groundwater table.	不普遍 Not common
設計及施工上的不足 Inadequate design and construction practice	過度陡斜的斜坡，例如在土力工程處成立前、欠缺嚴緊土力監察及設計的情況下建設的人造斜坡。	Oversteep slopes, *e.g.* overstep pre-GEO man-made slopes constructed without rigorous geotechnical investigation and design.	非常普遍 Very common
	含有鬆散填土的路堤。	Embankments comprising loose fill.	非常普遍 Very common
	斜坡表面排水設施不足，細節設計差劣，例如表面排水道設計未盡完善，於雨勢大時容易過度溢出。	Inadequate slope surface drainage provisions and poor detailing, *e.g.* inadequately designed surface drainage channels that are vulnerable to overspill during heavy rain.	非常普遍 Very common
	斜坡表面保護措施不足，細節設計差劣，例如排水設施不足，令建有不透水保護面的斜坡的地下水位偏高而產生水壓。	Inadequate slope surface protection provisions and poor detailing, *e.g.* wetting of the slope and build-up of water pressures behind impermeable slope surface covers due to inadequate drainage.	普遍 Common
不利的地形 Adverse topography	地形環境易受地面水集中排放或滲入影響，例如位於斜坡頂部平台低點或處於地面水可能溢流的道路轉彎處之下的斜坡。	Topographical setting susceptible to concentrated discharge or ingress of surface water, *e.g.* slopes situated below a low point of a crest platform or below a road bend from which surface water may overflow.	普遍 Common
斜坡維修不足 Inadequate slope maintenance	斜坡維修不足，例如除草、破裂護面、表面的排水道及疏水孔受阻塞等。	Inadequate slope maintenance, *e.g.* de-vegetation, cracked surface cover, blocked surface drainage channels and weepholes, *etc.*	非常普遍 Very common
運水設施維修不足 Inadequate maintenance of water carrying services	位置欠佳、有損毀的運水系統及水塘的滲漏。	Leakage from poorly-sited, defective water carrying services and reservoirs.	普遍 Common
多個不利的環境因素共同影響 Adverse combination of circumstances	連鎖效應	Knock-on effects.	不普遍 Not common
	註：很多崩塌均由多個原因引致。	Note: Many failures are due to a combination of factors.	

表3. 香港山泥傾瀉的一般成因。
Table 3. Generic factors contribute to the landslides in Hong Kong.

預防或減低山泥傾瀉風險的措施

「香港斜坡安全」一書提及政府採取了三大策略以應付香港的山泥傾瀉問題：

- 防止山泥傾瀉風險增加的趨勢；
- 改善斜坡狀況以減低山泥傾瀉風險；及
- 減低山泥傾瀉影響以降低山泥傾瀉的風險。

表4更具體顯示部份主要措施。圖36、37及38展示預防或緩減山泥傾瀉問題的工程例子。

預防或減低山泥傾瀉風險的措施 Measures to Prevent or Reduce the Risk of Landslides			
造成山泥傾瀉的天然因素 Natural causes of landslides		造成山泥傾瀉的人為因素 Human causes of landslides	
	措施 Measures		措施 Measures
暴雨 Heavy rainfall	• 堅固的斜坡設計 Robust slope design • 適當的排水系統 Adequate drainage system	設計或施工上的不足 Inadequate / improper design or construction	• 釐定及改善斜坡設計標準 Set and improve slope safety standards • 審查斜坡設計 Audit slope design • 工程施工監察 Monitoring of construction works
不利的地質 Adverse geology	• 岩土研究 Research and development • 城市規劃 Town planning • 斜坡設計指引 Technical guides on design	缺乏維修 (圖36) Lack of maintenance (Figure 36)	• 釐定及改善斜坡維修標準 Set and improve slope maintenance standards • 定期維修 — 政府部門及私人斜坡業主的責任 Regular monitoring - responsibility of private slope owners and relevant government departments • 對私人斜坡進行安全篩選 Safety screening of private slopes • 提供公眾教育及資訊 Public education and information

表4. 預防或減低山泥風險的措施。
Table 4. Measures to prevent or reduce the risk of landslides.

圖36. 定期維修斜坡能有效減低山泥傾瀉風險。
Figure 36. Regular slope maintenance can effectively reduce landslide risk.

Measures to Prevent or Reduce the Risk of Landslides

It is mentioned in the booklet on "Hong Kong Slope Safety" that three major strategies are employed by the Government to combat landslide problems in Hong Kong:

- Stop the increasing trend of the landslide risk;
- Reduce landslide risk by improving slope conditions; and
- Reduce landslide risk by reducing landslide consequence.

Table 4 shows some key measures in more concrete terms. Examples of engineering works to prevent or mitigate the landslides problems are shown in Figures 36 - 38.

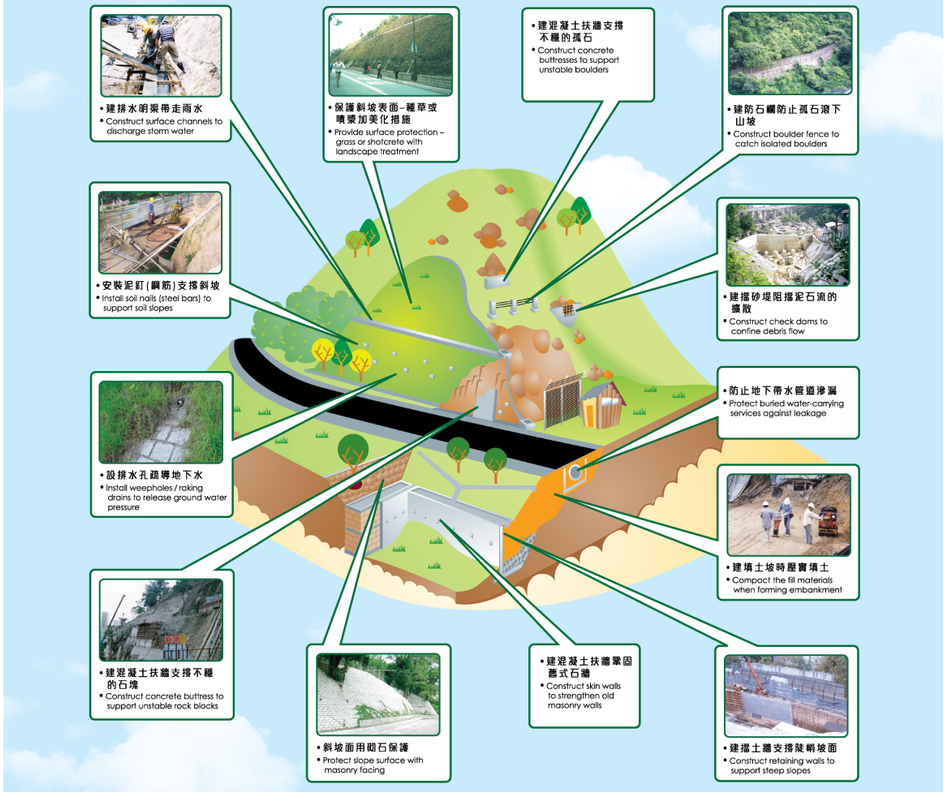


圖37. 防止及防治山泥傾瀉的一些常用工程方法。
Figure 37. Common engineering works to prevent or mitigate landslides.

山泥傾瀉警報系統

土力工程處與香港天文台負責管理山泥傾瀉警報系統，以提醒公眾注意豪雨期間的山泥傾瀉危險。本港的山泥傾瀉大多由豪雨引起。我們會根據即時降雨量數據及香港天文台的降雨量預測資料，利用土力工程處對山泥傾瀉與降雨量關係的認知，識別何時山泥傾瀉危險會處於高水平，以決定是否透過傳媒發出山泥傾瀉警報。

山泥傾瀉警報旨在提醒市民減低可能面對的山泥傾瀉危險。發出山泥傾瀉警報亦啟動政府部門之間的緊急應變服務，以便迅速動員人手及其它資源來處理山泥傾瀉事故。

一旦預測到豪雨將可能導致多宗山泥傾瀉，天文台便會發出山泥傾瀉警報。不過，即使在沒有發出山泥傾瀉警報的時候，個別的山泥傾瀉事件仍有可能不時發生。土力工程處每年均接獲約三百至四百宗山泥傾瀉報告，以及聯同香港天文台發出平均三次山泥傾瀉警報。大部分山泥傾瀉屬於小規模，但偶然會有較大規模的事故。山泥傾瀉，尤其是大規模的山泥傾瀉，可導致人命傷亡、財物損失及道路阻塞。山泥傾瀉警報旨在提醒公眾注意可能出現的山泥傾瀉危險，與天文台發出的黃色、紅色及黑色暴雨警告有所不同，因為暴雨警告的作用是提醒市民注意豪雨的出現。

是否發出或取消山泥傾瀉警報，乃由香港天文台台長與土力工程處總監共同決定。若預料24小時的降雨量足夠導致多宗山泥傾瀉，便會發出山泥傾瀉警報。發出山泥傾瀉警報的準則是基於受豪雨影響的面積範圍、降雨量的強度及受影響斜坡的數目。除此之外，短期降雨量預測等最新氣象資料，亦會一併考慮(圖39)。

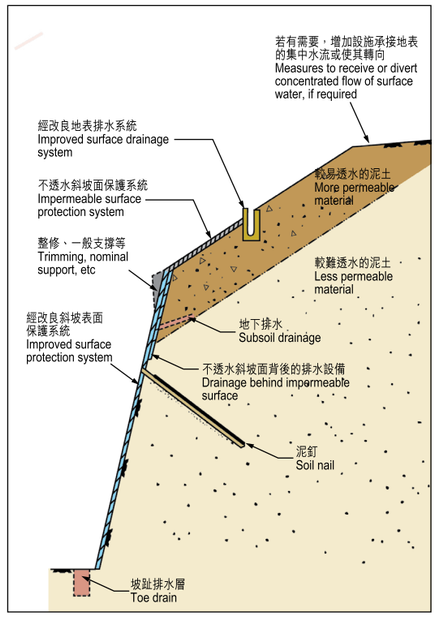


圖38. 防止山泥傾瀉的一些常用工程方法。
Figure 38. Common engineering works to prevent landslides.

無論是天氣或山泥傾瀉的預測，都並非絕對準確。因此，有可能出現發出山泥傾瀉警報，但是山泥傾瀉數目不多的情況。同樣，若豪雨是突然其來，當局可能未趕及發出山泥傾瀉警報，便已發生多宗山泥傾瀉。隨着斜坡安全的改善，政府會定期檢討發出及取消山泥傾瀉警報的準則。

Landslip Warning System

The GEO and the Hong Kong Observatory (HKO) jointly operate the Landslip Warning System to alert the public to the landslide danger during periods of heavy rainfall. Most landslides in Hong Kong are caused by heavy rainfall. By using a combination of real-time rainfall data and rainfall forecasts from the HKO, and based on GEO's study on the landslip/rainfall relationship, the Government is able to identify instance when landslide danger is high and to issue the Landslip Warning through the media.

The purpose of the Landslip Warning is to alert the public to reduce their exposure to possible danger from landslides. The issuing of the Landslip Warning also triggers an emergency system within government departments, that mobilizes staff and other resources to deal with landslide incidents.

The Landslip Warning is issued when it is predicted that numerous landslides will occur. Isolated landslides may occur from time to time when the Landslip Warning is not in force. Each year, on average, approximately three to four hundred landslides are reported to the GEO and the Landslip Warning is issued about three times. Most landslides are small, but occasionally large ones occur. Landslides, particularly when large, can cause casualties, damage property and block roads. The Landslip Warning draws the public's attention to the landslide danger. It is different from the Amber, Red and Black Rainstorm Warnings that are issued by the HKO to alert the public to the occurrence of heavy rain.

Decisions as to whether to issue or cancel the Landslip Warning are made jointly by the Director of the HKO and the Head of the GEO. The Landslip Warning will be issued if the 24-hour rainfall is expected to be heavy enough to cause numerous landslides. The criterion for the issue of the Landslip Warning is related to the size of the area receiving heavy rainfall, the rainfall intensity and the number of slopes in the affected area. The latest weather information available including short-term rainfall forecast is also considered (Figure 39).

Neither weather forecasting nor landslide prediction can be regarded as exact sciences. There will inevitably be occasions when the Landslip Warning is raised and not many landslides occur. Equally, if heavy rain develops suddenly and unexpectedly, landslides can occur before the Landslip Warning is issued. The criteria for the issue and cancellation of the Landslip Warning are reviewed regularly to take account of the gradual improvement in slope safety.

圖39. 山泥傾瀉警報系統。
Figure 39. Landslip Warning System.

在山泥傾瀉警報生效時，土力工程處會透過本地電台及電視台定時向市民廣播有關山泥傾瀉警報的消息，以及建議市民應採取的預防措施。香港斜坡安全網頁(http://hkss.cedd.gov.hk)亦會刊登山泥傾瀉警報的消息及土力工程處接到山泥傾瀉報告的數目。山泥傾瀉警報生效期間，市民應遠離斜坡或擋土牆，和留意山泥傾瀉的跡象(圖29)。任何人士，包括受不穩固斜坡或孤石威脅的居民，都可以前往民政事務處開設的臨時庇護中心暫避。行人應避免走近或停留在斜坡或擋土牆下(圖29)，特別是已懸掛或豎立山泥傾瀉警告牌的地方。當山泥傾瀉情況轉趨嚴重時，我們建議市民取消非必要的約會，盡量留在家中或安全的地方(圖29)。同時，駕車人士應避免在多山地區或張掛有山泥傾瀉警告標誌的道路行駛(圖29)。

滑坡指數

傳統上，一場雨的強度是以重現期來描述，重現期是指某一強度的雨它下一次出現的平均相隔時間。簡單地說，越大的降雨，它的重現期越長。然而，由於種種原因，重現期不是一個合適反映暴雨可引發山泥傾瀉能力的方法。

根據暴雨可引發山泥傾瀉的能力來量度其強度是一個較直接的方法。利用過往的降雨及山泥傾瀉紀錄可建立一個滑坡和雨量的關係模型。當知道某一場雨的雨勢和該場雨影響範圍內的人造斜坡數目，我們便可估計出該場雨可能引發山泥傾瀉的數目(圖40)。

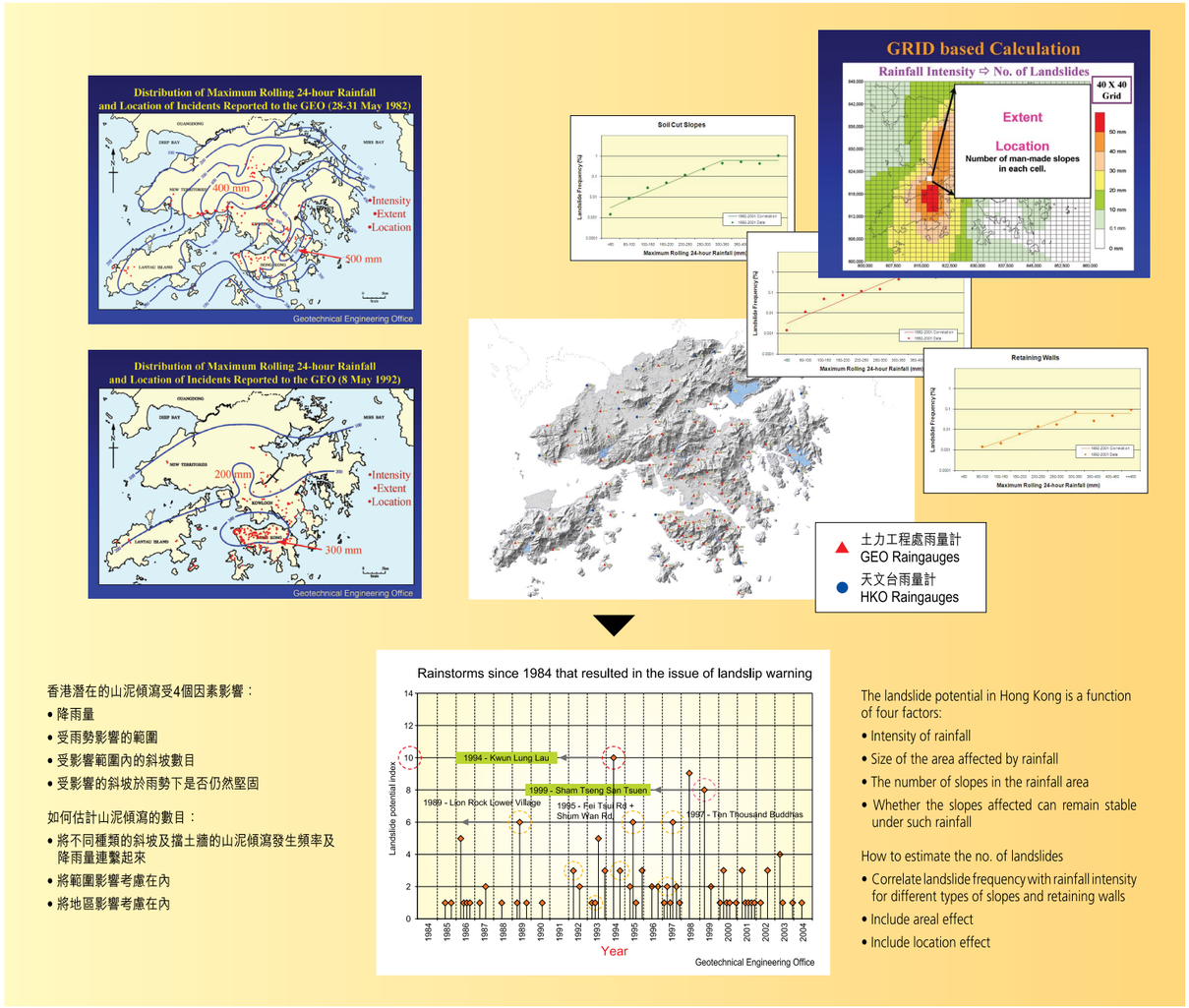


圖40. 香港滑坡指數。
Figure 40. Landslide Potential Index.

土力工程處研發出滑坡指數，該指數是根據暴雨可能引發山泥傾瀉的數目來計算。1994年7月在觀龍樓發生的山泥傾瀉導致5死3傷，我們將引發這宗不幸事件的暴雨，其滑坡指數定為10。這樣，一場滑坡指數為5的暴雨，其引發山泥傾瀉的數目可會是觀龍樓事件的一半。此外，滑坡指數是可大於10。暴雨的滑坡指數並不是一個預測值，它有助於在每場暴雨過後分析其嚴重程度及可引發山泥傾瀉的能力。

temporary shelters for the public including anyone whose dwelling is endangered by unstable slopes or boulders. Pedestrians should avoid walking or standing close to steep slopes (Figure 29), especially where landslip warning signs are erected. When the landsliding situation is becoming serious, members of the public are advised to cancel non-essential appointments and to stay at home or in a safe shelter (Figure 29). Motorists are advised to avoid driving in hilly areas or on roads with landslip warning signs (Figure 29).

Landslide Potential Index

The severity of a rainstorm is traditionally described by its return period, *i.e.* the average time until the next occurrence of a rainstorm of equal magnitude. The longer the return period, the more intense the rainstorm is. However, the return period is not an ideal measure of rainstorm severity for many reasons.

A more direct measure of the severity of a rainstorm in terms of specific consequences is the number of landslides it could cause. Using historical rainfall and landslides records, a statistical relationship between rainfall intensity and landslide frequency has been obtained. When the rainfall intensity of a rainstorm and the number of man-made slopes covered by the rainstorm are known, the number of landslides that could be triggered by the rainstorm can be estimated (Figure 40).

When the Landslip Warning is issued, local radio and television stations are notified and are requested to broadcast the Warning to the public at regular intervals, together with advice on the precautions that should be taken. The Hong Kong Slope Safety Website (http://hkss.cedd.gov.hk) also publishes the warning message and the number of landslide incidents reported to the GEO at regular intervals. When the Landslip Warning is in force, the public should keep away from slopes and watch out for signs of landslide danger (Figure 29). The Home Affairs Department opens

表5概述了11宗自1984年以來引致人命傷亡的山泥傾瀉事件、其所導致的後果及相對應暴雨的滑坡指數。圖41則顯示自1984年至今引致發出山泥傾瀉警報的暴雨的滑坡指數。

每場引致發出山泥傾瀉警報的暴雨，它的滑坡指數會在山泥傾瀉警報取消後一個星期內上載到香港斜坡安全網(http:/hkss.cedd.gov.hk)。在網頁內，你亦可以找到該年每場暴雨的滑坡指數。

結語

鑒於香港受天氣及地理環境影響，無論政府盡多少努力提升斜坡安全，山泥傾瀉的風險都不能完全消除。要保障市民安全，實有賴普羅大眾合作。因此政府經常進行公眾教育及社區宣傳活動，以提醒市民保持警覺，居安思危。

山泥傾瀉地點 Landslide Location	滑坡指數 LPI	發生日期 Date	所導致的後果 Landslide Consequence
堅尼地城觀龍樓 Kwun Lung Lau, Kennedy Town	10	1994年7月23日 23 July 1994	5人喪生及3人受傷 5 fatalities and 3 injuries
深井新村 Sham Tseng San Tsuen	8	1999年8月23日 23 August 1999	1人喪生、13人受傷、1間寮屋被摧毀及多間寮屋受到嚴重破壞 1 fatality, 13 injuries, a squatter dwelling was demolished and several other dwellings were severely damaged
沙田萬佛寺 Ten Thousand Buddhas' Monastery, Shatin	6	1997年7月2日 2 July 1997	1人喪生、1人受傷及1所觀音殿被毀壞 1 fatality, 1 injury and a building known as "Kun Yam Din" was damaged
香港仔深灣道 Shum Wan Road, Aberdeen	6	1995年8月13日 13 August 1995	2人喪生、5人受傷、3間船廠及1間工廠被摧毀 2 fatalities, 5 injuries, 3 shipyards and a factory were damaged
柴灣翡翠道 Fei Tsui Road, Chai Wan	6	1995年8月13日 13 August 1995	1人喪生及1人受傷 1 fatality and 1 injury
獅子山下村 Lion Road Lower Village	6	1989年5月21日 21 May 1989	2人喪生、3人受傷、2間寮屋被摧毀及另外16間寮屋被永久疏散 2 fatalities, 3 injuries, 2 squatter huts were damaged and another 16 huts were permanently evacuated
青山公路14咪半 Milestone 14 1/2 Castle Peak Road	3	1994年8月7日 7 August 1994	1人喪生及17人受傷 1 fatality and 17 injuries
薄扶林碧瑤灣 Baguio Villas, Pokfulam	3	1992年5月8日 8 May 1992	2人喪生 2 fatalities
灣仔堅尼地道近華仁書院 Kennedy Road below Wah Yan College, Wan Chai	3	1992年5月8日 8 May 1992	1人喪生 1 fatality
九華徑上村 Kau Wa Keng Upper Village	2	1997年6月4日 4 June 1997	1人喪生、5人受傷及1間寮屋被毀壞 1 fatality, 5 injuries and 1 squatter hut was damaged
葵涌象山村 Cheung Shan Estate, Kwai Chung	1	1993年6月16日 16 June 1993	1人喪生及5人受傷 1 fatality and 5 injuries

表5. 自1984年至今引致發出山泥傾瀉警報的暴雨的滑坡指數。
Table 5. The LPI of rainstorms that resulted in the issue of the Landslip Warning since 1984.

The GEO has developed an index, called the Landslide Potential Index (LPI) that is based on the probable number of landslides that could be caused by a given rainstorm. The well-known rainstorm of July 1994 that led to the landslide at Kwun Lung Lau with five deaths and three serious injuries is set at an LPI of 10. A rainstorm with an LPI of 5 could be half as severe as the Kwun Lung Lau rainstorm in causing landslides. A rainstorm with an LPI value greater than 10 is possible. The LPI of a rainstorm is not a predictive index. It helps to analyse the severity of a rainstorm after the event.

Table 5 gives the LPI value and information on consequences of those rainstorms occurring since 1984 which led to landslides causing fatalities. The LPI of rainstorms that resulted in the issue of the Landslip Warning since 1984 are presented in Figure 41. The LPI values of rainstorms in recent years are all relatively small.

The LPI of a rainstorm that results in the issue of the Landslip Warning would be uploaded onto the Hong Kong Slope Safety Website (http://hkss.cedd.gov.hk) within a week of cancellation of the Warning. The information will be kept in a running list for that year.

Conclusions

No matter how strenuous the efforts of the Government to improve slope safety are, given the natural constraints we face in Hong Kong in terms of climatic and geographical circumstances, it is obvious that landslide risks cannot be totally removed. For this reason, the Government conducts public education and community activities to remind people of the need to stay vigilant and be prepared for potential landslide hazards.

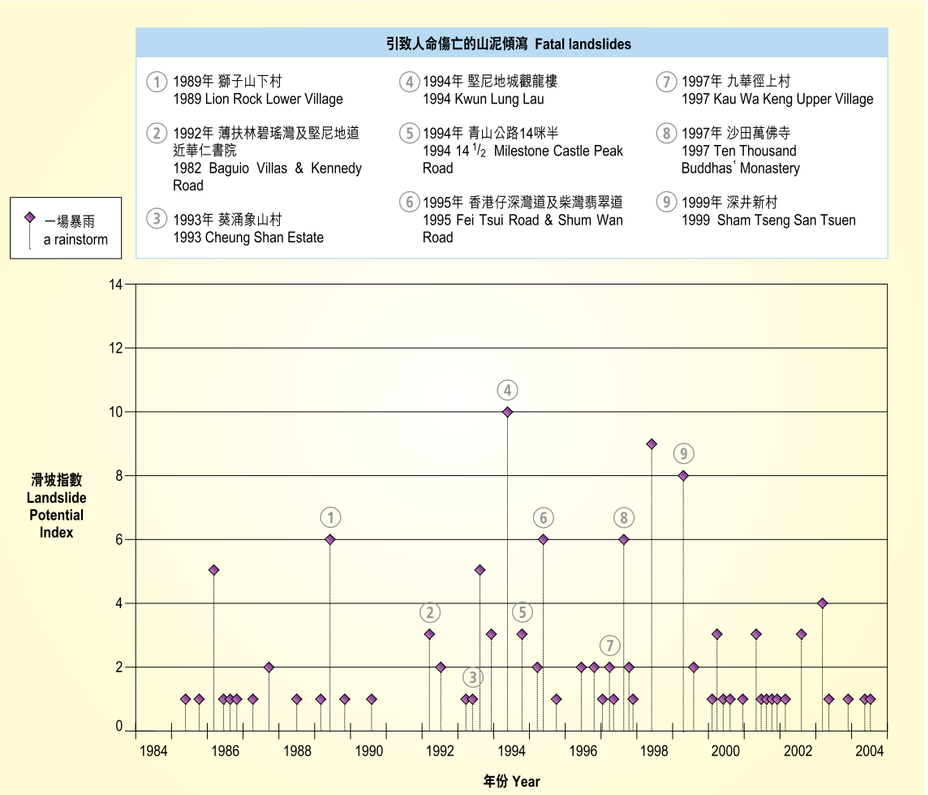


圖41. 1984年至今引致山泥傾瀉警報的暴雨。
Figure 41. Chart showing rainstorms since 1984 that resulted in the issue of landslip warning.

附錄A -1972年寶珊道山泥傾瀉

我們已將寶珊道山泥傾瀉事件製作成三維動畫光碟，以作為此書的輔助教材。而光碟內長達4分鐘的全文原稿如下：

廣東話 寶珊道山泥傾瀉

香港是世界上人口最稠密的地區之一。在土地日益緊缺的今天，發展工程需要在山區土地進行，否則這些土地就會被浪費。

1972年6月，九龍秀茂坪和香港寶珊道發生了兩次大規模山泥傾瀉，共造成138人死亡。其中，寶珊道山泥傾瀉造成了極其嚴重的人命傷亡及財產損失。寶珊道山泥傾瀉位於香港島西半山區，這裡山勢陡峭，暴雨期間容易發生山泥傾瀉。

在1972年山泥傾瀉災害發生之前，該地區間中有小型山泥傾瀉、出現裂縫及停工記錄。1972年6月的降雨量幾乎達到了平時的兩倍，為當時有記錄以來的第五高降雨量。暴雨持續了一天，位於寶珊道施工中的愛敦大廈後方發生嚴重山泥傾瀉。

當日早上，寶珊道發生了多宗小型山泥傾瀉，導致21號的花園下陷約兩米。山坡下方干德道的一處建築工地也發生大面積山泥傾瀉，年豐園後的斜坡有大量的水湧出。中午的一場暴雨使情況更加惡化，21號的花園地面又下降三米，年豐園後的斜坡湧出的水量大增，而干德道工地情況則更加嚴重。

事發前四個月安裝的打板樁因承受不住山泥傾瀉的泥沙石塊重量，發生扭曲變形。到晚上，寶珊道一段路面下陷已超過4米，一批居民已經撤離，以策安全。

災難當天早上，雖然情況很嚴重，但沒有人預料到接下來會發生什麼事故。整天狀況不斷惡化。打板樁繼續變形。下午5時10分，年豐園上方一處建築工地東面發生大面積山泥傾瀉，泥沙石塊沖過路面，將一幢位於旭龢道11號的四層高建築物部份淹沒。當時未有任何傷亡，而居民都撤離到安全地帶。終於在晚上8時55分發生了大規模山泥傾瀉，持續時間不到10秒。

寶珊道上方的山坡開始下滑，泥沙碎石穿過路面，沖毀21號的車房，車房繼而坍塌滑下山坡。泥石帶著巨大動量捲走了旭龢道11號的建築物，並繼續沖向旭龢大廈。滾下的泥石摧毀了12層高的旭龢大廈，坍塌的旭龢大廈撞上了一幢新翻修的大廈，景翠園的頂部。災害蔓延的範圍和速度令人震驚。

在此次災難中，67人喪生，2座住宅大廈及其它一些建築物被摧毀。事後調查結果顯示，造成了這次山泥傾瀉的三個因素是：山坡的岩土性質、罕見的持續大暴雨，以及私家建築工地深挖支撐不足。

6月18日的兩宗大災難及1976年另一宗嚴重的山泥傾瀉促使香港岩土工程進入新的發展。1977年，政府成立了今天的土力工程處。

土力工程處將會繼續為香港市民服務，確保類似寶珊道山泥傾瀉的災難不再發生。

Appendix A - 1972 Po Shan Road Landslide

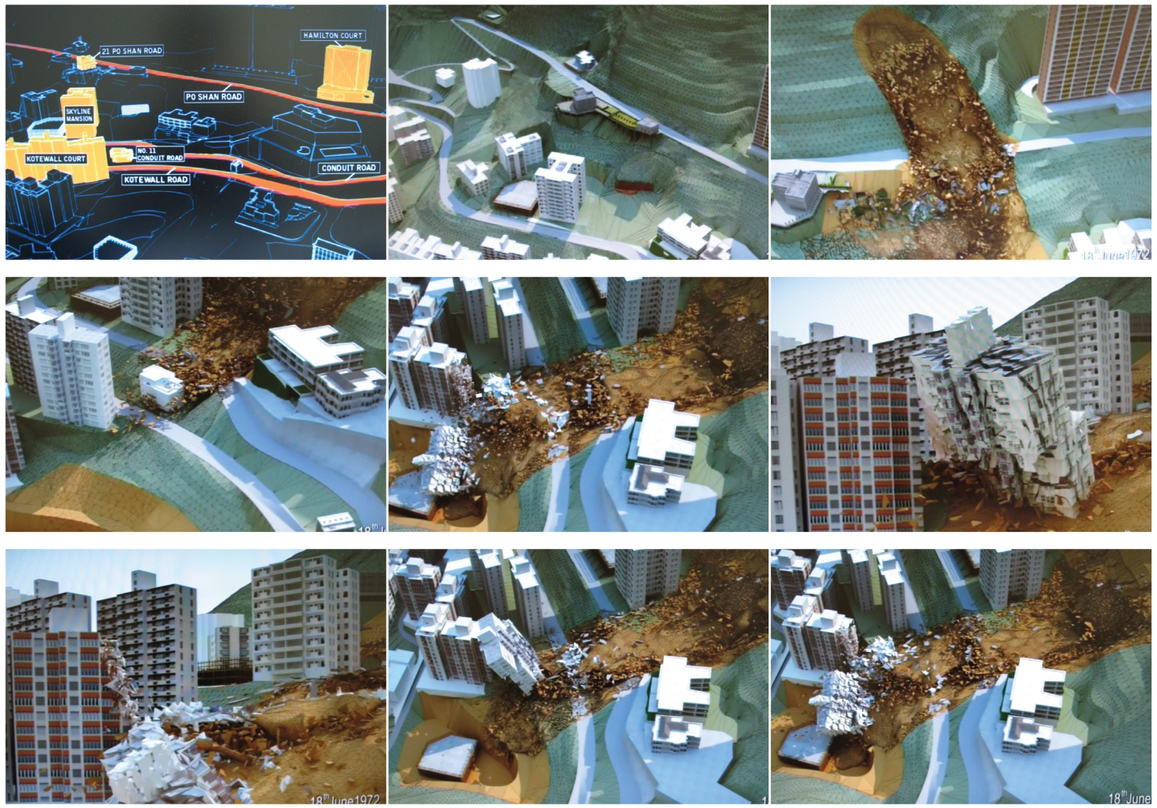
We have produced a 3D animation CD on the Po Shan Road Landslide as a supplementary background teaching materials to this booklet. The full script of this 4 minutes 3D animation is reproduced below.

English Po Shan Road Landslide

Hong Kong is one of the most densely populated areas in the world. With land a scarce commodity, construction work has to proceed in hilly locations which under normal circumstances would be left undeveloped.

In June 1972, two major landslides at Sau Mau Ping in Kowloon and Po Shan Road on Hong Kong Island killed a total of 138 people. The Po Shan Road landslide was the most devastating, in terms of loss of life and damage to property. The site of the Po Shan Road Landslide is in the western Mid-levels area of Hong Kong Island. The terrain here is steep and prone to landslides during heavy rainfall.

Prior to the 1972 disaster, there had been a history of minor landslides, cracks and aborted construction works in the vicinity of the fateful landslide. The rainfall in June 1972 was almost twice the average and the fifth highest on record at that time. Heavy rainfall persisted throughout the day and there was a large landslide behind Hamilton Court – a building under construction nearby on Po Shan Road.



普通话 **宝珊道山体滑坡**

香港是世界上人口最稠密的地区之一。在土地日益紧缺的今天，发展工程需要利用山区土地进行，否则这些土地就会被浪费。

1972年6月，九龙秀茂坪和香港岛宝珊道发生了两次大规模山体滑坡，共造成138人死亡。其中，宝珊道山体滑坡造成了极其严重的人命伤亡及财产损失。宝珊道山体滑坡位于香港岛西半山区，这里山势陡峭，暴雨期间容易发生山体滑坡。

在1972年山体滑坡灾害发生之前，该地区不时发生小型山体滑坡、出现裂缝以及停工记录。1972年6月的降雨量几乎达到了平时的两倍，为当时有记录以来的第五高降雨量。暴雨持续了一天，位于宝珊道施工中的爱敦大厦后方发生严重山体滑坡。

当日早上，宝珊道发生了多宗小型山体滑坡，导致21号的花园下陷约两米。山坡下方干德道的一处建筑工地也发生大面积的滑坡，年丰园后面的斜坡有大量的水涌出。中午的一场暴雨使情况更加恶化，21号的花园地面又下降三米，年丰园后的斜坡涌出的水量大增，而干德道工地情况则更加严重。

事发前四个月安装的打板桩因承受不住滑坡带来的泥沙石块的重量，发生扭曲变形。到晚上，宝珊道一段路面下陷已经超过4米，为安全起见，一批居民经已撤离。

灾难当天早上，虽然情况很糟糕，但没有人预料到接下来会发生什么事故。整天状况不断恶化。打板桩继续变形。下午5点10分，年丰园上方一处建筑工地东面发生大面积山体滑坡，泥沙石块冲过路面，将一幢位于旭龢道11号的四层高建筑物部份淹埋。当时未有任何伤亡，而居民都撤离到安全地带。终于在晚上8点55分发生了大规模山体滑坡，持续时间不到10秒。

宝珊道上方的山坡开始下滑，泥沙碎石穿过路面，冲毁21号的车库，车库继而坍塌滑下山坡。泥石带著巨大动量卷走了旭龢道11号的建筑物，并继续冲向旭龢大厦。滚下的泥石摧毁了12层高的旭龢大厦，坍塌的旭龢大厦撞上了一幢新翻修的大厦，景翠园的顶部。灾害蔓延的范围和速度让人震惊。

在此次灾难中，67人丧生，2座居民楼及其它一些建筑物被摧毁。事后调查结果显示，造成了这次山体滑坡的三个因素是：山坡的岩土性质，罕见的持续大暴雨，以及私家建筑工地深挖支撑不足。

6月18日的两宗大灾难及1976年另一宗严重山体滑坡促使香港岩土工程进入新的发展阶段。1977年，政府成立了今天的土力工程处。

土力工程处将会继续为香港市民服务，确保类似宝珊道山体滑坡的灾难不再发生。

In the morning a number of small landslides were observed on Po Shan Road which resulted in the garden of number 21 settling some 2 metres. Further down the slope, a building site on Conduit Road experienced a large landslide on a cut slope and water was seen emerging from the ground above Skyline Mansion. After a heavy rainstorm at midday, conditions worsened. The garden terrace dropped another 3 metres. The water flowing from the ground above Skyline Mansion increased considerably and the condition at the building site on Conduit Road deteriorated.

The sheet piling installed some 4 months prior to the failure distorted and buckled under the weight of the debris from the earlier landslide. By the end of the day a section of Po Shan Road had settled over 4 metres and a number of local residents had been evacuated as a precaution.

On the morning of the fateful day, conditions were bad, but no one could have imagined what was to follow. Throughout the day the conditions degenerated. The sheet piling continued to distort and at 5:10pm a large landslide to the east of the building site above Skyline mansions crossed the road and partially buried the four-storey building at number 11 Kotewall Road. There were no injuries at this time and the residents were evacuated to safety.

The major landslide occurred about 8:55pm – lasting no longer than 10 seconds.

The landslide started from the hill above Po Shan Road. Debris crossed the road and engulfed the garage at number 21. This then slipped down the hillside and toppled over. The landslide gathered momentum and swept away the property at number 11 Kotewall Road before continuing on to Kotewall Court. The force of the debris and landslide brought down the 12-storey tower block with the collapsing building hitting the upper part of the newly refurbished block at Greenview Gardens. The scale and speed of the catastrophe shocked everyone.

In all, 67 people lost their lives and 2 residential buildings and a number of other structures were obliterated. The forensic investigation concluded that three factors combined to cause the landslide; the nature of the material forming the hillside, the exceptionally intense and sustained rainfall and the inadequately supported deep cutting in the private building site.

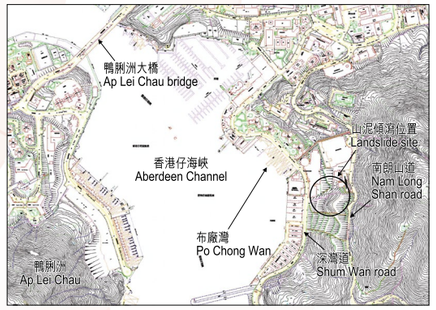
The two disasters of 18 June and further serious fatal landslides in 1976 brought about radical changes to geotechnical engineering in Hong Kong and in 1977. The Government created what is today the Geotechnical Engineering Office.

The Geotechnical Engineering Office continues to serve the people of Hong Kong to ensure that disasters like the Po Shan Road landslide will not occur again.

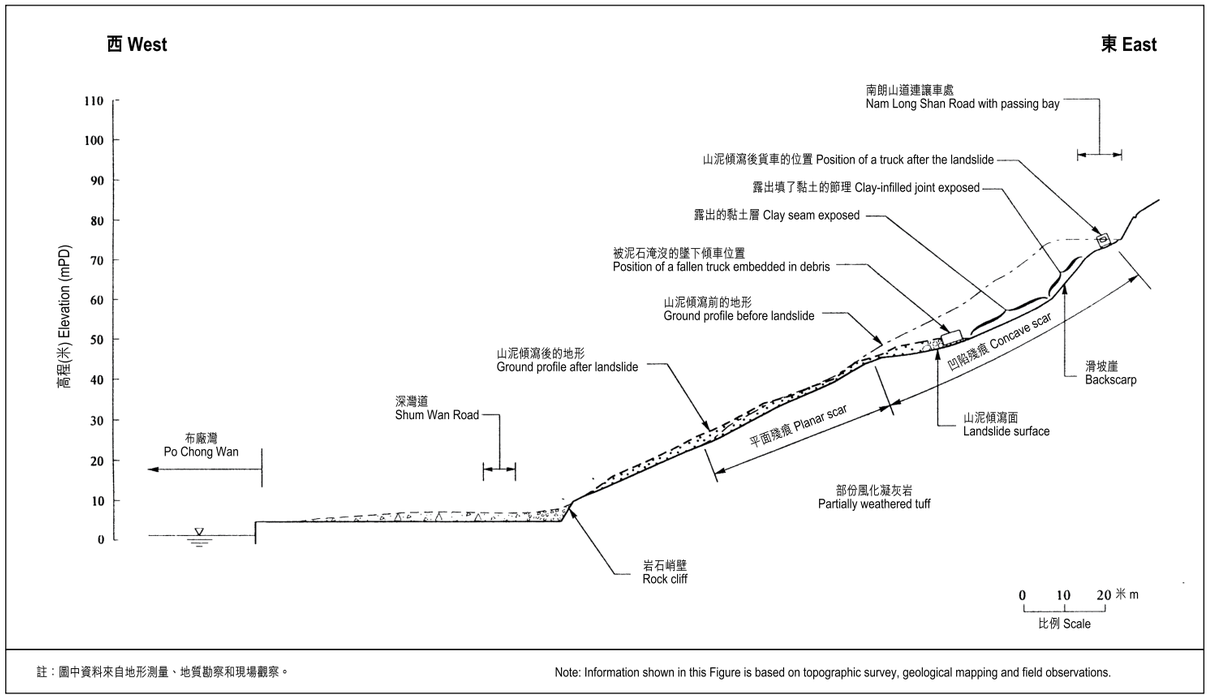
附錄B -1995年深灣道山泥傾瀉

一九九五年八月十三日凌晨大約四時，於香港仔深灣道對上的山坡發生山泥傾瀉(圖B-1)，使南朗山道一段30米長的路面包括以填土堤支撐的一段讓車處(圖B-2)一起崩塌。崩塌的泥石越過深灣道，並同時摧毀了海旁附近三間船廠及一間工廠(圖B-3)。這次山泥傾瀉導致2人喪生及5人受傷。

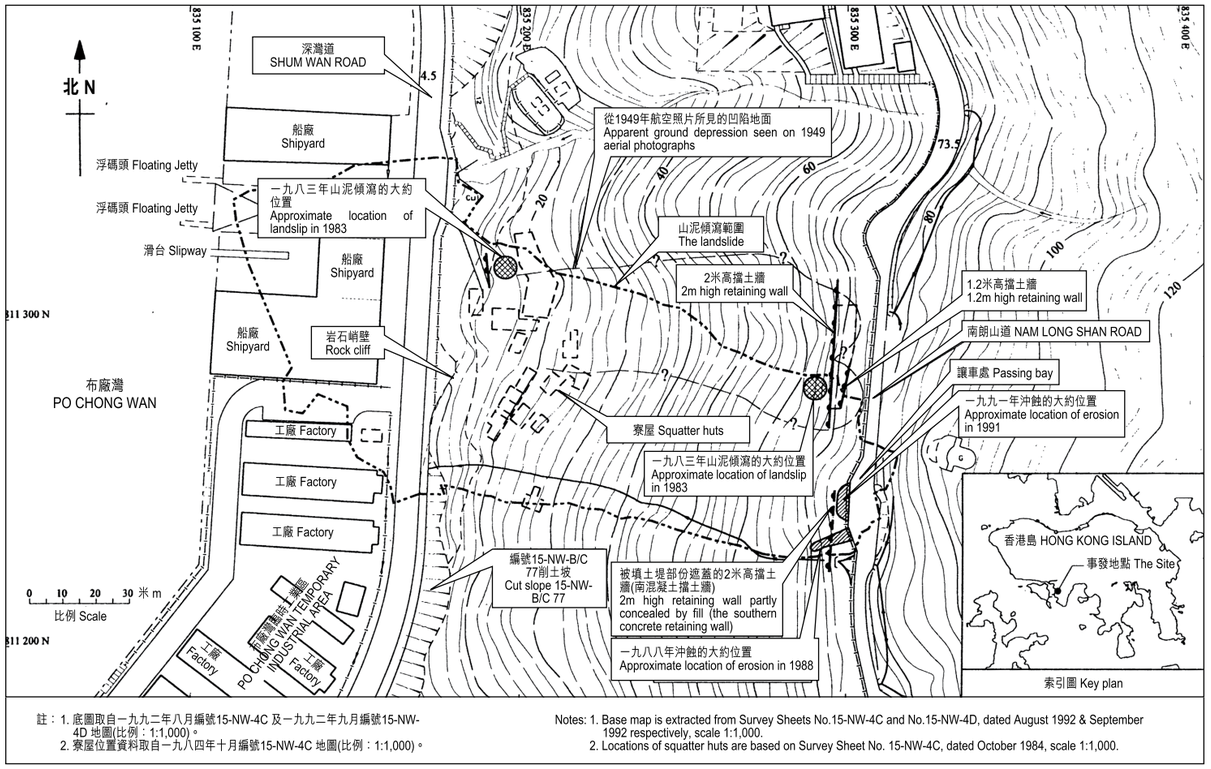
於一九九六年四月土力工程處出版了一份更詳盡深入的調查報告(圖B-4)，此報告共分兩冊，第一冊為黎佐賢爵士的獨立報告，記錄了他對於一九九五年八月深灣道的山泥傾瀉事件及所得教訓的意見。第二冊則由土力工程處所編寫，記述了山泥傾瀉調查的詳細結果。而此附錄會根據以上的調查報告對深灣道山泥傾瀉事件作一總結。



圖B-1. 深灣道山泥傾瀉地點的位置。
Figure B-1. Location of Shum Wan Road landslide site.



圖B-2. 崩塌地點剖面A-A。
Figure B-2. Section A-A through the landslide.



圖B-3. 山泥傾瀉位置圖。
Figure B-3. Site plan.

Appendix B - 1995 Shum Wan Road Landslide

At about 4 am on 13 August 1995, a landslide took place at the hillside above Shum Wan Road, Aberdeen (see Figure B-1 for location). It caused the collapse of a 30m long section of Nam Long Shan Road that included a passing bay supported by a fill embankment (Figure B-2). The landslide debris crossed Shum Wan Road and damaged three shipyards and a factory near the seafront (Figure B-3). The landslide resulted in two fatalities, and five other people were injured.

Readers may refer to the comprehensive investigation report issued by the Geotechnical Engineering Office in April 1996 (Figure B-4). The Report is presented in two volumes. Volume 1 contains the independent findings of Sir John Knill and the lessons to be learnt from it. Volume 2, prepared by the GEO, presents the detailed findings of the landslide investigation. The Appendix gives a summary of the Shum Wan Road landslide as revealed in the above investigation report.

圖B-4. 1995年深灣道山泥傾瀉調查報告。
Figure B-4. Report on the 1995 Shum Wan road landslide.

山泥傾瀉地點

概述

此次山泥傾瀉發生於深灣道與南朗山道之間的山坡(圖B-3)。在山泥傾瀉發生前，該山坡樹木茂盛，平均斜度為27度。在南朗山道對下山泥傾瀉範圍附近，有三幅混凝土擋土牆，其中兩幅分別約2米及1.2米高。在發生山泥傾瀉的地點，南朗山道闊度約5米，在靠近下山的一面有一讓車處。該讓車處由一幅約10米高的填土堤支撐，而此填土堤遮蓋了其中一幅2米高的擋土牆的一部份，在道路靠山的一邊有一幅4米高削土坡(有關削土坡、擋土牆等之譯解，請參考圖2之文字內容)。

建築歷史

南朗山道建於1945年之前(根據攝於1945年的航空照片)。南朗山道下方的兩幅約2米高的混凝土擋土牆當時已興建，而讓車處則是在一九七六至一九七七年間加建在一道新的填土堤上。而南朗山道下方約1.2米高的混凝土擋土牆，相信是在七十年代建造寮屋時築成的。自一九九七年以後，非法傾倒廢料的情況尤為明顯。

地表水及地下水

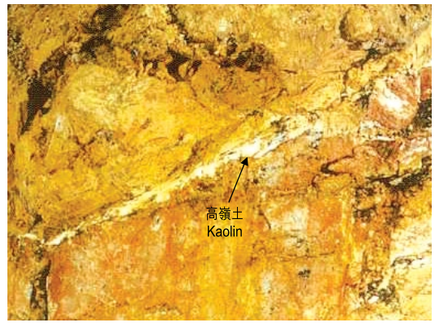
南朗山道對上山坡的地表水集於天然溪流及人造渠道，並經集水井排出至埋於道路下的跨道路排水管。

地下水的水位通常低於山泥傾瀉面。但山泥傾瀉後現場所見的滲流反映了短暫上層滯水情況的存在(請參考圖34上層滯水圖解釋的主要文字)。同時請參閱附錄B第5部份山泥傾瀉成因的診斷。

地質及山坡物質形成

山泥傾瀉地區的地質包含部份覆蓋在已風化火山岩(凝灰岩)之上的薄層坡積物。坡積物約於35,000至48,000年前形成。岩體內的風化於次垂直節理密集的地區尤為普遍。

在部份風化凝灰岩中的節理普遍填入達15毫米厚(圖B-5)的白黏土。廣闊的黏土層形成部份凹的崩塌殘痕基座(圖B-6)，包含了軟的微黃褐色黏土層(100毫米至350毫米厚)連高分解度凝灰岩碎片，存在於薄層軟白黏土之下。其後的X光繞射顯示兩種黏土均含有高嶺石，並可能包含多水高嶺石。



圖B-5. 風化凝灰岩中的節理填入高嶺土。
Figure B-5. Joints within the partially weathered tuff filled with white kaolin.

The Landslide Site

General setting

The landslide occurred at a hillside between Shum Wan Road and Nam Long Shan Road (Figures B-3). Prior to the landslide, the hillside was densely vegetated and had an overall gradient of about 27°. There were 3 concrete retaining walls in the vicinity of the landslide area below the Nam Long Shan Road. Two of the walls were about 2m in height and the third wall was about 1.2m high. Nam Long Shan Road was about 5m wide at the location of the landslide, and there was a passing bay on the downhill side of the road. The passing bay was supported by a fill embankment about 10m high from toe to crest. The passing bay embankment partly concealed one of the 2m high retaining walls. There was a 4m high cut slope on the uphill side of the road. (see Figure 2 of the text on the meaning of cut slope, retaining wall etc).

History of construction

Nam Long Shan Road was formed before 1945 (as evident from 1945 aerial photographs). The two 2m high concrete retaining walls below Nam Long Shan Road had been constructed by that time. The passing bay was constructed between 1976 and 1977 on a new fill embankment. The 1.2m high concrete retaining wall was likely to have been constructed in the 1970's as part of the squatter development. Signs of illegal dumping from Nam Long Shan Road are apparent since 1977.

Surface water and Groundwater

Surface water from the hillside above Nam long Shan Road is collected by natural stream courses and man-made channels and discharges into catchpits leading to cross-road drain pipes buried under the road.

The base groundwater level is generally below the landslide surface. However, seepage observed on site after the landslides suggested the presence of a transient perched water condition (see Figure 34 of the main text on the meaning perched water table). See also the discussion in section 5 of Appendix B on the diagnosis of the causes of the landslide.

Geology and slope forming materials

The geology at the landslide area comprised a thin mantle of colluvium overlying partially weathered volcanic rock (tuff). The colluvium was formed about 35,000 to 48,000 years ago. Weathering within the rock mass was more pervasive within the area of very closely spaced sub-vertical joints than elsewhere.

Joints within the partially weathered tuff were commonly infilled with white clay up to about 15mm thick (Figure B-5). An extensive clay seam formed part of the base of the concave landslide scar (Figures B-6). It comprised a soft yellowish brown clay layer (100mm to 350mm thick) with highly decomposed tuff fragments, underlain in palaces by a thin soft white clay. Subsequent X-ray diffraction showed that both clays contain kaolinite and probably halloysite.

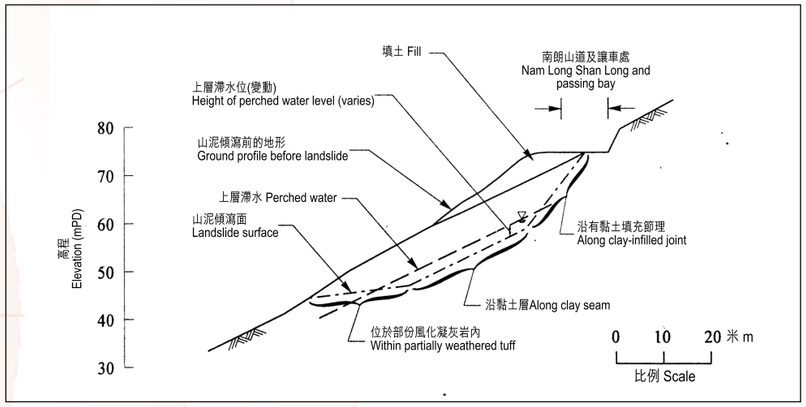
降雨量記錄

兩種土力工程處自動雨量計設於接近山泥傾瀉(圖B-8)的地方。山泥傾瀉地區的降雨模式及強度顯示於圖B-9。在4時發生的山泥傾瀉之前有暴雨紀錄。此暴雨的降雨強度回復期約為75年。

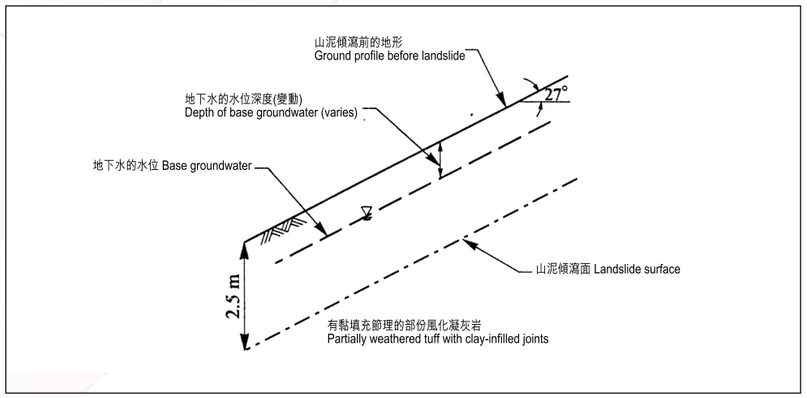
山泥傾瀉的情況

山泥傾瀉所造成的崩塌殘痕，高度為70米，闊度在南朗山道下方約為50米，而在深灣道對上處則約為90米。山泥傾瀉面的上部份形狀是凹陷的，從崩塌前地面計算，其深度達12米。山泥傾瀉面的下部是平坦的離開崩塌前地面(圖B-7)約2至3米。山泥傾瀉釋放了約26,000立方米的泥土和石塊，並為香港當時於過去20年最嚴重的山泥傾瀉。

從目擊者的訪問和多項相關資訊(包括警方和海洋公園的紀錄)，以及山泥傾瀉泥石的位置和細節(如擋土牆碎片、墜下的貨車、於填海土地上較完整風化石體的厚泥石片等)，可如圖B-10般編出崩塌的適當模式及次序。



圖B-6. 用作斜坡穩定性分析的事發地點代表性剖面圖 - 上部匙形滑動。
Figure B-6. Representative cross-section of the landslide for slope stability analyses - upper spoon-shaped slip.



圖B-7. 用作斜坡穩定性分析的事發地點代表剖面圖 - 下部平面滑動。
Figure B-7. Representative cross-section of the landslide for slope stability analyses - lower planar slip.

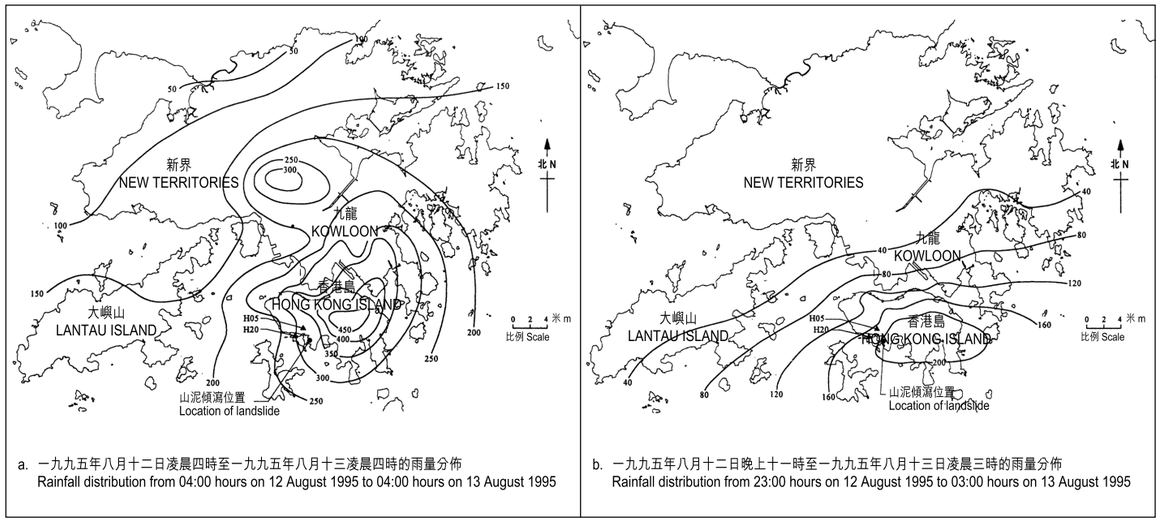
Rainfall Records

Two GEO automatic raingauges are located close to the landslide (Figure B-8). The rainfall pattern and intensity at the landslide area are illustrated in Figure B-9. There was heavy rain during the hours before the landslide at 4am. The return period of the rainfall intensities of this rainstorm is about 75 years.

Description of the Landslide

The landslide resulted in a 70m high scar, with a width varying from about 50m just below Nam Long Shan Road to about 90m above Shum Wan Road. The upper part of the landslide surface was concave in shape and was up to about 12m in depth below the pre-failure ground surface. The lower part of the landslide surface was planar and was 2 to 3m below the pre-failure ground surface (Figure B-7). The landslide released about 26,000m^3 of soil and rock and was the largest landslide in Hong Kong at that time over the past twenty years.

From the interview of eye-witnessess and review of lots of relevant and available information, including Police records and the Ocean Park records, plus the situation and details of landslide debris (*e.g.* retaining wall fragments, fallen trucks, the slab of debris of relatively intact weathered rock mass on the reclaimed land etc), the likely mode and sequence of failure can be constructed as shown in Figure B-10.



a. 一九九五年八月十二日凌晨四時至一九九五年八月十三凌晨四時的雨量分佈
Rainfall distribution from 04:00 hours on 12 August 1995 to 04:00 hours on 13 August 1995

b. 一九九五年八月十二日晚上十一時至一九九五年八月十三日凌晨三時的雨量分佈
Rainfall distribution from 23:00 hours on 12 August 1995 to 03:00 hours on 13 August 1995

圖B-8. 山泥傾瀉前的雨量分佈。
Figure B-8. Rainfall distribution prior to the landslide.

圖例 Legend: 200 等雨量線(毫米計) Isohyet of rainfall in millimetres ▲ 土力工程處雨量計 GEO Raingauge

山泥傾瀉成因的診斷

從擋土牆散落的泥石位置可見，在約凌晨四時發生主要山泥傾瀉之前，讓車處底下的填土堤曾發生輕微崩塌。這次的主要山泥傾瀉可分為兩部份，分別是上部一個匙形滑動和下部一個平面滑動。上部的匙形滑動是由黏土層的上層滯水壓力所觸發(請注意當時地下水的水位是低於山泥傾瀉面)。黏土層較毗鄰的部份風化凝灰岩薄弱，故在上部匙形滑動的底層的大部份地方，形成一個薄弱的平面。

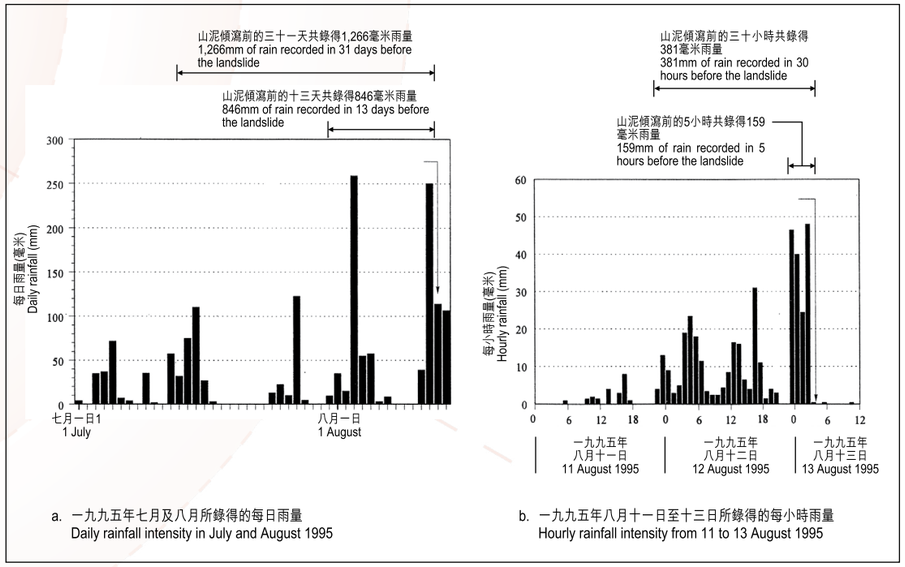
相反，在下部平面滑動處的地下水的水位頗高，在此情況下，此地區部份風化凝灰岩的岩塊可能崩塌，而部份沿著有黏土填充節理滑下。以上的匙形滑動所產生的土石負荷會觸發此崩塌。

另外，其他可構想的因素如寮屋、非法傾倒廢料，以及重形工程車輛等，當局在這次調查中亦曾逐一審查，但發現它們對崩塌並無顯著影響。

結論

主要的山泥傾瀉涉及差不多在同一時間發生的兩個明顯部份，崩塌的主要原因如下：

- 土地有薄弱層，即黏土層及冇黏土充填的節理；
- 連場豪雨後雨水滲入泥土；
- 南朗山道讓車處底下填土堤發生輕微崩塌；
- 由於排水系統部分淤塞，水沿南朗山道傾流而下，部份隨後流至事發的山坡(圖B-9)。



a. 一九九五年七月及八月所錄得的每日雨量
Daily rainfall intensity in July and August 1995

b. 一九九五年八月十一日至十三日所錄得的每小時雨量
Hourly rainfall intensity from 11 to 13 August 1995

圖B-9. 土力工程處編號H05雨量計的雨量記錄。
Figure B-9. Rainfall record of GEO raingauge No.H05.

Diagnosis of the Causes of the Landslide

It is known from the location of debris from the retaining wall that the main landslide at about 4am was preceded by a minor failure at the fill embankment below the passing bay. The main landslide comprised two parts, an upper spoon-shaped slip and a lower planar slip. The upper spoon-shaped slip was most likely triggered by a high perched water table on a weak clay seam (Note that the base groundwater level was well below the landslide surface). The clay seam was much weaker than the adjacent partially weathered tuff, and it formed a weak plane for a substantial part of the base of the upper spoon-shaped slip.

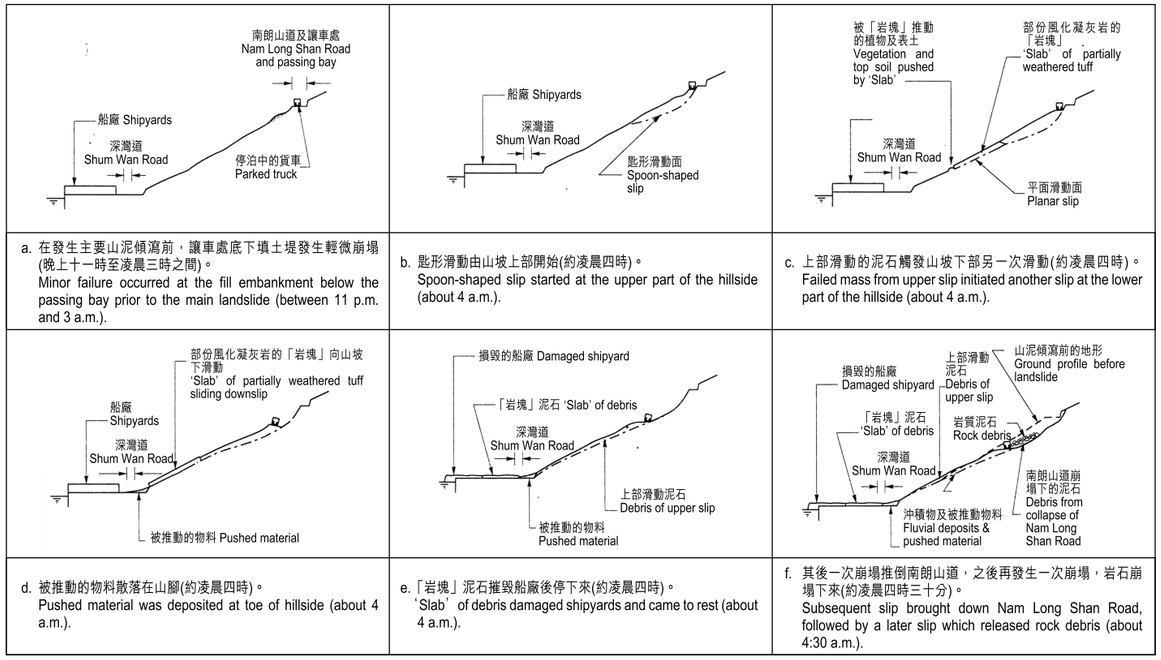
On the contrary, the base groundwater level at the location of the lower planar slip was high. The slab of partially weathered tuff in this area could have failed, partly along clay-filled joints, under such groundwater conditions. The loading associated with the debris from the spoon-shaped slip above would have triggered the failure.

Other conceivable factors, such as previous squatter activities, illegal dumping and passage of heavy construction vehicle, etc have also been examined. The effects of these factors were found to be not significant.

Conclusions

The main landslide involved two distinct parts that occurred almost simultaneously. The failure was caused principally by:

- the presence of weak layers in the ground, *i.e.* clay seams and clay-infilled joints;
- ingress of water during prolonged heavy rainfall;
- a minor failure of the fill embankment below a passing bay on Nam Long Shan Road; and
- water flowing along Nam Long Shan Road, because of partial blockage of its drainage system, and discharge of part of this water onto the hillside (Figure B-9).



a. 在發生主要山泥傾瀉前，讓車處底下填土堤發生輕微崩塌(晚上十一時至凌晨三時之間)。
Minor failure occurred at the fill embankment below the passing bay prior to the main landslide (between 11 p.m. and 3 a.m.).

b. 匙形滑動由山坡上部開始(約凌晨四時)。
Spoon-shaped slip started at the upper part of the hillside (about 4 a.m.).

c. 上部滑動的泥石觸發山坡下部另一次滑動(約凌晨四時)。
Failed mass from upper slip initiated another slip at the lower part of the hillside (about 4 a.m.).

d. 被推動的物料散落在山腳(約凌晨四時)。
Pushed material was deposited at toe of hillside (about 4 a.m.).

e. 「岩塊」泥石摧毀船廠後停下來(約凌晨四時)。
'Slab' of debris damaged shipyards and came to rest (about 4 a.m.).

f. 其後一次崩塌推倒南朗山道，之後再發生一次崩塌，岩石崩塌下來(約凌晨四時三十分)。
Subsequent slip brought down Nam Long Shan Road, followed by a later slip which released rock debris (about 4:30 a.m.).

圖B-10. 山泥傾瀉過程的圖解說明。
Figure B-10. Schematic representation of inferred sequence of events.

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