二零零五年八月二十日
芙蓉山村山泥傾瀉事件報告
山泥傾瀉調查結果
REPORT ON THE LANDSLIDE AT FU YUNG SHAN TSUEN OF 20 AUGUST 2005
FINDINGS OF THE LANDSLIDE INVESTIGATION

土力工程處報告系列第277號
GEO REPORT No. 277

茂盛土力工程顧問有限公司
Maunsell Geotechnical Services Ltd.

香港特別行政區政府

土木工程拓展署

土力工程處

GEOTECHNICAL ENGINEERING OFFICE

CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT

THE GOVERNMENT OF THE HONG KONG

SPECIAL ADMINISTRATIVE REGION

二零零五年八月二十日
芙蓉山村山泥傾瀉事件報告
山泥傾瀉調查結果
REPORT ON THE LANDSLIDE AT FU YUNG SHAN TSUEN OF 20 AUGUST 2005
FINDINGS OF THE LANDSLIDE INVESTIGATION

土力工程處報告系列第277號
GEO REPORT No. 277

茂盛土力工程顧問有限公司
Maunsell Geotechnical Services Ltd.

本報告源於二零零六年三月土力工程處
二零零五年八月二十日芙蓉山村山泥傾瀉事件報告
This report was originally produced in March 2006 as Report on the Landslide at Fu Yung Shan Tsuen of 20 August 2005

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

First published, March 2013

Prepared by:

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

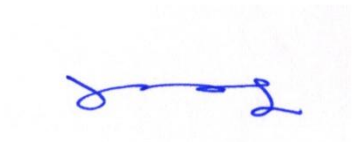
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

PREFACE

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

The Geotechnical Engineering Office also produces documents specifically for publication in print. These include guidance documents and results of comprehensive reviews. They can also be downloaded from the above website.

The publications and the printed GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the second last page of this report.



H.N. Wong
Head, Geotechnical Engineering Office
March 2013

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

EXECUTIVE SUMMARY

On 20 August 2005, a sizable landslide with a volume of about 400 m^3 occurred on a hillside that has been disturbed locally by past human activities at Fu Yung Shan Tsuen, Tsuen Wan, resulting in one fatality. The landslide took place during a severe rainstorm with a return period of about 100 years. A comprehensive investigation into the landslide was carried out by Maunsell Geotechnical Services Limited, under consultancy Agreement No. CE 15/2004 (GE), for the Geotechnical Engineering Office. This investigation included review of documentary information, analysis of rainfall records, interviews with witnesses to the landslide, site survey, ground investigation, theoretical stability analyses and diagnosis of the causes of failure.

The investigation concluded that the landslide was probably caused by the loss of soil suction and transient build-up of groundwater pressure in the near-surface materials following prolonged and intense rainfall. The following were diagnosed as contributory factors in the landslide:

(a) the properties and soil-water characteristic of the near-surface materials provided a hydrogeological setting that was conducive to the development of groundwater pressure following rainfall;

(b) the uncontrolled and illegal dumping of domestic refuse (comprising organic matter and fibrous materials with the capacity to retain water for a substantial period of time) over a significant portion of the subject hillside, gave rise to an unfavourable hydraulic boundary condition that probably promoted the build-up of high groundwater pressure over a large volume of the ground mass following prolonged and intense rainfall; and

(c) the over-steepening of the toe of the subject hillside, as inferred generally from the geomorphological setting, and locally from the 1964 aerial photographs and the presence of a break in slope on the adjacent unfailed hillsides, probably rendered the subject hillside more susceptible to rain-induced landslide.

Details of the investigation and its findings are presented in this report.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

CONTENTS

1. INTRODUCTION

At about 5:25 p.m. on 20 August 2005, during which time both the Amber Rainstorm Warning and the Landslip Warning were issued, a landslide (Incident No. 2005/08/0362), with a volume of about 400 m^3, occurred on a hillside that has been disturbed locally by past human activities at Fu Yung Shan Tsuen, Tsuen Wan (Figure 1 and Plates 1 & 2). One fatality was reported, and four registered squatter structures in the vicinity of the landslide were permanently evacuated following the failure.

Immediately following the incident, the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department (CEDD), commenced a detailed investigation into the fatal landslide. The investigation was undertaken by GEO's landslide investigation consultant, Maunsell Geotechnical Services Limited (MGSL). Topographic survey of the landslide area was carried out by the Survey Division of the CEDD.

The investigation was carried out between August 2005 and January 2006, and comprised the following key tasks:

(a) review of all known relevant documents relating to the development of the site, including previous assessments carried out within the squatter village and the sequence of events leading up to the landslide,

(b) interviews of witnesses to the landslide,

(c) topographic survey and detailed observations and measurements in the vicinity of the August 2005 landslide site,

(d) aerial photograph interpretation and engineering geological mapping,

(e) execution of a comprehensive programme of ground investigation to determine the subsurface conditions by drillholes, trial pits/trenches, insitu testing and laboratory testing,

(f) analysis of the rainfall records,

(g) theoretical slope stability analyses, and

(h) diagnosis of the probable causes of failure.

The findings of the investigation are presented in this report.

2. DESCRIPTION OF THE SITE

The August 2005 landslide site is located at Fu Yung Shan Tsuen on a NNW-SSE trending spur line descending from the southern side of Tai Mo Shan. The Shing Mun

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

Catchwater traverses the upper hillside area of Fu Yung Shan at an elevation of about 210 mPD, approximately 200 m to the north of the landslide site and at an elevation about 100 m higher (Figure 1). Fu Yung Shan Tsuen is located in the lower part of the hillside below the catchwater. A streamcourse descends from an overflow weir of the catchwater and traverses close to the toe of the landslide site (Figure 1 and Plate 3).

The August 2005 landslide occurred on the east-facing flank of the spur line, northwest of Chuk Lam Sim Yuen (Figure 2 and Plate 3). The densely vegetated hillside is inclined at an angle of about 28° to 34° (based on post-landslide topographic survey of the adjacent areas), and has been disturbed locally by human activities, such as formation of minor footpaths, dumping of domestic refuse and cultivation of fruit trees (Figure 2 and Plate 2). The hillside is not eligible for registration in the Government's Slope Catalogue, as it is not a man-made slope feature. The crest of the spur is about 20 m to the west of the landslide, with a relatively small catchment area of about 800 m^2 between the spur and the crest of the landslide.

A paved platform, covered by cement screed with a few old minor cracks, and a two-storey registered squatter structure (as registered by the Housing Department (HD) under their 1982 Squatter Structure Survey) are located at the crest of the August 2005 landslide (Plate 4). The platform is supported by a 2.5 m high dry-packed random rubble wall (Figure 2 and Plate 5), which is not registered in the Government's Slope Catalogue, as the wall does not meet the registration criteria in terms of its height (i.e. < 3 m high). The registered squatter structure at the crest (with squatter control survey No. RTW/4A/388, hereinafter referred to as squatter structure No. 388) comprises steel frames, plywood walls and a corrugated sheet roof. A cut slope up to 3.5 m high and inclined at about 60° is located behind squatter structure No. 388 (Plate 6). Further above the cut is a cluster of single-storey, flimsy registered squatter structures (with squatter control survey Nos. RTW/4A/389, 391-393, hereinafter referred to as squatter structures Nos. 389, 391-393) (Plate 7). Some vacant platforms (formerly occupied by other squatter structures), which are partly paved and partly used for cultivation of fruit trees, are located above and to the southwest of the landslide site (Figure 2 and Plate 1). A number of large boulders were observed on the hillside between these platforms and squatter structures Nos. 389, 391-393 (Plate 1).

A 1.2 m wide concrete paved footpath traverses across the mid-height of the subject hillside at a gradient of about 1 in 5. The footpath does not have any notable crossfall and no surface channel or upstand has been constructed alongside it. A concrete stairway leads from this footpath to squatter structures No. 388 and Nos. 389, 391-393 further uphill (Figure 2). Another concrete stairway leading from the footpath to the toe of the subject hillside is located to the south of the August 2005 landslide (Figure 2).

A two-storey, plastered brick, registered squatter structure with a corrugated sheet roof (with squatter control survey No. RTW/4A/516, hereinafter referred to as squatter structure No. 516) is located about 3 m to the east from the base of the landslide scar. A single storey, plastered brick, registered squatter structure with a corrugated sheet roof (with squatter control survey No. RTW/4A/526, hereinafter referred to as squatter structure No. 526), and another single storey flimsy wooden registered squatter structure (squatter control survey Nos. RTW/4A/528-529, hereinafter referred to as squatter structures Nos. 528-529) are located to the east of the toe of the landslide (Figure 2 and Plates 8 to 10).

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

The streamcourse traverses close to the toe of the August 2005 landslide. Some sections of the streamcourse close to the toe of the subject hillside have been lined with concrete. The streamcourse has been bridged over intermittently with concrete slabs to form platforms for past squatter settlement.

According to information provided by the Water Supplies Department (WSD), two galvanised iron fresh water pipes of 100 mm and 80 mm diameter respectively (both installed in 1987) are located across the landslide site (Figure 2). There are no records of previous leakage or bursting of the pipes, or complaints of loss of water supply pressure from the residents prior to the landslide. Many service conduits and cables, including street lamps and the associated conduits, over-head electricity/telephone cables and supporting poles, are located along the footpath and stairways.

There are no public stormwater drains at the landslide site that are maintained by the Drainage Services Department. However, a number of PVC drainage pipes, which were probably laid by the local residents, are observed within and in the vicinity of the landslide (Plates 5 & 11). The majority of these were found to have been abandoned, broken or blocked during the post-landslide inspections, except for the drainage pipe from squatter structure No. 388, which collects surface water from the roof of the structure and discharges it directly onto the hillside to the north of the landslide site (Figure 2 and Plate 6). A septic tank (according to the occupant of squatter structure No. 388, the septic tank was not used frequently in recent years) is located below squatter structure No. 388 and the associated overflow pipe discharges onto the hillside about 10 m to the north of the landslide site (Figure 2). There is no field evidence of leakage from the septic tank. No similar septic tanks or cesspits have been constructed for the squatter structures Nos. 389, 391-393 further uphill and sewage from these structures is discharged via a PVC pipe (which is in a dilapidated condition) onto the hillside to the north of the landslide site (Figure 2 and Plate 11).

Several warning signs advising of landslide danger in the squatter area were erected previously by the GEO in the vicinity of the landslide site, one of which was found within the landslide debris, one just beyond the toe of the landslide and one along the unfailed section of the footpath.

Based on the information obtained from the Lands Department (Lands D), the August 2005 landslide site is located on unleased and unallocated government land.

3. DESCRIPTION OF THE LANDSLIDE

A plan of the August 2005 landslide and a longitudinal section through the landslide are shown in Figures 3 and 4 respectively.

According to witnesses' accounts (including residents of Fu Yung Shan Tsuen, firemen, police officers and GEO inspection engineers), records from the Hong Kong Police Force (HKPF) and post-failure field observations, the August 2005 landslide occurred in successive phases between about 5:25 p.m. and 6:30 p.m. on 20 August 2005 (see Section 7). The failure occurred on a hillside that has been disturbed locally by past human activities (Section 2). The landslide scar is about 45 m in length (on plan), 18 m in width (maximum),

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

with a maximum depth of about 4 m, giving a total failure volume of about 400 m^3. The overall travel distance of the landslide debris is about 20 m (Figure 3). The main scarp of the landslide is about 10 m wide, 7 m high and inclined at an angle between 50° and 65° (Plates 5 & 12). Following the landslide, only the main scarp was exposed and the remainder of the landslide scar was covered by landslide debris. No adverse geological structures (such as relict joints, low strength infill, etc.) could be observed in the main scarp. No seepage or any other evidence of water flow was observed in the main scarp during the inspection in the morning of 21 August 2005. However, the exposed materials were notably wet and appeared to be saturated.

A section of the 2.5 m high (maximum 0.5 m thick) rubble wall, together with a 4.5 m by 2.5 m area of the platform above, collapsed during the landslide (Plate 5). A corner of squatter structure No. 388 was undermined by the failure. However, cracks or other signs of distress were not evident on the structure. The floor of squatter structure No. 388 was in a fair condition, with some old cracks on the floor slab probably due to minor settlement of the floor slab.

A 15 m long section of the footpath that traversed about the mid-height of the August 2005 landslide scar, and a 10 m long section of the stairway leading from the footpath to the squatter structures above collapsed during the landslide (Plate 13). The utilities in the vicinity of the landslide were damaged, including two water pipes, three electric poles, two telephone cable poles and two street lamps (with cable conduits and poles) (Plate 14). The landslide debris stopped in front of squatter structure No. 516, partly covering the streamcourse (Plate 15). Some fine debris (outwash material) was washed down the streamcourse for another 150 m but no damage was caused.

The landslide debris trail can be divided into the upper and lower parts respectively. The upper part mainly comprises reddish brown sandy clayey silt, rubble from the masonry retaining wall, concrete footpath and stairway fragments and associated handrails, electricity cable pole (denoted as E1, see Figure 3), lamp post (denoted as LP1) and cable conduits, fallen trees (denoted as T1, T2 & T3), sections of the broken fresh water pipes, together with fences and railing probably erected by the residents of the squatter structures. An intact raft of debris (with tree T3, see Figure 3 and Plate 16), and rubble from the masonry retaining wall at the crest, came to rest within the upper part of the debris trail.

The lower part of the landslide debris trail mainly comprises reddish brown to yellowish brown sandy clay/silt, concrete fragments and handrails of the footpath and stairway, some fallen trees and damaged utilities (Plate 15). Lamp post LP2 was found to lie beneath a section of the footpath handrail, both of which were originally alongside the footpath (Plate 17). Domestic refuse (comprising decomposing organic matter and fibrous materials, plastic bags, bottles, tin cans, broken household/electrical appliances, wood, etc.) was observed to be mixed with soil debris and to have been piled up against the fence along the lower eastern part of the debris trail near the toe adjacent to the streamcourse (the area was fenced off by the residents for the purpose of cultivation) to a height of about 2.5 m (Plate 18). The domestic refuse appeared to have been pushed towards the fence by the landslide debris.

The movement pattern of the landslide debris (based on the locations of objects as mapped within the debris, the original locations of which were known), including the failed materials and footpath and stairway fragments, fallen trees and broken utilities, etc. (Figure 5),

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

has been used to assess the mobility of the debris and the likely sequence of the collapse (see Section 7).

According to eye-witnesses' accounts and records obtained from the WSD, water was observed to be discharging from the broken 100 mm diameter water pipe (water did not discharge from the broken 80 mm diameter water pipe at the time of the inspection by the GEO's officer from the emergency control centre at about 9:45 p.m. on 20 August 2005) onto the landslide debris for at least 5 hours before the water supply was turned off by WSD at 12:05 a.m. on 21 August 2005. Post-failure inspection of the utilities indicates that the broken fresh water pipes were dislocated at the screw joints (which were generally in fair condition with no signs of deterioration, such as rusting or pin holes, being observed, see Plate 13) as a result of the failure. All surface drainage pipes leading to the failure scar were either abandoned, broken or blocked at the time of the inspection (Plate 11) with no signs of water flow from them (see Figure 2). There are no obvious signs of water flow (such as erosion gullies on the landslide debris) from the edge of the broken footpath and stairway. No other possible sources of concentrated surface water flow and ingress into the landslide area could be found based on field mapping and observations.

No signs of distress or deterioration of the adjoining hillside, such as tension cracks, were observed. There were also no signs of other obvious landslides or erosion along the streamcourse in the vicinity of the August 2005 landslide site. To the north of the landslide, the streamcourse has a higher elevation and the adjacent hillside area has an overall more gentle gradient. To the south of the landslide the overall gradient of the adjacent upper hillside area has been reduced by the extensive platform excavations associated with squatter structures. A small (about 1 m high) break in slope in the hillside to the north of the toe area of the landslide site, and a corresponding scarp to the south of the landslide toe area, are evident (Plate 19). It is possible that this feature is associated with a local instability or man-made excavation, as identified in the 1964 aerial photographs (see Section 4). Inspection of the toe of the hillside along the streamcourse indicates that it had not been undercut by the flowing water in the stream, which is consistent with the accounts by the residents that the stream flow had always been very minor.

A very minor detachment (about 2 m^3) was observed by the WSD on 19 August 2005 at a small cut slope above the catchwater, just downstream of an overflow weir at the head of the streamcourse that leads to the toe of the August 2005 landslide. According to the WSD, the landslide debris was washed away by the flow in the catchwater and did not cause any blockage of the catchwater on 20 August 2005.

4. HISTORY OF SITE DEVELOPMENT AND PAST INSTABILITY

The site history, which is summarised in Appendix A, has been determined from an interpretation of aerial photographs dating back to 1924 and a review of other available documentary information.

The earliest available aerial photographs show that in 1924, the location of the August 2005 landslide was a natural hillside. Development of Chuk Lam Sim Yuen commenced in 1927. The Shing Mun Catchwater was formed on the hillside above the landslide site around 1937. Anthropogenic activities such as construction of squatter

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

structures, cultivation (with a pond and weir structure), footpaths and temples to the east of the landslide site were evident in 1949.

Village development in the vicinity of the August 2005 landslide commenced in the early 1960's, and the squatter structures in close proximity to the landslide were formed between 1963 and 1976. By 1979, squatter structure development had peaked and no further significant squatter village development took place subsequently. The lower hillside area below the footpath that traversed the landslide site was used as a repository for domestic refuse notably from 1977 onwards. A number of squatter structures in Fu Yung Shan Tsuen were demolished between 1996 and 1998. After 2000, significant changes are not evident on the hillside.

There are no records of any previous reported landslides in the immediate vicinity of the August 2005 landslide, according to GEO's database of reported landslides, Natural Terrain Landslide Inventory (NTLI), Large Landslide Database (LLD) and the Enhanced NTLI data maintained by the GEO. The nearest recorded landslide incident (a minor landslide on the hillside below a footpath, with a failure volume of about 3 m^3) is about 20 m to the north of the landslide site (see Appendix A and Figure 6).

From a review of the 1964 aerial photographs, a possible area of local instability or a man-made excavation is indicated near the toe of the location of the August 2005 landslide. Two degraded topographical depressions, which are inferred to be relict landslides, are located about 30 m to the south of the landslide (Figure 6).

In connection with the Government's Non-Development Clearance (NDC) Programme to clear vulnerable squatters on slope safety grounds, the Geotechnical Control Office (GCO, renamed GEO in 1991) carried out inspections of the Fu Yung Shan area in 1985. The four registered squatter structures Nos. 388, 516, 526 and 528-529 (see Figure 2), which were permanently evacuated following the August 2005 landslide, were not recommended for clearance by the GCO in 1985 whilst some other squatter structures were subjected to NDC recommendations.

The GEO carried out NDC re-inspections of the Fu Yung Shan area in 1992. The four registered squatter structures Nos. 388, 516, 526 and 528-529, which were permanently evacuated following the August 2005 landslide, were recommended for clearance by the GEO under the NDC Programme in 1992. Clearances were carried out by HD and Lands D. A total of 290 structures were identified for clearance by the HD and re-housing offers were made to the occupants. Twenty families, which included the occupants of the four registered squatter structures Nos. 388, 516, 526 and 528-529, refused the re-housing offers and opted to stay put. According to records obtained from HD, these structures had not been cleared before the August 2005 landslide.

During the NDC Programme in 1992, some squatter structures were also recommended for clearance on 'Other Grounds' (i.e. clearance other than on geotechnical grounds). The squatter structures Nos. 389, 391-393 (Figure 2) were identified by HD for clearance under NDC Clearance No. TW 18/94 of the NDC Programme in 1994. Re-housing offers were made to the associated occupants. However, they refused the re-housing offers and opted to stay put. According to the records obtained from HD, these structures had not been cleared before the August 2005 landslide.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

5. ANALYSIS OF RAINFALL RECORDS

Rainfall data were obtained from the two nearest GEO automatic raingauges Nos. N38 and N03, which are located approximately 1.2 km to the west and 1.3 km to the east of the August 2005 landslide respectively (Figure 1). The raingauge transmits rainfall data at 5-minute intervals to the GEO and the Hong Kong Observatory (HKO). The daily rainfall recorded by the raingauges from 19 July 2005 to 23 August 2005, together with the hourly rainfall readings from 18 to 21 August 2005, are shown in Figure 7. The pattern of rainfall recorded at raingauge No. N03 was broadly similar to that recorded at raingauge No. N38 for durations up to about 24 hours, whereas the longer-duration rainfall was less intense at N03.

The Amber Rainstorm Warning was issued at 7:25 p.m. on 19 August 2005 and remained in force until 12:55 a.m. on 20 August 2005. The Amber Rainstorm Warning was issued again at 8:35 a.m. on 20 August 2005 and was in force until 9:10 p.m. on 20 August 2005. The Landslip Warning was issued at 9:00 p.m. on 19 August 2005 and remained in force until 6:15 a.m. on 22 August 2005.

The antecedent rainfall in the vicinity of the August 2005 landslide site was high (see Table 1). It was raining continuously for 24 hours from 5:30 p.m. on 19 August 2005 (with some very brief dry spells between mid-night and 1 a.m. on 20 August 2005, see Figure 8) up to the time of the landslide at about 5:25 p.m. on 20 August 2005, with a maximum 24-hour rolling rainfall of about 450 mm.

An analysis of the return periods for various durations of rolling rainfall recorded by raingauges Nos. N03 and N38, with reference to the historical rainfall data at the Hong Kong Observatory at Tsim Sha Tsui where records began in 1884 (Lam & Leung, 1994), shows that a rainfall duration of 10 days or more before the landslide was the most severe at raingauge No. N38, with a corresponding return period of more than 100 years (Table 1). The maximum return period for rainfall recorded at raingauge No. N03 is 73 years corresponding to the 31-day duration.

It has long been recognised by the Hong Kong Observatory (HKO) that the rainfall recorded in Tsim Sha Tsui may not be valid for other locations in Hong Kong (Peterson & Kwong, 1981; Lam & Leung, 1994) because of the spatial variability of rainfall in the hilly terrain of Hong Kong. Wong & Ho (1996b) suggested that the variability of rainfall at different locations could result from, inter alia, orographic effects. Evans & Yu (2001) analysed the 5-minute rainfall data of 46 GEO automatic raingauges throughout Hong Kong for the period of 1984 to 1997. The study concluded that the recurrence of extreme rainfall varies across Hong Kong and that rainfall return periods as calculated from rainfall data at the HKO are not necessarily applicable elsewhere. Hence, the rolling rainfall recorded by raingauges Nos. N03 and N38 were also assessed based on the statistical parameters derived by Evans & Yu (2001) from rainfall data recorded by the local raingauge No. N03 between 1984 and 1997 (raingauge No. N03 came into operation in June 1983 whereas raingauge No. N38 was not installed until October 1999). Based on the above, the 10-day and 12-day rainfalls at raingauge No. N38 were the most critical with a return period of more than 100 years (Table 1), whereas the maximum return period for the rainfall recorded at raingauge No. N03 is 34 years corresponding to the 24-hour rainfall.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

The maximum rolling rainfall for the 19 August 2005 rainstorm has been compared with the past major rainstorms recorded by raingauges Nos. N03 and N38 respectively between 1983 and 2004 (Figure 9). The 19 August 2005 rainstorm is the most severe for rainfall durations greater than 12 hours.

6. SUBSURFACE GROUND CONDITIONS

6.1 General

The subsurface conditions at the site were determined using information from desk and field studies. The desk study comprised a review of all the available data, whilst the field study included geological mapping and a ground investigation.

The solid geology underlying the site was previously mapped at 1:20,000 scale and 1:100,000 scale by GCO (1986) and Sewell et al (2000) as granodiorite. From the 1:20,000 scale map, an east-west boundary with coarse ash tuff is shown approximately 150 m to the north, and a feldsparphyric rhyolite dyke is shown along this boundary. A north-south trending fault is indicated about 600 m to the east along a streamcourse in Lo Wai. Colluvium (slope debris) is shown in an adjacent valley to the north-east (Figure 10).

Engineering geological mapping of the site as part of this investigation commenced on 21 August 2005 and continued until December 2005, as access was provided and ground investigation works were being undertaken.

6.2 Ground Investigation

The ground investigation, which comprised two phases, was undertaken under the supervision of MGSL to identify the nature and condition of the materials involved in the August 2005 landslide. The locations of the ground investigation stations are shown in Figure 11. The Phase I investigation was carried out mostly within the landslide scar by Inter-Pacific Ltd. from 2 September 2005 to 25 October 2005. This comprised one vertical drillhole, installation of a standpipe piezometer, seven trial pits, two trial trenches, one slope strip, 23 GCO probe tests, 13 insitu density tests, installation of four clusters of tensiometers (each cluster comprised three tensiometers with tips at various depths, see Section 6.5), together with vegetation clearance.

The Phase II investigation was carried out in the areas adjacent to the August 2005 landslide scar by DrilTech Ground Engineering Ltd. from 25 October 2005 to 15 December 2005. This comprised seven vertical drillholes, nine standpipe piezometers, two horizontal coreholes through the rubble wall, two trial pits and two slope strips. Field testing, comprising constant head permeability tests in the drillholes, four double ring constant-head infiltrometer tests, acoustic borehole televiewer surveys and packer (water absorption) tests were also carried out.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

6.3 Geology

Geological information has been compiled from the published data and site-specific ground investigation and engineering geological mapping. Geological and other related features observed by the Hong Kong Geological Survey (HKGS) at and near the August 2005 landslide site are shown in Figure 10. A geological plan and a cross-section through the landslide are shown in Figures 12 and 13 respectively.

The predominant insitu materials consist of medium- to coarse-grained granodiorite overlain by a relatively thin layer of residual soil (less than 500 mm). Superficial deposits comprising up to 3 m of colluvium and a thin mantle of fill were exposed in the main scarp. Fill was also encountered in the upper part of the landslide scar (about 1 m thick), and in trial pits Nos. TP6 to TP10 with thicknesses ranging from 0.2 m to 0.4 m. The fill generally comprised reddish brown, sandy silty clay with cobble- and gravel-sized rock fragments. In the middle to lower parts of the landslide scar, significant amounts of domestic refuse were observed on the surface and within trial pits Nos. TP4 and TP11 (Plates 20 & 21).

Colluvium was encountered in all the trial pits within and adjacent to the landslide scar (TP5 to TP10), ranging in thickness from 1.5 m in trial pit No. TP5 to 3 m in trial pit No. TP6 (the base of the colluvium was not established in trial pits Nos. TP7, TP8 and TP10 due to the presence of large colluvial boulders). The colluvium generally comprised sandy clay/silt with occasional cobbles and boulders. All drillholes outside the landslide scar encountered colluvium at the surface, ranging from 1.5 m to 4.2 m in thickness.

Completely decomposed granodiorite (CDGd) was encountered at the base of most trial pits within the August 2005 landslide scar. In the trial pits, the CDGd generally comprised yellowish brown, spotted white and black, sandy clayey silt, and was generally at the upper end of the weathering spectrum for completely decomposed material, with typical texture but limited structure visible (i.e. grading into a residual soil). No highly decomposed granodiorite or better material was exposed within the trial pits, except for some highly decomposed corestones in trial trench TT1a. In the drillholes, the CDGd was found to extend down to significant depths (about 20 m), with local variations in material composition (e.g. zones of clayey silt with little sand component). Relict structure was distinctive in most drillholes, typically at depths greater than 10 m, due to extensive manganese oxide infilling. Manganese oxide–rich zones were also observed within the soil matrix. To a lesser extent, kaolin clay was also found infilling relict joints and disseminated throughout the soil matrix, although no evidence of relative movement or obvious disturbance could be found below the identified failure surface of the landslide. Drillholes Nos. DH3 and DH8 near the crest and toe of the adjacent hillside respectively encountered corestone-bearing CDGd, whereas no corestones were encountered in the CDGd in drillhole No. DH7 near the centre of the landslide site. Where rock of weathering grade III or better was encountered, it comprised strong to very strong, light grey, moderately to slightly decomposed medium grained granodiorite with medium to closely spaced joints. Rockhead contours constructed from the eight drillholes within and adjacent to the landslide, indicate a rockhead inclination of about 27° towards the east and a possible subtle depression in the rockhead surface near drillhole No. DH7 (Figure 11). The thickness of the colluvium is generally fairly uniform and there is no indication of an irregular surface of the insitu CDGd.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

Residual soil was mainly exposed at the face of the main scarp and was typically 100 mm to 200 mm thick and comprised reddish to yellowish brown sandy silt/clay with no visible structure or texture. This material was generally absent from the trial pit exposures within the landslide scar, as it was probably removed by the landslide.

All the trial trenches and trial pits within the landslide scar encountered landslide debris ranging in thickness from 0.4 m in trial trench No. TT1 (near the base of the main scarp) to 1.8 m in trial pit No. TP4 (at the lower debris trail). The debris was variable but generally comprised reddish brown, sandy clayey silt with variable gravel, cobble and boulder sized rock fragments, concrete fragments and domestic refuse. The domestic refuse (comprising mainly decomposing organic material and plastic bags about 0.5 m to 0.8 m thick) was most prevalent in the lower debris trail area, and was commonly layered or mixed with soil/debris (Plates 20 & 21).

The failure surface was only exposed in the trial pits within the landslide scar (Plate 22) and typically comprised about 20 mm of grey/brown sandy silt/clay, which locally includes a narrow zone (approximately 0.5 m) of sheared and layered soil, best exposed in trial pit No. TP3 (Plate 23). The failure surface is located predominantly within CDGd. Locally, a zone of sheared/disturbed material was observed in trial pit No. TP3 to extend about 200 mm into the CDGd. The material on the failure surface was observed to be notably wet following the landslide and had a disturbed or remoulded appearance. No other evidence of relative movement, such as slickensiding, could be seen. Where there is a zone of sheared and layered soil, the failure surface was generally located near the base of the sheared zone (Plate 23).

6.4 <u>Soil Properties</u>

A series of laboratory tests were conducted at the Public Works Central Laboratory (PWCL) and the Hong Kong University of Science and Technology (HKUST) on samples retrieved during the ground investigation. The tests included moisture content tests, particle size distribution (PSD), Atterberg limits tests, chemical tests on soil and water samples, single stage isotropically consolidated undrained triaxial compression tests (referred to as CIU tests), consolidation tests, direct shear box tests, and stress path tests (with increasing pore water pressure at a constant deviator stress, referred to as ‘constant q’ tests). The tests were carried out in accordance with Geospec 3 (GEO, 2001). A summary of the laboratory test results is presented in Figures 14 to 16.

The average fines (i.e. silt and clay) content of the landslide debris was found to be 52%, with a range of 30% to 65%, whilst that of the colluvium and CDGd was 49% and 36% respectively, with ranges of 8% to 66% for colluvium and 19% to 62% for CDGd. The plasticity index of the fines of CDGd ranged from 7% to 20%, and the liquid limit ranged from 38% to 49%. The plasticity index of the fines of colluvium ranged from 14% to 37%, and the liquid limit ranged from 42% to 66%. The plasticity index of the fines of the landslide debris ranged from 11% to 35%, and the liquid limit ranged from 36% to 63%. The CDGd comprises slightly gravelly sandy clayey silt, sandy silt, sandy clayey silt, silty gravelly sand and silty sand. The silt in CDGd are predominantly intermediate plastic silt (Figure 15). The colluvium comprises sandy clay, sandy silt, gravelly sandy silt and occasionally gravelly sands. Highly plastic clay and silt were encountered in colluvium

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

(Figure 16). The landslide debris comprises sandy silt and sandy silty clay, which are intermediate to highly plastic clay and silt (Figure 14).

Results of the constant head permeability tests in drillholes and the double ring infiltrometer tests indicated permeability values ranging from 2.5×10^{-6} m/s to 6×10^{-5} m/s for colluvium, with an average value of 3.7×10^{-5} m/s. The field permeability values as determined from drillhole permeability tests in CDGd generally range from 2.3×10^{-6} m/s to 8.5×10^{-6} m/s, except for the test at about 11 m below ground surface which corresponded to a higher permeability value of 1.6×10^{-5} m/s.

The average dry and bulk unit weights of the landslide debris as determined from sand replacement tests are 10.7 kN/m^3 and 13.4 kN/m^3 respectively, with ranges of 10.1 kN/m^3 to 12 kN/m^3 obtained for the dry unit weight and 12.8 kN/m^3 to 14.7 kN/m^3 for the bulk unit weight. The dry unit weight of colluvium as determined from sand replacement tests ranged from 11 kN/m^3 to 14.6 kN/m^3, with an average value of 12.9 kN/m^3. The dry unit weight of CDGd as determined from undisturbed samples ranged from 13 kN/m^3 to 14.9 kN/m^3, with an average value of 14.1 kN/m^3.

The shear strength properties of CDGd and colluvium were assessed by CIU tests and constant q tests. Direct shear box tests were also undertaken on the failure surface using specimens prepared from block samples retrieved from the trial pits. The test results are summarised in Figures 15 and 16 respectively.

The shear strength parameters of CDGd from the CIU tests correspond to c' = 0 kPa and ϕ' = 35°. In the CIU tests, the CDGd samples showed variability in their behaviour upon shearing. A total of 18 CIU tests were carried out on eight samples located within and outside the landslide scar. Most of the test results display a dilative behaviour except six results which display a contractive behaviour. Amongst these six tests (performed on two samples), two of them indicate a significant post-peak reduction in undrained shear strength. The two samples with contractive behaviour are taken within the landside scar and have lower dry densities when compared to samples taken from adjacent ground. However, another sample obtained within the landslide scar with similar dry density shows dilative behaviour (see Figure 17). The constant q tests simulate more closely the stress paths experienced by a soil element in the field as the groundwater pressure increases following rainfall. The number of constant q tests carried out on CDGd samples are limited. The corresponding shear strength parameters are c' = 4 kPa and ϕ' = 31°. Direct shear box tests on the failure surface indicate that the range of shear strength parameters corresponded to c' = 0 kPa and ϕ' = 31°, and c' = 2 kPa and ϕ' = 37°.

In the CIU tests on the matrix material of colluvium, the samples showed a dilative behaviour upon shearing (Figure 16). The shear strength parameters from the CIU tests correspond to c' = 0 kPa and ϕ' = 37°. The number of constant q tests on colluvium samples are limited. The corresponding shear strength parameters are c' = 2 kPa and ϕ' = 40°. Overall, the laboratory tests illustrate that the shear strength parameters of the matrix material of colluvium are higher than those of CDGd.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

6.5 Groundwater Conditions

When the site was inspected about seven hours after landslide occurrence at about midnight, there was no safe access to the main scarp to ascertain whether there was any active seepage at the time. In the morning of 21 August 2005, the exposed material on the main scarp was observed to be very wet and appeared to be saturated. Active seepage was not observed from the main scarp or on the adjacent hillside. Gullying was observed within the soft remoulded debris deposits in the lower part of the debris trail, which was probably formed by the discharge of running water from the broken 100 mm diameter water pipe.

Seepage was encountered at the bottom of trial trench TT1 at 2.9 m depth, in trial pit No. TP2 at 2.2 m depth and in trial pit No. TP4 at 2.8 m depth. Chemical tests of samples of seepage water from trial pits indicate that the seepage is likely to be natural groundwater.

Post-landslide groundwater monitoring data from the seven drillholes (DH1, DH2, and DH4 to DH8) are tabulated in Table 2. Monitoring of groundwater levels in standpipes and standpipe piezometers between October and December 2005 indicated that the direction of groundwater flow is generally along the overall slope of the hillside (i.e. towards the southeast).

No significant rainfall occurred during the period of groundwater monitoring using piezometers. In general, over the monitoring period the groundwater is fairly low (about 6 to 10 m below ground surface) in the upper and middle portions of the hillside, whereas the groundwater level in the lower portion of the hillside is fairly close to the ground surface, especially for drillholes sunk close to the streamcourse (DH1 & DH8, Figures 11 & 12).

In three of the drillholes (i.e. DH1, DH2 & DH8), a pair of piezometers were installed with the upper one (open standpipe) within colluvium and the lower one (standpipe piezometer) within CDGd or CDGd/HDGd. In drillhole No. DH1, the water level in the upper standpipe is 1.35 m below ground level (i.e. about 3 m above base of colluvium) while the water level in the lower piezometer is 2.35 m below ground level (i.e. about 2 m above base of colluvium). In drillhole No. DH8, the water levels in the upper standpipe and lower piezometer are 0.43 m and 0.28 m below ground level respectively (i.e. both within colluvium). Drillhole No. DH2, which is at a much higher level (near the crest level of the landslide), only indicates a relatively deep base groundwater table in CDGd with no water level in the colluvium over the monitoring period.

Jetfill tensiometers were installed in four clusters adjacent to the August 2005 landslide in early September 2005. At each of the clusters, three tensiometers were installed at 1 m, 2 m and 3 m depths respectively. The suctions in the tensiometers were measured manually generally on a daily basis from September to December 2005. The measurements from the tensiometers, together with the daily rainfall, are shown in Figure 18.

The suction measurements indicate spatial variability, with the dry weather suction values ranging from about 5 kPa to about 60 kPa for the shallow tensiometers. The tensiometers in TS1 indicated notably higher suctions than those in the other three clusters of tensiometers. The variability in the response of the tensiometers at different locations and at different depths could be attributed to various factors, including variations in the soil-water characteristics of the surrounding ground mass, and the local infiltration and subsurface groundwater flow patterns.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

The suctions responded to rainfall but the rate of response as well as the magnitude of the changes varied for tensiometers at different locations and at different depths. A fairly heavy rainstorm occurred from 25 to 27 September 2005, with a daily rainfall of 275 mm recorded by raingauge No. N38 on 25 September 2005 (with a return period of about 25 years associated with the 5-minute rainfall, which was the most critical rainfall duration). The suctions at all four tensiometers at 1 m depth were completely eliminated. At 2 m depth, the suctions at TS1 and TS3 continued to drop after 3 days whereas at TS2 and TS4 the suctions had begun to recover.

It is noteworthy that small positive water pressures (of less than 5 kPa) were recorded by some of the tensiometers at shallow depths (Figure 18), which is indicative of transient build-up of groundwater pressure in the near-surface materials during the course of downward percolation of rainwater, even during the September rainstorm that was less severe than the rainfall preceding the August 2005 landslide. This suggests that much higher groundwater pressure probably built up during the previous more severe rainstorms. The monitoring data indicate that the reduction in suctions in response to rainfall infiltration may take some time to fully realize (of the order of a few days), and the subsequent rate of recovery (in terms of build-up of suctions) could be even slower (Figure 18). In addition, there is some indication of possible influence of preferential subsurface seepage at certain depths in addition to surface infiltration, where the suction values at depths reduced more notably and at a faster rate than those nearer the ground surface in a given cluster location.

7. PROBABLE SEQUENCE OF EVENTS

The probable sequence of events has been reconstructed from accounts given by eye-witnesses, records of the HKPF and the Fire Services Department (FSD), together with detailed field mapping of the August 2005 landslide by MGSL. Based on a synthesis of the information and corroboration of data from various sources, it is diagnosed that the landslide probably occurred in two main phases in a retrogressive manner with some subsequent further minor local landslides.

According to an occupant of squatter structures Nos. 528-529, the first phase of the failure occurred at around 5:25 p.m. on 20 August 2005 after he was alerted by the unusual barking of his dogs. He subsequently noticed that a landslide had occurred, which covered the lower part of the hillside and a detached section of the footpath (about 15 m length with tree T1 (Figure 3) above the footpath still remaining in place at that time but it was observed to be leaning towards the failed area), which traversed the middle of the hillside (Figure 19). He also noticed that the lamp post LP2 (Figure 3) had fallen over, the handrail along the footpath was overhanging and the 100 mm diameter water pipe alongside the footpath was broken and issuing water onto the landslide scar.

According to the occupants of squatter structures Nos. 526 and 528-529, the second phase of the failure occurred about 15 minutes following the initial failure (i.e. at around 5:40 p.m.) at the upper part of the landslide scar between the footpath and squatter structure No. 388 at the crest. The landslide debris of the second phase of the landslide, together with the fallen tree T1, displaced the footpath handrail further which came to rest over lamp post LP2 (Plate 17). The landslide debris, under the influence of the water flow from the broken fresh water pipe, travelled further towards squatter structure No. 526 and came to rest in front of the fence surrounding a cultivation area. The landslide debris from the second phase of

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

the failure travelled a shorter distance as compared to that associated with the initial phase of the collapse and came to rest in the upper and middle portions of the debris trail, depositing in some areas over the debris from the initial failure. The field observations generally corroborate the witnesses' accounts. The second phase of landsliding may have comprised two separate failures, according to the occupants of squatter structures Nos. 526 and 528-529, although this could not be ascertained by the field mapping.

A further minor detachment involved the failure and extension of the flank of the main scarp around the south side of the footpath (Figure 19), which might have been influenced by the water discharging from the broken water main.

The travel distance of the initial failure is about 20 m and the travel angle is about 20°. The travel distance of the subsequent failure is about 16 m with a corresponding travel angle of about 32°.

The occupant of squatter structures Nos. 528-529 did not report the incident immediately after the first landslide, which occurred at about 5:25 p.m., since his mobile phone was out of service. He later requested the occupant of squatter structure No. 516 to report the incident. According to HKPF's records, the incident was reported to HKPF at 6:54 p.m. by the occupant of squatter structure No. 516. The incident was referred to the FSD at 6:55 p.m. FSD officers arrived at Fu Yung Shan Road at 7:11 p.m. and then proceeded uphill on foot to the landslide site. FSD officers noticed a limb of a person protruding from the landslide debris below the collapsed section of the footpath at 9:08 p.m. The body was retrieved from the debris at 9:50 p.m. According to the FSD officers, the deceased was found near the broken edge of the footpath at the southern flank of the landslide (Figure 3 and Plate 13). The body of the victim was buried in the debris by about 0.5 m, with a leg below the knee being exposed (without any footwear). The victim's body was buried in the mud with his face pointing downward, and his head pointing uphill.

Based on the records from HKPF and the eyewitnesses' accounts of the residents of the Fu Yung Shan Tsuen, the deceased was not a resident of the squatter village but was probably a visitor to squatter structures Nos. 389, 391-393 (no residents were observed at these squatter structures during the course of the investigation and there are no obvious signs of occupation based on the derelict state of the structures).

8. THEORETICAL STABILITY ANALYSES

Theoretical stability analyses were carried out to assist the diagnosis of the mechanism and causes of the failure. These analyses were aimed to investigate the likely operative range of shear strength parameters along the failure surface corresponding to different possible groundwater levels at the time of the failure. The information used in these analyses was obtained from the published survey maps, post-failure topographical survey and ground investigation, laboratory tests, and field observations and measurements.

A cross-section of the August 2005 landslide site and the input parameters adopted in the analyses are shown in Figure 20. The pre-failure ground profile within the failed area was interpolated from the detailed topographic survey of the two flanks of the landslide undertaken after the failure. The thickness and extent of domestic refuse was estimated from

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

Table of Contents (English)

the volume of refuse at the toe of the failure scar, aerial photographs and eye-witnesses' accounts. The geological profile of the analysed failure surface, which corresponds to the initial failure, was determined from field mapping, ground investigation information and eye-witnesses' accounts. The possible local over-steepening observed from the 1964 aerial photographs and deduced from field mapping (Section 3) was also incorporated in the section analysed. A range of depths of groundwater level was assumed in the analyses to simulate the possible range of groundwater conditions at the time of failure.

The results of the analyses are presented in Figure 20 for a range of shear strength parameters of c' = 0 to 10 kPa and ϕ' = 28° to 35°. The results indicate that for the likely ranges of shear strength parameters on the failure surface, a groundwater level that is about 1.5 m to 2.5 m below ground level would have been sufficient for the failure to occur. With shear strength parameters of c' = 0 kPa and ϕ' = 35° derived from laboratory tests, a groundwater level about 1.9 m below ground level would have been sufficient for the failure to occur. This is generally consistent with the field observations and the groundwater monitoring results, suggesting that the theoretical stability analyses with the above assumptions are credible.

Once toe support was removed as a result of the initial failure, the upper steeper section of the hillside was liable to fail in a retrogressive manner. This is consistent with the eye-witnesses' accounts and the field observations.

9. DIAGNOSIS OF THE CAUSES OF THE LANDSLIDE

The close correlation between the severe rainfall and the timing of the collapse suggests that the 20 August 2005 landslide was triggered by rainfall. The failure occurred within natural material on a disturbed hillside of marginal stability. The subject hillside has been modified and disturbed by human activities, which contributed to making it more susceptible to rain-induced failure.

The rainfall preceding the landslide was prolonged and intense, with a return period of about 100 years. The rainstorm was the most severe in the area in the last 22 years for medium-duration and long-duration rainfall. The hillside had previously been subjected to more severe short-duration rainfall than that associated with the August 2005 rainstorm without any failure.

The subject hillside was assessed as being vulnerable to landslides by the GEO in 1992 under the NDC Programme, and NDC recommendations were made to clear the adjacent affected squatter structures on slope safety grounds. However, the occupants of the affected squatter structures opted to stay put and refused the re-housing arrangement offered by the HD. Warning signage of landslide danger had been erected by the GEO within and in the vicinity of the failed hillside prior to the August 2005 landslide, and Landslip Warning was issued at the time of the failure.

The location of the landslide coincided with an area where uncontrolled and significant refuse dumping probably took place after mid-1970s. Also, the geomorphological setting indicates that the affected hillside was undercut and generally over-steepened by the streamcourse in the past. Furthermore, evidence from API indicates the affected hillside may have been locally over-steepened near the lower portion of the landslide area. The

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

properties and soil-water characteristic of the near-surface materials provided a hydrogeological setting that was conducive to the development of groundwater pressure following rainfall. The presence of refuse that contains organic matter and fibrous materials probably provided an unfavourable hydraulic boundary, which promoted retention of moisture in the ground mass for a substantial period of time and substantial recharge following prolonged rainfall, hence contributing to wetting up of the near-surface materials, reducing soil suction and leading to development of positive groundwater pressure. Reference to the rate of response of tensiometers at different depths following the rainstorm in September 2005 indicates that the ground mass is likely to be less susceptible to the build-up of significant groundwater pressure due to intense short-duration rainfalls as compared with heavy, long-duration rainfalls. This may explain why the subject hillside did not experience any failure or distress in the decades following the uncontrolled (illegal) refuse dumping in the mid-1970s. Overall, there is no evidence of progressive deterioration of the hillside condition (e.g. development of tension cracks, etc.) having played a key role in causing the August 2005 landslide.

The tensiometer readings indicate that the soil-water characteristics of the ground mass response are such that the response to rainfall in the near-surface materials can take several days to fully realise and the rate of recovery of the pre-rainfall suction values can be even slower. The nature of the prolonged and severe rainfall, coupled with the soil-water characteristics of the ground mass, was probably conducive to the gradual build-up of high groundwater pressure in the near-surface materials over a fairly significant area. This corroborates with the field observations made shortly after the failure and the theoretical stability analyses.

The various potential sources of water ingress into the landslide area have been examined. Based on the detailed investigation, there is no evidence of leakage from the water pipes along the footpath or from the septic tank above, prior to the landslide. There is no indication of the footpath having acted as a channel bringing surface water flow from the uphill areas, and there is also no evidence of any concentrated overspilling of surface water from the footpath onto the landslide area. Furthermore, no uncontrolled discharge of surface water or sewage was directed towards the landslide area. Hence, the main source of water ingress was probably direct rainfall infiltration into the heavily vegetated hillside, together with subsurface seepage flow from the uphill areas.

The mechanism of the landslide involved progressive reduction of the suction in the ground mass due to ingress of rainwater, followed by the build-up of positive water pressures in the near-surface materials through non-vertical seepage flow within the heterogeneous ground mass (the possibility of perching of water level at the shallow depths in local areas cannot be precluded). There were no obvious signs that the landslide was structure-controlled, and the observational evidence suggests that it was not the result of reactivation of a relict failure. The instability comprises a typical rain-induced failure, with the failure surface located just below the colluvium/CDGd interface and exploiting the weaker upper horizon of the weathering profile where it starts to grade into a residual soil.

The mobility of the primary failure (with a travel angle of 20°) appears to be higher than that associated with landslides with a failure mechanism involving a sliding instability. This is likely to be due to the influence of the uncontrolled discharge of a large amount of water from the broken water main on the footpath due to the landslide.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

10. CONCLUSIONS

It is concluded that the August 2005 landslide at Fu Yung Shan Tsuen was triggered by rainfall. The landslide was probably caused by the loss of soil suction and transient build-up of groundwater pressure in the near-surface materials, following prolonged and intense rainfall, with a return period of about 100 years, that preceded the failure.

The following were diagnosed as contributory factors in the landslide:

(a) the properties and soil-water characteristic of the near-surface materials provided a hydrogeological setting that was conducive to the development of groundwater pressure in the near-surface materials following rainfall;

(b) the uncontrolled and illegal dumping of domestic refuse (comprising organic matter and fibrous materials with the capacity to retain water for a substantial period of time) over a significant portion of the subject hillside, gave rise to an unfavourable hydraulic boundary condition that probably promoted the build-up of high groundwater pressure over a large volume of the ground mass following prolonged and intense rainfall; and

(c) the over-steepening of the toe of the subject hillside, as inferred generally from the geomorphological setting, and locally from the 1964 aerial photographs and the presence of a break in slope on the adjacent unfailed hillsides, probably rendered the subject hillside more susceptible to rain-induced landslide.

11. REFERENCES

Evans, N.C. & Yu, Y.F. (2001). Regional Variation in Extreme Rainfall Values. Geotechnical Engineering Office, Hong Kong, 81 p. (GEO Report No. 115).

Geotechnical Control Office (1986). Sha Tin: Solid and Superficial Geology, Hong Kong Geology Survey, Map Series HGM20, Sheet 7, 1:20 000 scale. Geotechnical Control Office, Hong Kong.

Geotechnical Control Office (1988). Guide to Rock and Soil Descriptions (Geoguide 3). Geotechnical Control Office, Hong Kong, 186 p.

Geotechnical Engineering Office (2001). Model Specification for Soil Testing - Geospec 3. Geotechnical Engineering Office, Hong Kong, 340 p.

Irfan, T.Y. (1996). Mineralogy, fabric properties and classification of weathered granite rocks in Hong Kong, Quarterly Journal of Engineering Geology, vol. 29, pp 5-35.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

King, J.P. (1999). Natural Terrain Landslide Study - The Natural Terrain Landslide Inventory. Geotechnical Engineering Office, Hong Kong, 127 p. (GEO Report No. 74).

Lam, C.C. & Leung, Y.K. (1994). Extreme Rainfall Statistics and Design Rainstorm Profiles at Selected Locations in Hong Kong. Technical Note No. 86, Royal Observatory, Hong Kong, 89 p.

Peterson, P. & Kwong, H. (1981). A Design Storm Profile for Hong Kong. Technical Note No. 58, Royal Observatory, Hong Kong, 30 p.

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

Wong, H.N. & Ho, K.K.S. (1996a). Travel distance of landslide debris. Proceedings of the Seventh International Symposium on Landslides, Trondheim, Norway, vol. 1, pp 417-422.

Wong, H.N. & Ho, K.K.S. (1996b). Thoughts on the Assessment and Interpretation of Return Periods of Rainfall. Discussion Note DN 2/96, Geotechincal Engineering Office, Hong Kong, 19 p.

Table of Contents (English)

Table of Contents (English)

Table of Contents (English)

Table of Contents (English)

LIST OF TABLES

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

Table 1 - Maximum Rolling Rainfall at GEO Raingauges Nos. N03 and N38 for Selected Durations Preceding the Landslide on 20 August 2005 and Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)		End Time of Rainfall Duration (on 20 August 2005)		Estimated Return Period (Years)			
	Raingauge No. N38	Raingauge No. N03	Raingauge No. N38	Raingauge No. N03	Lam & Leung (1994)		Data of N03 in Evans & Yu (2001)	
					N38	N03	N38	N03
5 Minutes	7.5	7.5	9:15 a.m.	10:55 a.m.	<2	<2	<2	<2
15 Minutes	18.0	20.0	10:55 a.m.	11:00 a.m.	<2	<2	<2	<2
1 Hour	47.0	46.0	9:50 a.m.	11:05 a.m.	<2	<2	<2	<2
2 Hours	85.5	87.0	11:00 a.m.	11:05 a.m.	<2	<2	<2	2
4 Hours	135.5	132.0	11:45 a.m.	11:50 a.m.	3	3	3	3
12 Hours	278.0	270.0	5:25 p.m.	2:35 p.m.	9	8	17	15
24 Hours	449.0	453.5	5:25 p.m.	5:25 p.m.	25	26	32	34
48 Hours	597.5	558.5	5:25 p.m.	5:25 p.m.	51	35	49	33
4 Days	715.0	629.0	5:25 p.m.	5:25 p.m.	52	25	38	19
7 Days	833.5	711.5	11:05 a.m.	4:50 p.m.	80	29	65	26
10 Days	1062.5	810.5	5:25 p.m.	5:25 p.m.	269	37	>100	23
12 Days	1194.5	887.5	5:25 p.m.	5:25 p.m.	479	47	>100	24
15 Days	1194.5	887.5	5:25 p.m.	5:25 p.m.	254	28	65	13
31 Days	1727.0	1264.5	5:25 p.m.	5:25 p.m.	>1000	73	56	12

Notes :
(1) Maximum rolling rainfall was calculated from 5-minute rainfall data.
(2) Return periods were derived from Table 3 of Lam & Leung (1994) and using data from Evans & Yu (2001).
(3) According to the eye-witnesses' accounts, the initial landslide occurred at about 5:25 p.m. on 20 August 2005.
(4) The nearest GEO automatic raingauge to the landslide site is raingauge No. N38 located about 1.2 km to the west of the landslide site. GEO raingauge No. N03 is about 1.3 km to the east of the landslide site.

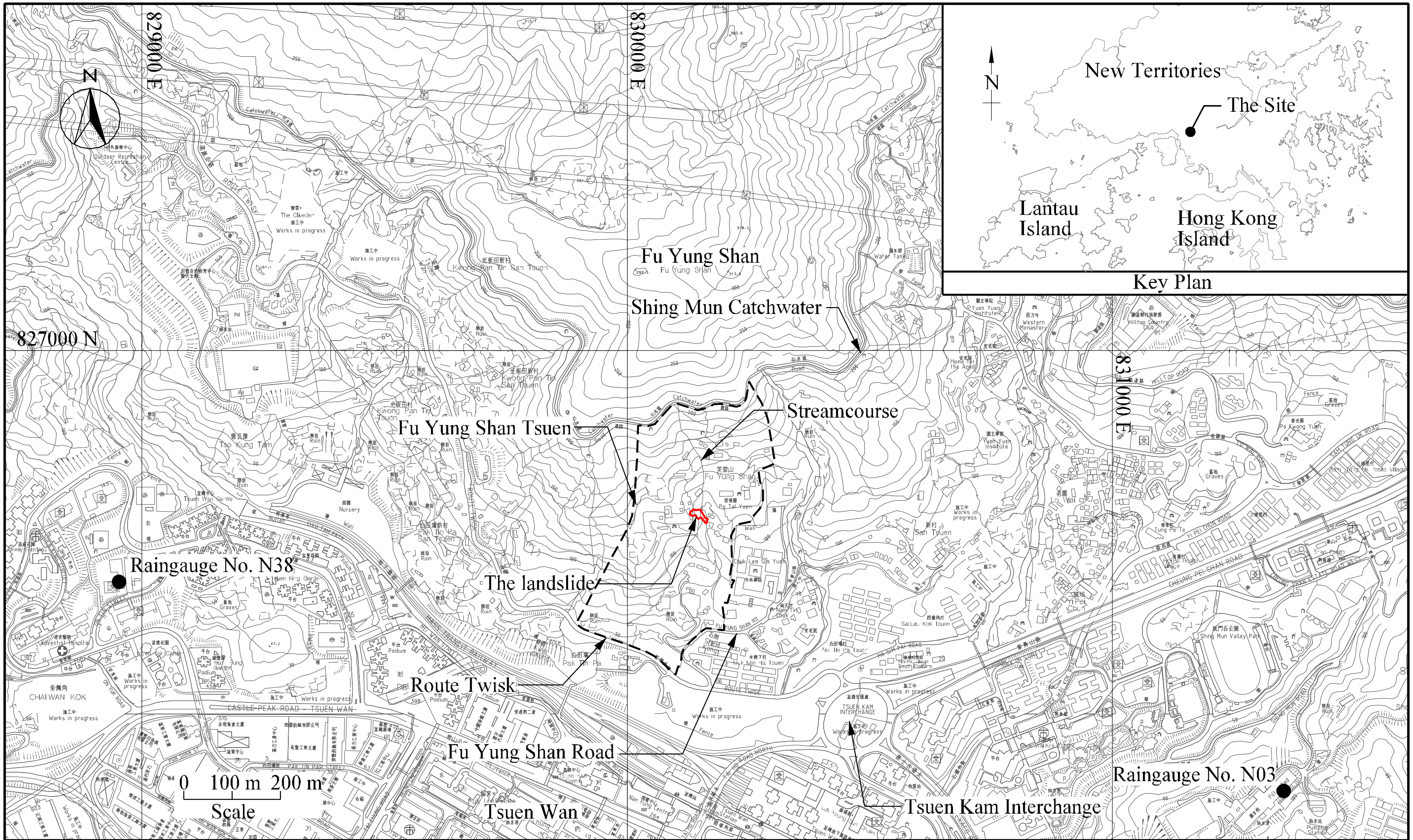
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

Table 2 - Summary of Groundwater Level Monitoring Results between October and December 2005

Drillhole No.	Ground Level (mPD)	Standpipe (Upper)			Piezometer (Lower)		
		Tip level (mPD)	Highest Measured Groundwater Level (metres below ground / mPD)	Geology of Response Zone	Tip level (mPD)	Highest Measured Groundwater Level (metres below ground / mPD)	Geology of Response Zone *
DH1	109.85	105.65	1.35 / 108.5	Colluvium	99.70	2.35 / 107.05	CDGd
DH2	123.07	120.57	Dry	Colluvium	106.34	8.64 / 114.43	CDGd
DH4	124.89	-	-	-	106.89	11.70 / 113.51	CDGd
DH5	121.10	-	-	-	101.53	14.78 / 106.32	C/HDGd
DH6	118.45	-	-	-	102.25	12.50 / 105.95	CDGd
DH7	112.53	-	-	-	98.93	5.79 / 106.74	C/HDGd
DH8	103.68	99.68	0.43 / 103.25	Colluvium	89.68	0.28 / 103.40	C/HDGd
Note:	* CDGd denoted completely decomposed granodiorite and HDGd denoted highly decomposed granodiorite.						

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

LIST OF FIGURES



Note : Base plan is extracted from 1 : 5000 survey sheets Nos. 6SE-B, 6SE-D, 7SW-A and 7SW-C dated March 2004.

Figure 1 - Location Plan

Table of Contents (English) Table of Contents (English) Table of Contents (English) Table of Contents (English)

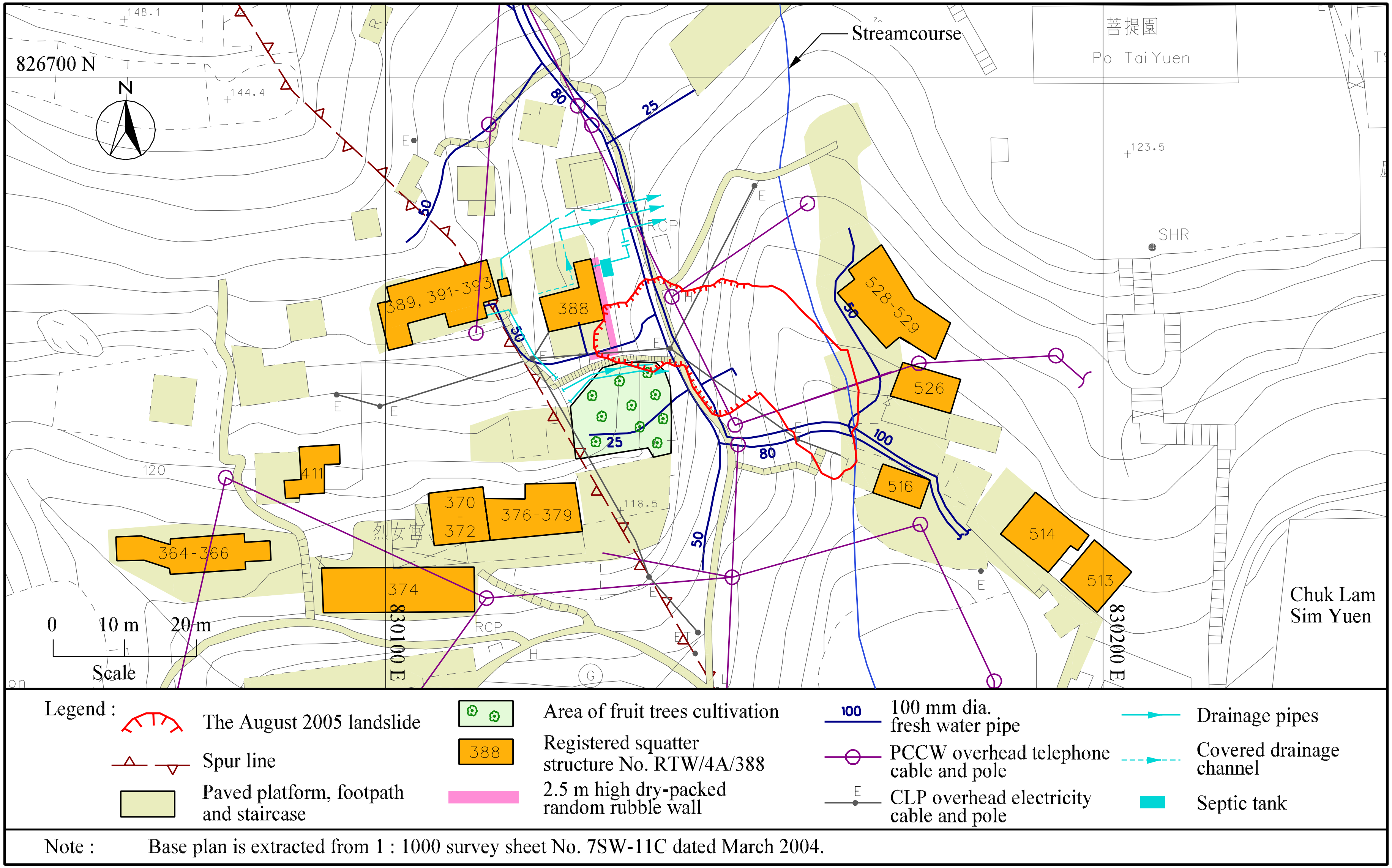


Figure 2 - Site Plan and Utilities

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

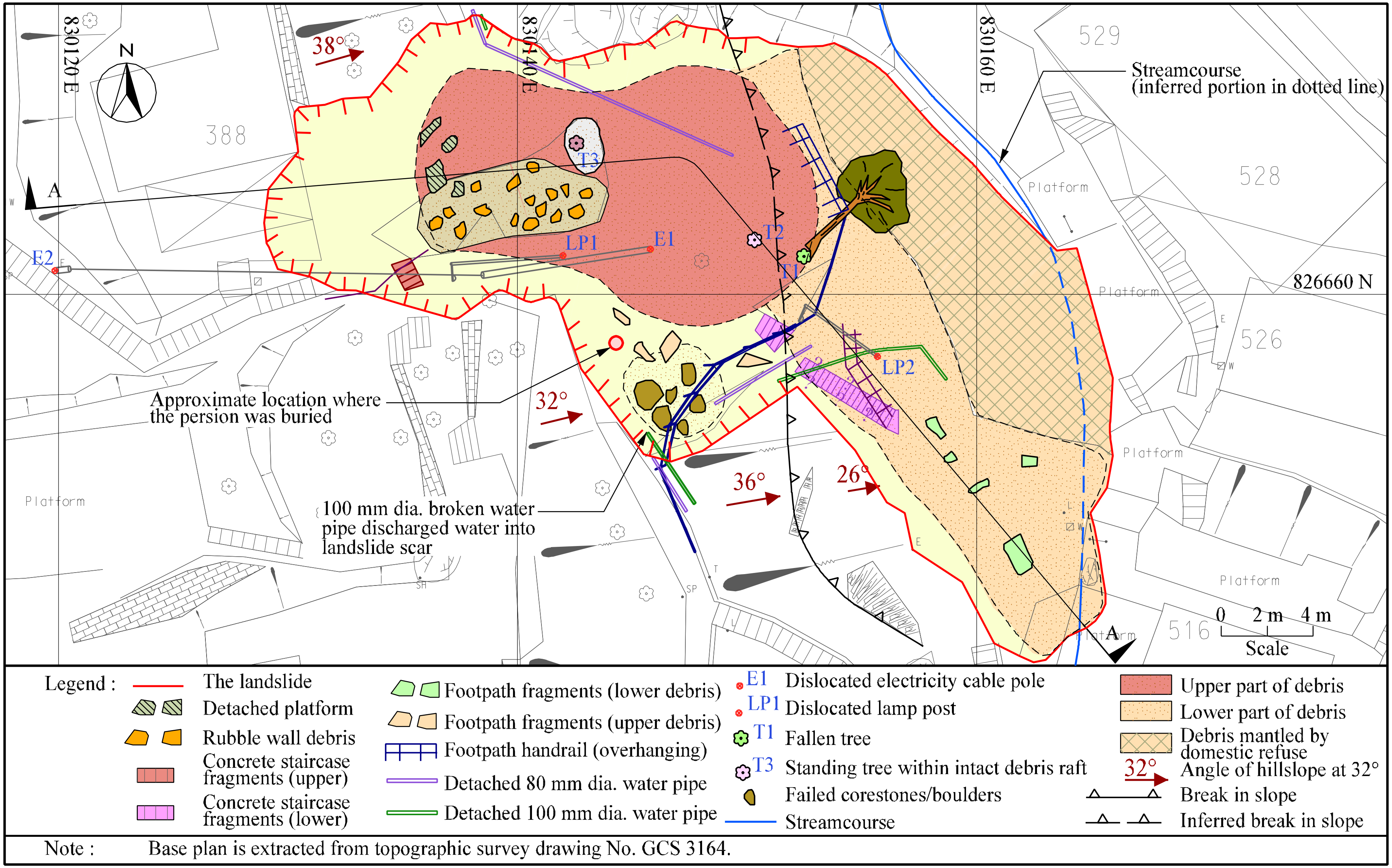
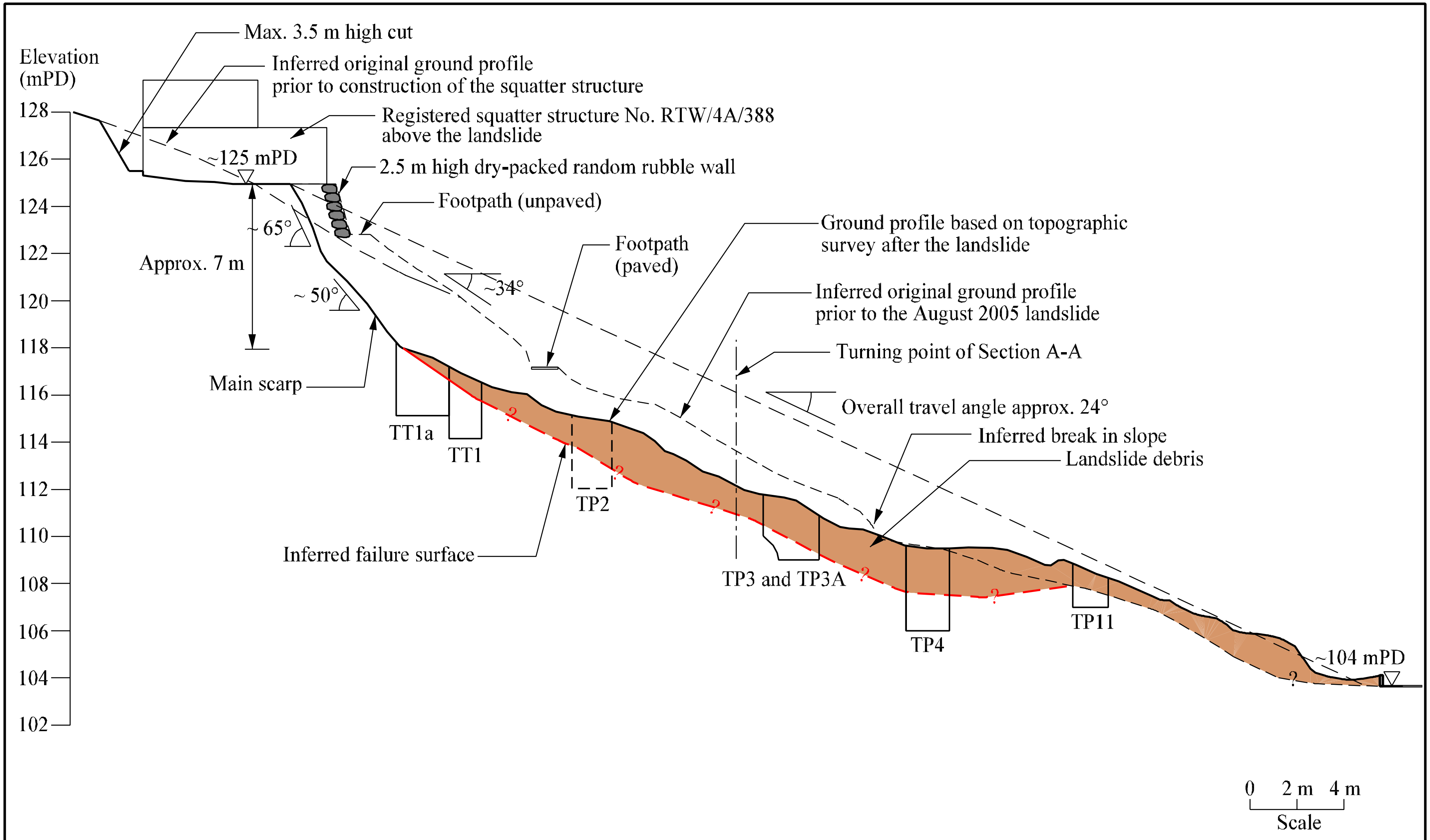


Figure 3 - Plan of the Landslide

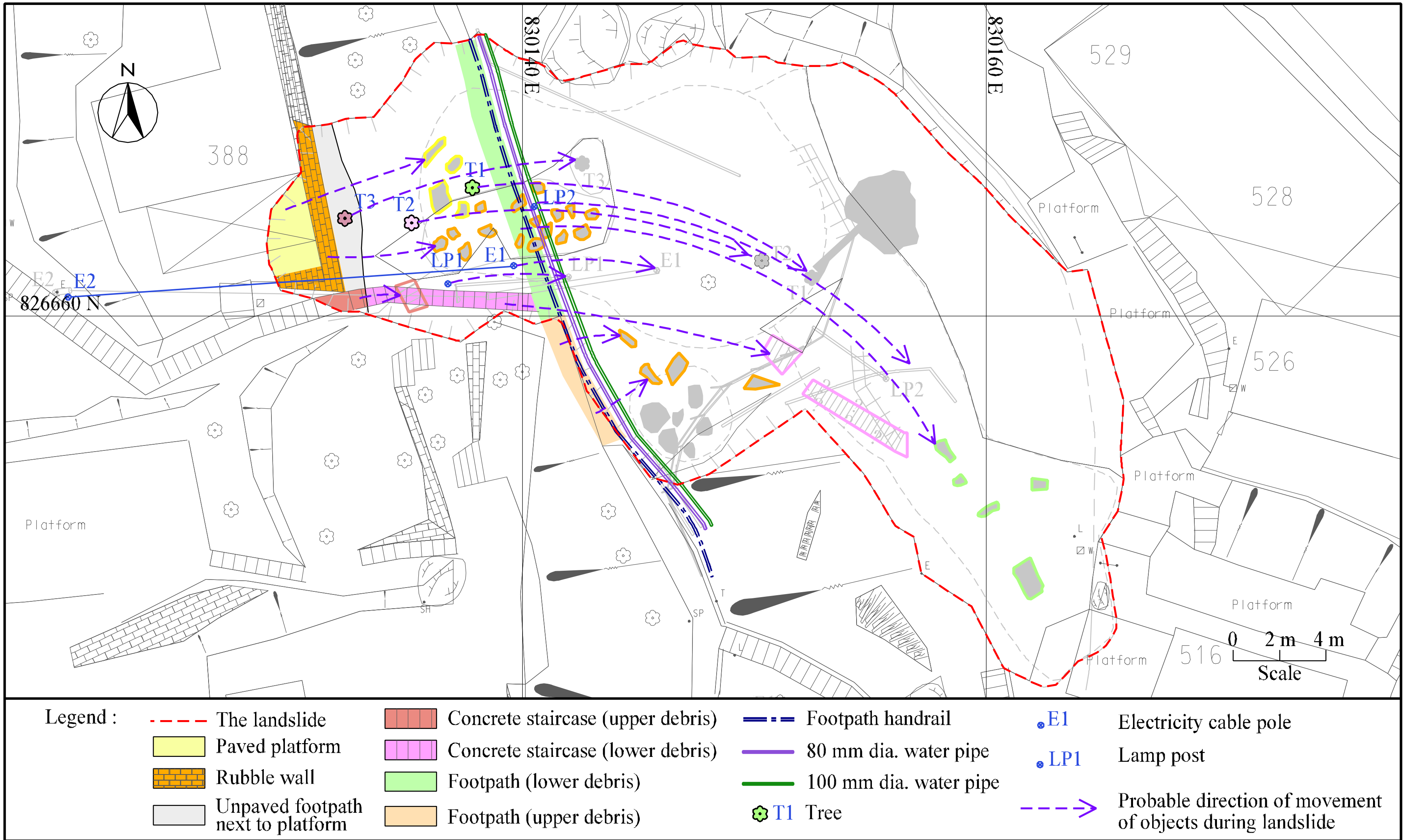
Table of Contents (English) Table of Contents (English) Table of Contents (English) Table of Contents (English)



Note : See Figure 3 for location of section and Figure 12 for geological section.

Figure 4 - Section A-A of the Landslide

Table of Contents (English) Table of Contents (English) Table of Contents (English) Table of Contents (English)



Note : Base plan is extracted for topographic survey drawing No. GCS 3164.

Figure 5 - Debris Mobility from Post-failure Observations and Eye-witnesses' Accounts

Table of Contents (English) Table of Contents (English) Table of Contents (English) Table of Contents (English)

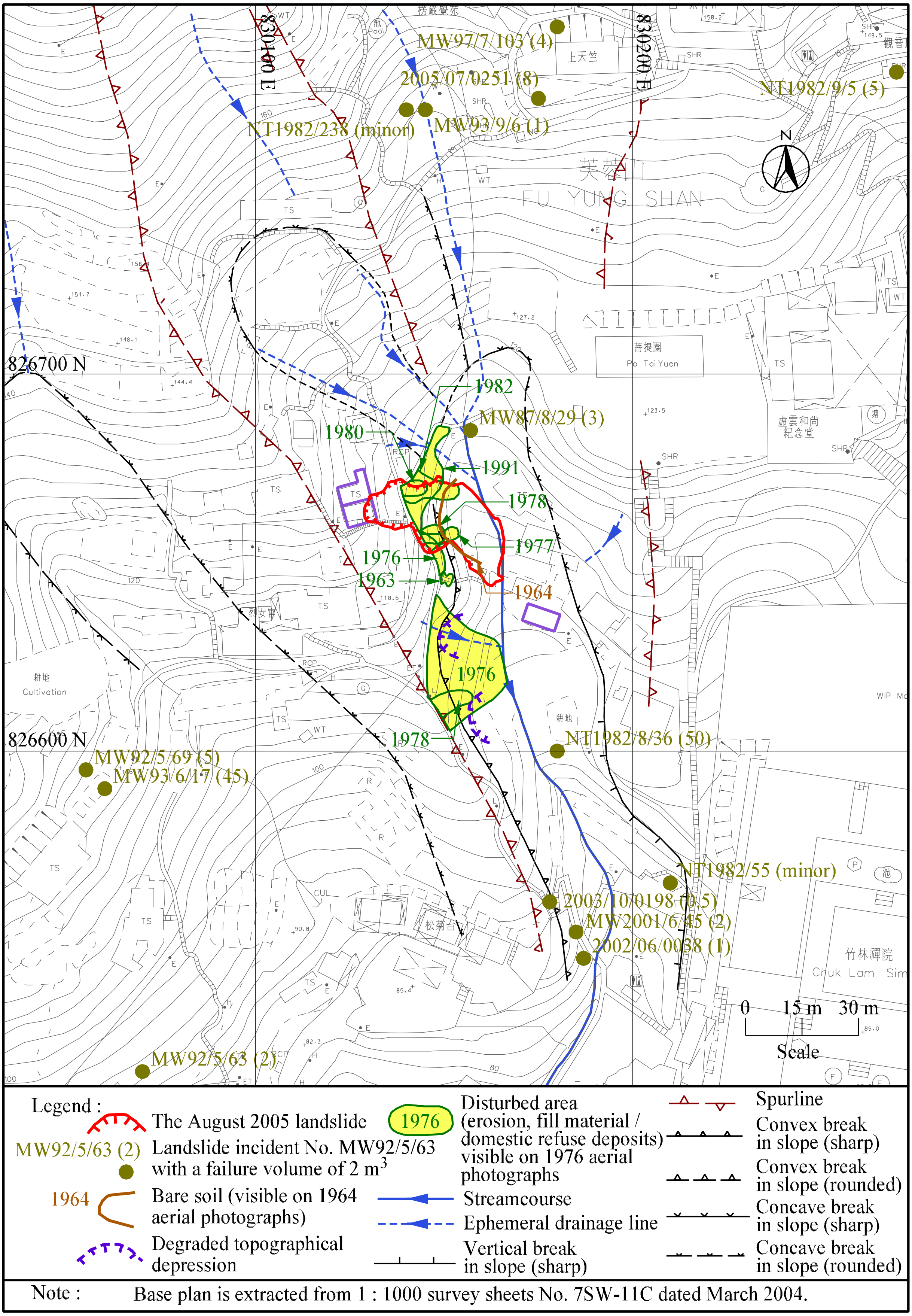
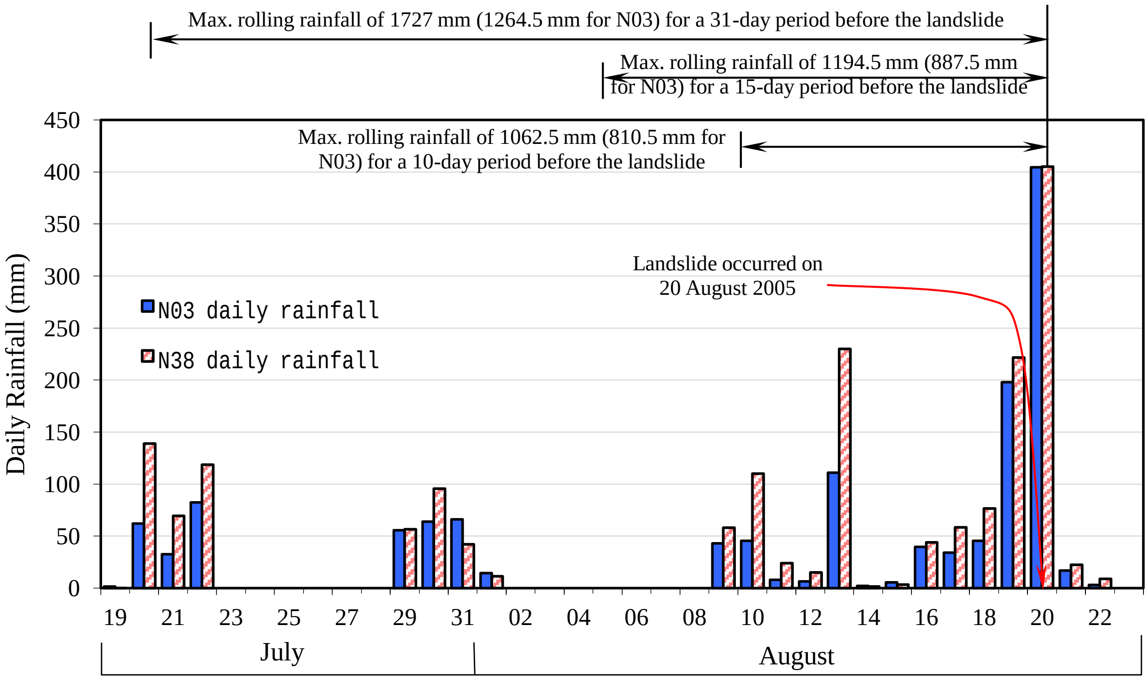
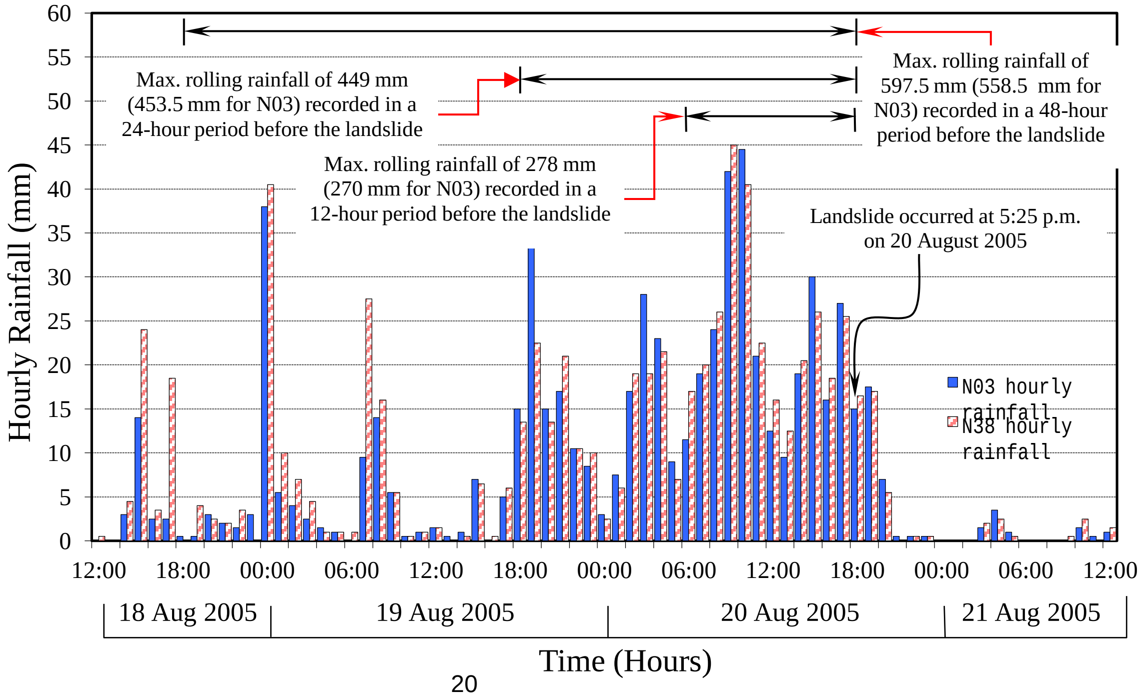


Figure 6 - Past Instabilities and Geomorphology

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)



(a) Daily Rainfall Recorded at GEO Raingauges Nos. N03 and N38 between 19 July 2005 and 23 August 2005



(b) Hourly Rainfall Recorded at GEO Raingauges Nos. N03 and N38 between 18 August 2005 and 21 August 2005

Figure 7 - Daily and Hourly Rainfall Records at GEO Raingauges Nos. N03 and N38

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

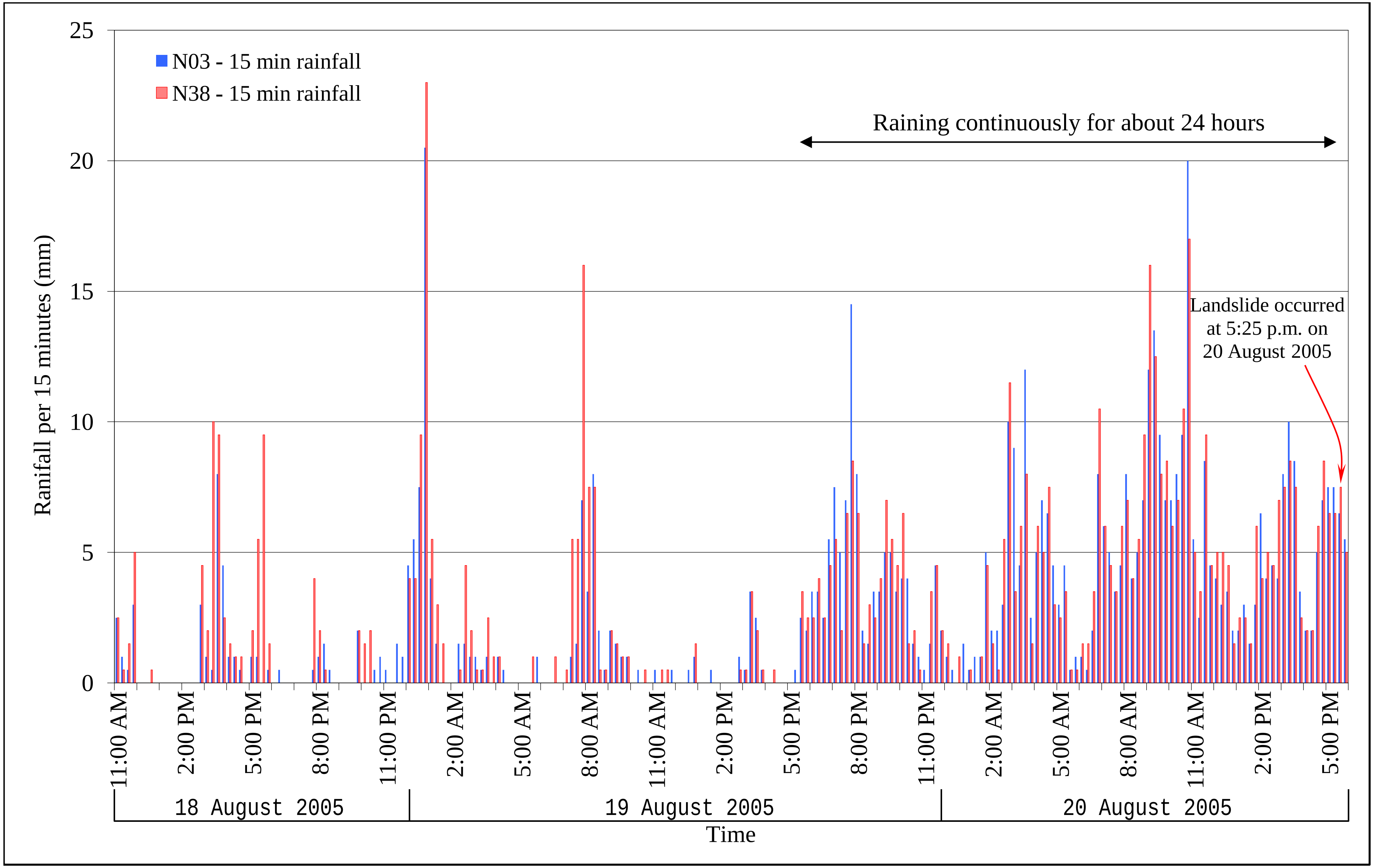
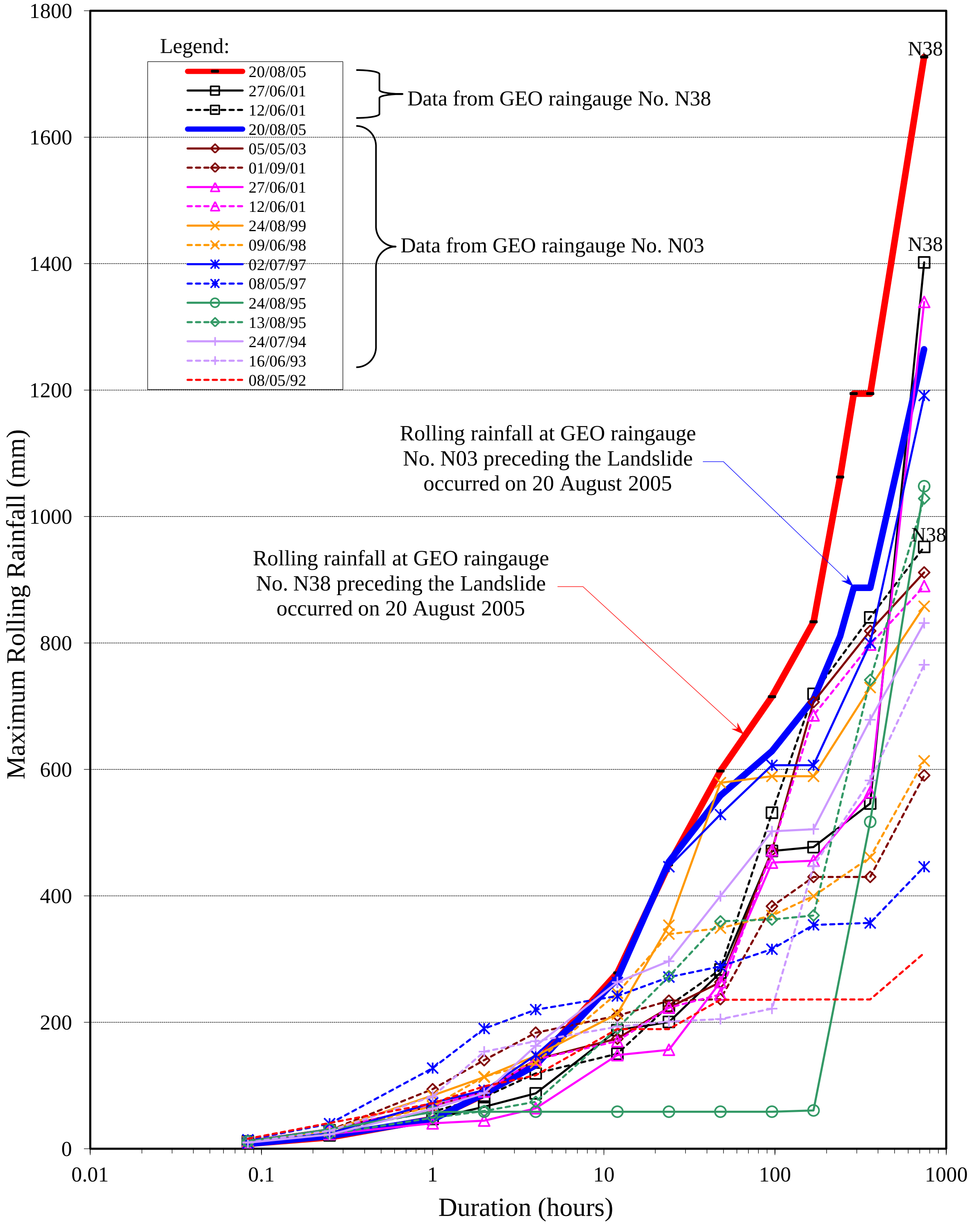


Figure 8 - 15-Minute Rainfall Records at GEO Raingauges Nos. N03 and N38

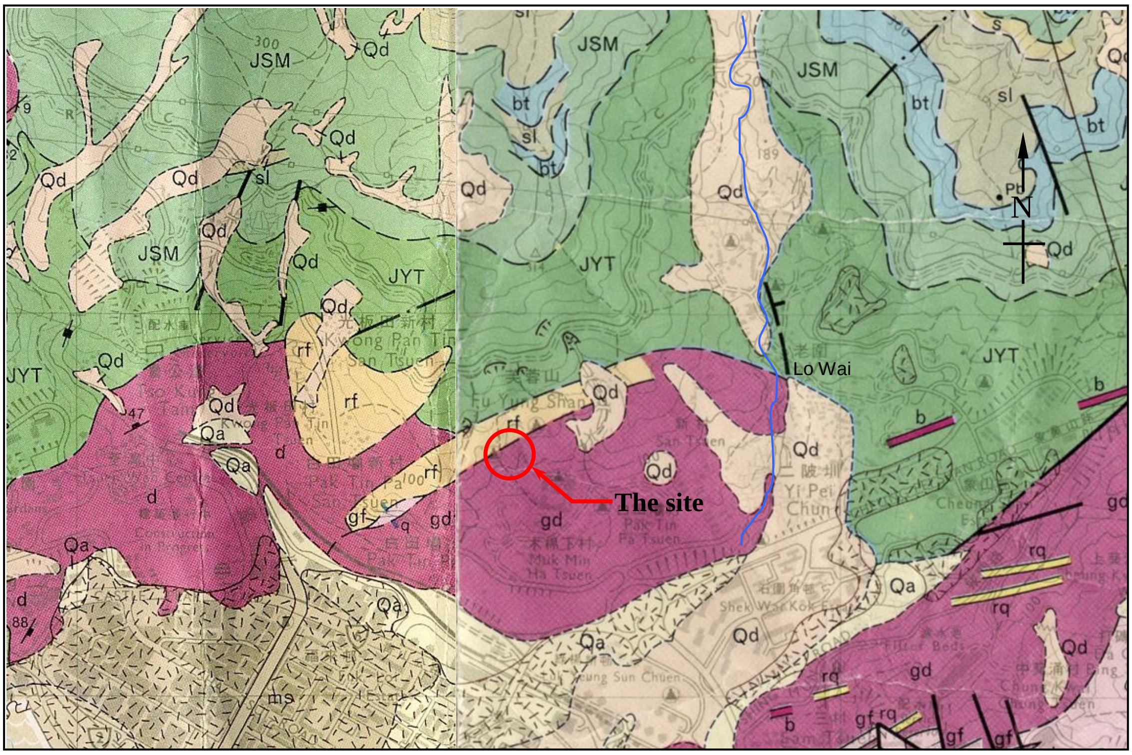


Notes: (1) Maximum rolling rainfall are evaluated from 5-minute readings from GEO raingauge No. N03 (about 1.3 km to the east of the site) and GEO raingauge No. N38 (about 1.2 km to the west).

(2) Rolling rainfall of previous rainstorms calculated at GEO raingauge No. N03 since June 1983 and at GEO raingauge No. N38 since October 1999 when the raingauges became operational.

Figure 9 - Maximum Rolling Rainfall for Previous Major Rainstorms at GEO Raingauges Nos. N03 and N38

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)



LEGEND:

0m 1000 m
Scale

SUPERFICIAL DEPOSITS

Qa	Pleistocene and Holocene Clay/silt, sand and gravel (Alluvium)	Qd	Sand, gravel, cobbles and boulders in silt matrix (Slope debris)
	Fill		

SOLID GEOLOGY

b	Basalt	JYT	Coarse ash crystal tuff (Tsuen Wan Volcanic Group)
rq	Quartzphyric rhyolite	gd	Granodiorite
rf	Feldsparphyric rhyolite		

GEOLOGICAL LINES

- Geological boundary, superficial deposits
- Geological boundary, solid rock (* Broken lines denote uncertainty)
- Fault (crossmark indicates downthrow side)
- Mineral vein
- Photogeological lineament

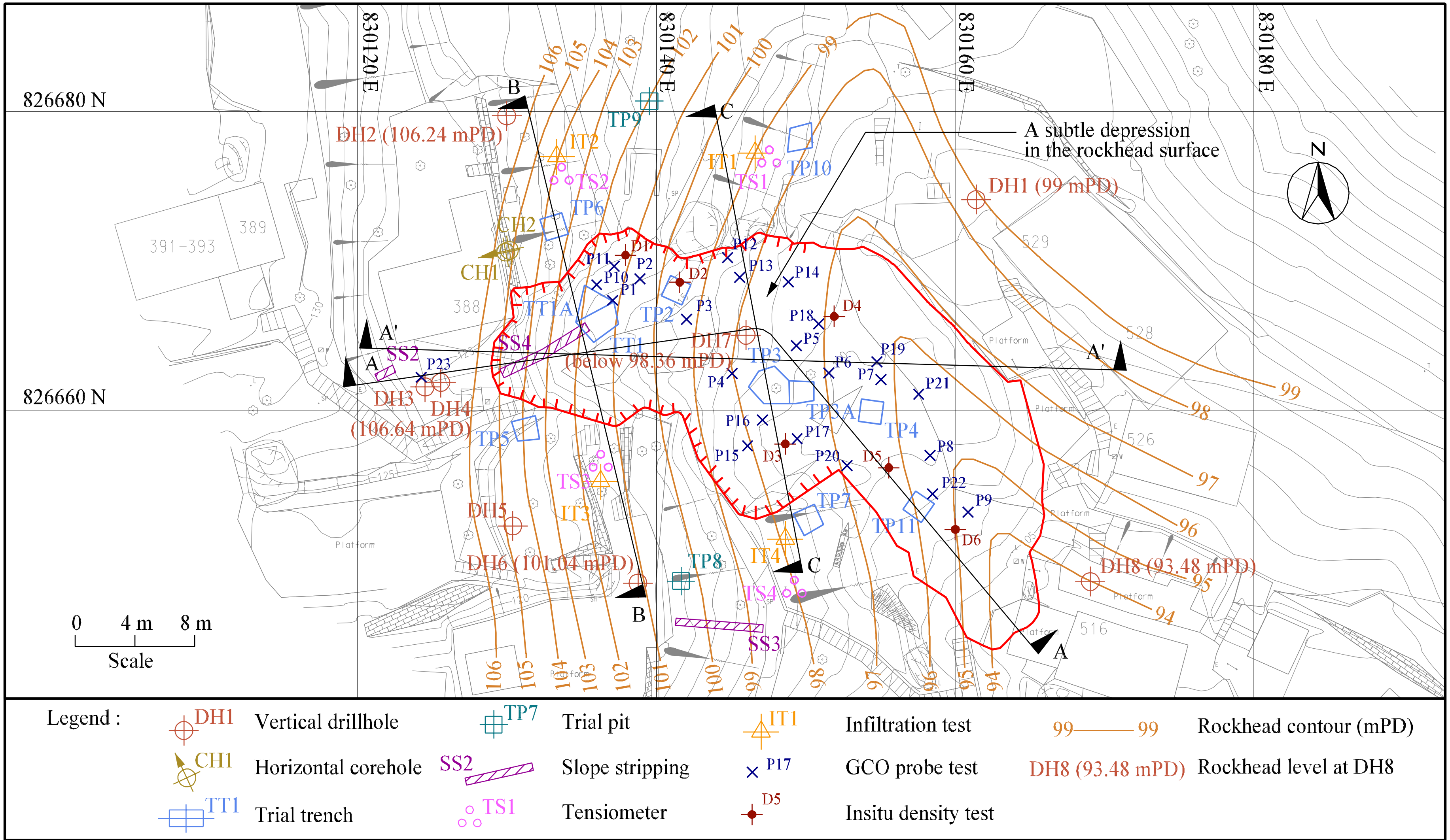
STRUCTURAL SYMBOLS

- 22 Intrusive contact
- Jointing for vertical

Note: Extracted from Hong Kong Geological Survey, Map Series HGM20, Sheets Nos. 6 and 7, 1:20 000 scale (GCO, 1986).

Figure 10 - Regional Geology

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)



Note : Ground investigation works were carried out by Inter Pacific Limited between 2/9/2005 and 25/10/2005 and by DrilTech Ground Engineering Limited between 25/10/2005 and 5/12/2005.

Figure 11 - Plan of Ground Investigation Works and Inferred Bedrock Contours

Table of Contents (English) Table of Contents (English) Table of Contents (English) Table of Contents (English)

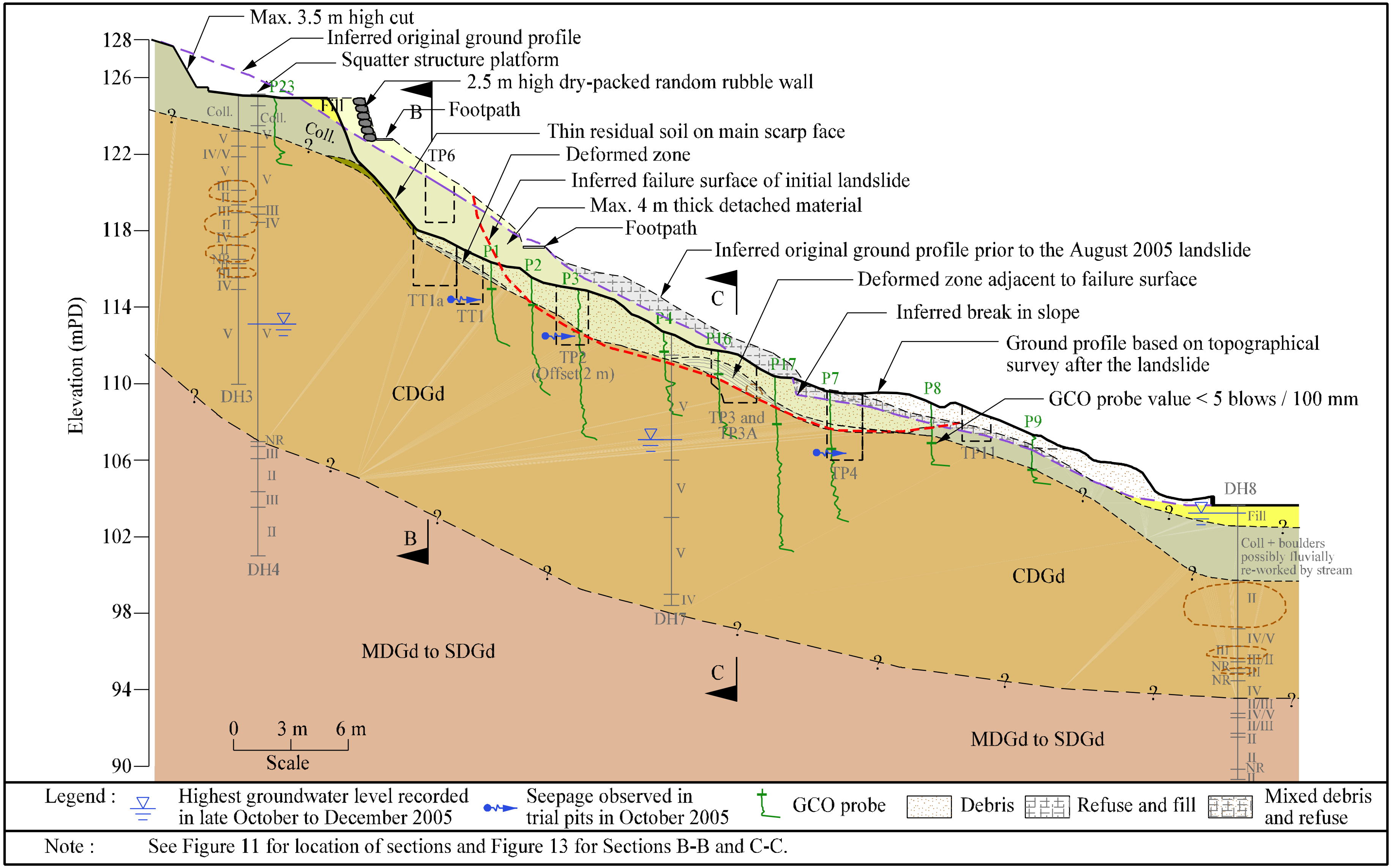
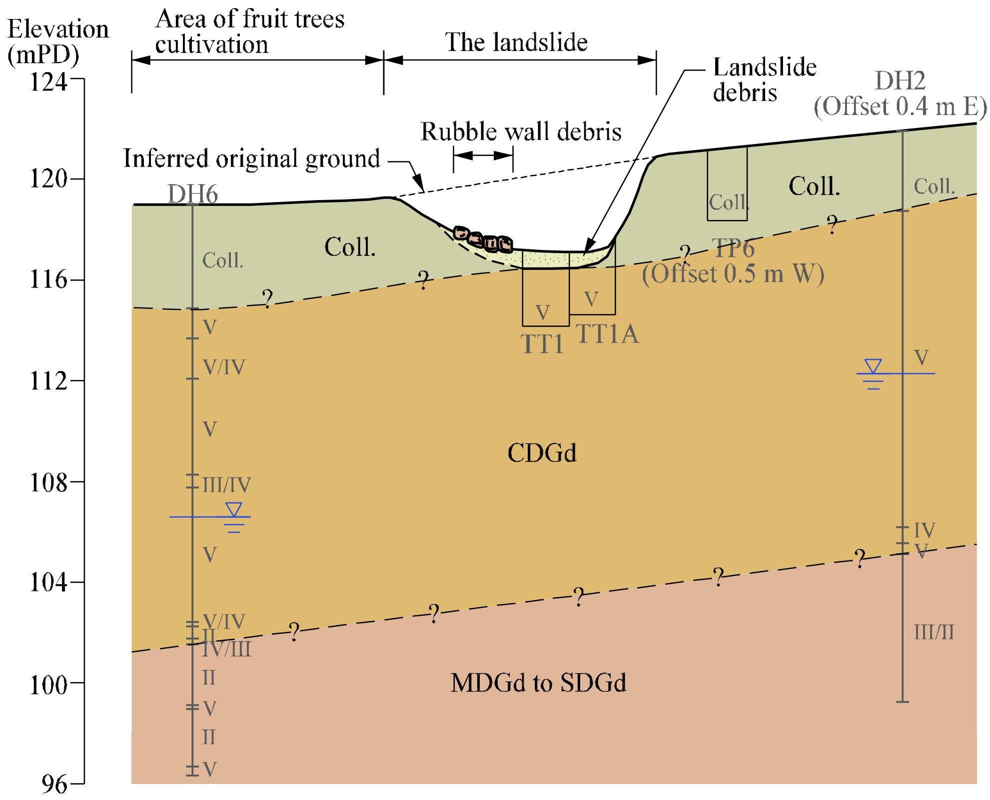
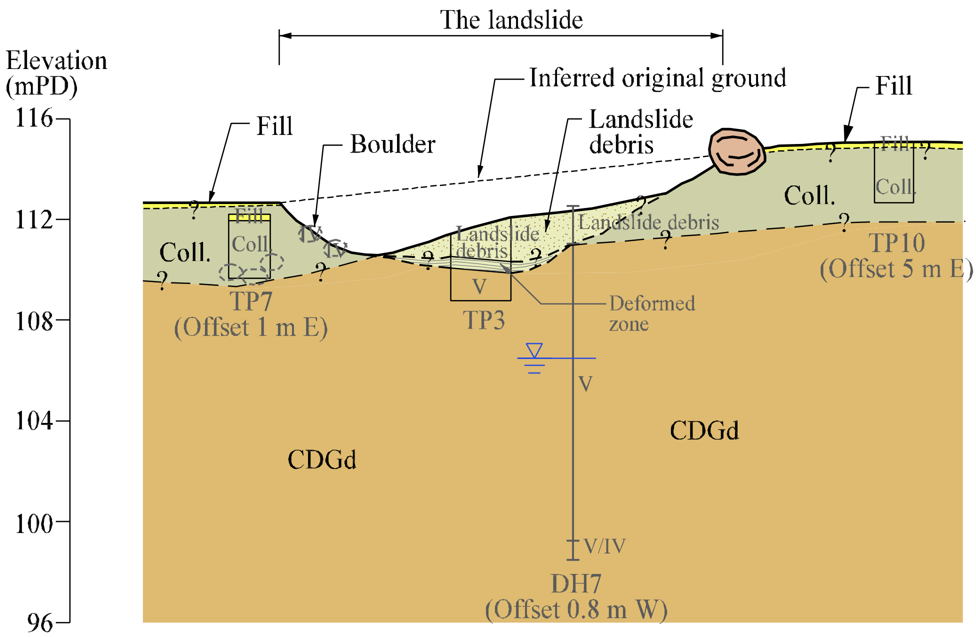


Figure 12 - Geological Section A-A of the Landslide

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)



Section B-B



Section C-C

Legend : Highest groundwater level recorded in late October to December 2005.

Note : See Figure 11 for location of sections.

Figure 13 - Geological Sections B-B and C-C of the Landslide

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

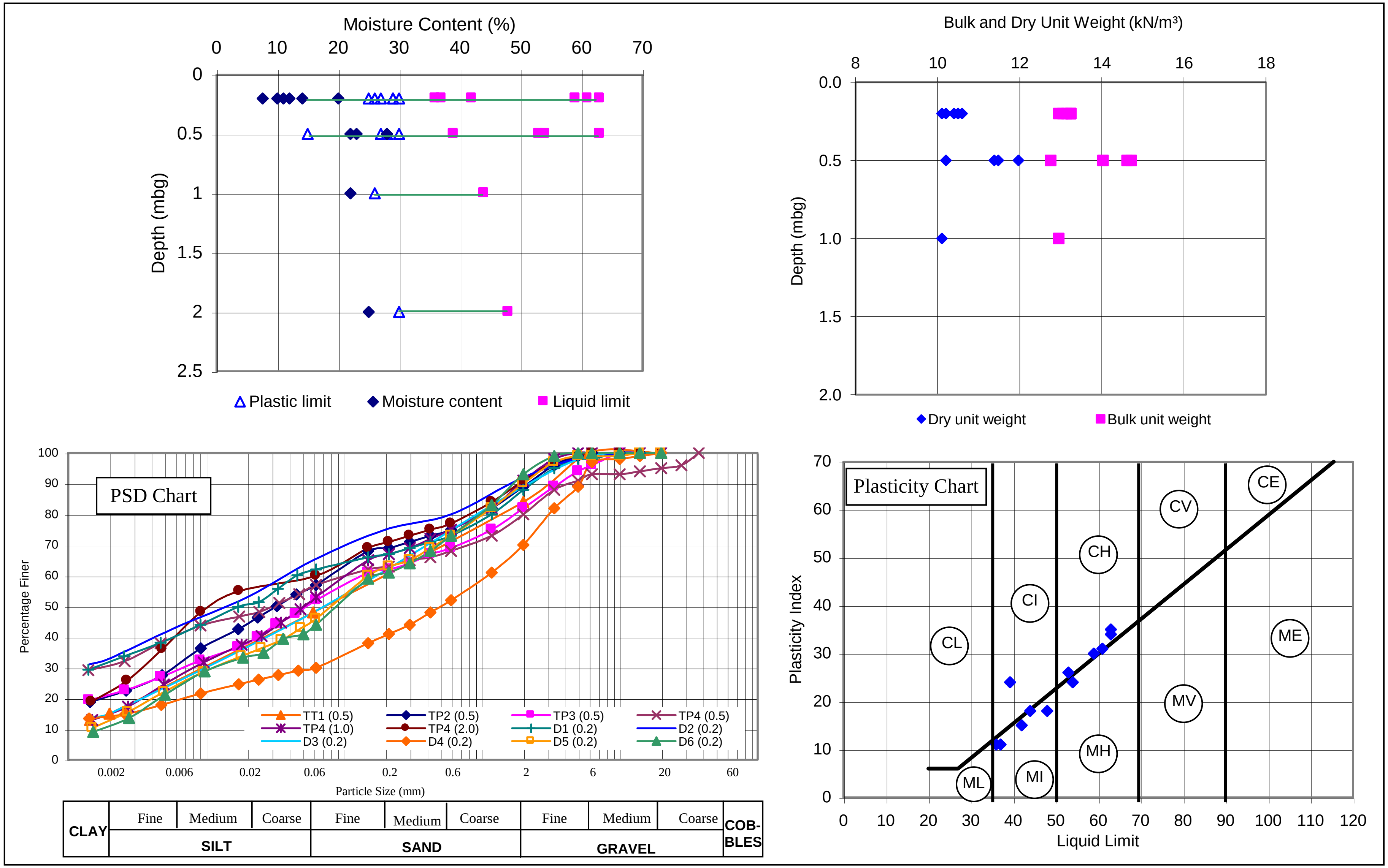


Figure 14 - Geotechnical Properties of Landslide Debris

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

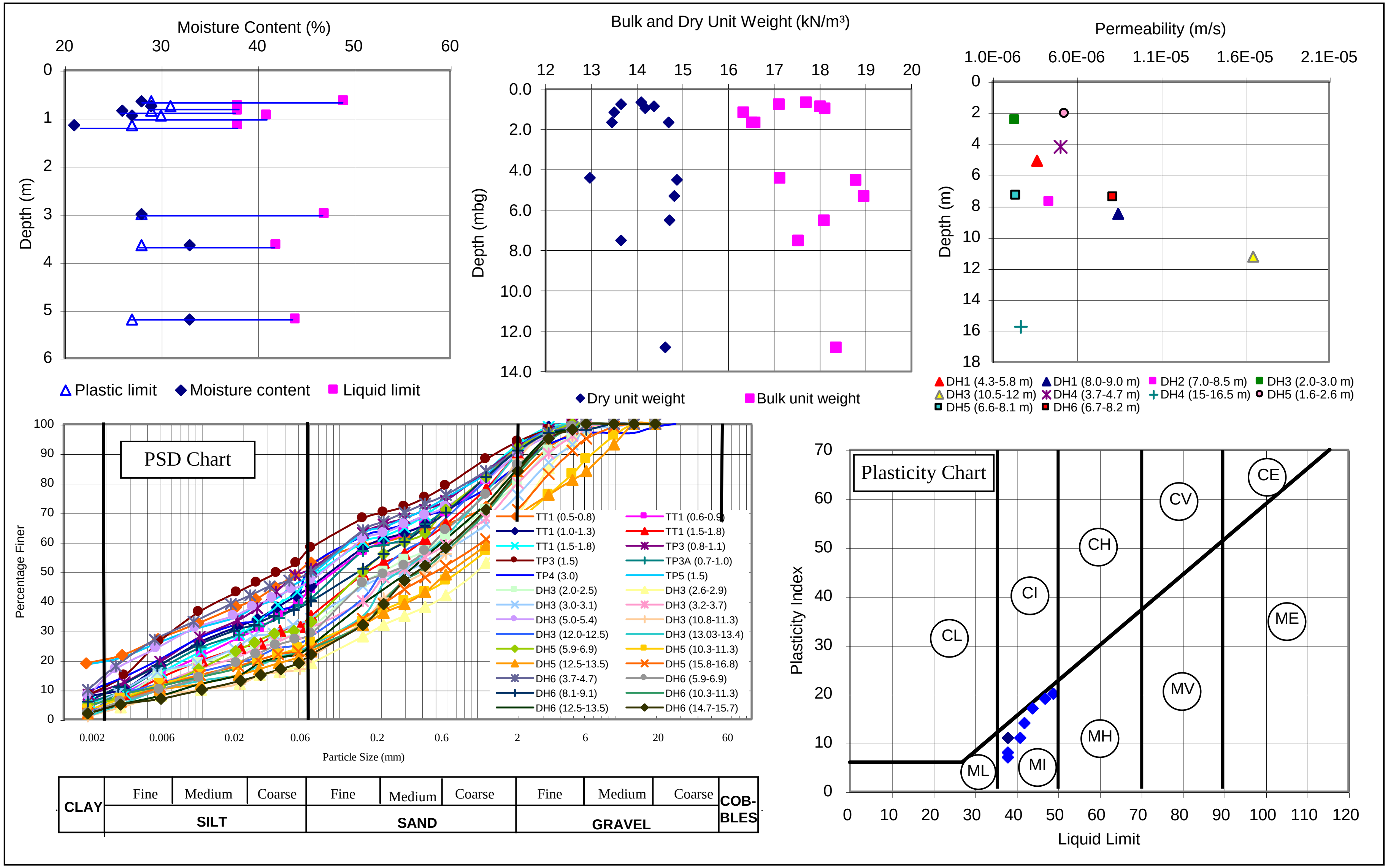
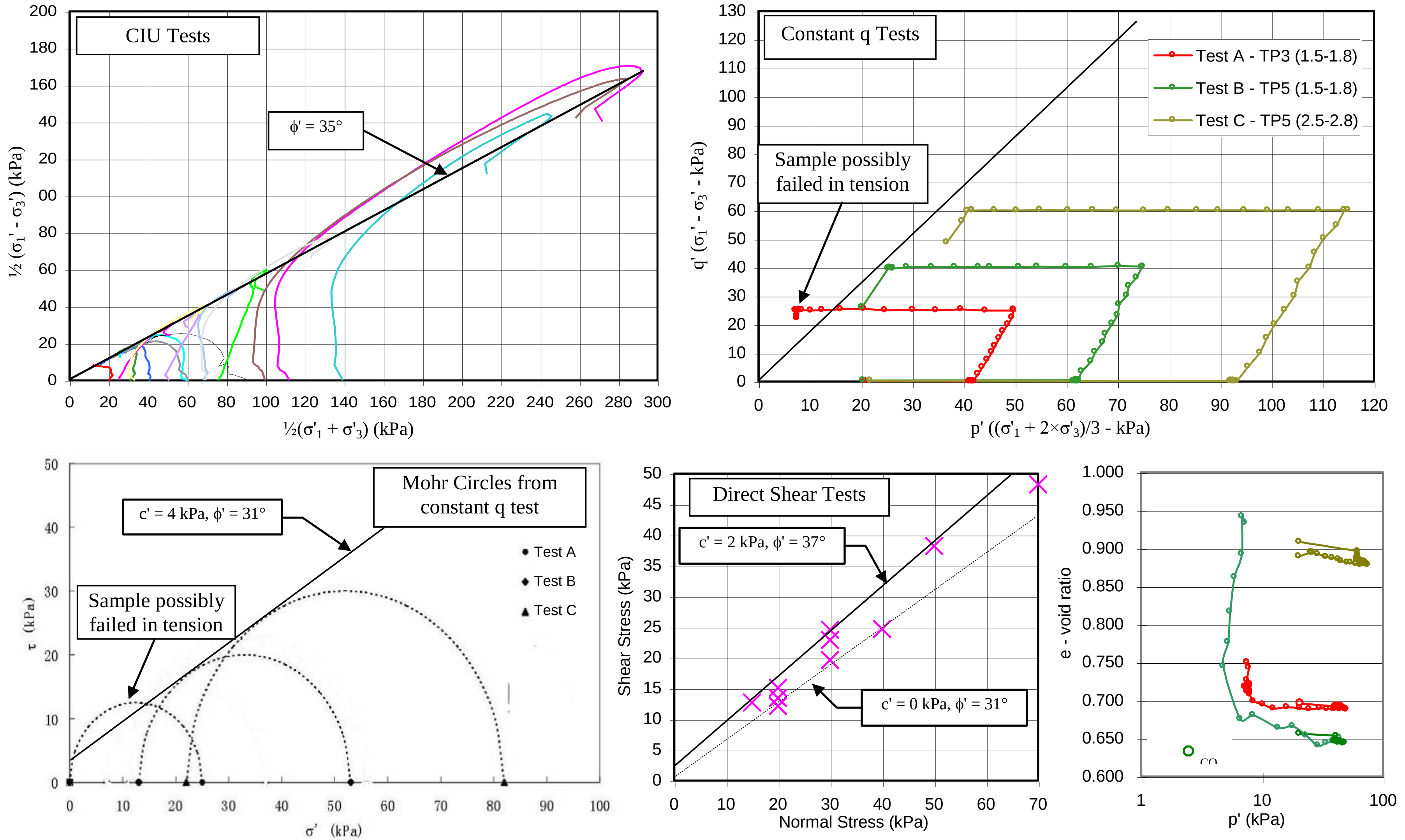


Figure 15 - Geotechnical Properties of Completely Decomposed Granodiorite (Sheet 1 of 2)

Table of Contents (English) Table of Contents (English) Table of Contents (English) Table of Contents (English)



Legend: * c' = cohesion, ϕ' = angle of shearing resistance, σ'_1 = maximum principal stress and σ'_3 = minimum principal stress.

Figure 15 - Geotechnical Properties of Completely Decomposed Granodiorite (Sheet 2 of 2)

Table of Contents (English) Table of Contents (English) Table of Contents (English) Table of Contents (English)

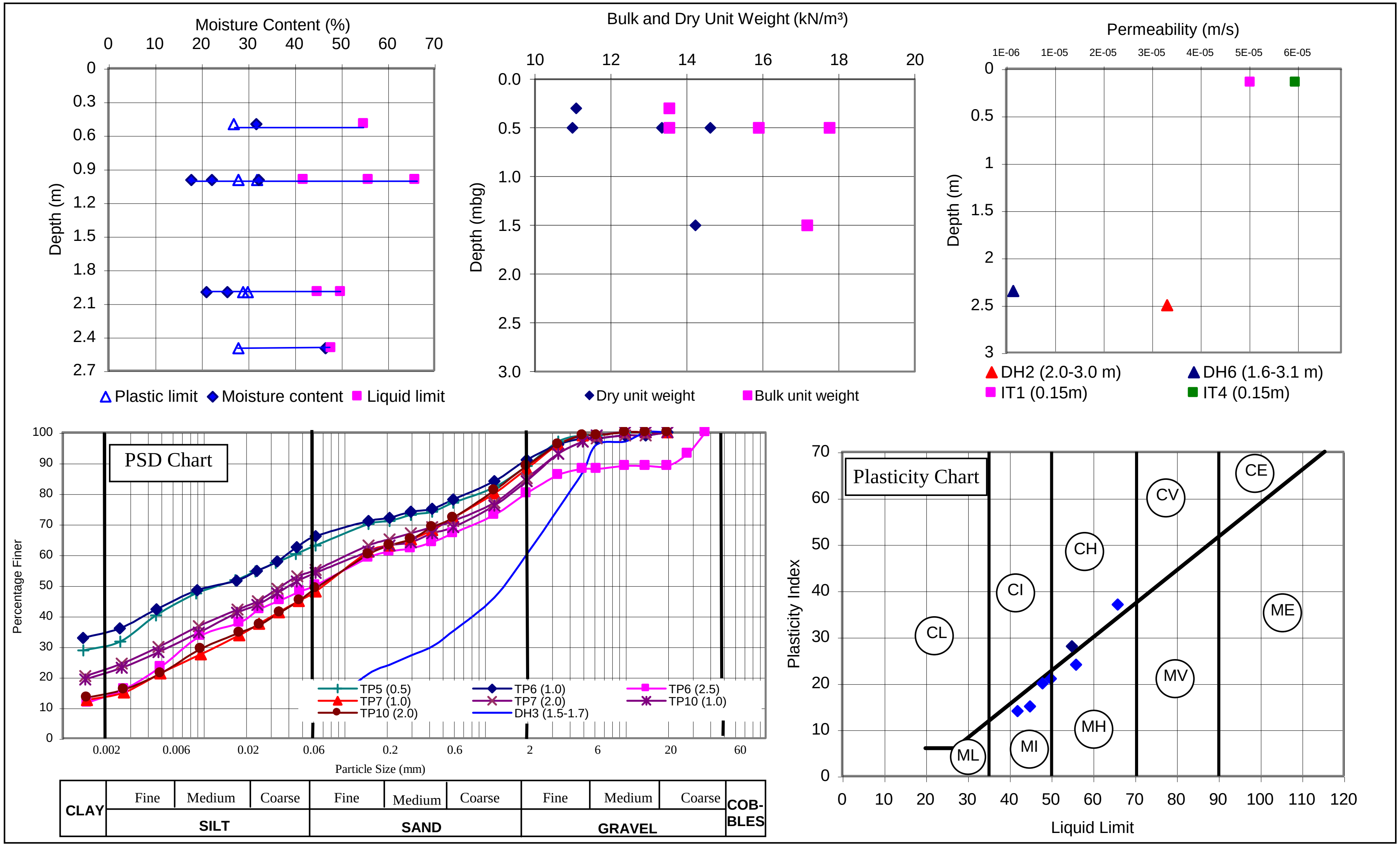
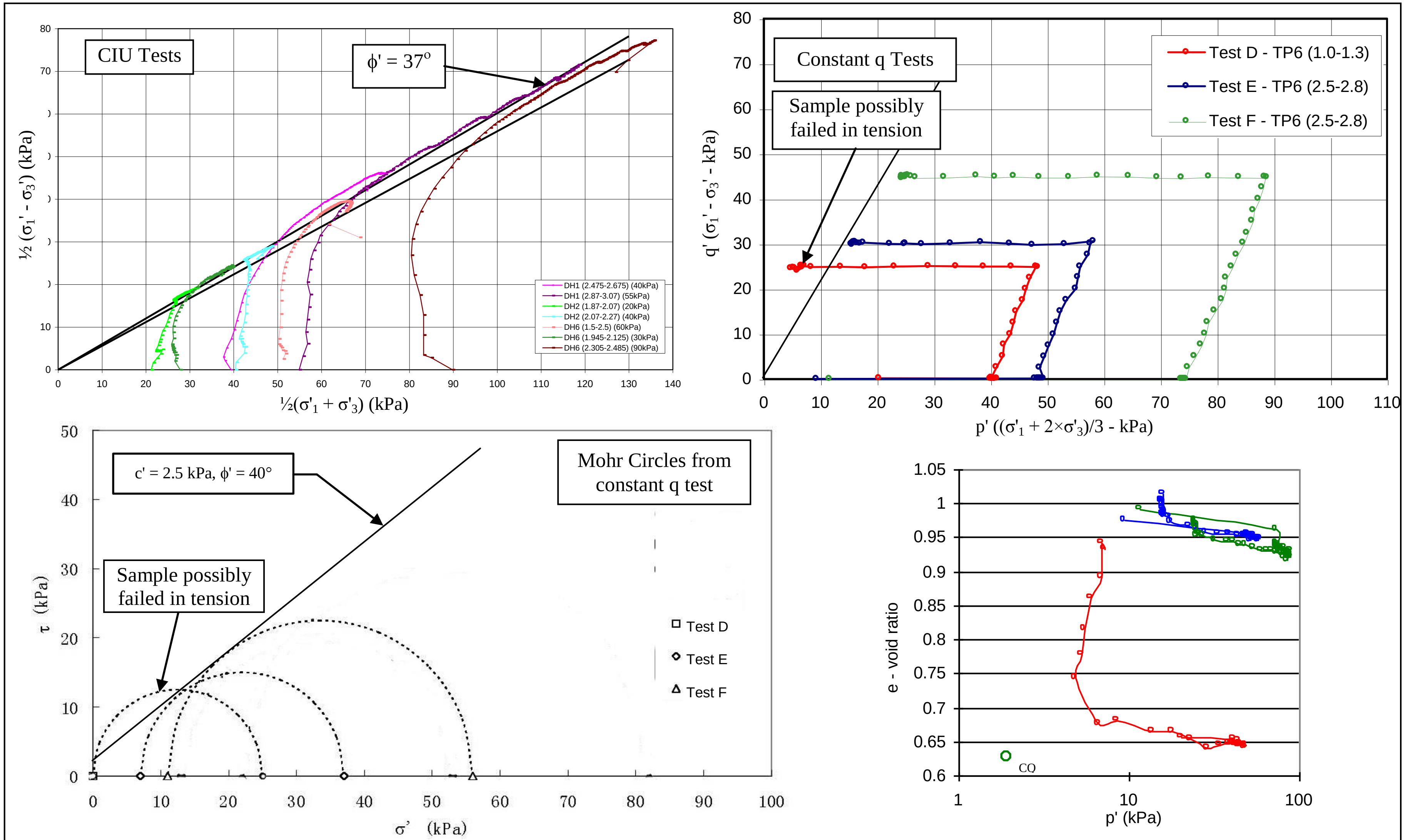


Figure 16 - Geotechnical Properties of Colluvium (Sheet 1 of 2)

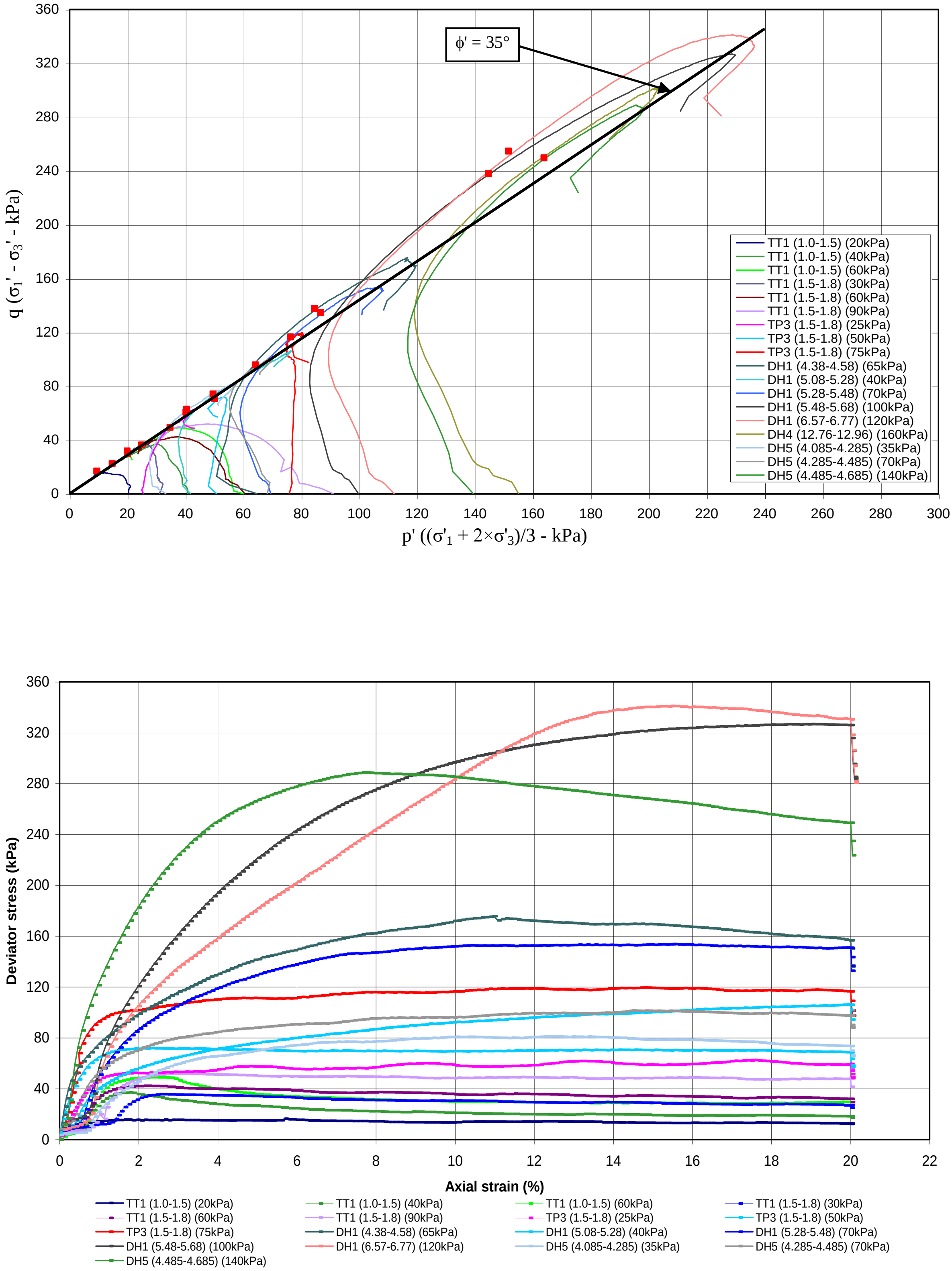
Table of Contents (English) Table of Contents (English) Table of Contents (English) Table of Contents (English)



Legend: c' = cohesion, φ' = angle of shearing resistance, σ'_1 = maximum principal stress and σ'_3 = minimum principal stress.

Figure 16 - Geotechnical Properties of Colluvium (Sheet 2 of 2)

Table of Contents (English) Table of Contents (English) Table of Contents (English) Table of Contents (English)



Legend:	σ'_1 = maximum principal stress and σ'_3 = minimum principal stress.

Figure 17 - p'-q Plot and Stress-strain Curves of CIU Tests Carried Out on CDGd

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

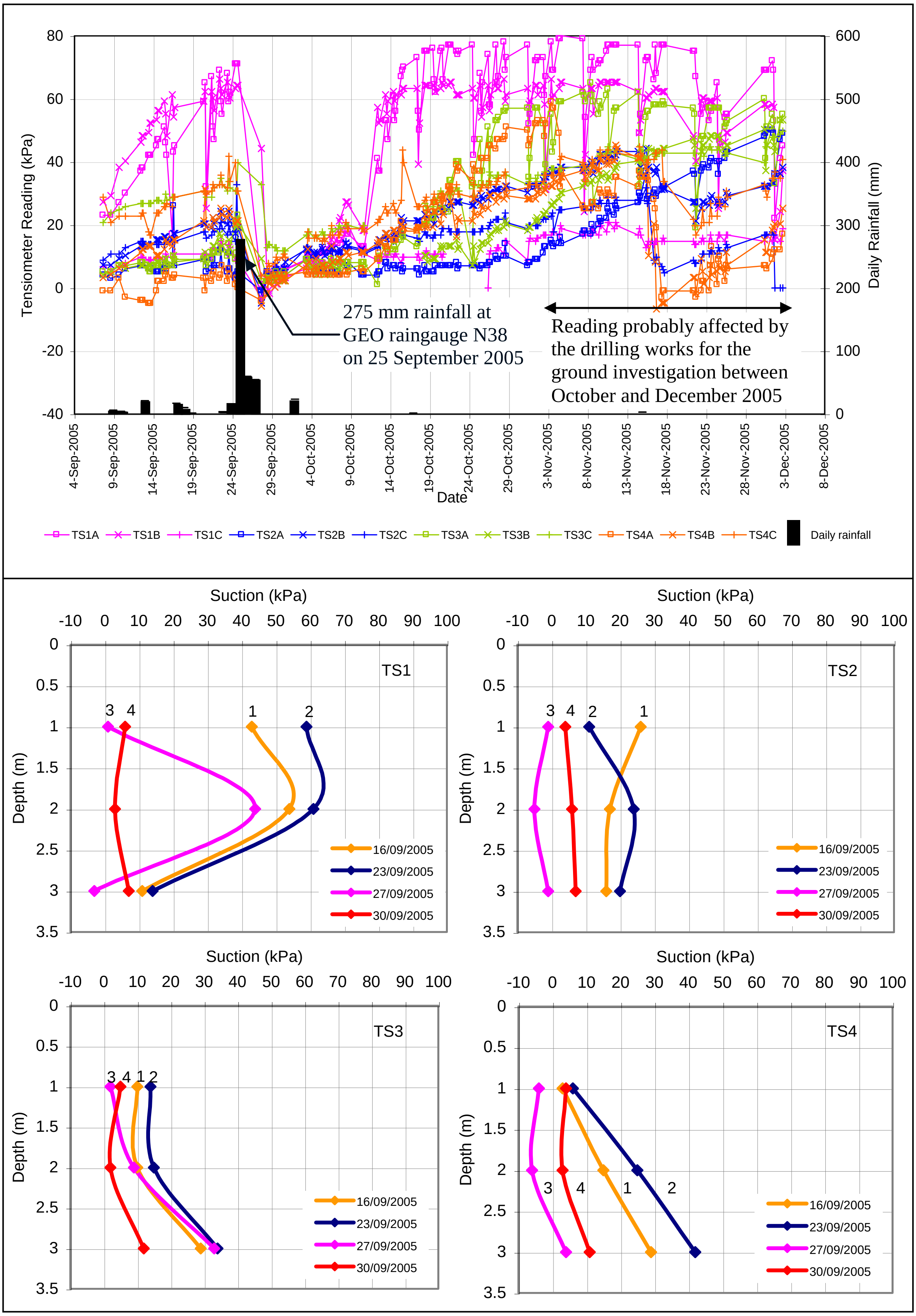
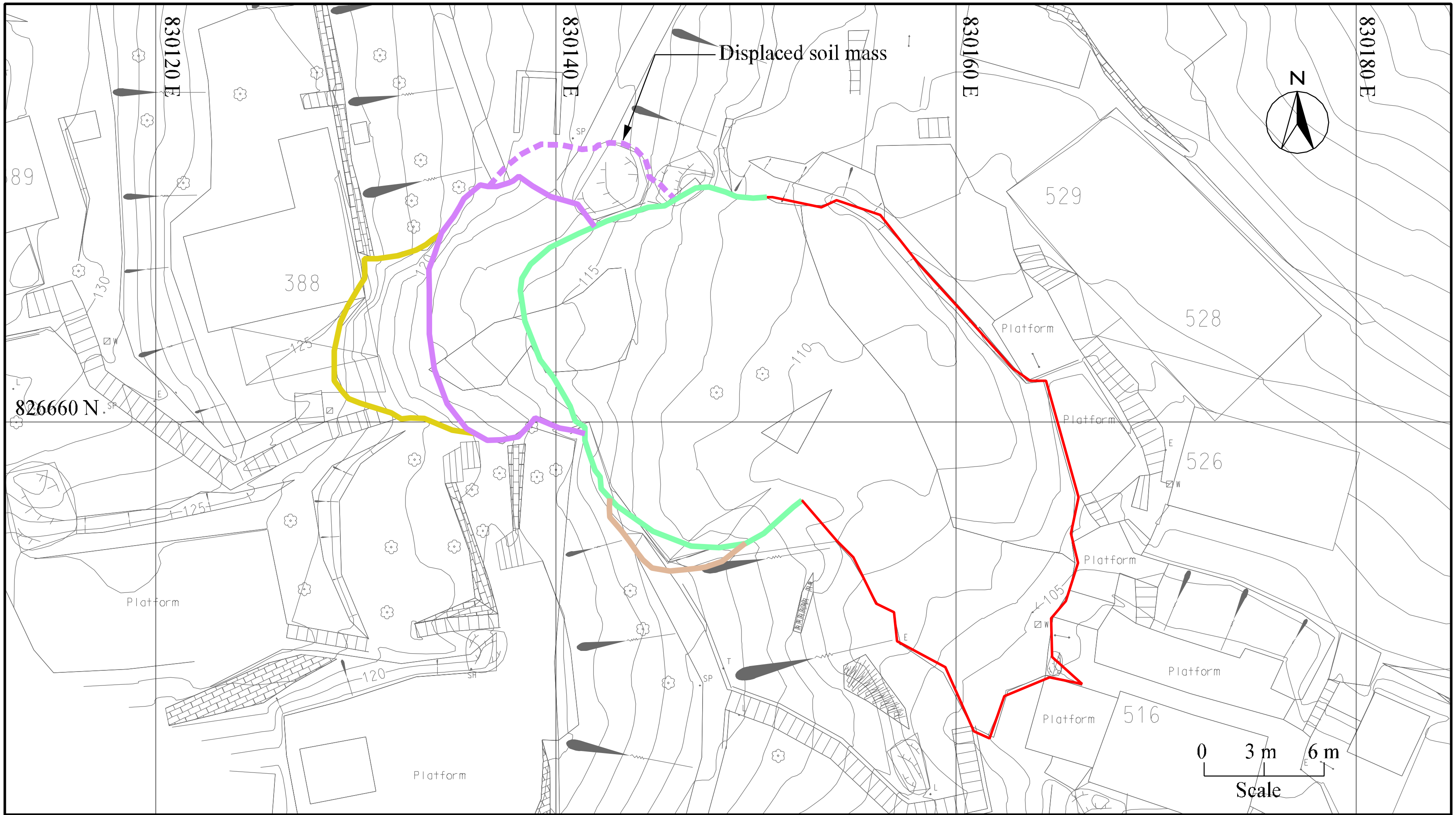


Figure 18 - Records of Tensiometer Readings

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

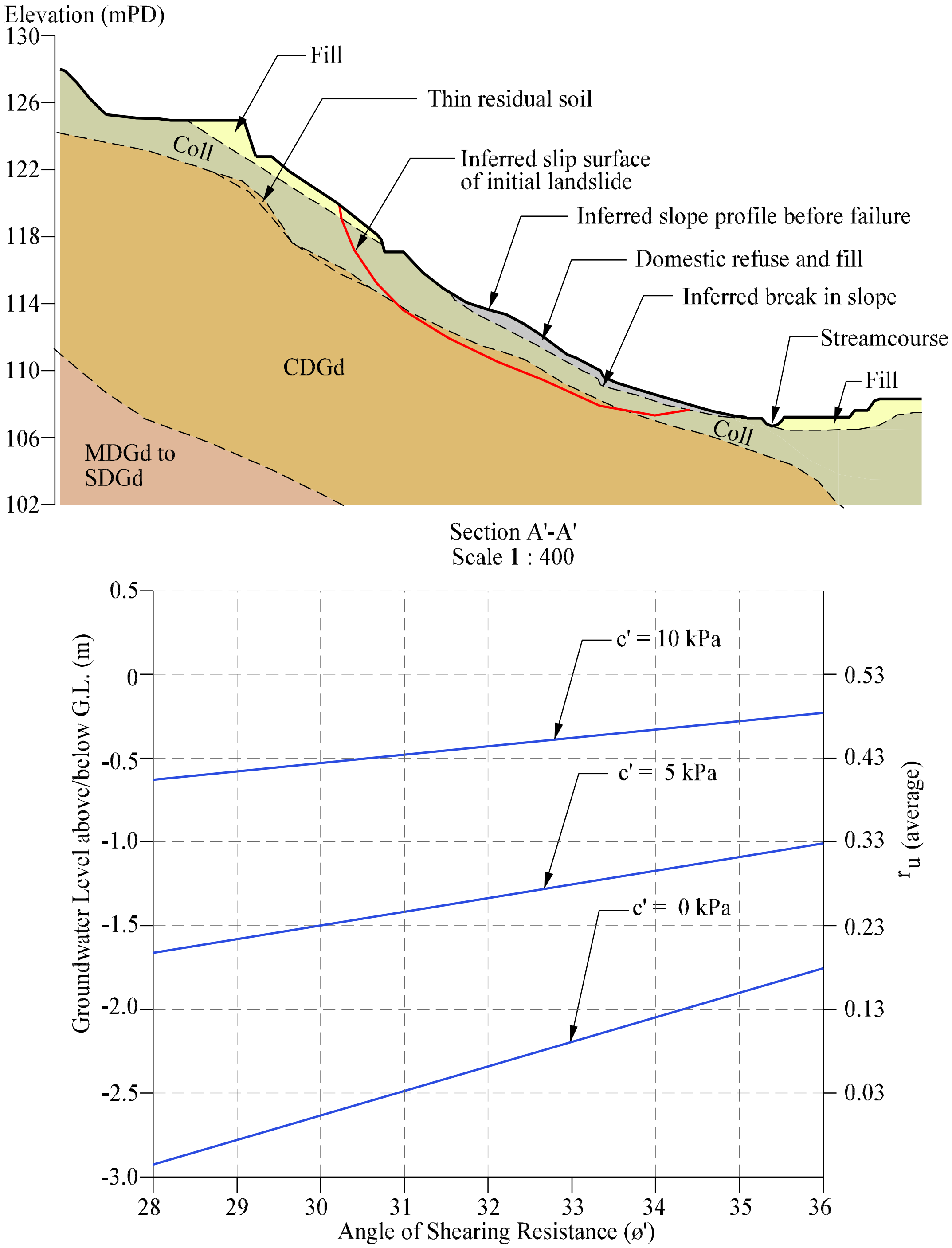


Legend : The landslide Initial failure Second phase (major) Second phase (minor) Minor collapse under footpath

Note : Base plan is extracted from topographic survey drawing No. GCS 3164.

Figure 19 - Probable Sequence of Failure

Table of Contents (English) Table of Contents (English) Table of Contents (English) Table of Contents (English)



Legend : Factor of safety equal to unity

Notes :

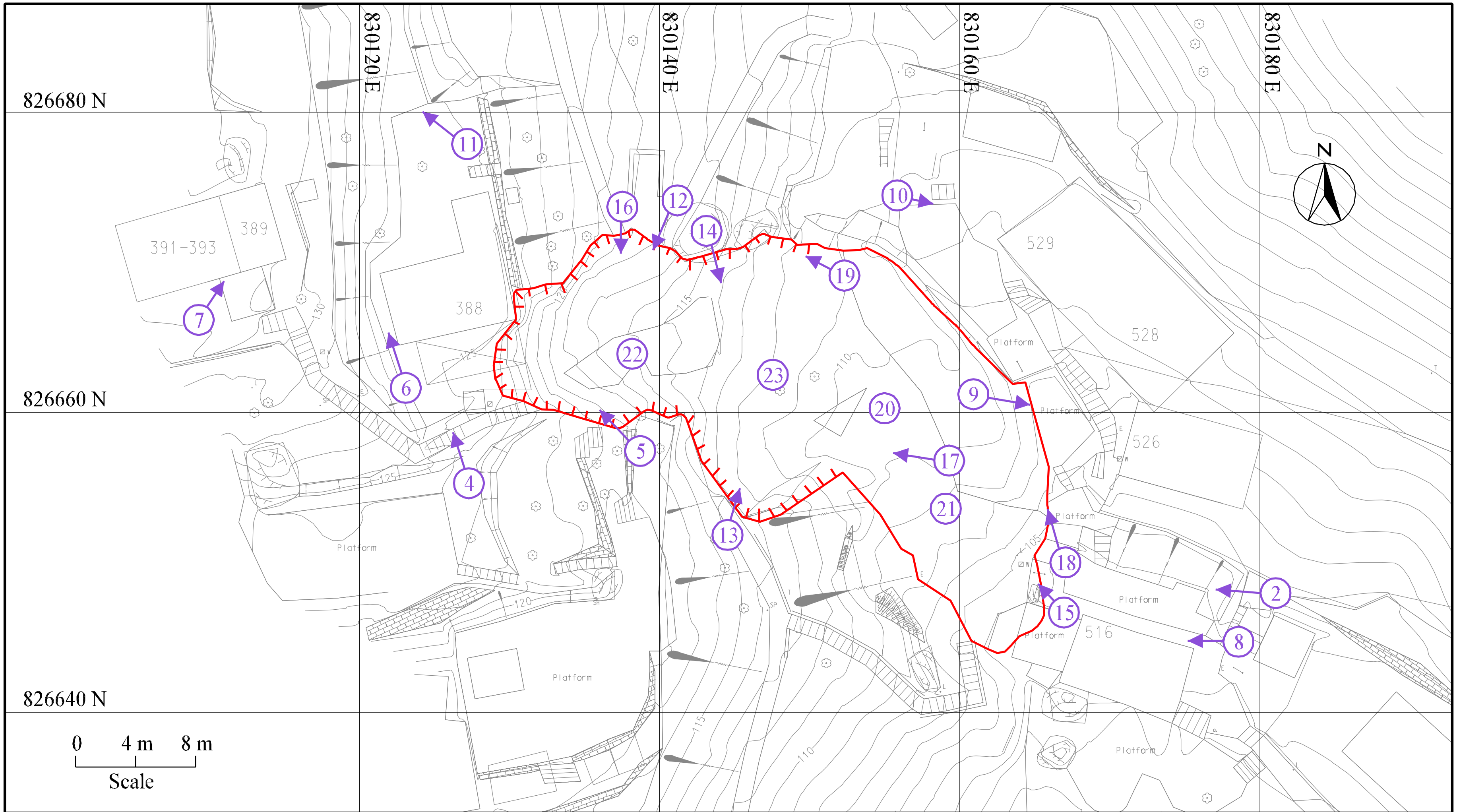
(1) The pre-failure slope profile and the failure surface are based on topographical survey, photographic records, post-failure observations and field mapping.

(2) r_u values shown are the average along the failure surface corresponding to each groundwater level.

(3) See Figure 11 for location of section.

Figure 20 - Summary of Theoretical Stability Analyses

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)



Legend : (12) → Location and direction of photograph

Note : Base plan is extracted from topographic survey drawing No. GCS 3164.

Figure 21 - Locations and Directions of Photographs Taken

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

LIST OF PLATES

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

Plate 1 - Oblique Aerial View of the 20 August 2005 Landslide
(Photograph taken on 22 August 2005)

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

Plate 2 - Front View of the 20 August 2005 Landslide
(Photograph taken on 21 August 2005)

Note: See Figure 21 for location and direction of photograph.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

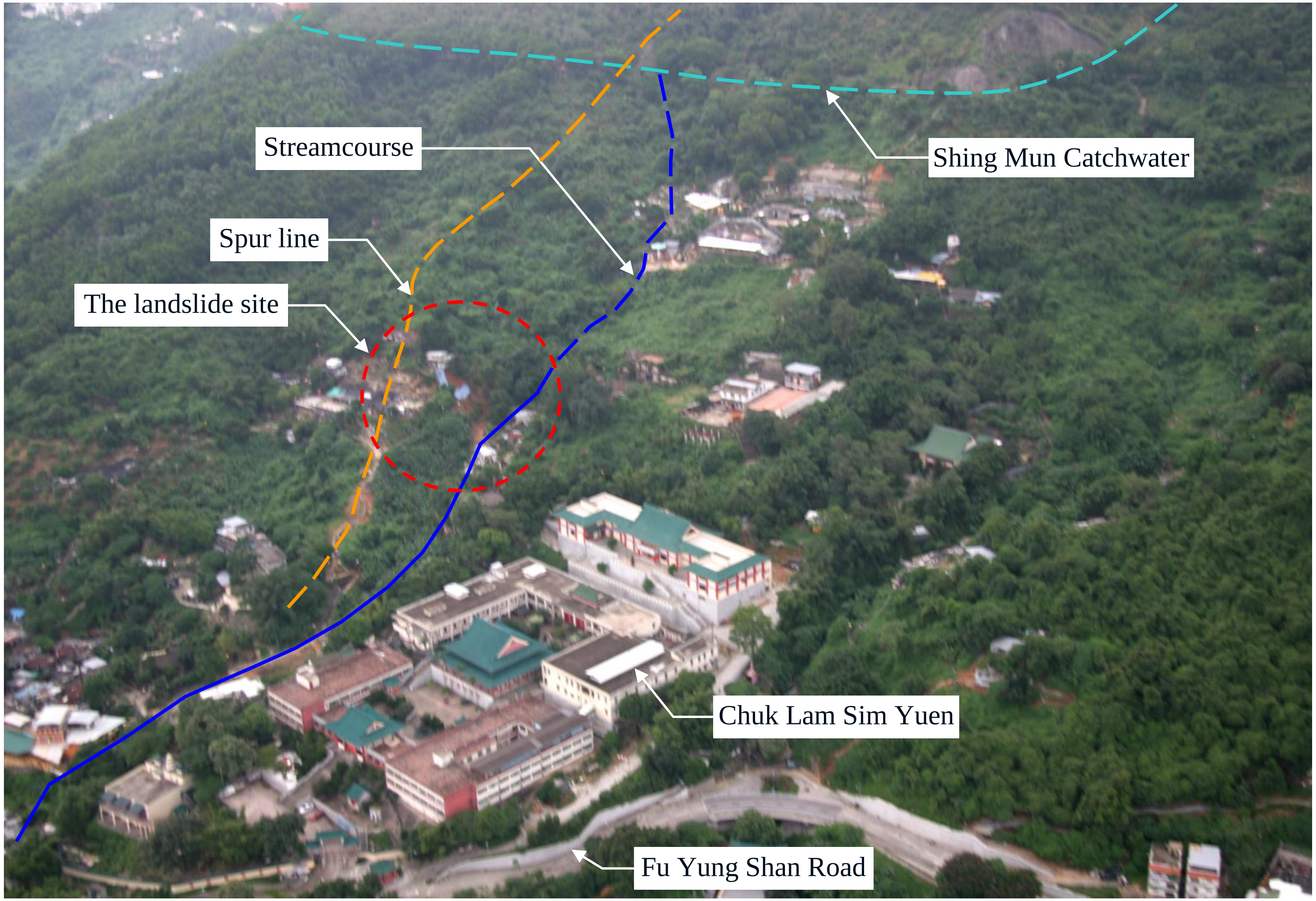


Plate 3 - General View of Fu Yung Shan Tsuen
(Photograph taken on 22 August 2005)

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

Plate 4 - Registered Squatter Structure No. RTW/4A/388
at the Crest of the Landslide Scarp
(Photograph taken on 29 August 2005)

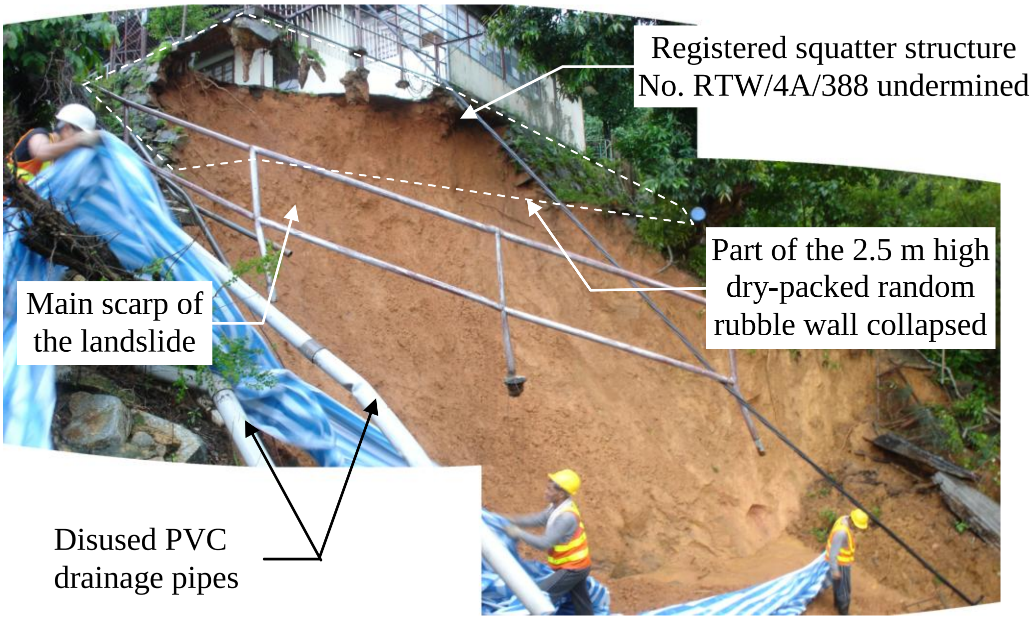


Plate 5 - View of the Main Scarp of the Landslide and the Undermined
Registered Squatter Structure No. RTW/4A/388
(Photograph taken on 21 August 2005)

Note: See Figure 21 for locations and directions of photographs.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

Plate 6 - Drainage Pipe and the Cut Slope behind Registered Squatter Structure No. RTW/4A/388
(Photograph taken on 21 August 2005)

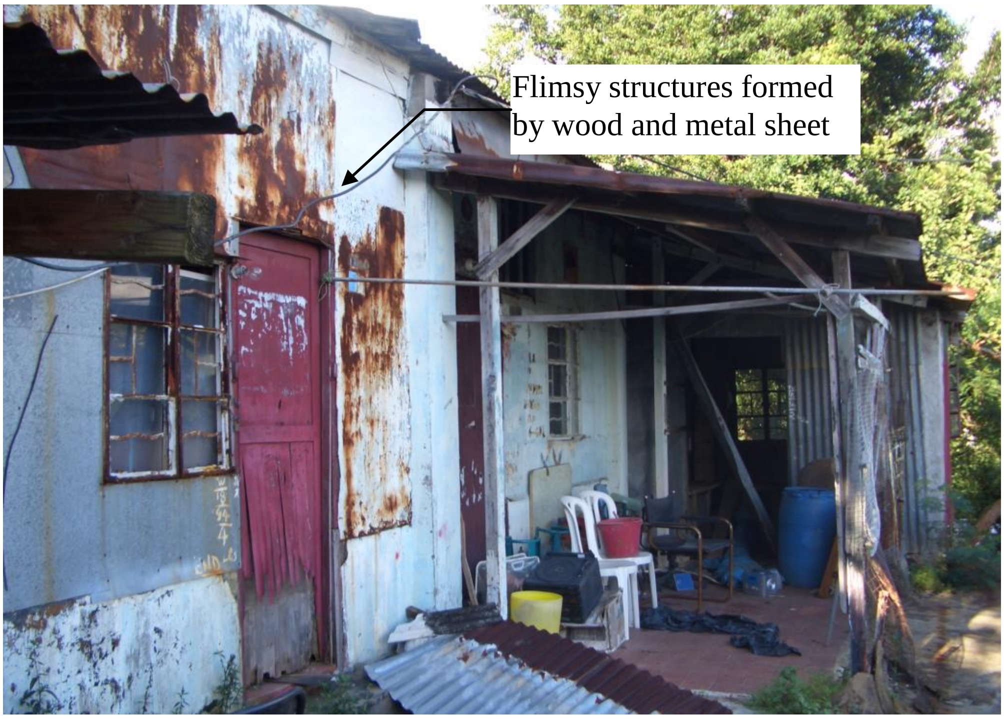


Plate 7 - Registered Squatter Structures Nos. RTW/4A/389, 391-393
(Photograph taken on 13 September 2005)

Note: See Figure 21 for locations and directions of photographs.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

Plate 8 - Registered Squatter Structure No. RTW/4A/516
(Photograph taken on 21 August 2005)

Plate 9 - Registered Squatter Structure No. RTW/4A/526
(Photograph taken on 5 December 2005)

Note: See Figure 21 for locations and directions of photographs.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

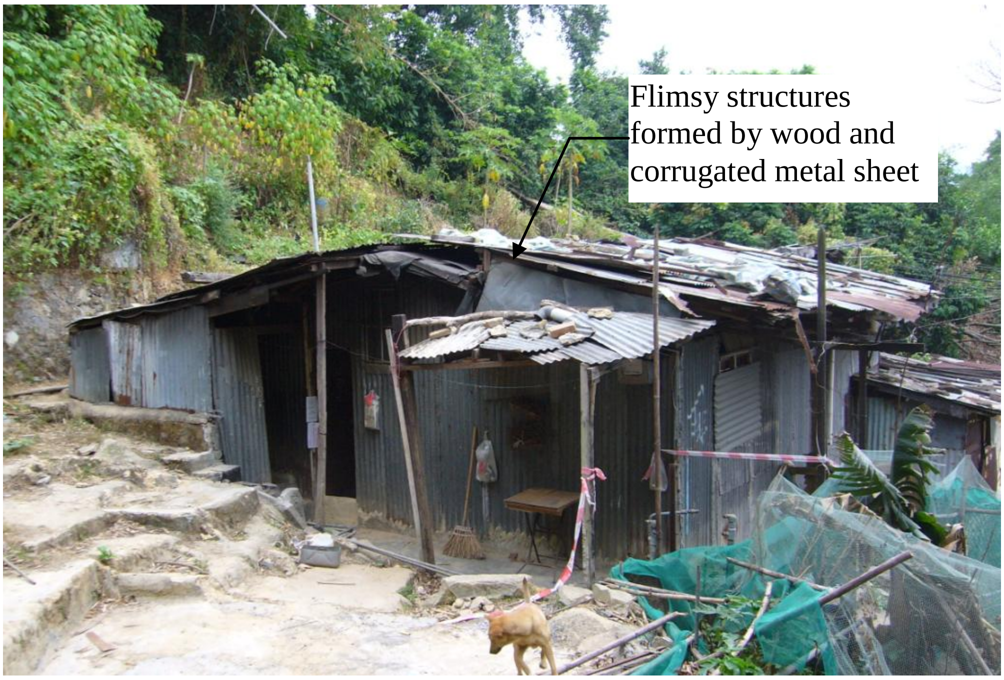


Plate 10 - Registered Squatter Structure No. RTW/4A/528-529
(Photograph taken on 5 December 2005)

Plate 11 - PVC Drainage Pipes Leading from Squatter
Structures Nos. RTW/4A/389, 391-393
(Photograph taken on 6 December 2005)

Note: See Figure 21 for locations and directions of photographs.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

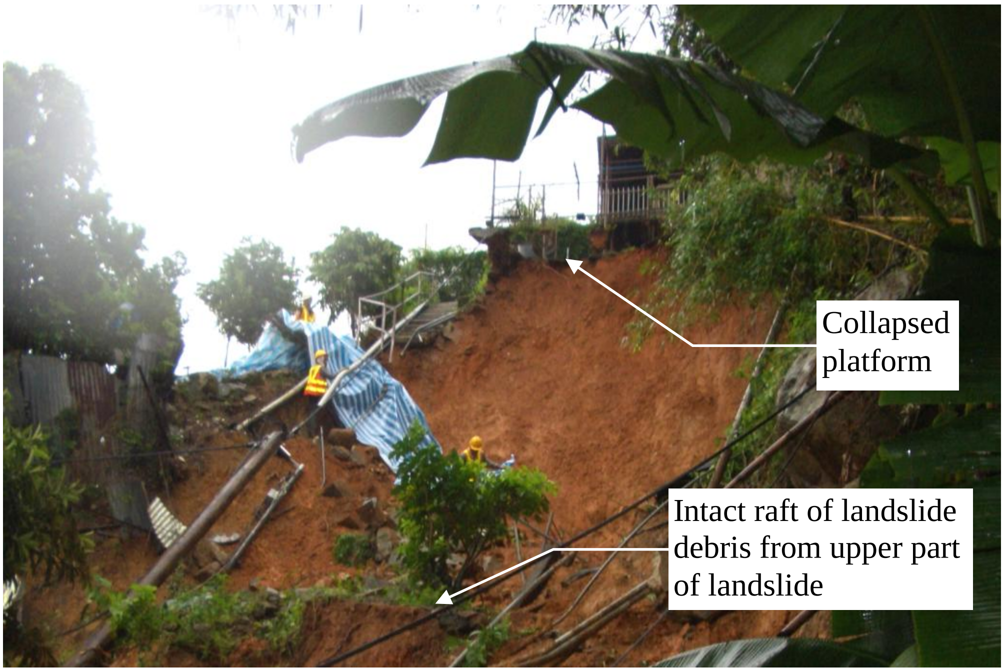


Plate 12 - The Main Scarp and the Southern Flank of the Landslide
(Photograph taken on 21 August 2005)

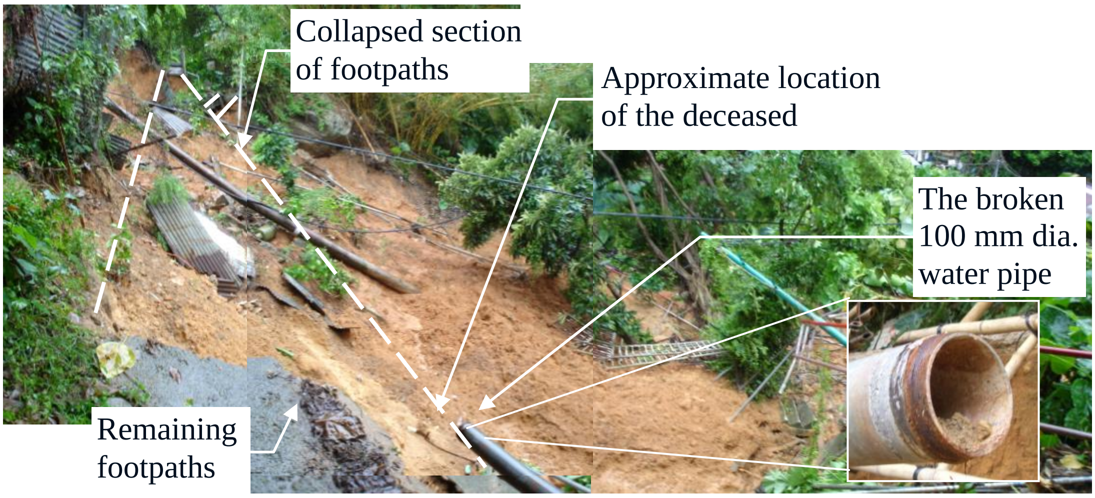


Plate 13 - The Collapsed Footpath and the Broken
100 mm Diameter Water Pipe
(Photograph taken on 21 August 2005)

Note: See Figure 21 for locations and directions of photographs.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

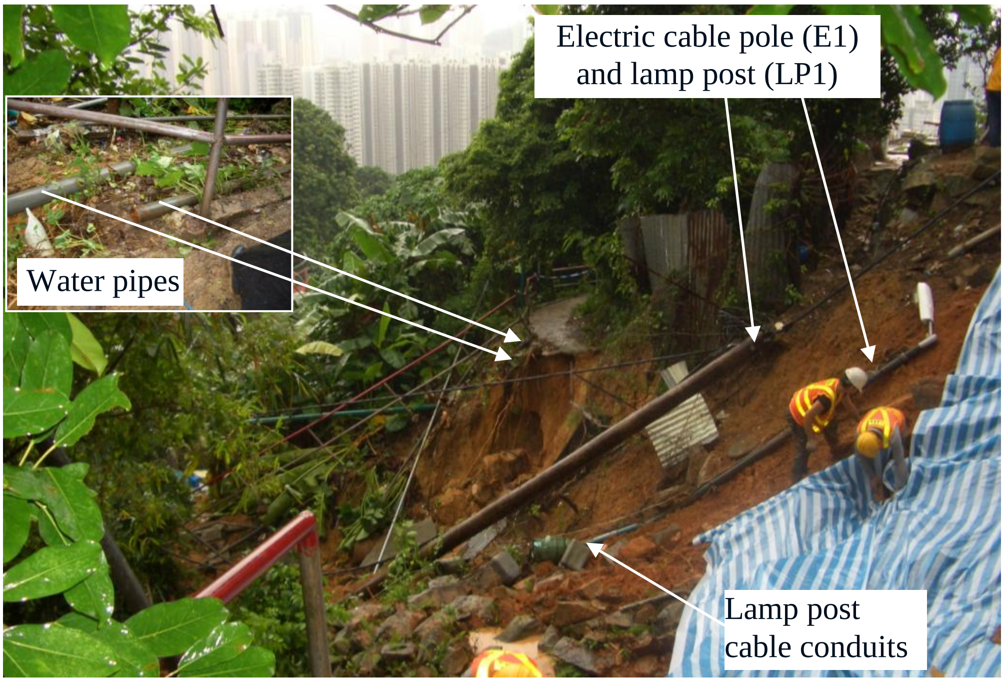


Plate 14 - View of the Damaged Utilities
(Photograph taken on 21 August 2005)

Plate 15 - View of the Lower Part of the Landslide Debris near the Toe of the Landslide
(Photograph taken on 21 August 2005)

Note: See Figure 21 for locations and directions of photographs.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

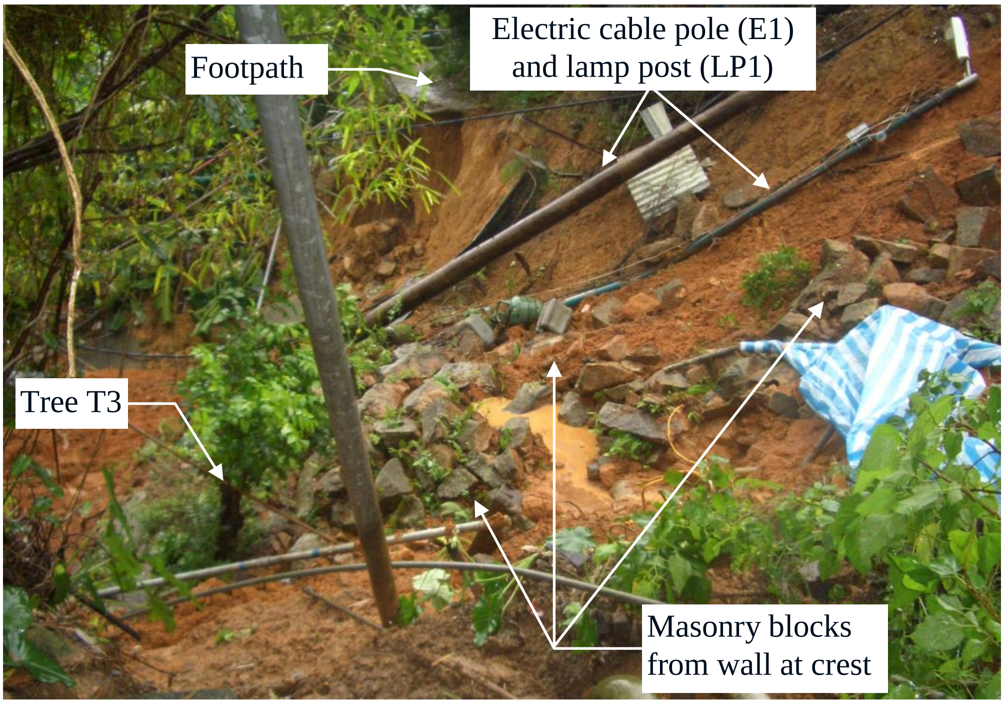


Plate 16 - View of the Upper Part of the Landslide Debris
(Photograph taken on 21 August 2005)

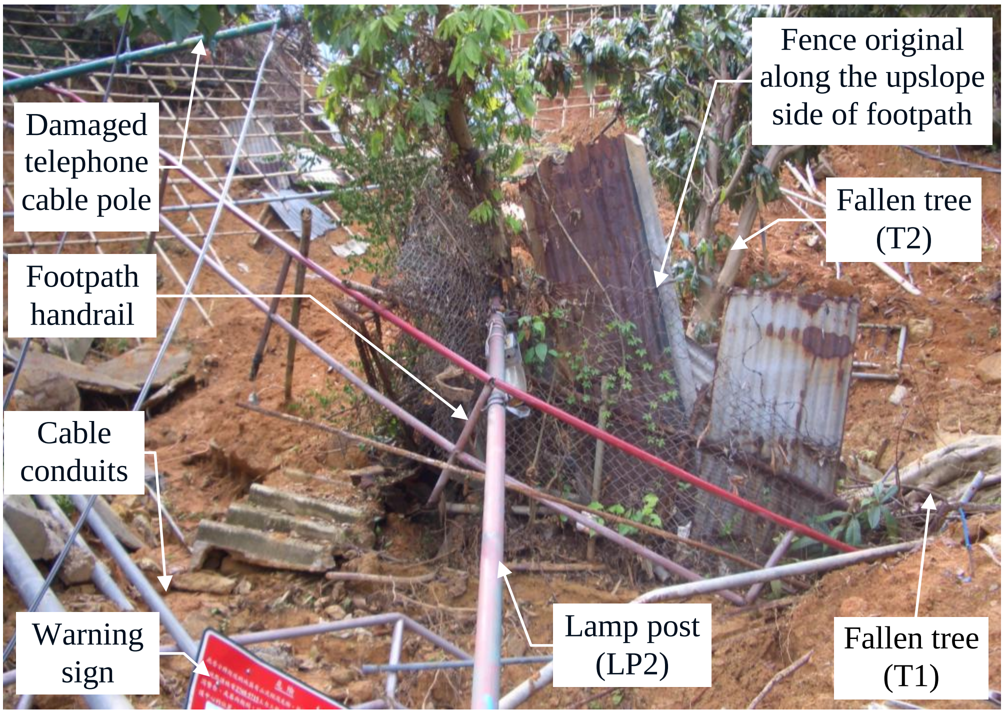


Plate 17 - Lamp Post LP2 beneath the Footpath Handrail
(Photograph taken on 7 September 2005)

Note: See Figure 21 for locations and directions of photographs.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

Plate 18 - Domestic Refuse Transported along with the Landslide Debris
(Photograph taken on 21 August 2005)

Plate 19 - Break in Slope on the Adjacent Hillside to the North of the Landslide
(Photograph taken on 13 September 2005)

Note: See Figure 21 for locations and directions of photographs.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

Plate 20 - Trial Pit TP4 Showing Landslide Debris Containing Deformed Domestic Refuse Layers
(Photograph taken on 17 October 2005)

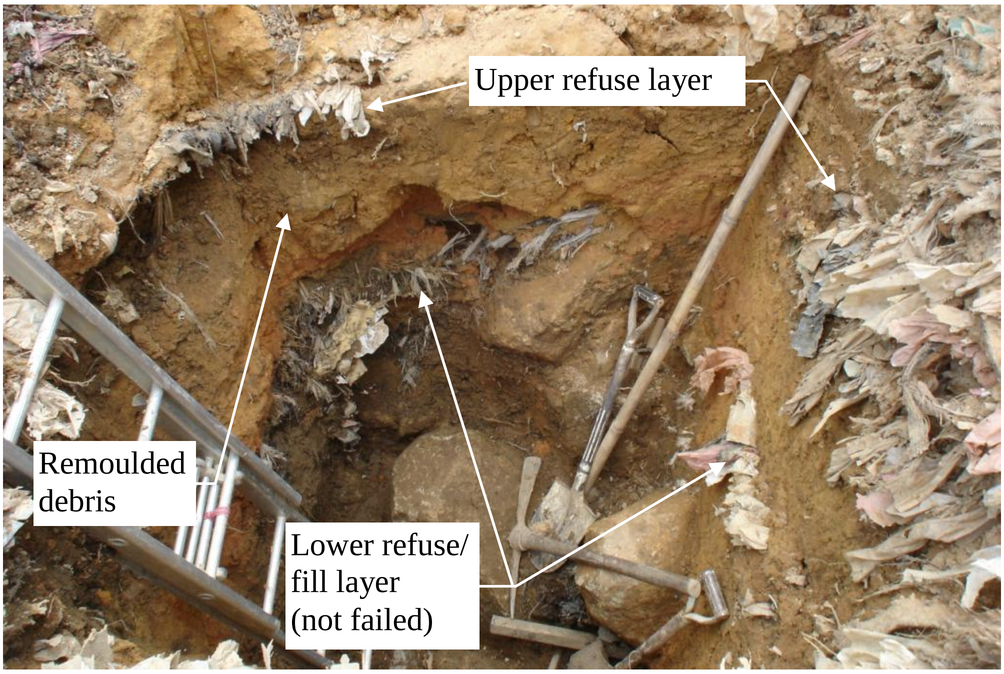


Plate 21 - Trial Pit TP11 Showing Upper and Lower Layers of Domestic Refuse
(Photograph taken on 25 October 2005)

Note: See Figure 21 for location and direction of photograph.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

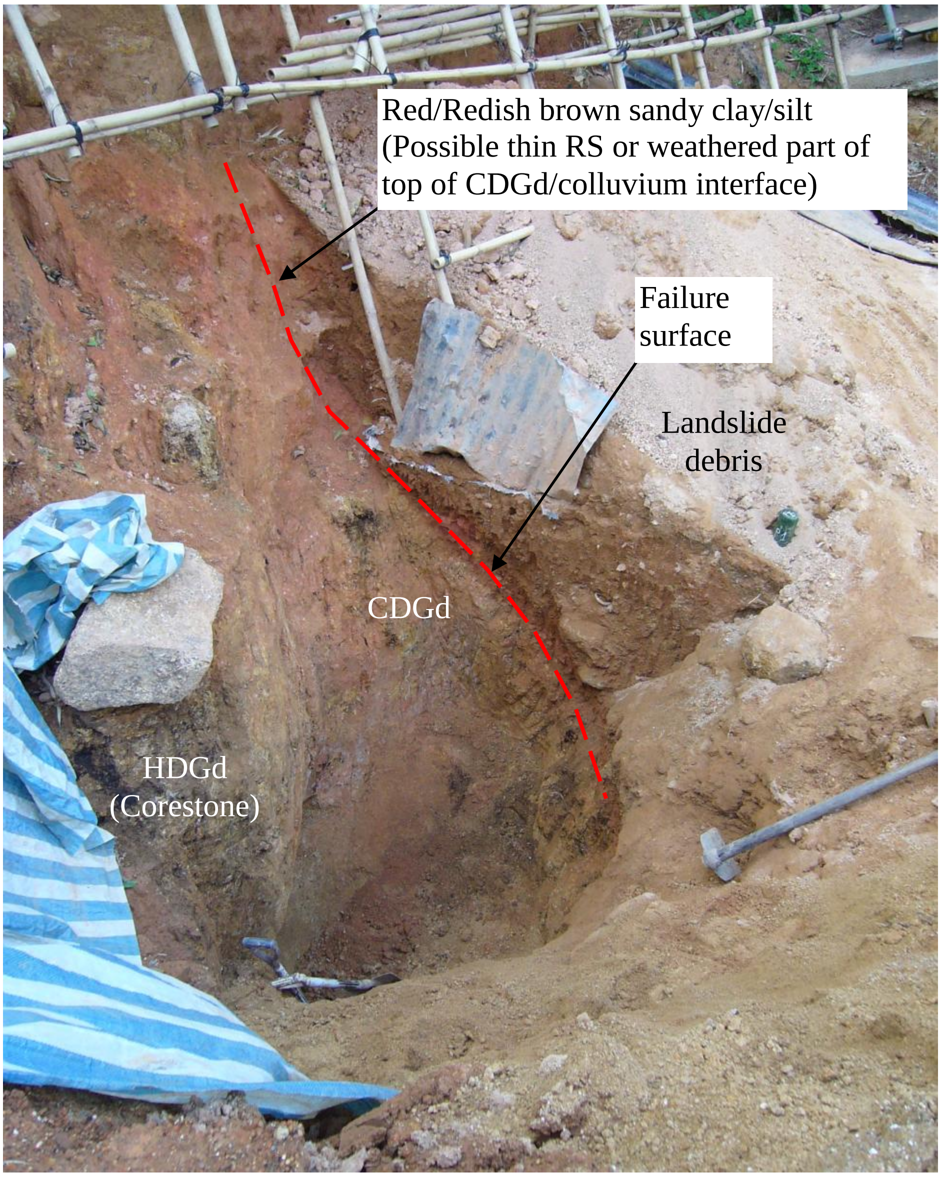


Plate 22 - The Failure Surface Exposed in Trial Trench TT1
(Photograph taken on 22 September 2005)

Note: See Figure 21 for location and direction of photograph.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

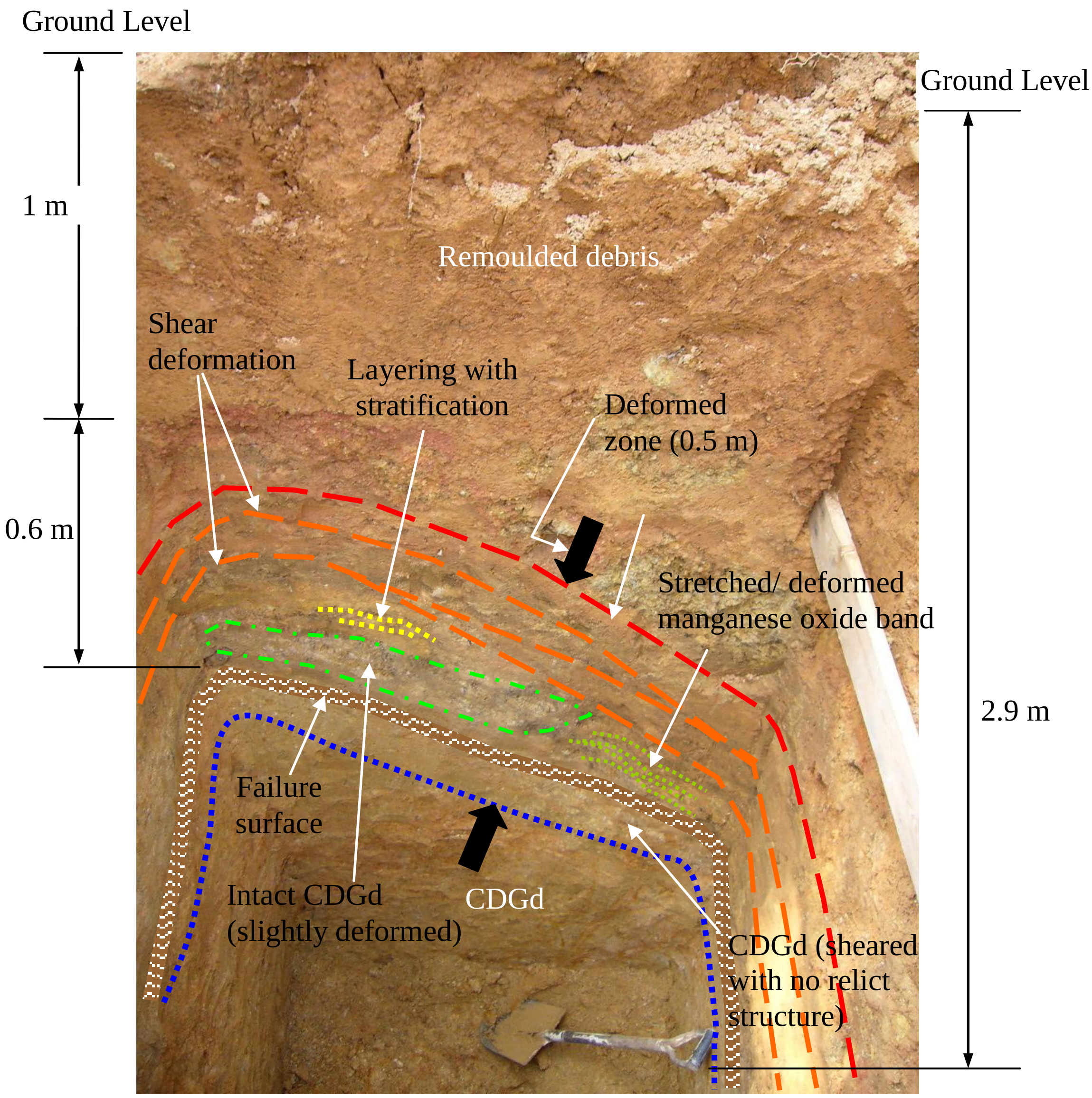


Plate 23 - The Failure Surface and Deformed Zone Exposed in Trial Pit TP3 (Photograph taken on 22 September 2005)

Note: See Figure 21 for location and direction of photograph.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

APPENDIX A

SITE DEVELOPMENT HISTORY

CONTENTS

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

A1. INTRODUCTION

References

The development history of Fu Yung Shan Tsuen has been determined from:

(a) old survey maps,

(b) an interpretation of aerial photographs taken between 1924 and 2004, and

(c) documentary records from GEO's files.

Location of areas and features referred to in the following sections are shown in Figure A1.

A2. SITE DEVELOPMENT

The earliest available aerial photographs taken in 1924 show that the study area appears to comprise natural hillside with a north-south trending streamcourse separating two generally north-south trending spurlines. For ease of reference, the spurlines have been designated as Spurline-W (along the western side of the streamcourse) and Spurline-E (along the eastern side of the streamcourse). Both spurlines and their adjacent flanks do not appear to have been modified by anthropogenic activities. The west-facing flank of Spurline-W, on which the August 2005 landslide occurred, is notably steeper than the adjacent flank of Spurline-E. Some agricultural terraces were noted at the location of the present Chuk Lam Sim Yuen.

Aerial Photos Nos. Y00120-1 (5,800 ft)

Development of Chuk Lam Sim Yuen commenced in 1927 and the first temple structure was completed in 1932

Record photos in Chuk Lam Sim Yuen

By 1937, Shing Mun Catchwater, traversing the terrain upslope of the landslide site has been constructed.

As-built plans of contract No. 52 of 1937 from WSD
Aerial Photos Nos. Y00689 (20,000 ft)

By 1949, Po Tai Yuen has been constructed along Spurline-E and Chuk Lam Sim Yuen has extended. An area of high reflectivity can be observed within the streamcourse immediately to the west of the Chuk Lam Sim Yuen which corresponds to a cultivation area and a man-made pond/weir. Construction of a platform between Chuk Lam Sim Yuen and the pond can also be observed.

Aerial Photos Nos. Y2007 (5,800 ft)

Apart from a grave site (G1) observed along the western flank of the Spurline-W, its adjacent flanks appear unmodified by any apparent anthropogenic activities. Spurline-E is generally covered by scattered trees and shrubs, with Spurline-W appearing to remain lightly

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

vegetated by grasses and shrubs.

By 1954, the platform constructed in 1949 between Chuk Lam Sim Yuen and the pond extended. Spurline-W appears to be unaffected by any human activity.

Aerial Photos Nos. Y02729-30 (29,200 ft)

By 1963, further development at Po Tai Yuen, Chuk Lam Sim Yuen and building on the platform to the east of the weir is observed which include the formation of minor buildings, cut slopes, retaining walls and connecting footpaths.

Aerial Photos Nos. Y09036-37 (3,900 ft), Y09120-21 (8,000 ft)

A footpath (FP1) can be observed extending across the August 2005 landslide site, similar to the present alignment, to a recently constructed platform, to the north of the landslide site, upon which several structures have also been constructed. This footpath does not appear to have been surfaced and appears narrower than at present. A grave (G2) has been constructed above and to the east of the platform. An area of high reflectivity is evident below the footpath FP1, which is likely to be localised erosion caused by human passage between FP1 to the pond area near the streamcourse.

Squatter structure No. RTW/4A/516 (see Figure 2 for the locations of registered squatter structures) has been constructed along the eastern side of the streamcourse immediately to the north of the pond area.

Trees broadly cover the upper hillside area of Spurline-W upslope from the footpath FP1. The area downslope from footpath FP1 and to the west of the streamcourse is generally covered with shrubs and a few scattered trees.

By 1964, an area of high reflectivity (L1) can be observed along the downslope side of the footpath FP1. The area may correspond to an area of localised instability, possibly caused by undercutting by the streamcourse or due to excavation. The western and southern flanks of feature L1 can be clearly discerned to comprise sharp convex breaks in slope, with the northern flank appearing more rounded and gradual. The vegetation growth previously observed in the 1963 aerial photographs covering this location is generally no longer present with only the lower section of the reflective area showing evidence of the continued presence of a vegetation cover.

Aerial Photos Nos. Y11313-14 (1,800 ft), Y11149-50 (1,800 ft), Y11276-77 (2,700 ft)

Squatter structures Nos. RTW/4A/514 and RTW/4A/526 have been constructed along the eastern side of the streamcourse.

By 1967, the reflective area L1 appears even more pronounced. The vegetation growth previously observed covering the lower section of the slope is no longer evident, with the entire area now generating high reflectivity. Detailed interpretation of the area is problematic due

Aerial Photos Nos. Y13483-85 (3,900 ft)

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

to the high reflectivity and lack of image contrast.

A squatter structure has been constructed along the eastern side of the pond. Several squatter structures have also been constructed along the western flank of Spurline-W to the south of the grave G1. A series of agricultural terraces have been constructed along Spurline-W to the NW of the August 2005 landslide.

By 1969, the area along the western flank of Spurline-W has been significantly modified by anthropogenic activities following the construction of numerous squatter structures (including squatter structures Nos. RTW/4A/364-366) together with their associated cut platforms. The squatter structure No. RTW/4A/388, which was affected in the 2005 landslide, has been constructed. No evidence of significant fill tipping can be seen downslope of this structure.

Aerial Photos Nos. 15380-82 (4,000 ft)

Several squatter structures have also been constructed along the eastern bank of the streamcourse including squatter structure No. RTW/4A/513 and two other squatter structures to the east of squatter structure No. RTW/4A/516.

By 1972, the extent of agricultural terraces to the NW of the August 2005 landslide constructed between 1964 and 1967, have been further extended.

Aerial Photos Nos. 2279, 81 (13,000 ft)

The construction of squatter structures along the western flank of Spurline-W has expanded considerably. Detailed assessment of the structures using 1973 low altitude aerial photographs indicated a total of 11 structures had been constructed during this period (including squatter structures Nos. RTW/4A/370-372, 374, 376-379, 389, 391-393, 411 and some other squatter structures to the north). The intervening area between the squatter structures appears generally reflective, suggesting continued erosion or earthwork/paving by the squatters. A stairway leading from footpath FP1 to squatter structures Nos. RTW/4A/388, 389, 391-393 was formed.

Aerial Photos Nos. 3261-63 (5,000 ft)

By 1975, a squatter structure appears to have been built on a platform adjacent to the streamcourse, which commenced in 1973.

Aerial Photos Nos. 11794-95 (12,500 ft)

By 1976, additional squatter structures have been constructed along the eastern bank of the streamcourse including squatter structures Nos. RTW/4A/528-529 and a few squatter structures to the south, as well as some squatter structures to the northwest of Po Tai Yuen.

Aerial Photos Nos. 15463-64 (4,000 ft)

The previously observed high reflective area L1 can be broadly observed. Both the southern and northern flanks of the feature remain evident with the northern flank obscured by vegetative re-growth.

Several small accumulations of reflective materials are evident

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

along the downslope side of footpath FP1. These may either relate to emplaced materials or localised erosion. Given the height of the aerial photographs, this cannot be determined effectively.

A footpath (FP2) is visible extending from the footpath FP1 to a squatter structure on the eastern side of the streamcourse to the north of squatter structures Nos. RTW/4A/528-529.

By 1977, the previously observed areas of erosion and/or material emplacement along the downslope side of the footpath are generally obscured by vegetation cover and no longer evident. However, a linear section of high reflectivity can be observed extending into the head of the high reflective area L1 and may relate to a local erosion.

Aerial Photos Nos. 19734-35 (4,000 ft), 20070-71 (4,000 ft)

By 1978, minor areas of highly reflective material can be observed along the downslope side of the footpath FP1 and may relate to locally deposited bodies of fill or domestic refuse.

Aerial Photos Nos. 24061-62 (4,000 ft)

A cluster of squatter structures have been constructed to the north of squatter structures Nos. RTW/4A/528-529.

The refuse collection point (RCP) has been recently constructed at the junction of footpaths FP1 and FP2.

By 1979, the eastern bank of the streamcourse has now become densely occupied by squatter structures.

Aerial Photos Nos. 27492, 94 (4,000 ft)

By 1980, an area of high reflectivity can be observed along the downslope side of the RCP. The reflective material appears to correspond to locally deposited fill material or domestic refuse.

Aerial Photos Nos. 32966-67 (4,000 ft)

By 1982, an expanded area of reflective terrain is evident along the downslope side of the footpath FP1. The area appears to be utilized as a repository for loose material deposits (possibly fill or domestic refuse).

Aerial Photos Nos. 43124-25 (3,000 ft), 43859-60 (2,500 ft)

The hillside on the downslope side of the footpath FP1 is now being utilized as a banana plantation.

By 1984, the highly reflective area previously identified in the 1980 and 1982 aerial photographs has become obscured by vegetative re-growth. An access stairway has been constructed from footpath FP1 down towards the streamcourse.

Aerial Photos Nos. 56548-49 (4,000 ft)

By 1987, an area of localised reflectivity can be observed on the downslope side of the footpath FP1 with an extent similar to that initially observed in 1980 and remains visible and generally reflective in the 1988 aerial photographs too.

Aerial Photos Nos. A09886-87 (4,000 ft), A10493-94 (4,000 ft), A10503-04 (4,000 ft)

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

By 1991, the area of high reflectivity located on the downslope side of footpath FP1 has expanded considerably.

Aerial Photos Nos.
A27540-41 (4,000 ft)

A structure (to the east of squatter structure No. RTW/4A/376-379 originally constructed in 1972) has been demolished.

By 1992, the area of high reflectivity observed in 1991 has become obscured by vegetative.

Aerial Photos Nos.
A30483-84 (5,000 ft),
A32637-38 (4,000 ft)

There are no significant changes that can be observed from the aerial photographs between 1993 and 1995.

By 1996, general clearance of minor structures along the streamcourse has taken place.

Aerial Photos Nos.
A35973-74 (4000 ft),
CN5647-48 (10000 ft),
A38141, 52 (5000 ft),
CN9556-57 (10000 ft),
CN12369-70 (10000 ft)
A14217-18 (4,000 ft),
A15816-178 (4,000 ft)

By 1998, clearing of a large number of squatter structures within the streamcourse has been carried out with only scattered structures remaining. Clearance of the squatter structures along Spurline-W has also been carried out with the platform areas remaining exposed and open.

Aerial Photos Nos.
A48357-58 (4,000 ft)

The area affected by the August 2005 landslide is completely obscured by vegetation.

By 1999, an area of high reflectivity can be observed along the downslope side of the footpath FP1. The location is similar to the area of reflectivity previously observed in 1978.

Aerial Photos Nos.
CN22681-82 (4,000 ft),
CN25102-03 (8,000 ft)

There are no significant changes that can be observed from the aerial photographs between 2000 and 2004.

Aerial Photos Nos.
CN28065-66 (5,500 ft),
CW31688-89 (7,000 ft),
CW32673-74 (4,000 ft),
RW01544-45 (4,000 ft),
CW42645-46 (4,000 ft),
CW47196-97 (4,000 ft),
CW49880-81 (8,000 ft),
CW57011-12 (4,000 ft),
CW59195-96 (4,000 ft)

A3. PREVIOUS ASSESSMENT

The August 2005 landslide did not involve any registered slope features and there were no previous engineering works/studies carried out within or in the vicinity of the landslide.

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

A3.1 Non-Development Clearance Programme

In accordance with the Government's policy of offering re-housing to occupants of registered squatter structures who are in immediate and obvious danger or those especially vulnerable to landslide risk, studies have been carried out by the GCO (renamed Geotechnical Engineering Office (GEO) in 1991) to identify squatter areas and specific squatter structures that need to be cleared under the Non-Development Clearance (NDC) Programme since the mid-1980's. The studies include terrain classification mapping, aerial photograph interpretation (API) and reference to records of landslide casualties, to identify areas of potential landslide hazard. Squatter structures that warrant clearance are identified following field inspections by GCO (or GEO). Recommendations for squatter clearance on slope safety grounds were made by GCO (or GEO) and the re-housing of squatter occupants are implemented by the Lands Department (Lands D) and the Housing Department (HD).

GCO Instruction No. 2/89 Non-Development Clearance and Restoration Works in Squatter Areas

Method Statement entitled "Squatter Clearance Studies for Tung Yeung, Tse Mei, Fuk Tak New and Ling Nam New (Upper) Villages"

Under the NDC Programme, the GCO inspected the Fu Yung Shan Tsuen in 1985. Clearance recommendations on slope safety grounds were given by GCO to HD on 30 December 1985 (Figure A2). The squatter structures Nos. RTW/4A/388, RTW/4A/516, RTW/4A/526 and RTW/4A/528-529 affected by the August 2005 landslide, which were located within the NDC inspection boundary, had not been recommended for clearance at that time.

GEO memo ref. No. (15) in GCMd 2/E1/RA4 (W) date 30/12/1985

The clearance and re-housing was carried out by Lands D and HD under Clearance No. TW 15/87, which was completed in November 1989. A total of 43 squatter structures were cleared.

HD memo ref. No. (98) in TW/C 32/3/93 dated 30/11/1989

In May 1992, the GEO undertook to re-inspect all of the previously inspected New Territories squatter villages under the NDC Programme. Site inspections of the Fu Yung Shan Tsuen were carried out in October 1992 under the 1992/93 NDC Re-inspection Programme. Clearance recommendations on slope safety grounds were given by GEO to HD on 12 November 1992 (Figure A2). The squatter structures Nos. RTW/4A/388, RTW/4A/516, RTW/4A/526 and RTW/4A/528-529 affected by the August 2005 landslide were recommended for clearance during this re-inspection.

GEO Report No. AR 1/93 dated August 1993; Re-inspection of Squatter Villages in the New Territories: July 1992 to June 1993 Executive Summary

GEO memo ref. No. (26) in GCMd 4/13/RA11 II date 12/11/1992

The clearance and re-housing was carried out by Lands D and HD under Clearance No. TW 8/92, which commenced in July 1993. A total of 290 structures were screened for clearance by the HD and re-housing arrangements were offered to these families. During the course of the clearance, about 60 squatter structures, which were not recommended for clearance by GEO in 1992, were also included in the NDC Programme on 'Other Grounds' (i.e. security reasons, management). The squatter structures Nos. RTW/4A/389, 391-393 (Figure A2) were recommended for clearance by HD in

HD memo ref. No. (190) in TW/C 1/7/83 dated 1/6/1993

HD memo ref. No. (79) in TW/C 1/7/93 dated 29/11/1994

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

November 1994 under Clearance No. TW 18/94. Clearance and re-housing was carried out between 1993 and 1996.

On 26 April 1995, the Clearance No. TW 8/92 was completed (Figure A3). A total of 20 families refused the re-housing arrangement offered and insisted to stayput on site, which included the occupants of the squatter structures Nos. RTW/4A/388, RTW/4A/389, 391-393, RTW/4A/516, RTW/4A/526 and RTW/4A/528-529 affected by the August 2005 landslide. These squatter structures had not been cleared when the 20 August 2005 landslide occurred. Some residents of Fu Yung Shan Tsuen claimed that the squatter structures Nos. RTW/4A/389, 391-393 were at times used by drug addicts who do not reside in Fu Yung Shan Tsuen.

HD memo ref. No. (114) in TW/C 7/3/93 III dated 22/3/1995

HD memo in HD(C) NTW 7/7/VI dated 22/12/2005

In September 2001, GEO re-inspected the close proximity of the streamcourse area in Fu Yung Shan Tsuen under 2001-2002 Inspection Programme (Near Stream Course). The re-inspection revealed that apart from the squatter structures, whose clearance was recommended by GEO in 1992, no additional squatter structures are required for clearance.

GEO memo ref. No. (2) in GCMd 4/13/11 sf9(S) date 30/11/2001

A3.2 Geotechnical Area Studies Programme

Geotechnical data relating to the study area were compiled as part of the GCO's Geotechnical Area Studies Programme (GASP) Report No. II, Central New Territories (GCO, 1987). The data was shown on a 1:20 000 scale map, which is used for regional appraisal and strategic planning purposes. The Engineering Geology Map indicates that the landslide site comprises coarse ash tuff of the Repulse Bay Formation. The Geotechnical Land Use Map (GLUM) identifies the hillside near the landslide as being Class II terrain (i.e. terrain with moderate geotechnical limitations), whereas Class III terrain (terrain with high geotechnical limitations) is identified along the drainage line adjacent to the landslide site. The Generalised Limitations and Engineering Appraisal Map (GLEAM) classifies the hillside of the study area as a "zone of potential for development". The Physical Constraints Map (PCM) shows no classification for the open hillside terrain of the study area although it classifies the terrain within the drainage line adjacent the landslide site as "zone of constraints for development".

GASP Report No. II, Central New Territories (GCO, 1987)

A4. PAST INSTABILITIES

The history of instability within the study area has been determined from a review of relevant documentary information (Figures 6 & A4).

NTLI, Enhanced NTLI, LLD, GEO's database of reported landslides

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

According to GEO's database of reported landslides, Natural Terrain Landslide Inventory (NTLI), Large Landslide Database (LLD), as well as Enhanced NTLI data maintained by the GEO, there are no records of any previous reported landslides in the immediate vicinity of the August 2005 landslide site.

Based on the GEO's database of reported landslides, a total of 30 landslide incidents were recorded in the Fu Yung Shan Tsuen (see Table A1 and Figure A4) and 14 of them are located within a radius of 150 m from the August 2005 landslide site (see Figure 6). These 14 landslide incidents mostly occurred on man-made features with a volume ranging from 0.5 m^3 to 50 m^3 and mostly affecting squatter structures and some landslides resulting in permanent evacuation of those squatter structures. The nearest incident (Incident No. MW87/8/29) was a minor landslide below footpath FP2 (see section A2), which occurred adjacent to the streamcourse at about 20 m northeast of the landslide site with a failure volume of about 3 m^3.

A5. REFERENCES

Geotechnical Control Office (1987). Geotechnical Area Studies Programme - Central New Territories. Geotechnical Control Office, Hong Kong, GASP Report No. II, 165 p. plus 4 maps.

Geotechnical Engineering Office (1992). Non-development Clearance Programme, 1992 Re-inspection Programme Fu Yung Shan. Drawing No. GCMd 92/39, Geotechnical Engineering Office, Hong Kong.

Geotechnical Engineering Office (1993). Re-inspection of Squatter Villages in the New Territories: July 1992 to June 1993 Executive Summary. Report No. AR 1/93, Geotechnical Engineering Office, Hong Kong, 15 p. plus 2 drgs.

King, J.P. (1999). Natural Terrain Landslide Study - The Natural Terrain Landslide Inventory. Geotechnical Engineering Office, Hong Kong, 127 p. (GEO Report No. 74).

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

LIST OF TABLE

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

Table A1 - Past Slope Instabilities in Fu Yung Shan Tsuen from GEO's Database of Reported Landslides

Incident No.	Type of failure	Feature Involved	Volume of Failure (m^3)	Consequence
NT82/55	Landslide	Soil cut slope	Minor (<50)	2 squatter structures permanently evacuated
NT82/238	Rockfall	Soil cut slope	Minor (<50)	1 squatter structures permanently evacuated
NT82/240	Landslide	Soil cut slope	~40	Catchwater blocked
NT82/8/36	Retaining Wall failure, washout	Retaining wall, natural streamcourse	Major (>50)	20 squatter structures permanently evacuated
NT82/9/5	Landslide	Soil cut slope	~5	2 squatter structures permanently evacuated
MW87/8/28	Landslide	Soil cut slope	3	SC and access affected
MW87/8/29	Washout	Hillside below footpath	3	Footpath affected
MW88/7/1	Subsidence	Soil cut slope	0	1 squatter structure permanently evacuated
MW89/5/61A	Landslide	Soil cut slope	2	Access affected
MW89/5/61B	Landslide	Soil cut slope	1	Access affected
MW89/5/66	Landslide	Soil cut slope	0.5	1 squatter structure permanently evacuated
MW92/5/63	Landslide	Soil cut slope	2	Hut affected
MW92/5/69	Landslide	Soil cut slope	2.5	2 squatter structures permanently evacuated
MW93/6/15	Retaining wall failure	Retaining wall	2	1 squatter structure temporarily evacuated
MW93/6/16	Landslide	Soil cut slope	1.5	Footpath affected
MW93/6/17	Landslide	Hillside below footpath	45	Footpath affected
MW93/9/6	Landslide	Natural hillside	1	2 squatter structures permanently evacuated
MW94/7/33	Landslide	Soil cut slope	15	Road affected
MW94/8/44	Landslide	Soil cut slope	2	1 squatter structures permanently evacuated
MW97/5/9	Landslide	Soil cut slope	3	Road affected
MW97/5/34	Landslide	Soil cut slope	35	Access affected
MW97/7/102	Landslide	Soil cut slope	10	2 squatter structures permanently evacuated
MW97/7/103	Landslide	Soil cut slope	4	1 squatter structures permanently evacuated
MW97/8/15	Landslide	Soil cut slope	10	Road affected
MW2001/6/45	Landslide	Hillside below footpath	2	Footpath affected
2002/06/0038	Landslide	Soil cut slope	1	Footpath affected
2003/10/0198	Landslide	Soil cut slope	0.5	Footpath affected
2005/06/0181	Landslide	Soil cut slope	100	Hut affected
2005/07/0251	Landslide	Fill slope	8	Footpath affected
2005//8/0362 (The August 2005 landslide)	Landslide	Hillside below footpath	400	One fatality, 4 squatter structures permanently evacuated

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

LIST OF FIGURES

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

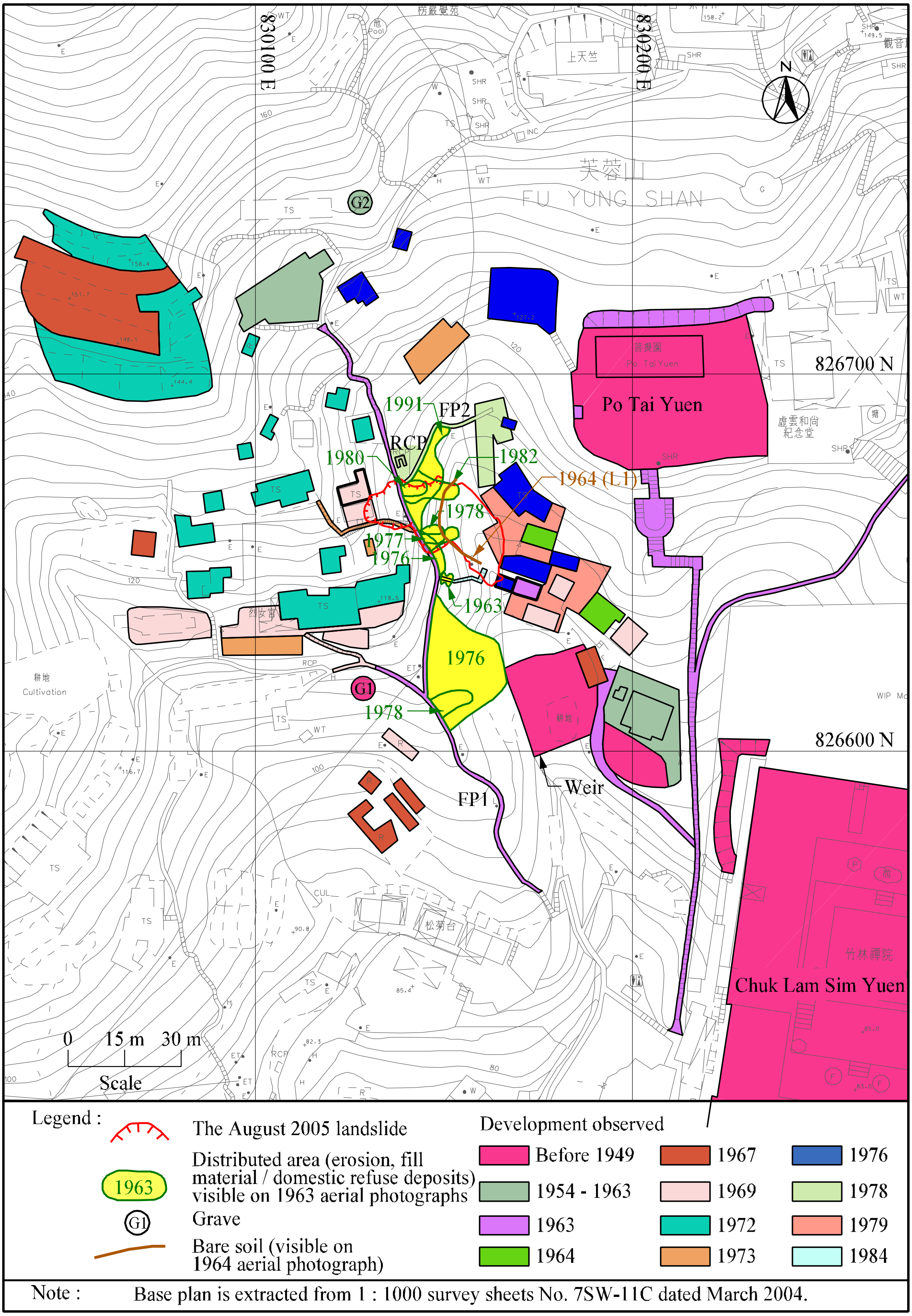
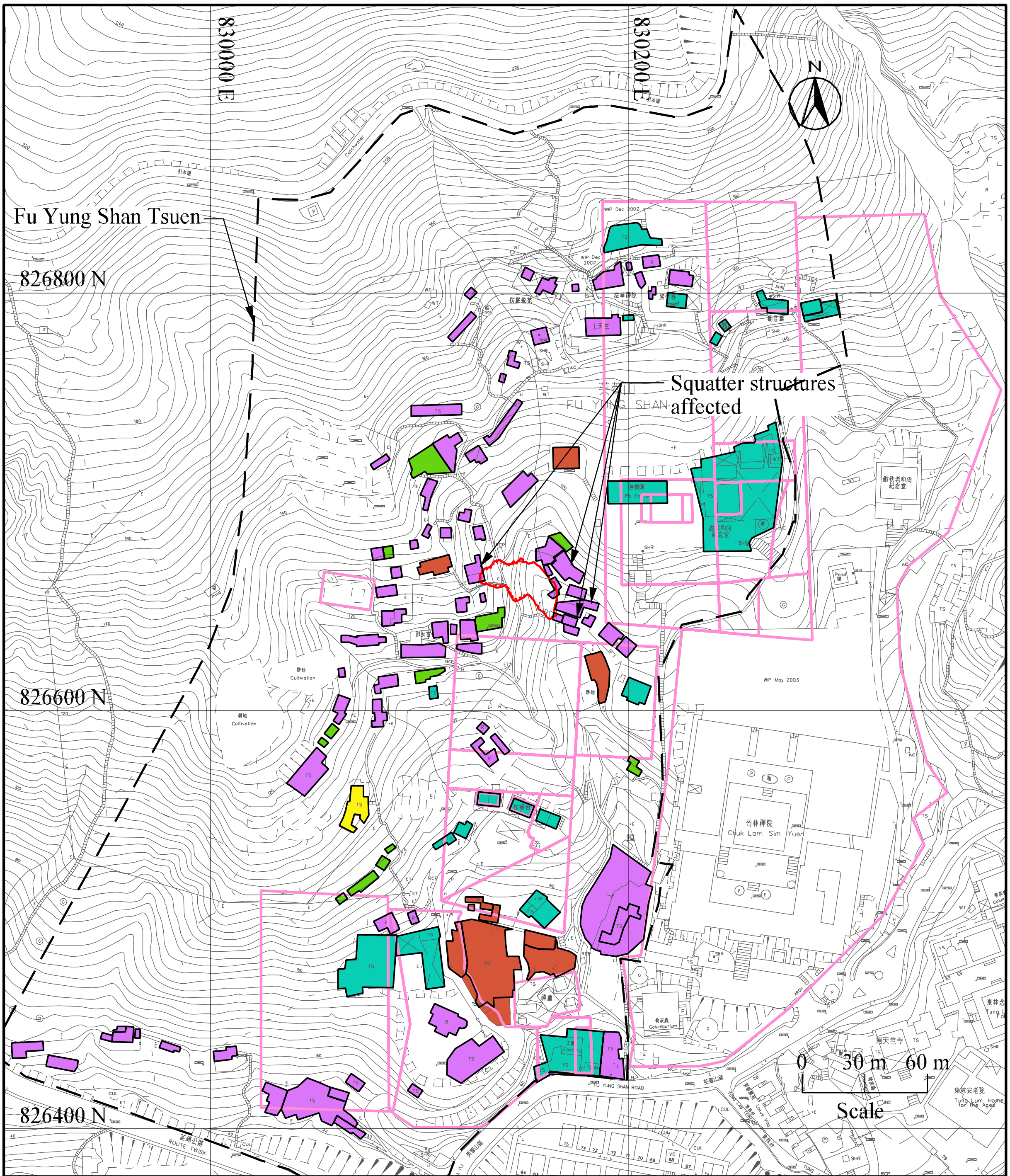


Figure A1 - Site History

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)



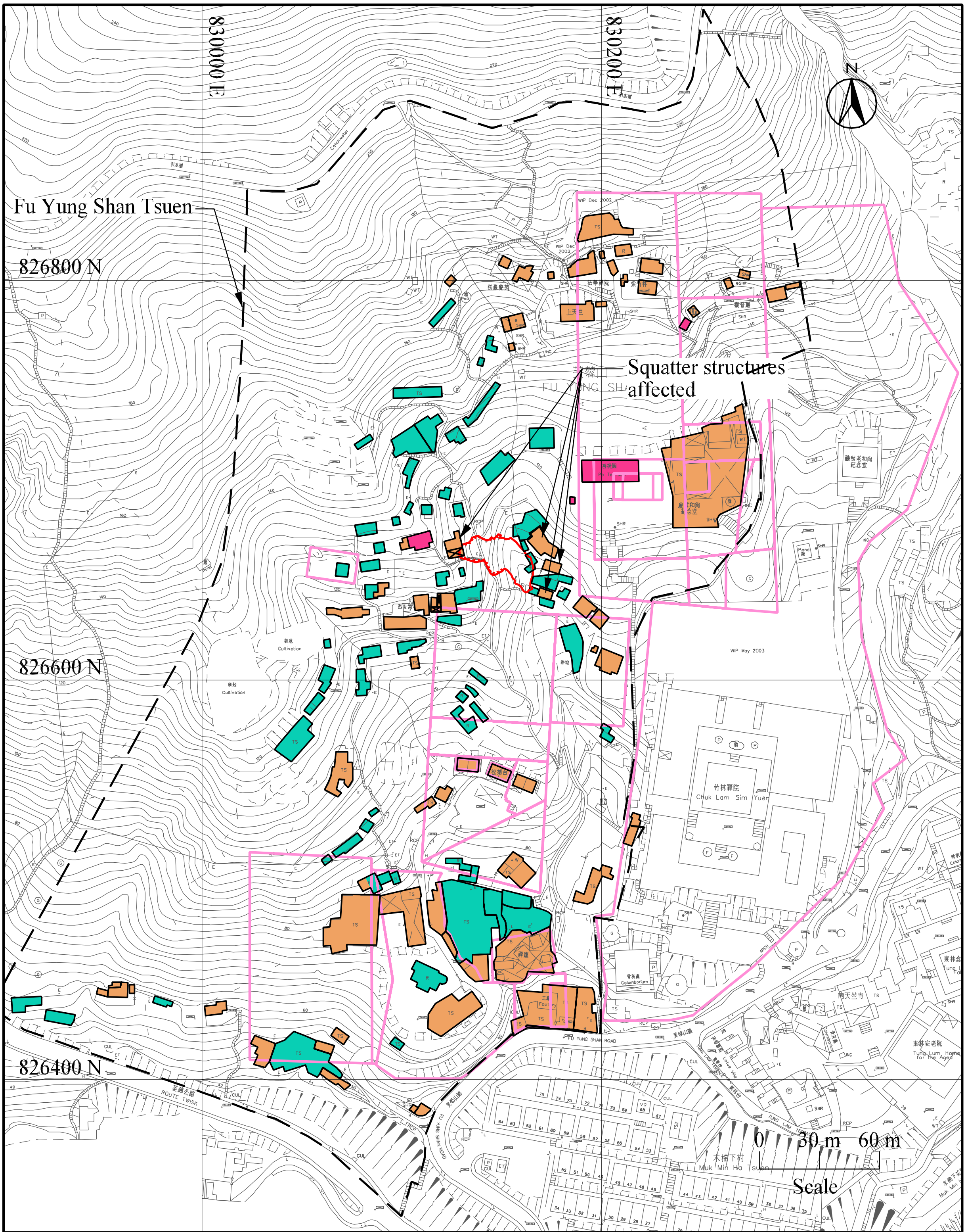
Legend :

- The August 2005 landslide
- Private leased land
- Structure recommended for permanent evacuation following landslide in June 1993
- Non-development Clearances recommended by GCO in 1985 (under Clearance No. TW 15/87)
- Non-development Clearances recommended by GEO in 1992 (under Clearance No. TW 8/92)
- Non-development Clearances recommended by HD in 1994 (under Clearance No. TW 3/94, TW 14/94, TW 18/94)
- Existing structures previously not recommended for clearance before August 2005 landslide

Note : Base plan is extracted from 1 : 1000 survey sheets No. 6SE-15D, 6SE20B, 7SW-11C and 7SW-16A dated March 2004.

Figure A2 - Non-development Clearances Recommendations

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)



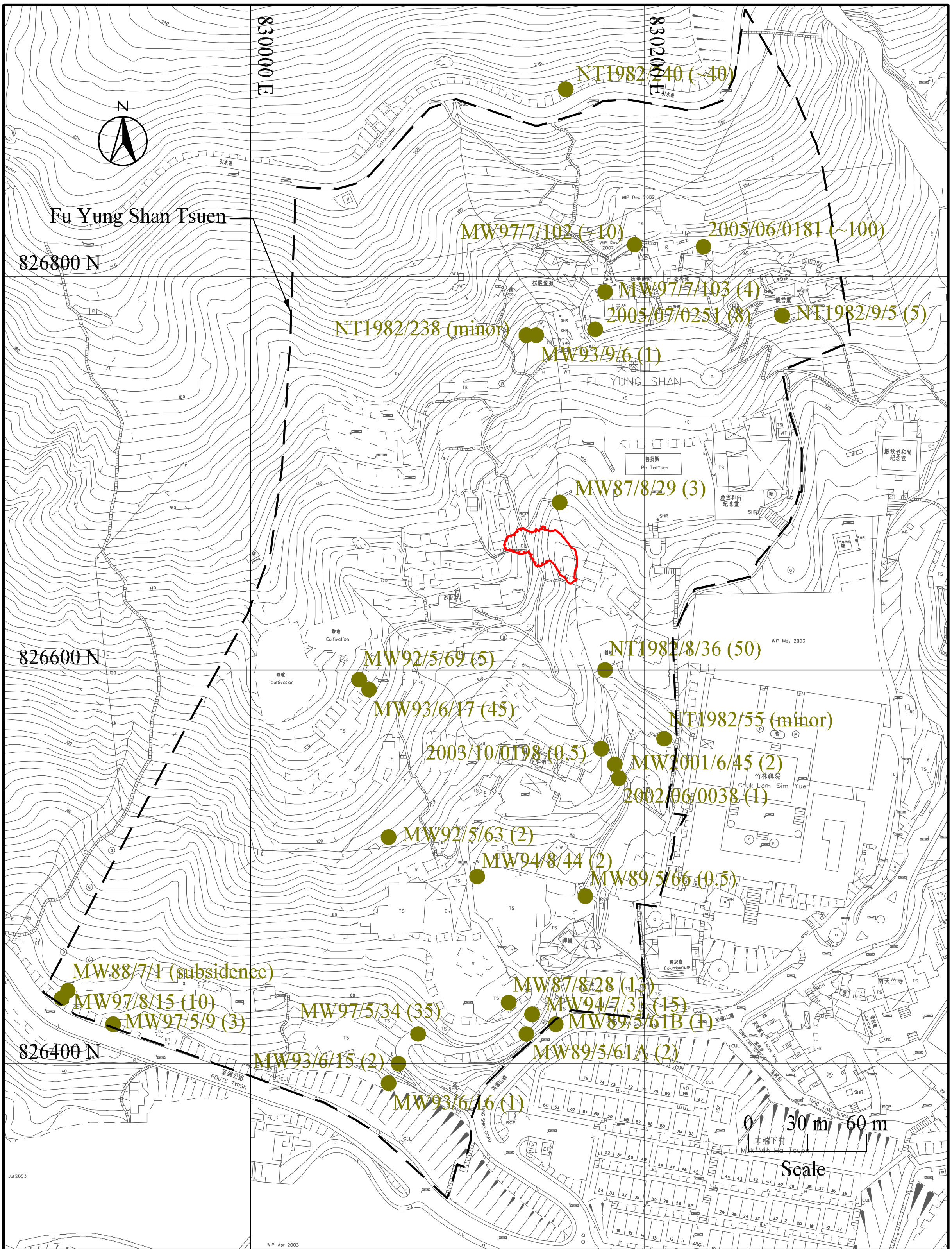
Legend :

- The August 2005 landslide
- Private leased land
- Structures cleared/demolished prior to August 2005 landslide
- Structures occupied prior to August 2005 landslide
- Structures not cleared prior to August 2005 landslide but with no signs of inhabitant

Note : Base plan is extracted from 1 : 1000 survey sheets No. 6SE-15D, 6SE20B, 7SW-11C and 7SW-16A dated March 2004.

Figure A3 - Clearances Status of Squatter Structures Prior to August 2005 Landslide

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)



Legend :

The August 2005 landslide

MW92/5/63 (2) Landslide incident No. MW92/5/63 with a failure volume of 2 m^3

Note : Base plan is extracted from 1 : 1000 survey sheets No. 6SE-15D, 6SE20B, 7SW-11C and 7SW-16A dated March 2004.

Figure A4 - Previous Reported Landslides within Fu Yung Shan Tsuen

Table of Contents (English)
Table of Contents (English)
Table of Contents (English)
Table of Contents (English)

二零零五年八月二十日
芙蓉山村山泥傾瀉事件報告
山泥傾瀉調查結果

茂盛土力工程顧問有限公司

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

序言

土力工程處的一貫政策，是向公眾及岩土工程業界公開有參考價值的資料。爲此，我們選擇部分內部報告，編製成爲土力工程處報告 (GEO Reports)。 這些報告可於土木工程拓展署網頁 (http://www.cedd.gov.hk) 下載。 我們亦印備部份土力工程處報告，並以印刷成本價發售。

土力工程處亦製備了一些文件的印刷版，包括指引文件和綜合檢討結果，這些文件亦可於上述網頁下載。

上述刊物系列及土力工程處報告印刷版，均由政府新聞處負責售賣，購買方法詳載於本報告末頁。

土力工程處處長
汪學寧
二零一三年三月

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

Table of Contents (Chinese)

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

摘要

二零零五年八月二十日，荃灣芙蓉山村一處曾遭人爲活動局部擾動的山坡發生一宗山泥傾瀉，崩塌體積約 400 立方米，導致一人喪生。該宗山泥傾瀉是在一場約百年一遇的嚴重暴雨期間發生。其後，茂盛土力工程顧問有限公司受土力工程處委託(合約編號 CE 15/2004 (GE))，就事件進行全面調查。調查工作包括翻查資料文件、分析雨量記錄、訪問山泥傾瀉目擊人士、進行現場測量、場地勘探、以理論方法進行穩定性分析及判斷事件的成因。

調查所得的結論是，山泥傾瀉可能是在長時間的嚴重暴雨下，表層物質失去土壤毛管吸力以及地下水壓力瞬間增加所致。以下推斷是促使山泥傾瀉的因素：

(a) 表層物質的性質及水土特性提供了一個有利於地下水壓力在降雨後增加的水文地質條件；

(b) 該山坡大部分地段有未受管制和非法傾倒的家居垃圾(含有有機物質及纖維物質，能夠長時間保留水份)，形成不利的水力邊界條件，促使地下水壓力可能在長時間的暴雨後，在大範圍的山坡內急劇增加；以及

(c) 從整體地貌佈局、一九六四年的航空照片以及附近未崩塌的山坡上存在的坡度折曲等，可以推斷出該山坡的坡腳過於陡峭，可能使該山坡更容易出現由雨水引發的山泥傾瀉。

上述調查的詳情及結果載列於本報告內。

目錄

Table of Contents (Chinese)

1. 引言

二零零五年八月二十日大約下午五時二十五分，在黃色暴雨警告和山泥傾瀉警告生效下，荃灣芙蓉山村一處曾遭人爲活動局部擾動的山坡發生了一宗崩塌體積約 400 立方米的山泥傾瀉(事件登記編號爲 2005/08/0362)(圖 1 及照片 1 和 2)。事件導致一人喪生及附近四所已登記寮屋的住戶要永久遷離。

土木工程拓展署轄下的土力工程處於事發後立即對這次山泥傾瀉事件進行詳細調查。作爲土力工程處的山泥傾瀉調查顧問，茂盛土力工程顧問有限公司(MGSL)負責這次調查工作。山泥傾瀉場地的地形測量則由土木工程拓展署轄下的測量部負責進行。

調查於二零零五年八月至二零零六年一月間進行，主要任務如下：

(a) 就事發地點的發展歷史，包括以往在寮屋區進行的評估和連串引致山泥傾瀉發生的事件，翻查所有已知的有關記錄；

(b) 訪問目擊山泥傾瀉的人士；

(c) 於事發地點附近進行地形測量、詳細的觀察和量度；

(d) 航空照片判釋和工程地質測繪；

(e) 進行全面的場地勘探，採用鑽探、現場試驗和實驗室試驗等來確定地下情況；

(f) 分析雨量記錄；

(g) 以理論方法分析崩塌山坡的穩定性；以及

(h) 判斷導致崩塌發生的可能成因。

本報告列載這次調查的結果。

2. 事發地點的描述

二零零五年八月發生的山泥傾瀉的地點位於芙蓉山村，該處位於大帽山南坡的一處西北偏北與東南偏南向的下降山嘴。城門引水道橫貫於芙蓉山的上部，高程約 210 mPD，距離山泥傾瀉現場以北約 200 米，並高出約 100 米(圖 1)。芙蓉山村位於山坡的下部，引水道下方。一條溪流自引水道的溢流堰往下，流經山泥傾瀉現場底部的附近(圖 1 和照片 3)。

二零零五年八月的山泥傾瀉事件發生於山嘴的東側、竹林禪院的西北面(圖 2 和

照片 3)。植被茂密的山坡仰角約爲 28°至 34°(根據山泥傾瀉後鄰近範圍的地形測量推測)；並曾遭人爲活動局部擾動，例如修建小路、傾倒家居垃圾和種植果樹(圖 2 和照片 2)。該山坡由於並非人造斜坡，並不符合標準登記入政府斜坡記錄冊。山嘴的頂部距離山泥傾瀉現場以西約 20 米，與滑坡頂部之間有一較小的集水區，面積約爲 800 平方米。

二零零五年八月山泥傾瀉的頂部有一個帶有數條舊微裂縫的水泥板平台和一所兩層高的登記寮屋(於一九八二年的房屋署寮屋調查中登記)(照片 4)。平台由一幅 2.5 米高的不規則砌石牆支撐(圖 2 和照片 5)，由於該砌石牆的高度不符合登記標準(即 < 3 米)，因此並沒有登記入政府斜坡記錄冊。在滑坡上方的登記寮屋(寮屋管制登記編號爲 RTW/4A/388，下文將簡稱爲 388 號寮屋)由鋼架、夾板牆和波紋狀鐵皮屋頂組成。388 號寮屋後面有一幅 3.5 米高、仰角約爲 60°的削坡(照片 6)。削坡以上有一叢單層及簡陋的登記寮屋(寮屋管制登記編號爲 RTW/4A/389, 391-393，下文將簡稱爲 389, 391-393 號寮屋)(照片 7)。在滑坡西南面上方有一些空置的平台(之前搭建有其他寮屋)，部分平台有鋪築而其餘部分則用作種植果樹(圖 2 和照片 1)。在這些平台和 389, 391-393 號寮屋之間的山坡上有一些大塊孤石(照片 1)。

橫跨山坡的中部，有一條 1.2 米寬、傾斜度約爲 1：5 的混凝土小路。該小路沒有明顯的橫向排水斜面，而兩側亦沒有設置排水溝或擋水板。一段混凝土梯級從小路引向 388 號寮屋和位於山坡更高處的 389, 391-393 號寮屋(圖 2)。另一段位於二零零五年八月山泥傾瀉現場南邊的混凝土梯級則從小路引至山坡的底部(圖 2)。

距離滑坡底東面約 3 米的地方，有一所兩層高、由磚砌塗灰泥牆及波紋狀鐵皮屋頂組成的登記寮屋(寮屋管制登記編號爲 RTW/4A/516，下文將簡稱爲 516 號寮屋)；還有一所單層、由磚砌塗灰泥牆及波紋狀鐵皮屋頂的組成登記寮屋(寮屋管制登記編號爲 RTW/4A/526，下文將簡稱爲 526 號寮屋)。另外在滑坡腳東面還有一所由木材搭建的單層簡陋登記寮屋(寮屋管制登記編號爲 RTW/4A/528-529，下文將簡稱爲 528-529 號寮屋)(圖 2 及照片 8 至 10)。

在二零零五年八月滑坡腳的附近，有一溪流流經。接近山坡腳的部分溪流的水道有混凝土鋪築。在溪流上有部分被混凝土平台跨過，以往用作搭建寮屋。

根據水務署提供的資料，有兩條直徑分別爲 100 毫米和 80 毫米鍍鋅鋼的食水供水管(均於一九八七年安裝)橫跨山泥傾瀉現場(圖 2)。在發生山泥傾瀉之前，並沒有水管滲漏、爆裂的記錄或當地居民投訴水壓不足的情況。沿著小路和梯級，裝置了很多公用設施的管道和電纜，包括街燈及其電線管道、高架的電纜/電話線和支撐杆等。

在滑坡現場並無屬於渠務署維修範圍的公共雨水溝，可是在現場和其鄰近地方發現有一些可能是由當地居民鋪設的聚氯乙烯排水管(照片 5 和 11)。在山泥傾瀉後的調查中發現，這些排水管大多已棄置、損壞或堵塞，除了 388 號寮屋的排水管，匯集屋頂的雨水後直接排放到滑坡以北的山坡上(圖 2 和照片 6)。在 388 號寮屋的下方有一個化糞池(據 388 號寮屋的戶主所述，這個化糞池近幾年已很少使用)，該化糞池的溢水管將溢流排放至距離滑坡處以北約 10 米外的山坡上(圖 2)。現場並沒有跡象顯示該化糞池曾經漏水。在上方山坡較遠處的 389, 391-393 號寮屋並未設有類似的化糞池。這

些寮屋的污水是通過一條聚氯乙烯管(已損壞不堪)排放到滑坡以北的山坡上(圖 2 和照片 11)。

土力工程處在滑坡附近的寮屋區豎立了幾個山泥傾瀉的危險警告牌，其中一個在滑坡泥石中發現，一個剛好在滑坡腳旁，另一個則在未受破壞的小路旁。

根據地政總署的資料顯示，二零零五年八月的山泥傾瀉現場位於一幅未批租和未撥用的政府土地上。

3. 山泥傾瀉的描述

二零零五年八月山泥傾瀉的平面圖和縱剖面圖分別載於圖 3 和圖 4。

根據目擊人士描述(包括芙蓉山村居民、消防員、警員和視察現場的土力工程處工程師）、香港警務處的記錄和山泥傾瀉後的實地觀察，二零零五年八月二十日的山泥傾瀉大約在下午五時二十五分到六時三十分之間分階段發生(見第 7 部分)。崩塌發生在曾遭人為活動局部擾動的山坡上(見第 2 部分)。崩塌殘痕約 45 米長(平面圖上)、18 米寬(最大)、最深約為 4 米、崩塌體積約 400 立方米。滑坡泥石整體的滑動距離約為 20 米(圖 3)；主斷崖約 10 米寬、7 米高、仰角介乎 50°至 65°(照片 5 和 12)。在山泥傾瀉後只有主斷崖外露，其餘的崩塌殘痕均被滑坡泥石所覆蓋。在主斷崖表面沒有發現不良的地質構造(比如殘留節理、低強度的填充等)。在二零零五年八月二十一日早上的視察中，並沒有發現主斷崖表面有滲流或其他水流的跡象。但是，外露的岩土明顯濕潤，似乎處於飽和狀態。

一段 2.5 米高(最厚為 0.5 米)的砌石擋土牆隨同其上邊的一幅面積約 4.5 米乘 2.5 米的平台在山泥傾瀉中倒塌(照片 5)。388 號寮屋的一角在山泥傾瀉中遭到掏蝕，但是其結構表面並沒有明顯的裂縫或破壞。388 號寮屋內的地面狀況屬一般，有一些可能是由於地板曾經輕微沉降而形成的舊裂縫。

橫跨二零零五年八月滑坡中部的一段 15 米長小路和連接該小路及其上方的寮屋的一段 10 米長梯級均在此次山泥傾瀉中崩塌(照片 13)。在此次山泥傾瀉事件中，鄰近的公用設施亦遭破壞，包括兩條水管、三根電線杆、兩根電話線杆和兩支街燈(包括電線管道及燈柱)(照片 14)。滑坡泥石在 516 號寮屋前停止，將部分溪流覆蓋了(照片 15)。部分細粒泥石(沖刷沉積物)沿溪流沖刷至 150 米外的地方，但並沒有造成任何破壞。

滑坡泥石軌跡可以分為上、下兩部分，上部主要包括紅褐色含砂的黏質粉土、從砌石擋土牆上掉下來的石塊、混凝土小路和梯級的碎塊及其扶手、電纜杆(標為 E1，圖 3)、燈柱(標為 LP1)和電纜管道、倒下的樹木(標為 T1、T2 及 T3)和斷截的供水管段，還有部分可能是由寮屋居民建造的柵欄和扶手。一整片泥石(連同樹 T3，見圖 3 和照片 16)以及從滑坡頂部的砌石擋土牆上掉下來的石塊，停在泥石軌跡的上部。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

位於下部的滑坡泥石軌跡主要包括紅褐色到黃褐色砂質黏土/粉土、小路及梯級的混凝土碎塊及其扶手、一些倒下的樹和損壞的公用設施(照片 15)。燈柱 LP2 被發現倒在一段小路的扶手之下，兩者之前都並排在小路旁(照片 17)。滑坡泥石夾雜著家居垃圾(含有腐爛的有機物質和纖維物質、塑膠袋、瓶子、鐵罐頭、損壞的家居/電器用具、木材等等)，堆積在泥石軌跡下部近東邊及溪流附近的一列圍網(由村民圍起作耕種用途)，達到大約 2.5 米高(照片 18)。家居垃圾似曾被泥石推至圍網處。

泥石流動性的評估與崩塌的大概過程(見第 7 部分)，是根據滑坡泥石的移動模式(根據泥石中物件的繪測位置和原本的位置)，包括崩塌的物件、小路及梯級的碎塊、倒下的樹和損壞的公用設施等(圖 5)而推算得出。

根據目擊人士的描述和水務署的記錄，一條直徑爲 100 毫米的水管斷開並將水排放至滑坡泥石至少持續五小時，直至二零零五年二十一日凌晨零時零五分水務署切斷供水前爲止(但在二零零五年八月二十日晚上大約九時四十五分，當土力工程處緊急事故控制中心人員視察時，現場一條已斷開的、直徑 80 毫米水管並沒有水流出來)。根據山泥傾瀉後的檢查時顯示，供水管是因爲山泥傾瀉而導致在螺旋接頭的地方脫位斷開的(接頭的狀況尚可，並沒有毀壞的跡象，例如生銹、銹蝕孔，見照片 13)。在山泥傾瀉後的檢查期間，所有通往崩塌痕跡的地面排水管都已廢棄、損壞或是堵塞了(照片 11)，當時並沒有任何水流的跡象(圖 2)。在小路和梯級的崩塌邊沿上沒有發現任何明顯的水流跡象(例如滑坡泥石上的侵蝕沖溝)。根據現場觀察和勘察顯示，並沒有其他可能的集中地表水源流進滑坡區域。

鄰近山坡沒發現諸如張力裂縫之類的破壞或狀況變壞跡象，在二零零五年八月山泥傾瀉現場附近的溪流旁邊，也沒發現其他明顯崩塌或侵蝕的跡象。在滑坡的北面，溪流高程比較高而其鄰近的山坡整體地勢較平緩。在滑坡南面上方的山坡，由於搭建寮屋已開挖成多個平台，令整體坡度變得較平緩。在滑坡腳北面鄰近的山坡上可以看到一處小的坡度折曲(約 1 米高)，及在滑坡腳南面有一處相關的斷崖(照片 19)。根據一九六四年的航空照片顯示，這些特徵可能和一處局部不穩定有關或曾經被人工開挖(見第 4 部分)。沿著山坡底部的溪流觀察，顯示該山坡底部並沒有到受溪流的侵蝕，這與當地村民描述溪流的流水量一直非常少是一致的。

水務署在二零零五年八月十九日，曾發現在引水道對上的一幅小型削坡上有一處輕微崩塌(約 2 立方米)，位置剛好在溢流堰的下游，即通往二零零五年八月發生的山泥傾瀉現場附近的溪流頂端。根據水務署報告，崩塌的泥石已被引水道的水流沖刷帶走，並沒有在二零零五年八月二十日造成引水道的堵塞。

4. <u>事發地點的發展歷史和過往的不穩定記錄</u>

事發地點的發展歷史是根據自一九二四年起至今的航空照片判釋和翻查其他有關的檔案而確定的，並撮述在附錄 A。

現存最早的航空照片顯示，二零零五年八月山泥傾瀉的現場在一九二四年是一處天然山坡。竹林禪院始建於一九二七年。在山泥傾瀉現場上方的山坡的城門引水道

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

於一九三七年左右建成。從一九四九年起，這裏開始有人爲的活動，例如：搭建寮屋、耕作(包括興建池塘和水堰)及在山泥傾瀉現場東邊修建小路和寺廟。

從六十年代初開始，二零零五年八月山泥傾瀉現場附近就出現村落發展，在滑坡附近的寮屋則在一九六三年至一九七六年間建成。直到一九七九年，寮屋發展達到高峰，隨後沒有進一步的大型寮屋搭建。從一九七七年起，橫跨山泥傾瀉現場的小路下方的山坡用作傾倒家居垃圾的地點。從一九九六年至一九九八年間，芙蓉山村的寮屋大量被清拆。二零零零年以後，山坡上就再沒有重大的變化。

根據土力工程處的山泥傾瀉資料庫、山體滑坡目錄(NTLI)、大型滑坡資料庫(LLD)和山體滑坡目錄擴大版的資料顯示，在二零零五年八月山泥傾瀉現場鄰近的地區並沒有任何山泥傾瀉的記錄。在距離山泥傾瀉現場北面約 20 米的地方，是曾經發生山泥傾瀉而距離最近的地點(在山坡上的小路下面發生小型崩塌，體積約 3 立方米)(見附錄 A 和圖 6)。

翻查一九六四年的航空照片，可以發現在接近二零零五年八月山泥傾瀉的底部，可能有一處局部不穩定或曾經被人工開挖。在滑坡南面約 30 米，有兩處推斷爲滑坡殘址的退化的凹陷地形(圖 6)。

因應政府以斜坡安全理由，對容易遭到山泥傾瀉威脅的寮屋進行非發展性清拆(NDC)計劃，土力工程處在一九八五年勘察了芙蓉山地區。因二零零五年八月山泥傾瀉事件而要永久遷離的四所編號爲 388、516、526 和 528-529 的登記寮屋(圖 2)，在一九八五年並沒有被土力工程處納入建議清拆的範圍內，儘管有其他的寮屋納入 NDC 建議。

土力工程處在一九九二年再次在芙蓉山地區進行 NDC 的勘察。因二零零五年八月山泥傾瀉事件而要永久遷離的四所編號爲 388、516、526、528-529 的登記寮屋，在一九九二年的 NDC 計劃中被土力工程處納入建議清拆的範圍內。清拆由房屋署和地政總署執行。房屋署確定共有 290 所寮屋要清拆，並且爲其住戶提供住所安置。20 個家庭包括該四所編號爲 388、516、526 和 528-529 的寮屋住戶拒絕接受安置，並選擇留下來。根據房屋署所提供的記錄，這些寮屋在二零零五年八月山泥傾瀉事件之前一直未清拆。

在一九九二年的 NDC 計劃執行期間，一些寮屋亦因“其他理由”而被建議清拆(即並非受到山泥傾瀉威脅的理由)。在一九九四年編號 TW18/94 清拆計劃中，房屋署確定 389, 391-393 號寮屋(圖 2)亦要清拆，而有關住戶亦獲提供住所安置。但是，他們拒絕接受安置並選擇留下來。根據房屋署所提供的記錄，這些寮屋在二零零五年八月山泥傾瀉事件之前一直未清拆。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

5. 雨量記錄分析

降雨量資料來自距離二零零五年八月山泥傾瀉現場最近的土力工程處編號 N38 和 N03 自動雨量計，分別位於現場以西約 1.2 公里和以東約 1.3 公里(圖 1)。雨量計每隔五分鐘傳送雨量資料至土力工程處和香港天文台。二零零五年七月十九日至八月二十三日的每日雨量，以及二零零五年八月十八日至八月二十一日的每小時雨量均在圖 7 顯示。編號 N03 雨量計在約 24 小時內的降雨量變化與編號 N38 雨量計所錄得的大致相同，但編號 N03 雨量計在較長時段所錄得的降雨量相對較少。

黃色暴雨警告信號在二零零五年八月十九日下午七時二十五分發出，並持續至二零零五年八月二十日凌晨零時二十五分。黃色暴雨警告信號在二零零五年八月二十日早上八時三十五分再次發出，並持續至當天晚上九時零十分。山泥傾瀉警告則在二零零五年八月十九日晚上九時正發出，並持續至二零零五年八月二十二日早上六時十五分。

二零零五年八月山泥傾瀉現場一帶，在事發前的降雨量很高(見表 1)。從二零零五年八月十九日下午五時十五分起持續降雨長達 24 小時(在當日午夜至二零零五年八月二十日凌晨一時之間有幾次很短暫的停歇，見圖 8)，直到二零零五年八月二十日下午大約五時二十五分發生山泥傾瀉事件爲止，其間最大的 24 小時滾存降雨量約爲 450 毫米。

參考香港天文台從一八八四年開始在尖沙咀所錄得的過往降雨量資料(Lam & Leung，一九九四)，對編號 N03 和 N38 雨量計在不同時段所錄得的滾存降雨量的重現期作出分析。分析結果顯示，在事發前，編號 N38 雨量計所錄得的 10 天或以上的滾存降雨量最爲嚴重(表 1)，相應的暴雨重現期超過 100 年。根據事發前 31 天的滾存降雨量，在編號 N03 雨量計處的最大暴雨重現期是 73 年。

香港天文台一直肯定的是，香港地勢較爲多山，降雨量在不同區域有差異，令在尖沙咀天文台所錄得的降雨量未必適用於香港其他地方(Peterson & Kwong，一九八一；Lam & Leung，一九九四)。Wong & Ho(一九九六 b)提出，導致不同地方降雨量有差異的其中一個原因是山勢地形的影響。Evans & Yu(二零零一)分析了從一九八四年到一九九七年間，分佈香港各處共 46 個土力工程處自動雨量計的五分鐘降雨記錄。研究所得出的結論是，在香港各地暴雨重現的次數並不一致，而根據尖沙咀天文台的降雨量統計資料計算得出的暴雨重現期在其他的地方並不一定適用。因此，編號 N03 和 N38 雨量計所錄得的滾存降雨量亦採用了 Evans & Yu(二零零一)從編號 N03 雨量計，於一九八四年到一九九七年間所錄得的降雨量記錄得出的統計資料，進行評估(編號 N03 雨量計於一九八三年六月開始運作，而編號 N38 雨量計到一九九九年十月才安裝)。根據上述方式計算，編號 N38 雨量計在事發前 10 天和 12 天的滾存降雨量最大，相應的重現期超過 100 年(表 1)；根據 24 小時降雨量，編號 N03 雨量計的最大暴雨重現期是 34 年。

二零零五年八月十九日的暴雨的最大滾存降雨量，已分別和編號 N03 及 N38 雨量計自一九八三年到二零零四年間所錄得的歷次暴雨記錄作比較(圖 9)。就爲時超過 12 小時的雨量而言，二零零五年八月十九日的暴雨是有記錄以來最嚴重的。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

6. 事發地點的地下情況

6.1 概述

事發地點的地下情況是根據翻查檔案和實地研究所得的資料而確定的。檔案研究工作包括翻查所有現存的資料，而實地研究工作則包括地質測繪及場地勘探。

土力工程處(一九八六)和 Sewell et al (二零零零)測繪的比例分別為 1：20,000 和 1：100,000 的地質圖顯示，事發地點的基岩為花崗閃長岩。從 1：20,000 比例的地質圖可見，與粗粒凝灰岩形成的一條東西走向邊界在事發地點以北約 150 米的地方，沿此邊界有一條長石斑岩。在事發地點以東約 600 米的老圍，有一條沿著溪流的南北走向的斷層。在事發地點東北面鄰近的山谷中分佈有坡積物(圖 10)。

作為此次調查工作一部分的場地工程地質測繪，於二零零五年八月二十一日展開，並隨著搭建臨時通道與及後的場地勘探工作持續進行至二零零五年十二月。

6.2 場地勘探

場地勘探工作在 MGSL 的監督下分兩個階段展開，以確定在二零零五年八月的山泥傾瀉事件中岩土的特性和情況。場地勘探站的位置見圖 11。第一階段勘探工作主要在崩塌殘痕內進行，由太平洋洲際有限公司負責並於二零零五年九月二日至十月二十五日期間展開。勘探工作包括一個垂直鑽孔、一個測壓管、七個探井、兩個探槽、一條斜坡條狀表土剝露、23 個 GCO 輕型動力觸探、13 個原位密度試驗、裝置四組張力計(每組包括三個不同深度的張力計，見第 6.5 部分)，以及清理植被。

第二階段的勘探工作在二零零五年八月的崩塌殘痕外圍進行，由鑽達地質工程有限公司負責並於二零零五年十月二十五日至十二月十五日期間展開。勘探工作包括七個垂直鑽孔、九個測水管及測壓管、兩個在砌石牆上的水平取芯鑽孔、兩個探井和兩條斜坡條狀表土面剝露。現場試驗包括鑽孔內的恒定水頭滲透試驗、四個恒定水頭雙環滲透儀試驗、鑽孔超聲波成像探測和壓水(汲收)試驗。

6.3 地質

地質資料是從已發表的數據、事發現場的場地勘探和工程地質測繪中整理出來的。香港地質調查組在二零零五年八月的山泥傾瀉現場及附近觀察到的地質及其他相關特徵在圖 10 展示。滑坡處的地質圖和剖面圖分別見圖 12 和 13。

事發現場的主要岩性組成為中粗粒花崗閃長岩，上覆一層相對較薄的殘積土(少於 500 毫米)。地表沉積物在滑坡主斷崖處外露，包括一層薄的填土覆蓋著一層厚達 3 米的坡積物。在崩塌殘痕的上部發現有填土(約 1 米厚)，而且在探井編號 TP6 到 TP10 中也觀察到一層 0.2 米至 0.4 米厚的填土。填土一般為紅褐色含砂的粉質黏土，夾雜著卵石和礫石大小的石塊。在崩塌殘痕的中至下部的表面和探井編號 TP4 及 TP11 中，

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

均發現有大量家居垃圾(照片 20 和 21)。

在崩塌殘痕及附近山坡的所有探井(編號 TP5 到 TP10)中，都發現有坡積物，厚度從探井編號 TP5 的 1.5 米到探井編號 TP6 的 3 米不等(探井編號 TP7、TP8 和 TP10 中，由於存在大塊坡積石塊，坡積物的底部未能確定)。坡積物一般由砂質黏土/粉土組成，偶有夾雜中礫和巨礫。在崩塌殘痕外圍的所有鑽孔均在地面發現坡積物，厚度爲 1.5 米至 4.2 米。

在二零零五年八月的崩塌殘痕內大多數探井的底部，都發現有全風化花崗閃長岩(CDGd)。在探井中顯露的 CDGd 一般由呈黃褐色，帶黑色及白色斑點的含砂的黏質粉土組成，屬風化質譜靠近頂部的全風化物；帶有原岩典型的組織但只能觀察得到部分結構(即按風化分級爲殘積土)。除了探槽編號 TT1a 內有一些高度風化的芯石外，在探井內並沒有發現高度風化花崗閃長岩(HDGd)或較淺風化的物質。在鑽孔中發現 CDGd 延伸很深(約 20 米)及物質成份出現局部的變化(例如微含砂的黏質粉土區)。在大多數鑽孔中，由於有大量氧化錳的填充，殘留結構的特徵有明顯的區別，尤其在超過 10 米的深度。土壤基質亦發現含有豐富的氧化錳區。其次，在殘留節理中亦充填有高嶺土，並散佈在土壤基質中，然而在滑坡破壞面以下並沒有發現相對移動和明顯的擾動跡象。分別位於毗鄰山坡坡頂和坡腳，鑽孔編號 DH3 和 DH8 中發現帶有芯石的 CDGd，但在滑坡中部的鑽孔編號 DH7 中卻沒有發現 CDGd 帶有芯石。勘探得的風化等級三級或更佳的岩石，是由堅硬到非常堅硬的、淺灰色、中度到輕度風化、中粒的花崗閃長岩組成，具中等到密集間距的節理。根據滑坡內和附近的八個鑽孔資料建構出的基岩等高線顯示，岩面向東傾斜約 27°並在鑽孔編號 DH7 附近可能會有輕微的凹陷(圖 11)。坡積物的厚度一般都很平均，並沒有證據顯示 CDGd 有不規則的表面。

殘積土主要在滑坡主斷崖表面外露，一般厚 100 毫米至 200 毫米，由紅褐色至黃褐色砂質粉土/黏土組成，沒有明顯結構或組織。殘積土一般均沒有在崩塌殘痕內的探井中發現，可能是在山泥傾瀉時被帶走。

在崩塌殘痕內的所有探槽和探井內都發現滑坡泥石，厚度從探槽編號 TT1(在滑坡主斷崖底部附近)的 0.4 米到探井編號 TP4(在泥石軌跡下部)的 1.8 米不等。滑坡泥石呈多樣性，但一般都爲紅褐色含砂的黏質粉土，夾雜著體積如砂礫、卵石、孤石等大小不一的石塊、混凝土碎塊及家居垃圾。家居垃圾(主要由腐爛的有機物質和塑膠袋組成，大概厚 0.5 米到 0.8 米)多數分佈在泥石軌跡下部，並普遍成層狀或與泥土/滑坡泥石混合一起(照片 20 和 21)。

破壞面只有在崩塌殘痕內的探井中顯露(照片 22)，一般是由 20 毫米厚的灰色/褐色砂質粉土/黏土組成，局部包括一個狹長的剪切及層狀土帶(約 0.5 米)，並在探井編號 TP3 中可以清楚看到(照片 23)。破壞面主要在 CDGd 內。在探井編號 TP3 的局部位置可以看到一個剪切/擾動土壤區一直延伸進 CDGd 內約 200 毫米。山泥傾瀉後，破壞面的土壤非常濕潤，並有擾動和重塑的現象。現場沒有發現其他相對移動的證據例如擦痕面等。在剪切及層狀土帶內，破壞面一般位於剪切帶的底部(照片 23)。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

6.4 土壤的特性

本次調查中對場地勘探時取得的樣本，分別在工務中央試驗所(PWCL)和香港科技大學(HKUST)進行了一系列的實驗室試驗，包括含水量試驗、粒徑分佈試驗、阿太堡界限試驗、土樣本和水樣本的化學試驗、單階段各向等壓固結不排水三軸壓縮試驗(簡稱 CIU 試驗)、固結試驗、直剪試驗和應力路徑試驗(在恒偏應力下逐漸增加孔隙水壓力，簡稱“恒偏應力”試驗)。所有試驗均參照 Geospec 3 (土力工程處，二零零一)進行，試驗結果摘要載於圖 14 至圖 16。

滑坡泥石的細粒土(即粉土和黏土)平均含量爲 52%，範圍介乎 30%至 65%之間；坡積物和 CDGd 細粒土的平均含量分別爲 49%和 36%；對於坡積物，幅度介乎 8%至 66%；對於 CDGd，幅度介乎 19%至 62%。CDGd 的細粒土的塑性指數介乎 7%至 20%之間，液限則介乎 38%至 49%。坡積物的細粒土的塑性指數介乎 14%至 37%之間，液限則介乎 42%至 66%。滑坡泥石的細粒土的塑性指數介乎 11%至 35%之間，液限則介乎 36%至 63%。CDGd 由含礫砂的黏質粉土、砂質粉土、以及含砂的黏質粉土、粉質礫砂和粉質砂土組成。CDGd 中的粉土主要爲中塑性粉土(圖 15)。坡積物由砂質黏土、砂質粉土、礫砂粉土組成，偶然發現有砂礫。坡積物主要爲高塑性黏土和粉土(圖 16)。滑坡泥石由砂質粉土和含砂的粉質黏土組成，主要爲中塑性至高塑性黏土和粉土(圖 14)。

在鑽孔進行的恒定水頭滲透試驗和地面雙環滲透試驗結果顯示，坡積物的滲透系數範圍介乎 2.5×10^{-6} m/s 到 6×10^{-5} m/s 之間，平均值爲 3.7×10^{-5} m/s。在鑽孔進行的滲透試驗顯示，CDGd 的滲透系數一般爲 2.3×10^{-6} m/s 到 8.5×10^{-6} m/s 之間，除了在離地面約 11 米深處的一次試驗錄得較高的滲透系數達 1.6×10^{-5} m/s。

填沙法試驗結果顯示，滑坡泥石的平均乾容重和單位重量分別爲 10.7 kN/m^3和 13.4 kN/m^3，乾容重介乎 10.1 kN/m^3 至 12 kN/m^3，單位重量介乎 12.8 kN/m^3 至 14.7 kN/m^3。坡積物的乾容重介乎 11 kN/m^3 至 14.6 kN/m^3，平均值爲 12.9 kN/m^3。從 CDGd 原狀樣本得出的乾容重介乎 13 kN/m^3 至 14.9 kN/m^3，平均值爲 14.1 kN/m^3。

CDGd 和坡積物的抗剪強度特性是從 CIU 試驗和恒偏應力試驗來評估。從探井中取得的塊樣中，也準備了破壞面的試件進行了直剪試驗。試驗結果的摘要分別見圖 15 和圖 16。

從 CDGd 的 CIU 試驗中得出的抗剪強度參數爲有效黏聚力 $c' = 0$ kPa 和有效內摩擦角 $\phi' = 35°$。在 CIU 試驗中，CDGd 試件在剪力作用下表現出不同性質。在崩塌殘痕內外，一共有八個樣本，總共進行了 18 次 CIU 試驗。除了在六次試驗中，試件顯示出收縮性的狀態之外，大部分試驗結果均顯示試件在試驗過程中出現膨脹性的狀態。在這六次試驗中(在兩個樣本上進行)，其中兩次顯示不排水抗剪強度在峰值後明顯減弱。這兩個表現出有收縮性的試件是取自崩塌殘痕內的樣本，其乾容重比附近取得的樣本較低。但是另一個取自崩塌殘痕內，具有相近乾容重的樣本在試驗過程中卻表現出膨脹性的狀態(圖 17)。恒偏應力試驗能更近似的模擬現場土壤單元經歷在降雨後地下水壓力增加的應力路徑。在 CDGd 樣本進行有限次數的恒偏應力試驗，相應的抗剪強度參數爲 $c' = 4$ kPa 和 $\phi' = 31°$。對破壞面進行的直剪試驗顯示抗剪強度參數範圍是

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

c' = 0 kPa 和ϕ' = 31° 及 c' = 2 kPa 和ϕ' = 37°。

在對坡積物基質進行的 CIU 試驗中，試件在剪力作用下表現出膨脹性的狀態(圖 16)。從 CIU 試驗中得出的抗剪強度參數爲 c' = 0 kPa 和 ϕ' = 37°。在坡積物樣本進行有限次數的恒偏應力試驗，相應的抗剪強度參數爲 c' = 2 kPa 和ϕ' = 40°。整體試驗結果顯示坡積物基質的抗剪強度參數比 CDGd 高。

6.5 地下水的情況

事發約七小時後，接近午夜時分進行的現場視察，因當時沒有通往主斷崖的安全通道，未能確定是否存在滲流。二零零五年八月二十一日早上的視察中發現，外露在主斷崖上的岩土非常潮濕，似乎處於飽和狀態。在主斷崖和附近山坡上沒有發現滲流。在泥石軌跡下部已重塑及軟化的泥石中發現的沖溝，可能是斷開的、直徑爲 100 毫米的水管溢流造成。

在探槽編號 TT1 中 2.9 米深、探井編號 TP2 中 2.2 米深和探井編號 TP4 中 2.8 米深，均發現滲流。從探井中滲流取得的水樣進行的化學試驗指出，這些滲流很可能是天然地下水。

山泥傾瀉發生後，在七個鑽孔(編號 DH1、DH2 和 DH4 到 DH8)中錄得的地下水位監測資料列於表 2。從二零零五年十月至十二月期間，測水管及測壓管監測到的地下水位顯示，地下水大致跟隨山坡的整體坡向流動(即向東南方)。

在利用測壓管監測地下水期間，沒有較大的降雨量。一般而言，在監測期間，山坡上部和中部的地下水位比較低(離地面以下約 6 米至 10 米深)，而山坡下部的地下水位則相當接近地面，特別是在靠近溪流的鑽孔(編號 DH1 和 DH8，圖 11 和圖 12)。

在三個鑽孔中(即編號 DH1、DH2 和 DH8)，分別在上層的坡積物和下層的 CDGd 或 CDGd/HDGd 中各安裝了一個測壓管。在鑽孔編號 DH1 中，上部測水管的水位距離地面以下 1.35 米(即坡積物底部以上約 3 米)，而下部測壓管的水位則距離地面以下 2.35 米(即坡積物底部以上約 2 米)。在鑽孔編號 DH8 中，上部測水管和下部測壓管的水位分別距離地面以下 0.43 米和 0.28 米(均在坡積物內)。在較高處的鑽孔編號 DH2 (與滑坡頂部標高相約)，只有在 CDGd 層顯示出一個較深的基層地下水位，在監測期間在坡積物中沒有水位記錄。

二零零五年九月初，在滑坡附近安裝了四組張力計。每組分別在 1 米、2 米和 3 米深的位置各裝置了一個張力計。從二零零五年九月到十二月，張力計量度得的毛管吸力每日均以人手記錄。張力計的讀數和每日降雨量見圖 18。

毛管吸力的讀數顯示出區域性的差異，較淺的張力計在乾燥天氣時量度得的毛管吸力數值介乎約 5 kPa 到約 60 kPa。張力計 TS1 量度得的毛管吸力比其他三組張力計

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

量度得的明顯較高。由於多種不同因素，不同地點、不同深度的張力計的反應有所差異，這些因素包括周圍土體的水土特性的差異、在局部地區滲水及地下水流動模式。

毛管吸力對降雨是有反應的，但其反應速度和量值的變化隨著張力計處於不同位置和不同深度而有所不同。二零零五年九月二十五日至二十七日，發生了一場頗大的暴雨，編號 N38 雨量計在九月二十五日錄得的每日降雨量達到 275 毫米(以五分鐘的降雨量爲最關鍵性的時段，相應的重現期爲 25 年)。四個在 1 米深處的張力計中的毛管吸力全部消失。在 2 米深處，TS1 和 TS3 中的毛管吸力在 3 天後繼續下降，而 TS2 和 TS4 中的毛管吸力已開始恢復。

值得注意的是，一些位於較淺深度的張力計錄得小量的正水壓(小於 5 kPa) (圖 18)，這說明即使九月份的暴雨沒有八月份發生山泥傾瀉的暴雨那麼嚴重，在雨水向下滲透期間，表層物質的地下水壓力亦曾瞬間增加。這意味著八月份較嚴重的暴雨可能曾經引發更大的地下水壓力的增加。監測資料顯示，雨水滲入而引起毛管吸力的減退可能需要一段時間才徹底完成(約數天)，而往後恢復的速度(以毛管吸力的增加作爲依據)可能更慢(圖 18)。此外，有跡象顯示除了表面滲水之外，在某深度的優選地下滲流亦可能對毛管吸力產生影響；在某一組張力計上，較深處的毛管吸力比靠近地表的毛管吸力減退得更快及更明顯。

7. 山泥傾瀉大致的事發經過

山泥傾瀉大致的事發經過，是根據目擊人士所作出的描述、香港警務處和消防處的事件報告以及由 MGSL 於二零零五年八月在山泥傾瀉現場所做的詳細勘察重組而成。綜合來自各方的資料並經過相互印證後，推斷山泥傾瀉主要分爲兩個階段以牽引方式發生，並再觸發一些局部的小型崩塌。

根據 528-529 號寮屋居民的描述，第一階段的崩塌在二零零五年八月二十日下午大約五時二十五分發生，當時他警覺到他所飼養的犬隻發出異常的吠聲。他隨後注意到山泥傾瀉經已在山坡較低的部分發生，以及一段橫跨山坡中間的小路經已斷落(約 15 米的長度，小路上面的樹 T1(圖 3)當時雖仍在原處，但是已經見到它向崩塌區域傾斜)(圖 19)。同時，他也注意到燈柱 LP2(圖 3)已經倒下，沿著小路旁的欄杆懸垂著，以及沿著小路一條直徑爲 100 毫米的水管也斷開了，並將水排放到崩塌殘痕上。

根據 526 和 528-529 號寮屋居民的描述，在第一階段崩塌發生後約 15 分鐘，即下午五時四十分左右，第二階段崩塌在滑坡的上部、位於小路和上方 388 號寮屋之間的位置發生。第二階段崩塌的泥石，連同倒落的樹 T1，進一步推移小路的欄杆至燈柱 LP2 上方的位置才停下來(照片 17)。滑坡泥石被斷開的供水管流出的水流所影響，進一步向 526 號寮屋移動，並在一片耕種區周圍的柵欄前停下來。與第一階段崩塌的滑坡泥石相比較，第二階段崩塌的滑坡泥石滑動的距離比較短，並在崩塌殘痕的中部和上部停下來，部分堆積在第一階段崩塌的滑坡泥石的上面。現場觀察也證實了目擊人士所述。根據 526 和 528-529 號寮屋居民的描述，第二階段崩塌又可再分成兩次崩塌，但這卻無法從現場的地質測繪而確定。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

沿著南面斷崖近小路處，可能受到斷開水管排出的水流所影響而發生了進一步小型崩塌，導致主斷崖側翼的崩塌和擴大(圖 19)。

第一階段崩塌的泥石滑動的距離約爲 20 米，而運行角度約爲 20°。第二階段崩塌的泥石滑動的距離約爲 16 米，運行角度約爲 32°。

由於手提電話失效，528-529 號寮屋居民在下午約五時二十五分發生第一階段的山泥傾瀉後並沒有立即向當局報告。他其後要求 516 號寮屋居民報告此次事件。根據香港警務處的記錄，此次事件是由 516 號寮屋居民於下午六時五十四分報告的。消防處接報的時間是下午六時五十五分。消防員於傍晚七時十一分抵達芙蓉山路，然後徒步登山至山泥傾瀉現場。消防員在晚上九時零八分，在接近崩塌的小路下面的滑坡泥石中，發現有人的腿部伸出，並於晚上九時五十分從泥石中挖出屍體。根據消防員的描述，死者是在南面斷崖側翼(圖 3 和照片 13)接近崩塌的小路的邊緣發現的。死者被埋在泥中約 0.5 米深，露出膝蓋以下的小腿(沒有鞋)，臉朝向下，頭朝向山坡上方。

根據香港警務處的記錄和芙蓉山村居民的描述，死者並不是寮屋區的居民，可能是一名到訪 389, 391-393 號寮屋的訪客(在調查期間並沒有發現該等寮屋的住戶，這些寮屋看來已被棄置及明顯沒有人居住的跡象)。

8. 理論穩定性分析

是次調查亦以理論方法分析山坡的穩定性，以協助判斷山泥傾瀉發生的機理和成因。這些分析旨在研究在山泥傾瀉發生時，破壞面的抗剪強度參數對應不同的地下水位情況下有可能的範圍。用於分析的資料來自已出版的測量圖、滑坡後的地形測量、場地勘探、實驗室試驗、現場觀察和實地量度。

二零零五年八月山泥傾瀉現場的剖面圖，以及分析所採用的參數，載於圖 20。崩塌前滑坡區域的地形剖面，是根據山泥傾瀉發生後，在滑坡斷崖兩側所進行的詳細地形測量結果推斷得出。山坡上家居垃圾的厚度和範圍是根據崩塌殘痕底部垃圾的體積、航空照片以及目擊人士的描述而推斷得出。分析所採用的地質剖面，即相應爲第一階段崩塌的破壞面，是根據地質測繪、場地勘探資料以及目擊人士的描述來確定。在一九六四年的航空照片中觀察到，並在地質測繪中推斷出可能是局部變得過於陡峭的山坡(見第 3 部分)，也一併在剖面的分析中考慮。在分析中假設一系列不同的地下水位深度，以模擬山泥傾瀉發生時有可能出現的地下水位情況。

以抗剪強度參數範圍爲 $c' = 0$ kPa 至 10 kPa 和 $\phi' = 28°$至 35°的分析結果詳見圖 20。結果顯示，在破壞面抗剪強度可能的範圍內，地下水位約在離地面約 1.5 米至 2.5 米的情況下已足以引發山泥傾瀉。以實驗室試驗得出抗剪強度參數 $c' = 0$ kPa 和$\phi' = 35°$作分析，地下水位在離地面約 1.9 米時就足以引發山泥傾瀉。這與現場觀察和地下水位監測結果大致吻合，表明根據以上的假設作出的理論穩定性分析是可信的。

一旦第一階段崩塌發生而導致土體失去支撐，上部山坡較陡峭的部分就很大機會以牽引方式崩塌下來。這與目擊人士的描述和現場的觀察一致。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

9. 山泥傾瀉成因的判斷

從暴雨和發生崩塌的時間的緊密關係顯示出，二零零五年八月二十日發生的山泥傾瀉事件是由降雨所引起。山泥傾瀉在一個處於臨界穩定狀態的、被擾動的山坡的天然土體上發生。該山坡曾被人為修整和擾動，使之更易出現雨水引發的山泥傾瀉。

在山泥傾瀉前的降雨歷時很長且強度很大，相應為百年一遇的暴雨。此次暴雨是過去 22 年以來，在該地區的中時段和長時段持續降雨中最為嚴重的一次。與二零零五年八月的暴雨相比，這山坡之前曾遭受過多次更為嚴重的短時段暴雨但沒有出現崩塌。

該處山坡曾在一九九二年的 NDC 計劃下，被土力工程處評定為容易發生崩塌的地點，而受此次事件影響的寮屋，亦曾以斜坡安全理由在 NDC 計劃下建議清拆。然而，受影響的寮屋住戶拒絕接受由房屋署所提供的安置並選擇留下來。在二零零五年八月山泥傾瀉之前，土力工程處已在山坡附近豎立了警告牌，警告有山泥傾瀉的危險，亦在事發時發出了山泥傾瀉警告。

發生山泥傾瀉的位置，與七十年代中期以來有未受管制和大型的垃圾傾倒區恰巧重疊。同時，地貌環境上也顯示受影響的山坡曾被掏蝕，並在過去因溪流流水的影響而變得非常陡峭。而且，從航空照片判釋所見的證據，也表明受影響的山坡接近崩塌位置較低的部分可能局部變得過於陡峭。表層物質的岩土及水土特性提供了一個有利於地下水壓力在降雨後增加的水文地質條件。山坡上的垃圾含有有機物質及纖維物質，可能形成不利的水力邊界條件，促使水份長時間保留在土壤中及在長時間降雨後提供相當的水份補給，因而令表層物質變得非常濕潤和土壤毛管吸力減少及引致地下水壓力的形成。參考在二零零五年九月的暴雨下，張力計在不同深度的反應速度，顯示相比起長時段降雨，短時段暴雨並不是太容易引起土體的地下水壓力明顯地增加。這也說明為何該處山坡自七十年代中期以來已有未受管制(非法)的傾倒垃圾，但幾十年以來均未有發生崩塌和破壞。總體而言，沒有證據顯示山坡狀況漸進變壞(例如形成張力裂縫等)是構成二零零五年八月的山泥傾瀉的關鍵因素。

張力計的讀數顯示土體的水土特性是：表層物質可能需要幾天的時間才徹底反映降雨後的反應，而往後恢復至降雨前的毛管吸力值的速度可能更慢。持續的暴雨配合土體的水土特性，可能是導致在山坡大範圍的表層物質中，地下水壓力逐步增加至高位的原因。這點可以從崩塌後不久在現場的觀察及從理論穩定性分析中得以證實。

對於各種有可能滲入滑坡區域的水源，都進行了調查。經過詳細研究，沒有證據顯示在山泥傾瀉之前，沿著小路的供水管以及上方的化糞池有滲漏。現場沒有跡象顯示小路曾有如排水溝般，匯集較高處山坡的地面水流向滑坡區域，也沒有跡象顯示有集中的地面水溢流，從小路流入滑坡區域。此外，也沒有未受管制的地面水或污水直接排放到滑坡區域。因此，水的主要來源很可能是降雨直接滲入到被茂密的植被所覆蓋的山坡中，以及來自山坡上方的地下滲流。

山泥傾瀉的機理包括由於雨水的滲入，導致土體中土壤的毛管吸力逐步減少，緊接著表層物質中正水壓力在非均質土體中，通過非垂直滲流而增加(不排除在局部區

域較淺層的土壤中存在上層滯水位的可能性)。現場沒有明顯的跡象顯示山泥傾瀉是受地質構造控制的；可見的跡象亦指出，這次事件並不是一個殘留崩塌重新活躍的結果。這次山泥傾瀉事件是一個由降雨所引發的典型崩塌，其破壞面剛好位於坡積物與 CDGd 的交界面之下，剝露出的風化剖面上層較弱的泥層，而此部分開始分類爲殘積土。

第一階段崩塌泥石的流動性(運行角爲 20°)似乎比一般以滑動不穩定性爲崩塌機理的山泥傾瀉相關的流動性爲高。這很有可能是山泥傾瀉後，沿小路旁斷開的水管排出大量水流所導致。

10. 結論

調查所得的結論是，二零零五年八月發生於芙蓉山村的山泥傾瀉事件是由降雨所引發的。山泥傾瀉可能是由於該處在發生崩塌之前遭遇了一場約百年一遇的嚴重暴雨，表層物質失去土壤毛管吸力以及地下水壓力瞬間增加所致。

以下推斷是促使山泥傾瀉的因素：

(a) 表層物質的性質及水土特性提供了一個有利於地下水壓力在降雨後增加的水文地質條件；

(b) 該山坡大部分地段有未受管制和非法傾倒的家居垃圾(含有有機物質及纖維物質，能夠長時間保留水份)，形成不利的水力邊界條件，促使地下水壓力可能在長時間的暴雨後，在大範圍的山坡內急劇增加；以及

(c) 從整體地貌佈局、一九六四年的航空照片以及附近未崩塌的山坡上存在的坡度折曲等，可以推斷出該山坡的坡腳過於陡峭，可能使該山坡更容易出現由雨水引發的山泥傾瀉。

11. 參考書目

Evans, N.C. & Yu, Y.F. (二零零一) Regional Variation in Extreme Rainfall Values. 土力工程處，香港，81 頁。(土力工程處第 115 號報告)。

土力工程處 (一九八六) Sha Tin: Solid and Superficial Geology, Hong Kong Geology Survey, Map Series HGM20，第 7 張，比例 1:20 000。土力工程處，香港。

土力工程處 (一九八八) Guide to Rock and Soil Descriptions (Geoguide 3). 土力工程處，香港，186 頁。

土力工程處 (二零零一) Model Specification for Soil Testing - Geospec 3. 土力工程處，香港，340 頁。

Irfan, T.Y. (一九九六) Mineralogy, fabric properties and classification of weathered granite rocks in Hong Kong, Quarterly Journal of Engineering Geology, vol. 29, 第 5-35 頁。

King, J.P. (一九九九) Natural Terrain Landslide Study - The Natural Terrain Landslide Inventory. 土力工程處，香港，127 頁。(土力工程處第 74 號報告)。

Lam, C.C. & Leung, Y.K. (一九九四) Extreme Rainfall Statistics and Design Rainstorm Profiles at Selected Locations in Hong Kong. Technical Note No. 86, 香港天文台，89 頁。

Peterson, P. & Kwong, H. (一九八一) A Design Storm Profile for Hong Kong. Technical Note No. 58, 香港天文台，30 頁。

Sewell, R.J., Campbell, S.D.G., Fletcher, C.J.N., Lai, K.W. & Kirk, P.A. (二零零零) The Pre-Quaternary Geology of Hong Kong. 土力工程處，香港，181 頁及 4 張地圖。

Wong, H.N. & Ho, K.K.S. (一九九六 a) Travel distance of landslide debris. Proceedings of the Seventh International Symposium on Landslides, Trondheim, Norway, vol. 1, 第 417-422 頁。

Wong, H.N. and Ho, K.K.S. (一九九六 b) Thoughts on the Assessment and Interpretation of Return Periods of Rainfall. Discussion Note DN 2/96，土力工程處，香港，19 頁。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

<u>表目錄</u>

表 1 - 土力工程處編號N03和N38雨量計於二零零五年八月二十日山泥傾瀉前之選定時段所錄得的最高滾存降雨量及其估計的重現期

時段	最高滾存降雨量 (毫米)		降雨時段完結時間 (於二零零五年八月二十日)		估計的重現期 (年)			
	編號 N38 雨量計	編號 N03 雨量計	編號 N38 雨量計	編號 N03 雨量計	Lam & Leung (1994)		Evans & Yu N03的資料 (2001)	
					N38	N03	N38	N03
五分鐘	7.5	7.5	上午九時十五分	上午十時五十五分	<2	<2	<2	<2
十五分鐘	18.0	20.0	上午十時五十五分	上午十一時	<2	<2	<2	<2
一小時	47.0	46.0	上午九時五十分	上午十一時零五分	<2	<2	<2	<2
二小時	85.5	87.0	上午十一時	上午十一時零五分	<2	<2	<2	2
四小時	135.5	132.0	上午十一時四十五分	上午十一時五十分	3	3	3	3
十二小時	278.0	270.0	下午五時二十五分	下午二時三十五分	9	8	17	15
二十四小時	449.0	453.5	下午五時二十五分	下午五時二十五分	25	26	32	34
四十八小時	597.5	558.5	下午五時二十五分	下午五時二十五分	51	35	49	33
四日	715.0	629.0	下午五時二十五分	下午五時二十五分	52	25	38	19
七日	833.5	711.5	上午十一時零五分	下午四時五十分	80	29	65	26
十日	1062.5	810.5	下午五時二十五分	下午五時二十五分	269	37	>100	23
十二日	1194.5	887.5	下午五時二十五分	下午五時二十五分	479	47	>100	24
十五日	1194.5	887.5	下午五時二十五分	下午五時二十五分	254	28	65	13
三十一日	1727.0	1264.5	下午五時二十五分	下午五時二十五分	>1000	73	56	12

註 :
(1) 最高滾存降雨量是以五分鐘雨量記錄計算。
(2) 降雨重現期是採用 Lam & Leung （一九九四） 表3 及 Evans & Yu （二零零一）之資料計算。
(3) 跟據目擊者的描述，最初段的山泥傾瀉大約在二零零五年八月二十日下午五時二十五分發生。
(4) 土力工程處編號N38雨量計是距離山泥傾瀉現場最近的自動雨量計,位於事發現場以西約1.2千米。土力工程處編號N03雨量計則位於事發現場以東約1.3千米。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

表 2 - 二零零五年十月至十二月期間地下水位監測結果摘要

鑽孔編號	地面標高 (mPD)	測水管(上部)			測壓管(下部）		
		管底之標高 (mPD)	測量到的最高水位 (離地面深度/ mPD)	反應區域地質情況	測頭之標高 (mPD)	測量到的最高水位 (離地面深度 / mPD)	反應區域地質情況*
DH1	109.85	105.65	1.35 / 108.5	坡積物	99.70	2.35 / 107.05	CDGd
DH2	123.07	120.57	乾	坡積物	106.34	8.64 / 114.43	CDGd
DH4	124.89	-	-	-	106.89	11.70 / 113.51	CDGd
DH5	121.10	-	-	-	101.53	14.78 / 106.32	C/HDGd
DH6	118.45	-	-	-	102.25	12.50 / 105.95	CDGd
DH7	112.53	-	-	-	98.93	5.79 / 106.74	C/HDGd
DH8	103.68	99.68	0.43 / 103.25	坡積物	89.68	0.28 / 103.40	C/HDGd
備註:	* CDGd 表示全風化花崗閃長岩、HDGd 表示高度風化花崗閃長岩						

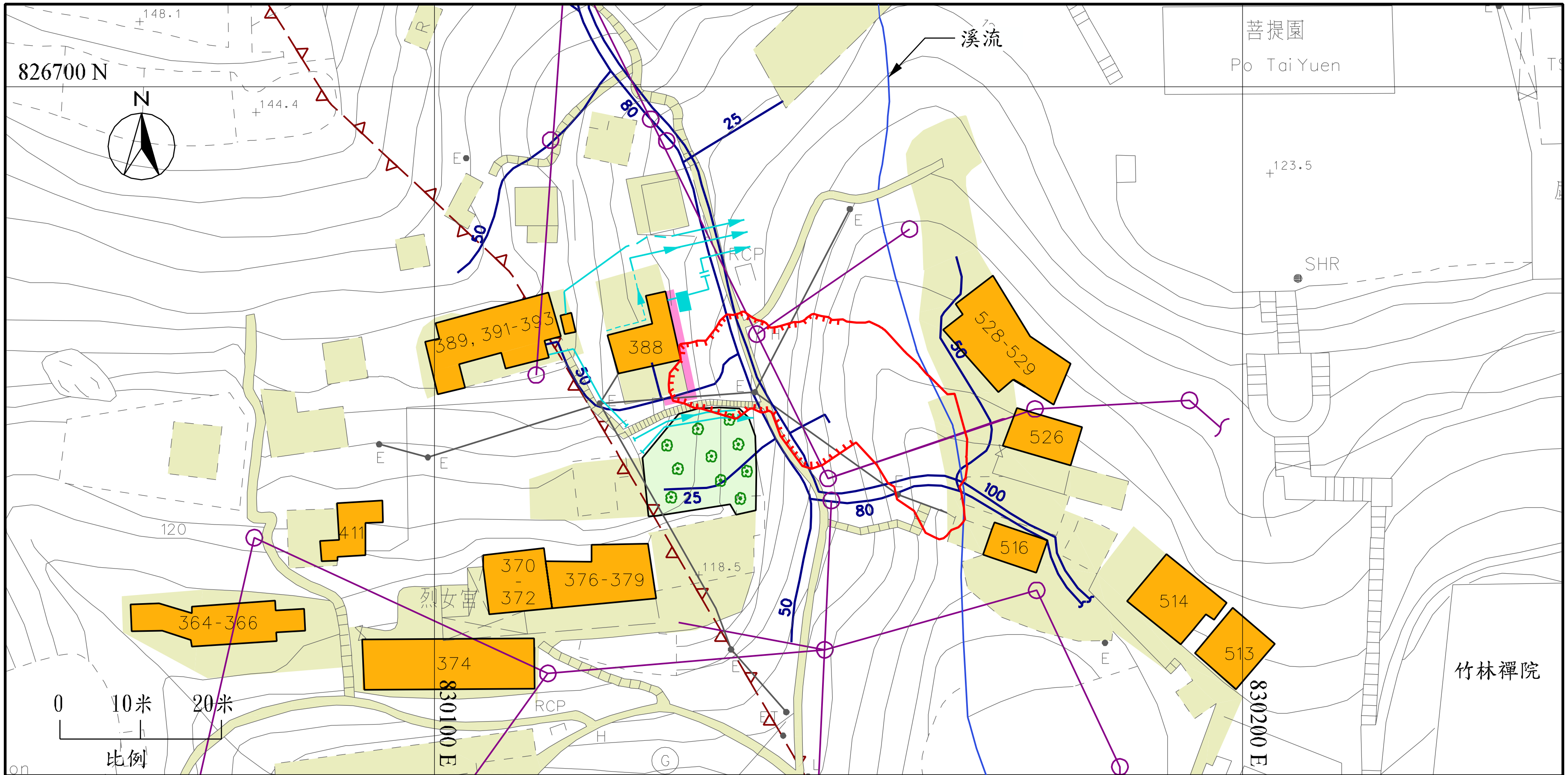
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

圖目錄

註： 底圖取自二零零四年三月編號 6SE-B, 6SE-D, 7SW-A 及 7SW-C 測量圖（比例 1:5000）。

圖1 － 山泥傾瀉位置圖

Table of Contents (Chinese) Table of Contents (Chinese) Table of Contents (Chinese) Table of Contents (Chinese)



圖例：

	二零零五年八月的山泥傾瀉		果樹種植區	100	直徑100毫米食水管		排水管
	山嘴	388	登記寮屋編號RTW/4A/388		電訊盈科高架電話線和線杆		有蓋排水渠
	鋪築的平台、小路和梯級		2.5米高不規則砌石墻	E	中華電力高架電纜和電線杆		化糞池

註： 底圖取自二零零四年三月編號 7SW-11C 測量圖（比例 1:1000）。

圖2 － 山泥傾瀉現場平面圖及公用設施

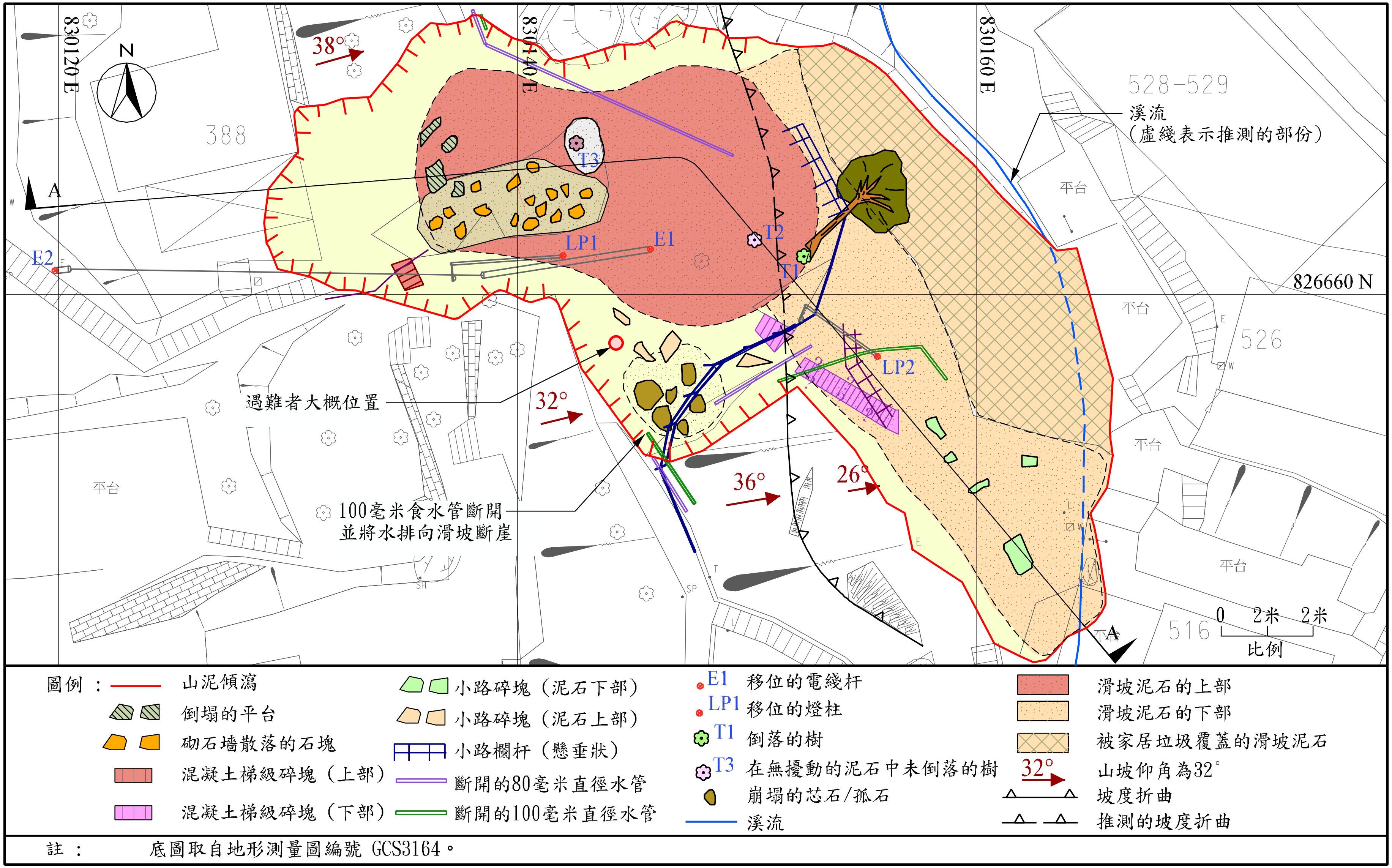
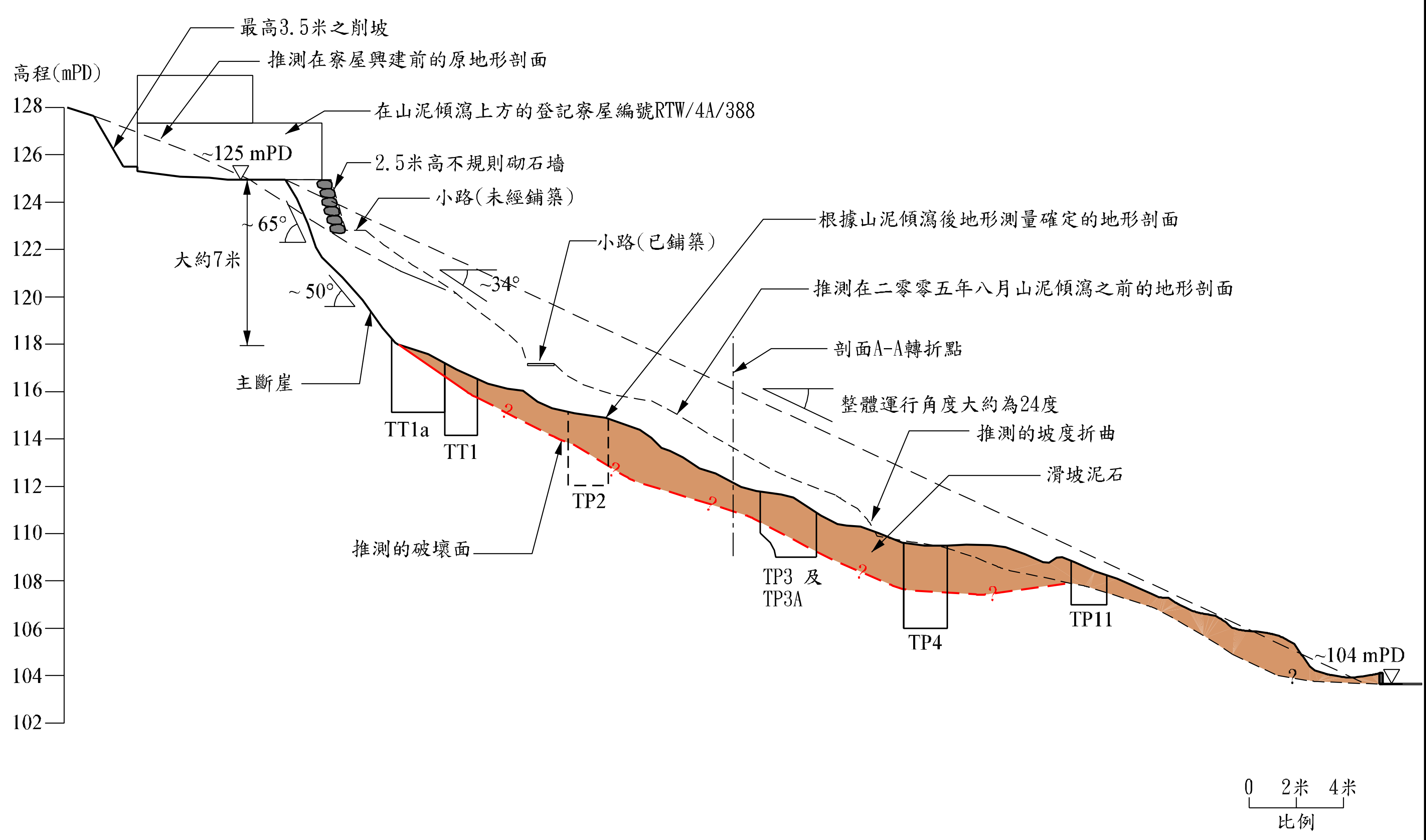


圖3 － 山泥傾瀉平面圖

Table of Contents (Chinese)　Table of Contents (Chinese)　Table of Contents (Chinese)　Table of Contents (Chinese)



註 ： 剖面位置見圖3，地質剖面見圖12。

圖4 － 山泥傾瀉剖面A-A

Table of Contents (Chinese) Table of Contents (Chinese) Table of Contents (Chinese) Table of Contents (Chinese)

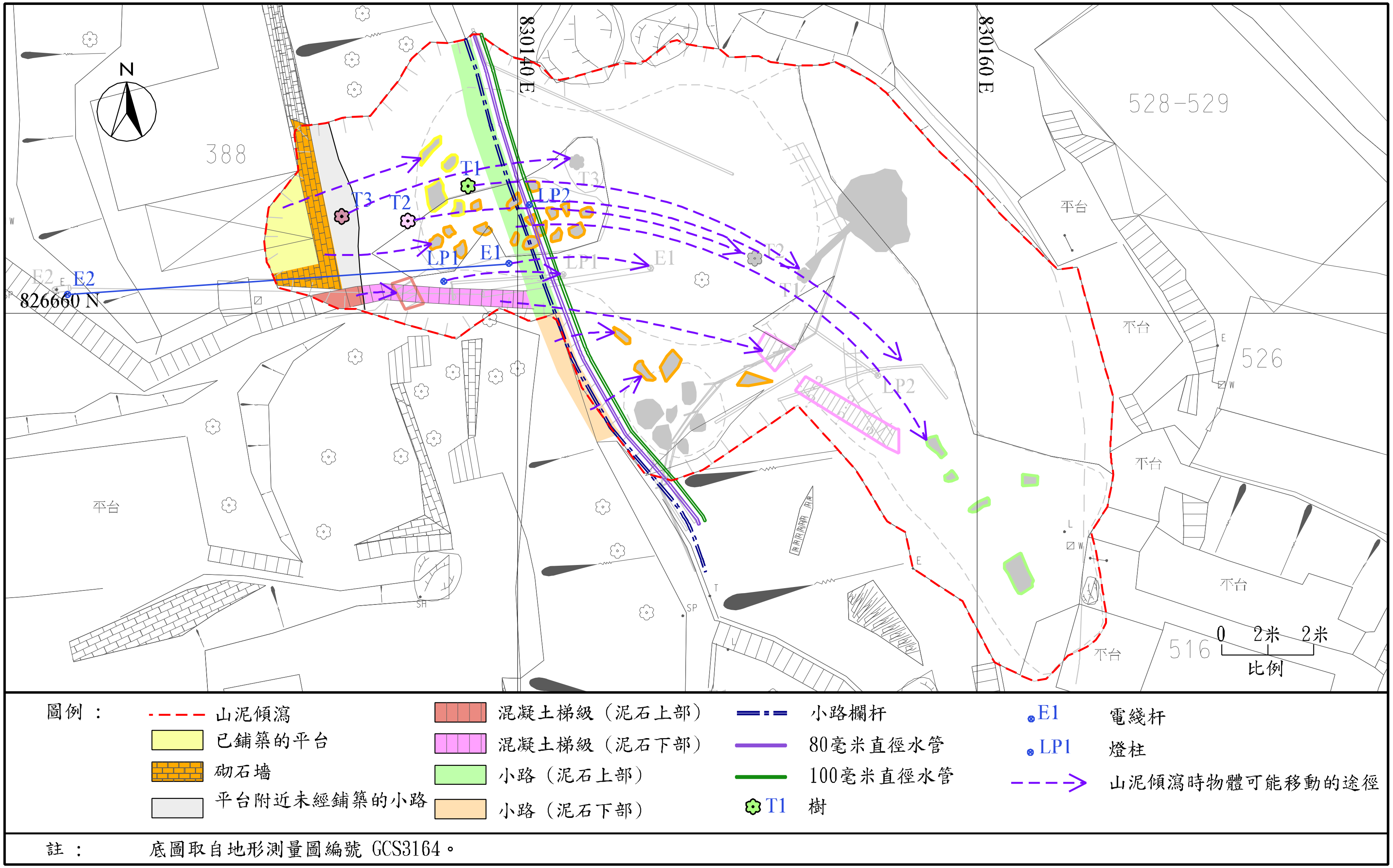


圖5 – 根據山泥傾瀉後觀察及目擊人士描述的泥石流動性

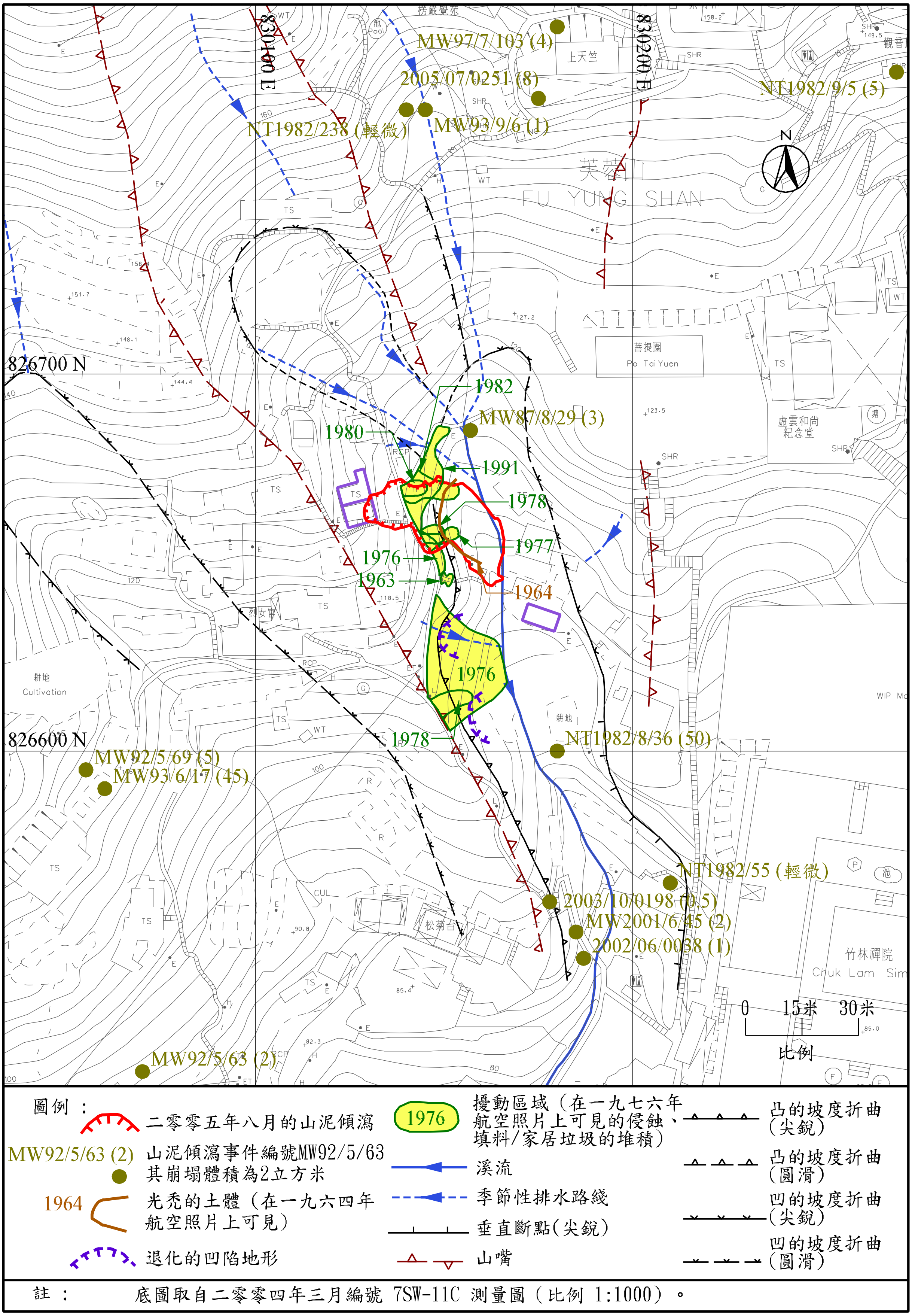
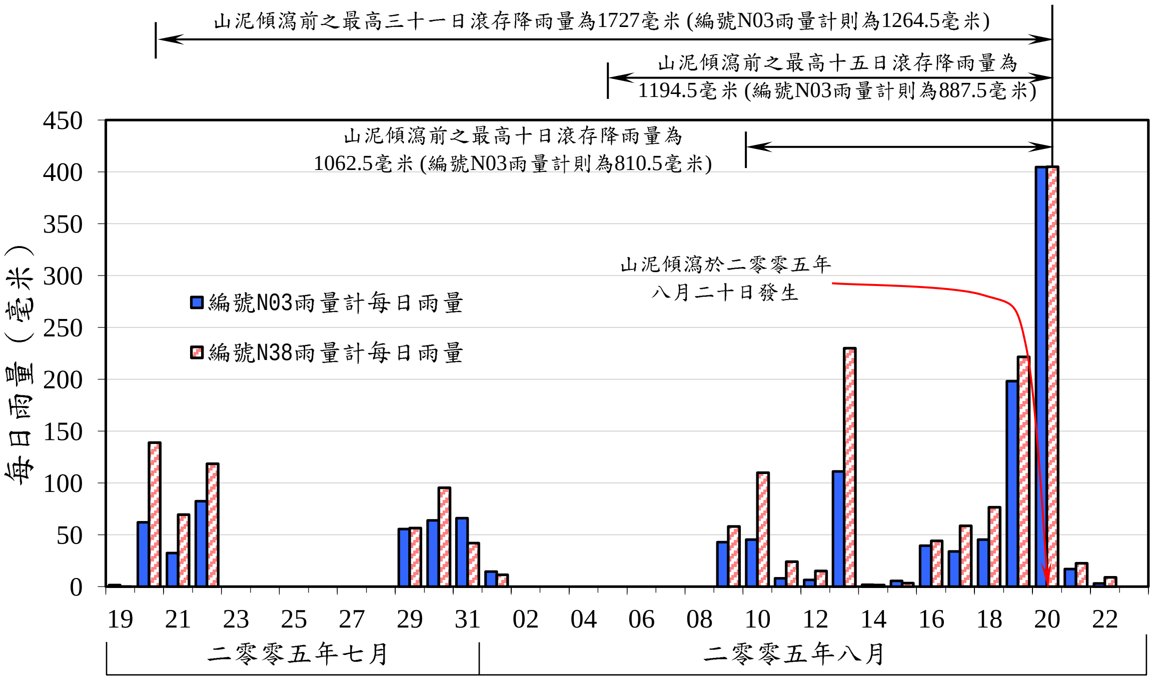
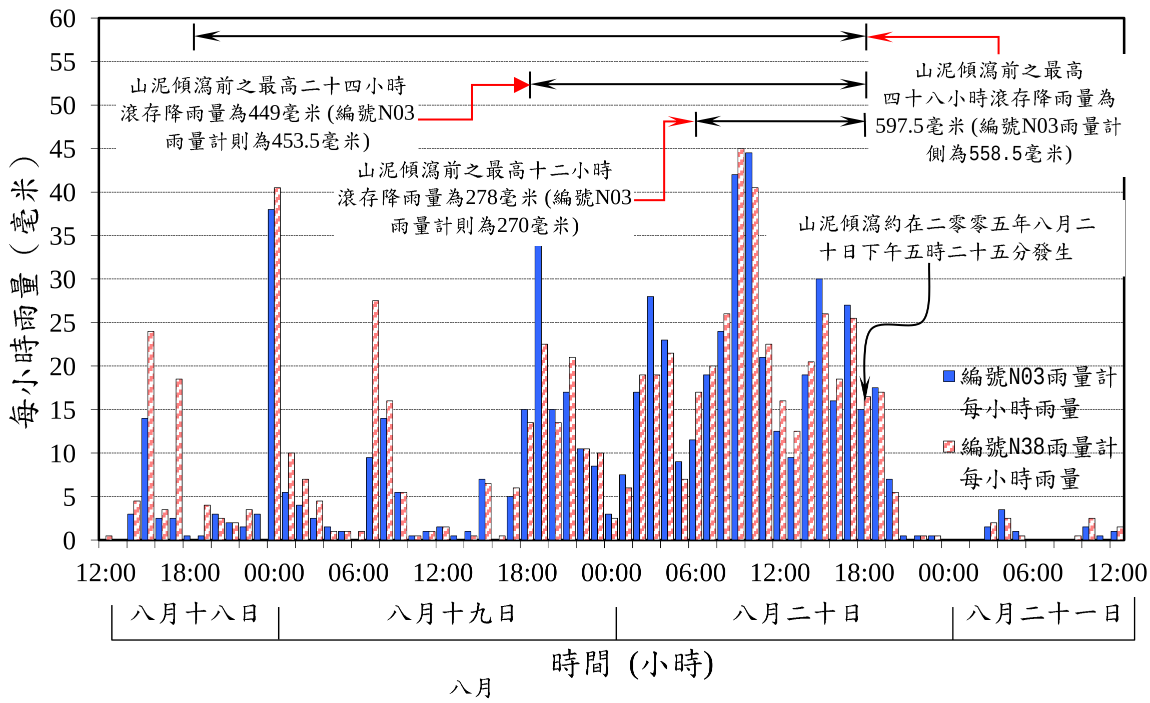


圖6 － 事發地點以往的不穩定性和地貌

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)



(a) 土力工程處編號N03和N38雨量計於二零零五年七月十九日至二零零五年八月二十三日所錄得的每日降雨量



(b) 土力工程處編號N03和N38雨量計於二零零五年八月十八日至二零零五年八月二十一日所錄得的每小時降雨量

圖7 - 土力工程處編號N03和N38雨量計的每日和每小時雨量記錄

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

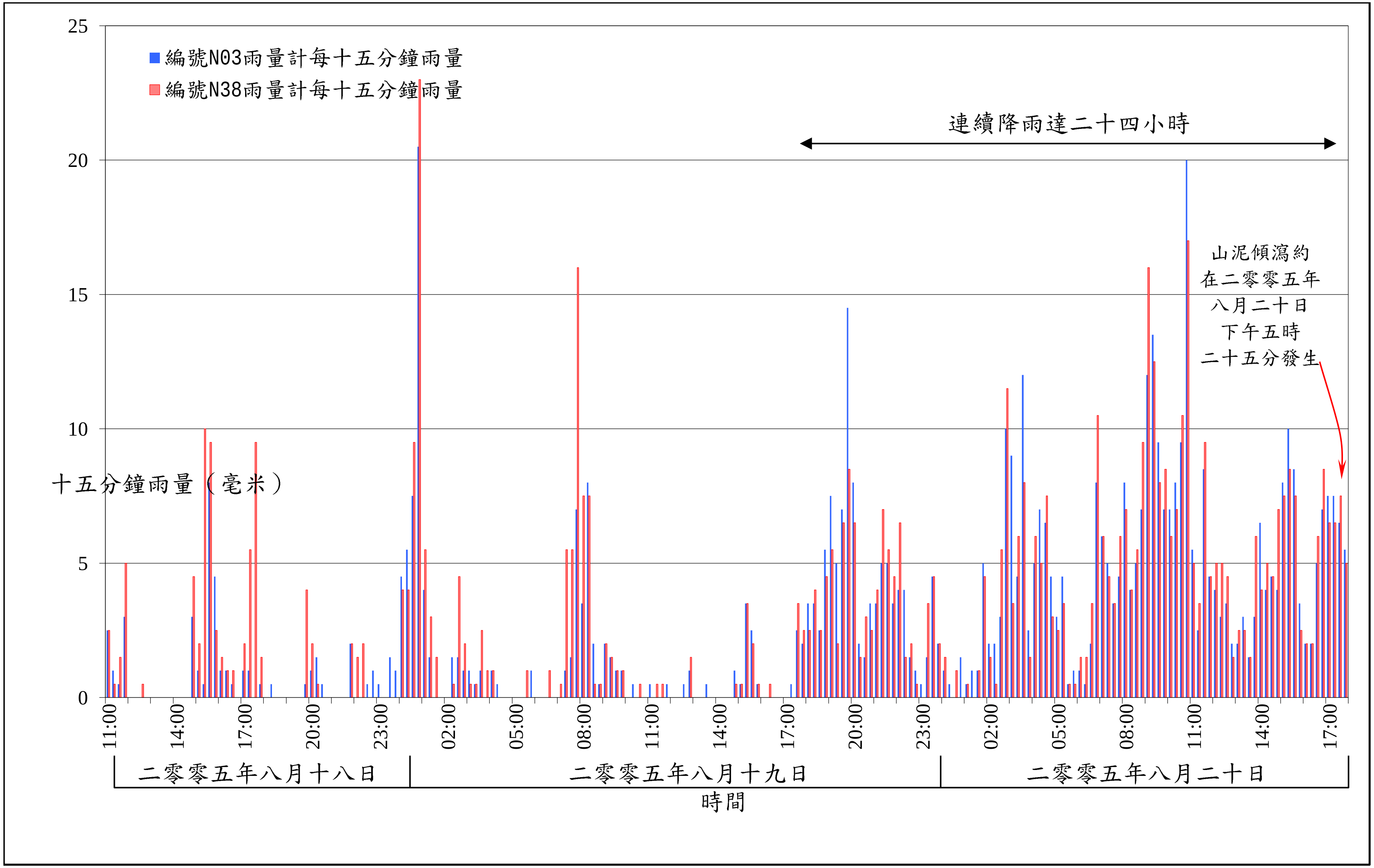
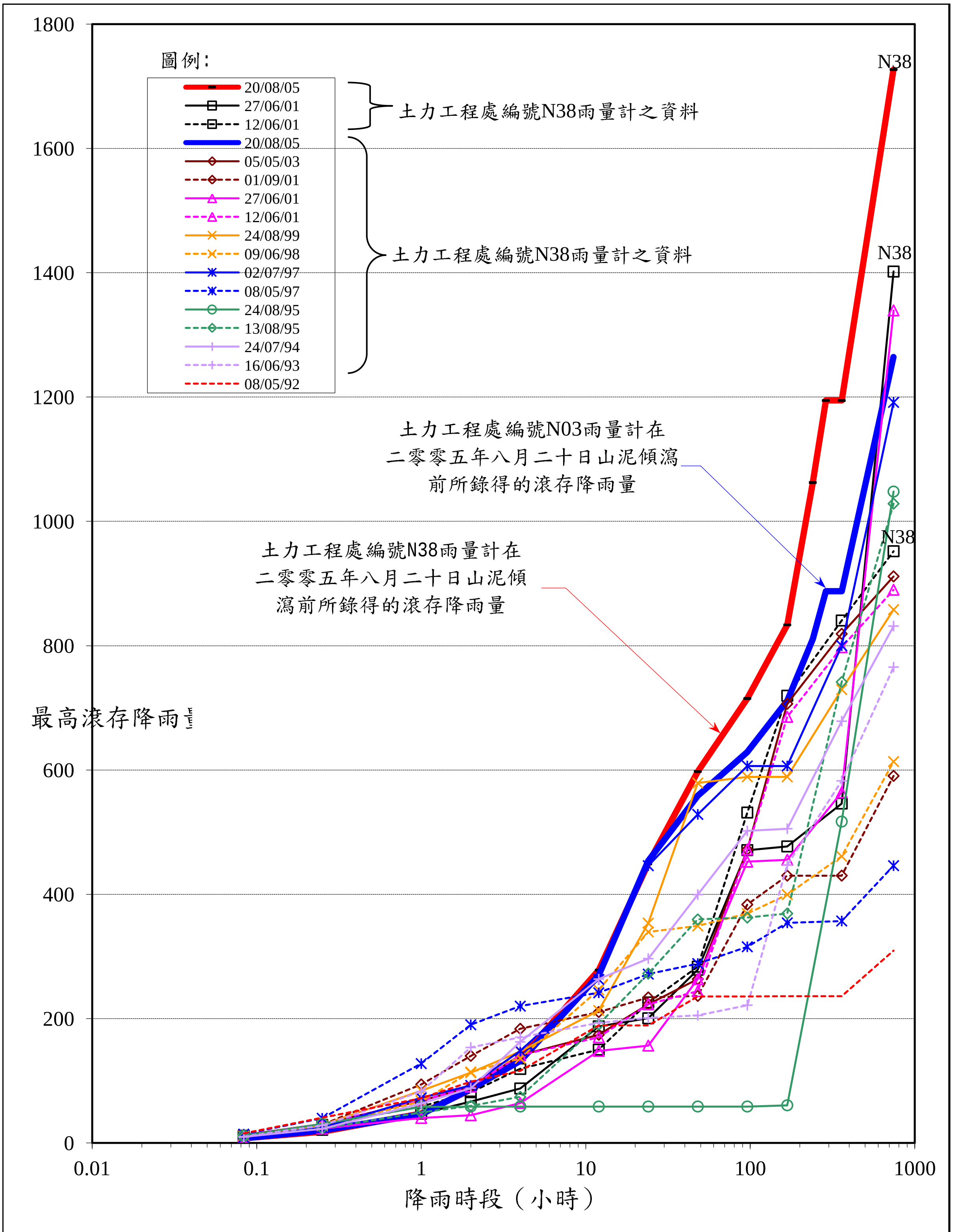


圖8 - 土力工程處編號N03和N38雨量計的每十五分鐘雨量記錄

Table of Contents (Chinese) Table of Contents (Chinese) Table of Contents (Chinese) Table of Contents (Chinese)



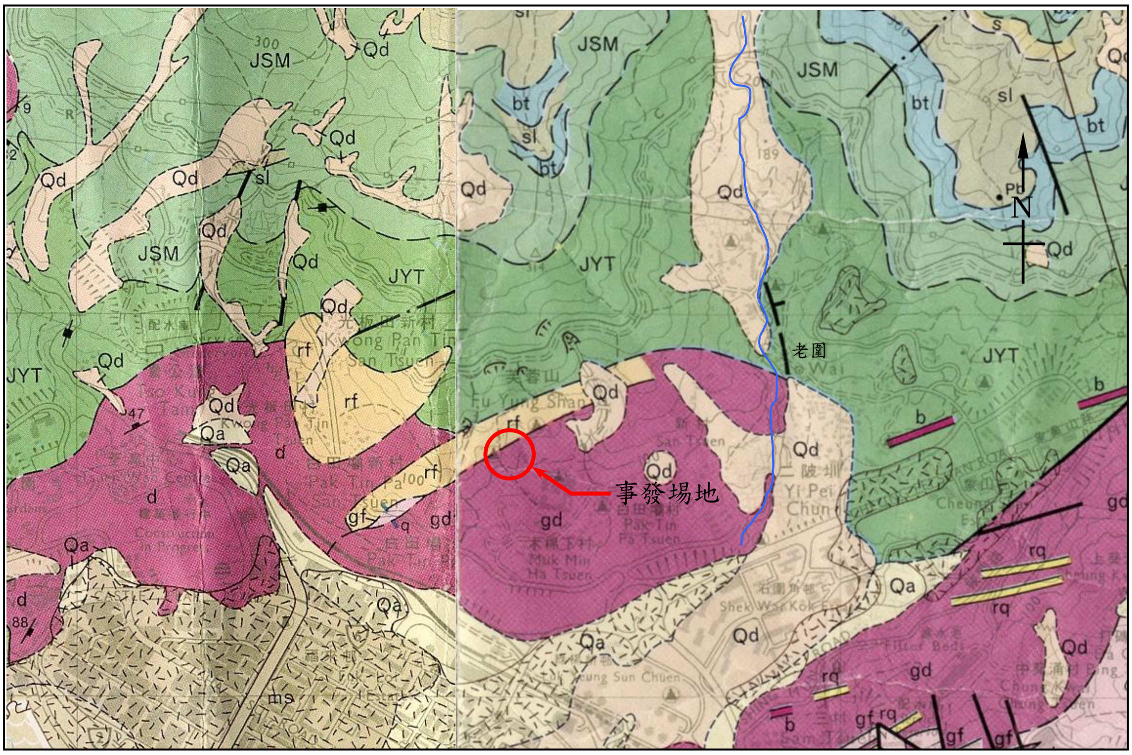
註: (1) 最高滾存降雨量是以五分鐘雨量記錄計算，資料來自土力工程處編號N03及N38雨量計（分別位於事發現場以東約1.3千米及事發現場以西約1.2千米）。

(2) 歷次豪雨中所錄得的最高滾存降雨量均計算自土力工程處編號N03及N38雨量計，分別從一九八三年六月及一九九九年十月開始運作。

圖 9 - 土力工程處編號N03和N38雨量計於歷次暴雨中錄得的最高滾存降雨量

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)



0 米　1000 米

比例

圖例：

地表沉積

Qa　黏土/粉砂、砂和礫石（冲積物）

Qd　砂、礫至漂礫、基質為粉砂（坡積物）

填土

基岩地質

b　輝綠岩

JYT　粗火山灰晶屑凝灰岩（荃灣群）

rq　石英斑岩

gd　花崗閃長岩

rf　長石斑岩

地質界綫

地表沉積地質界綫

基岩地質界綫（*虛綫表示推測界綫）

斷裂（短劃/指向下降盤）

礦脉

航攝地質綫性影像

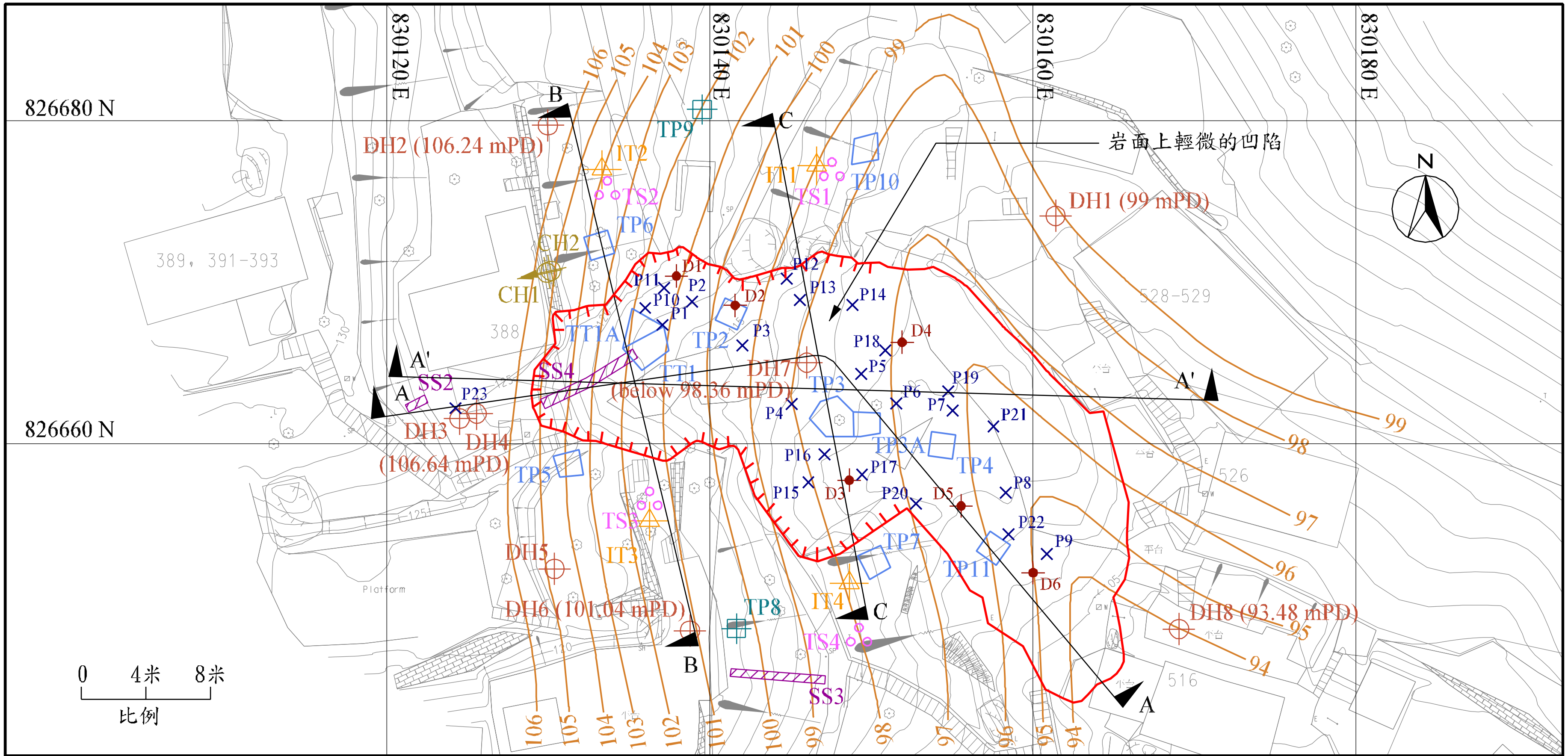
構造符號

22　侵入接觸

垂直節理

註：　引自香港地質調查組，地圖組別 HGM20，圖幅編號 6 和 7，比例 1:20 000（土力工程處，一九八六）。

圖 10 - 區域地質圖

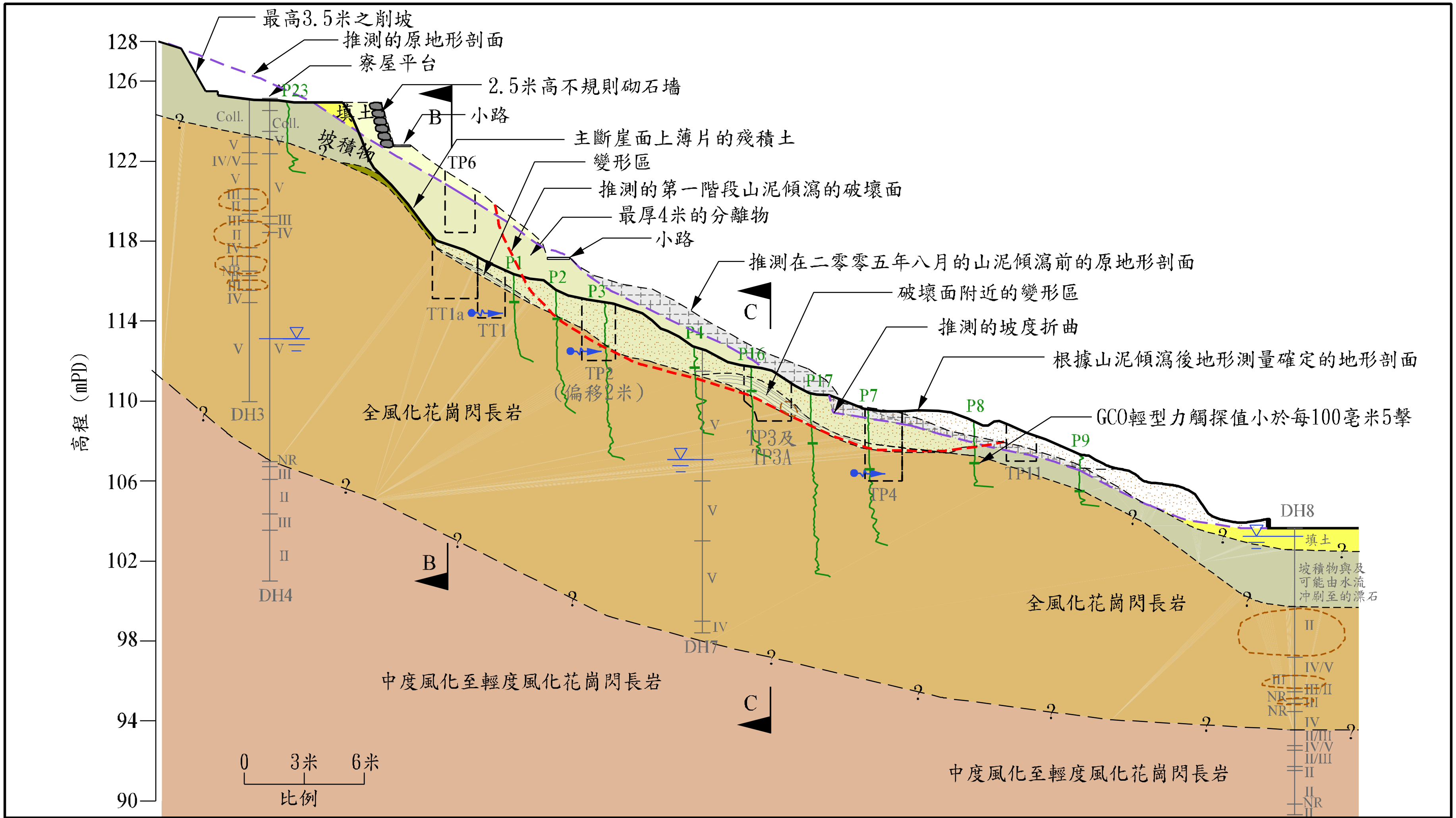


圖例：

DH1	垂直鑽孔	TP7	探井	IT1	滲透試驗	99——99	基岩等高綫 (mPD)
CH1	水平鑽孔	SS2	條狀表土剝露	× P17	GCO輕型動力觸探	DH8 (93.48 mPD)	鑽孔DH8的岩面高程
TT1	探槽	TS1	張力計	D5	原位密度試驗		

註： 太平洋洲際有限公司於二零零五年九月二日至二零零五年十月二十五日及鑽達地質工程有限公司於二零零五年十月二十五日至二零零五年十二月五日進行了場地勘探工作。

圖11 – 場地勘探和推斷的基岩等高綫平面圖

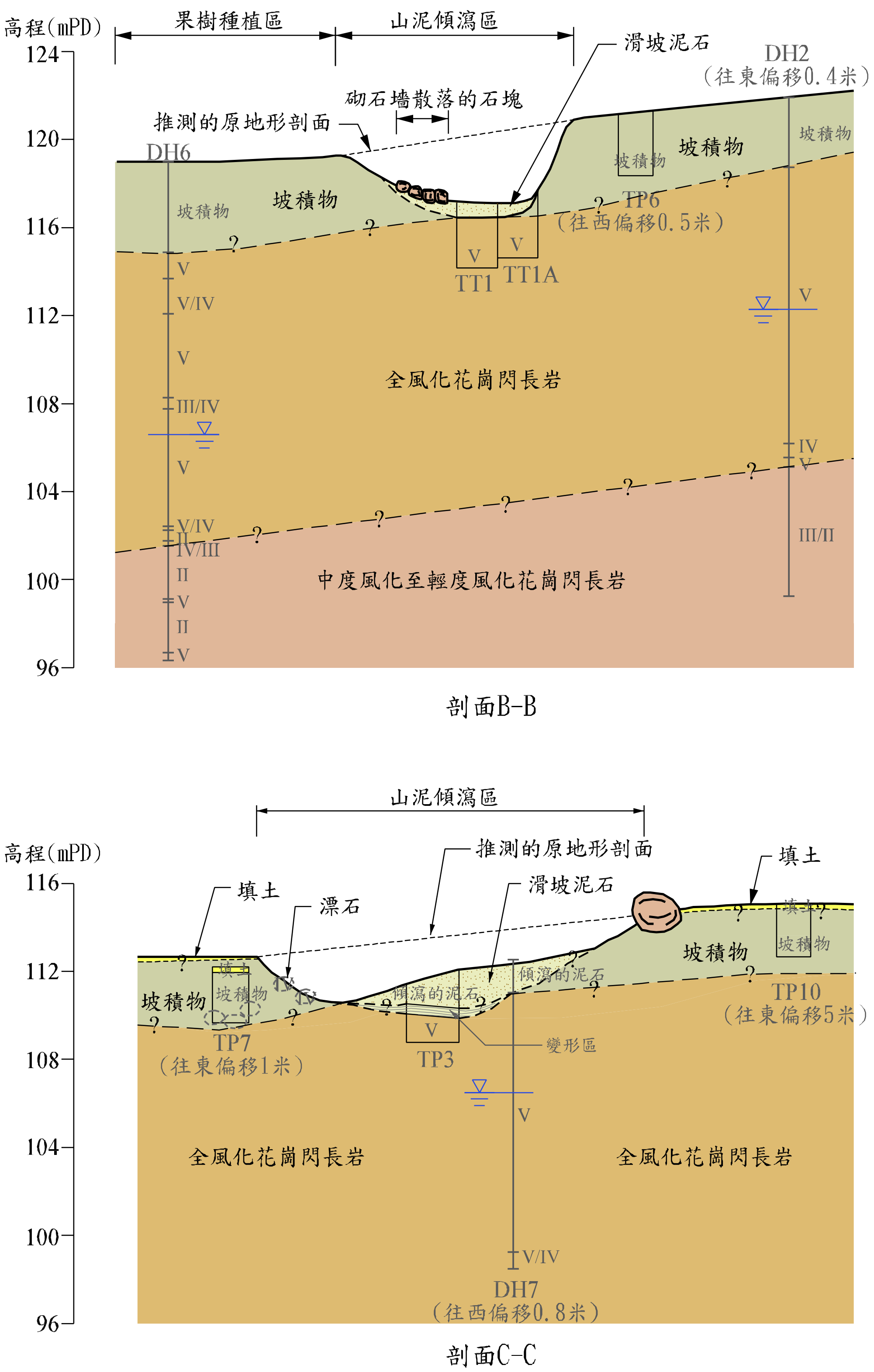


圖例：	二零零五年十月至十二月測量得的最高地下水位	二零零五年十月在探井中觀察到的滲流	GCO輕型動力觸探	滑坡泥石	垃圾及填土	泥石和垃圾的混合物

註： 剖面位置見圖11，剖面B-B, C-C見圖13。

圖12 – 山泥傾瀉地質剖面A-A

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)



圖例： 二零零五年十月至十二月測量得的最高地下水位

註： 剖面位置見圖11。

圖13 – 山泥傾瀉的地質剖面B-B和C-C

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

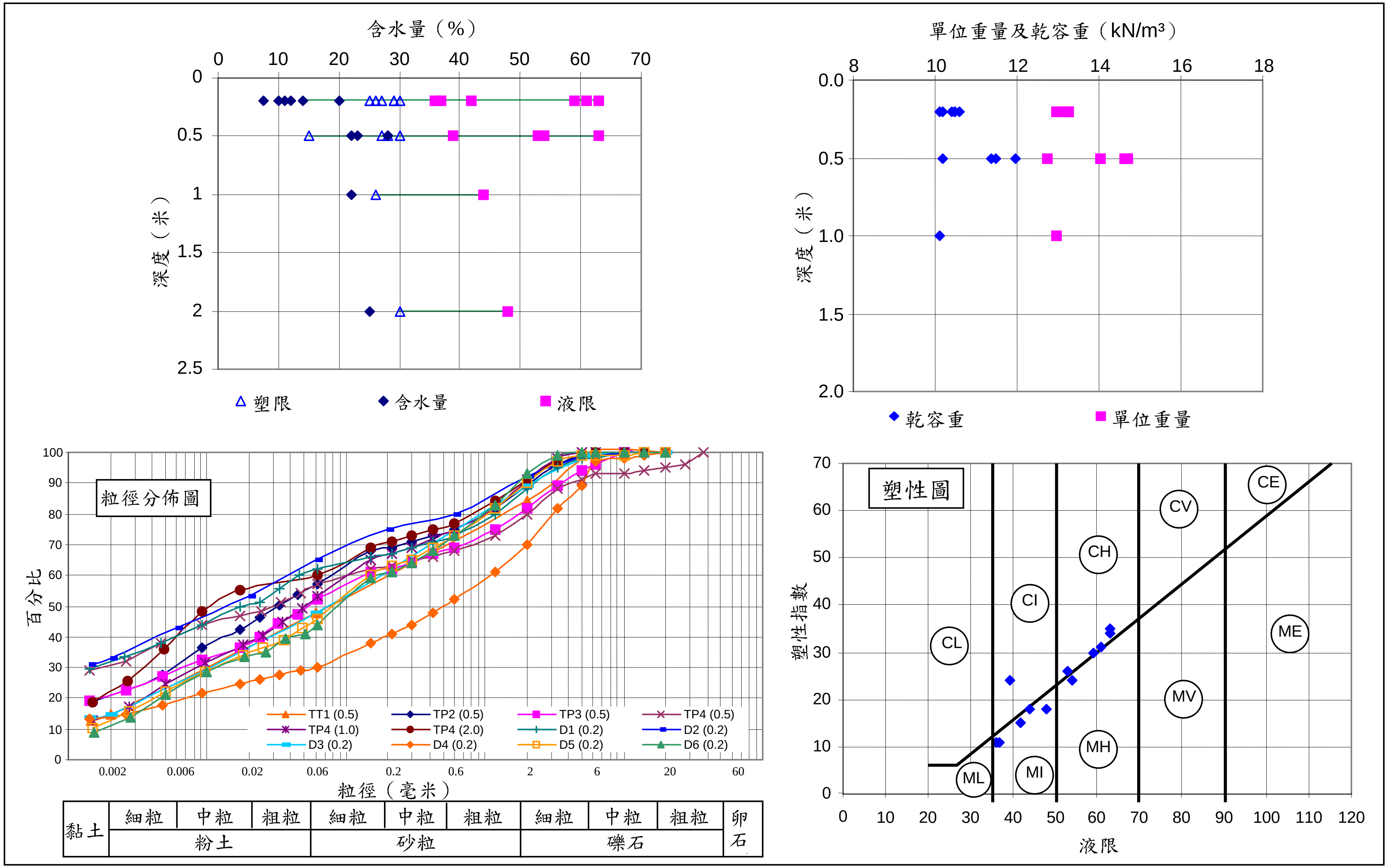


圖 14 – 山泥傾瀉泥石的岩土特性

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

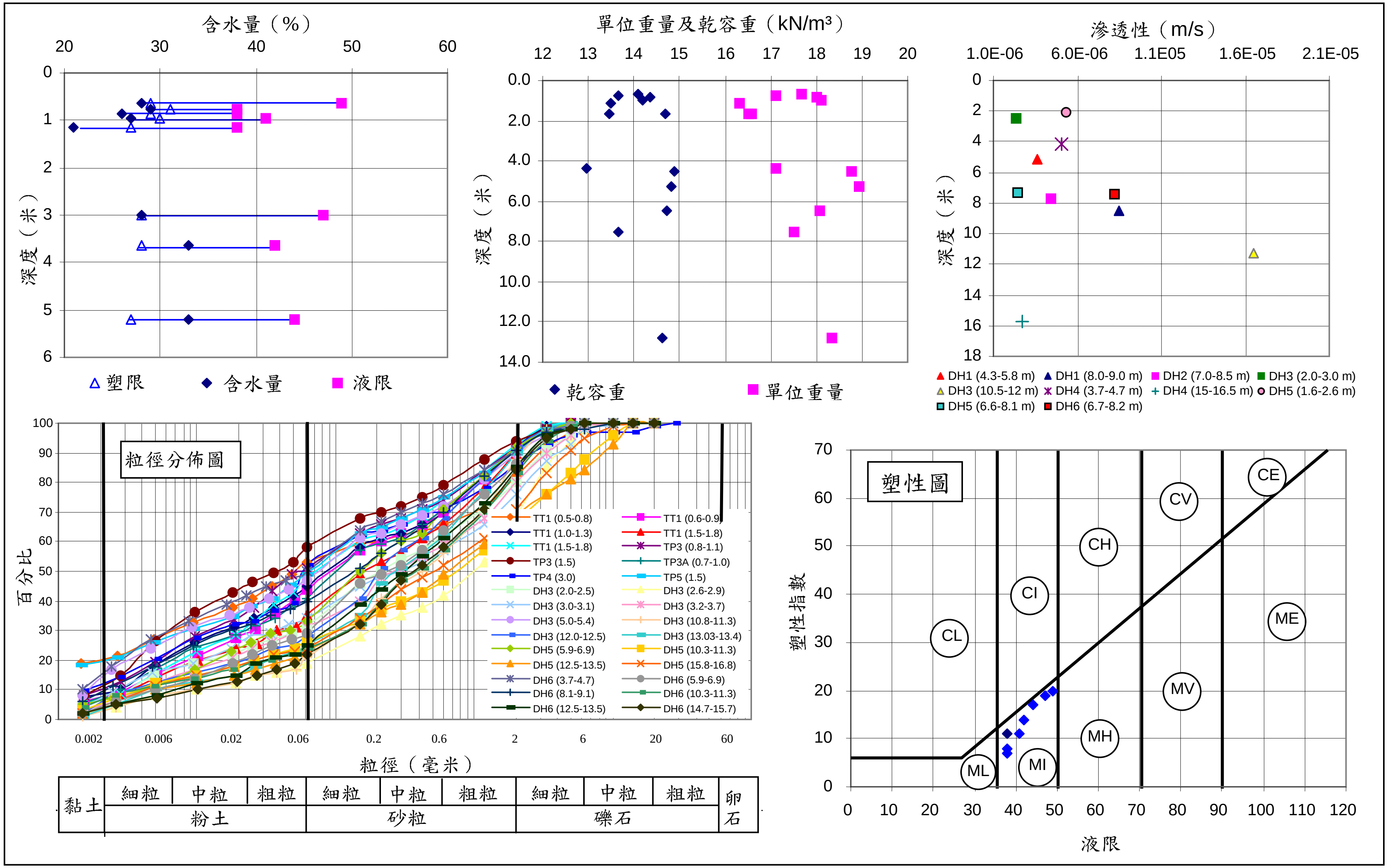
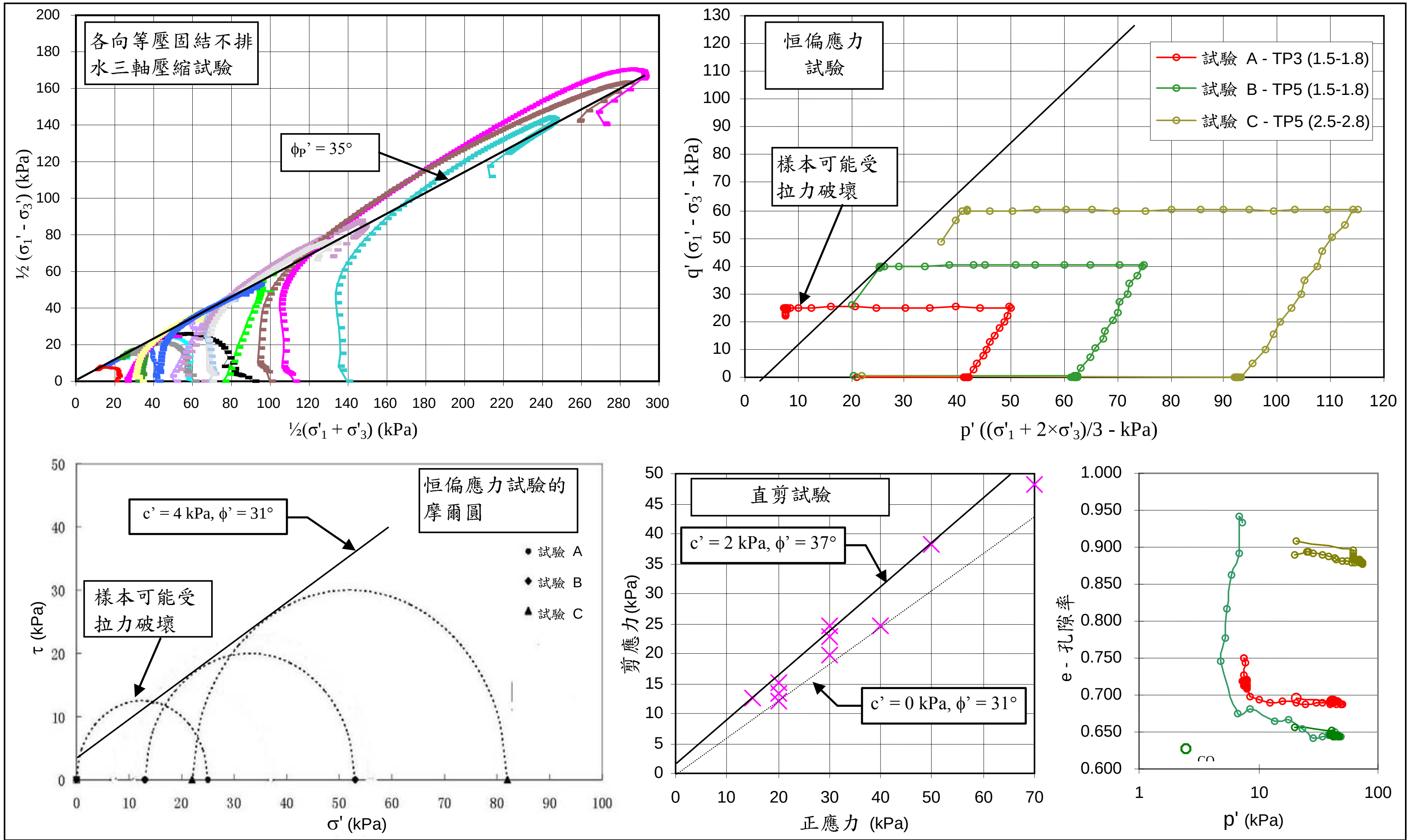


圖 15 - 全風化花崗閃長岩的岩土特性（第一頁）

Table of Contents (Chinese) Table of Contents (Chinese) Table of Contents (Chinese) Table of Contents (Chinese)

Table of Contents (Chinese) Table of Contents (Chinese) Table of Contents (Chinese) Table of Contents (Chinese)



圖例: σ'1 =最大有效主應力, σ'3 =最小有效主應力, c' =黏聚力, ϕ' =抗剪角

圖 15 - 全風化花崗閃長岩的岩土特性（第二頁）

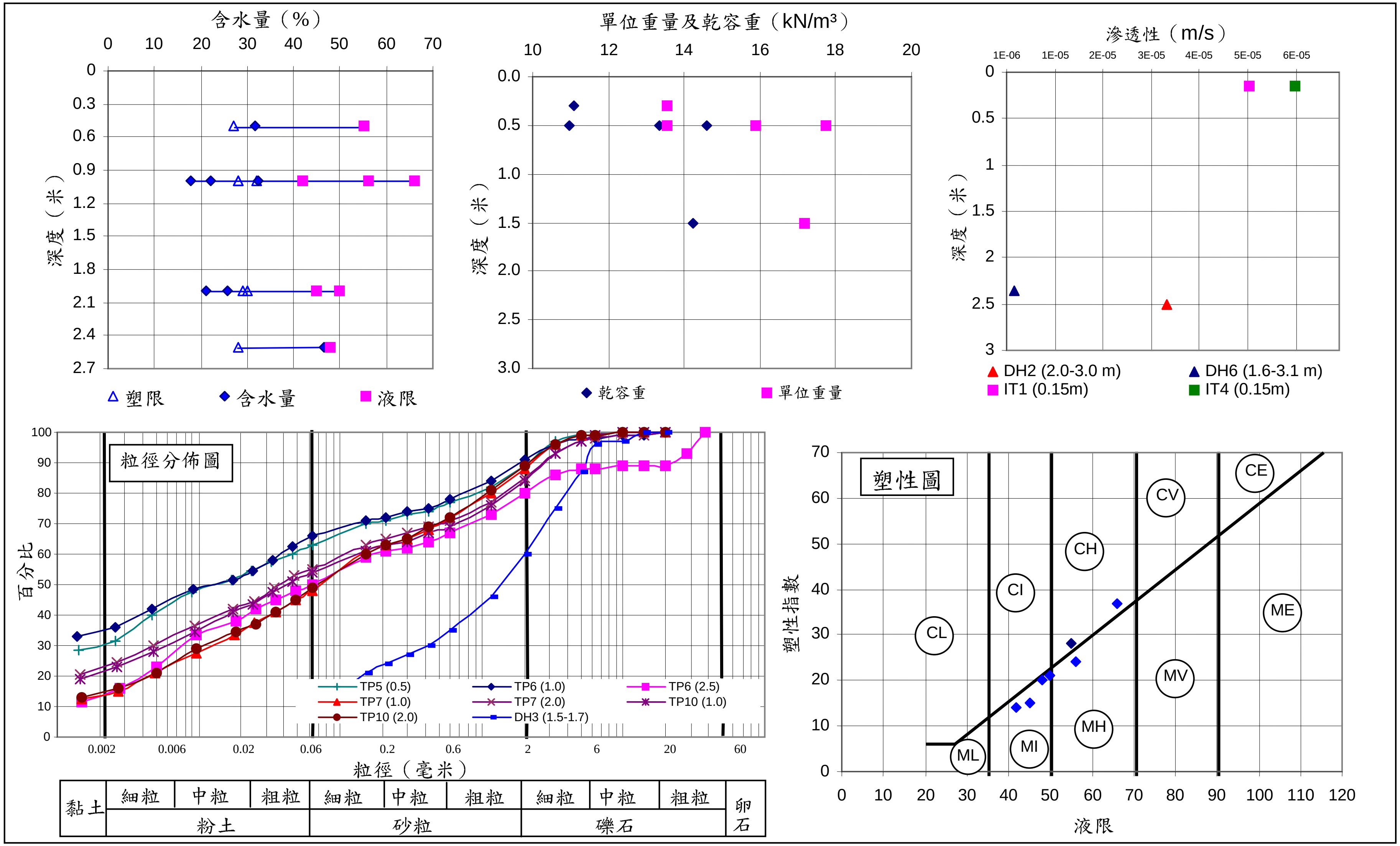


圖 16 - 坡積物的岩土特性（第一頁）

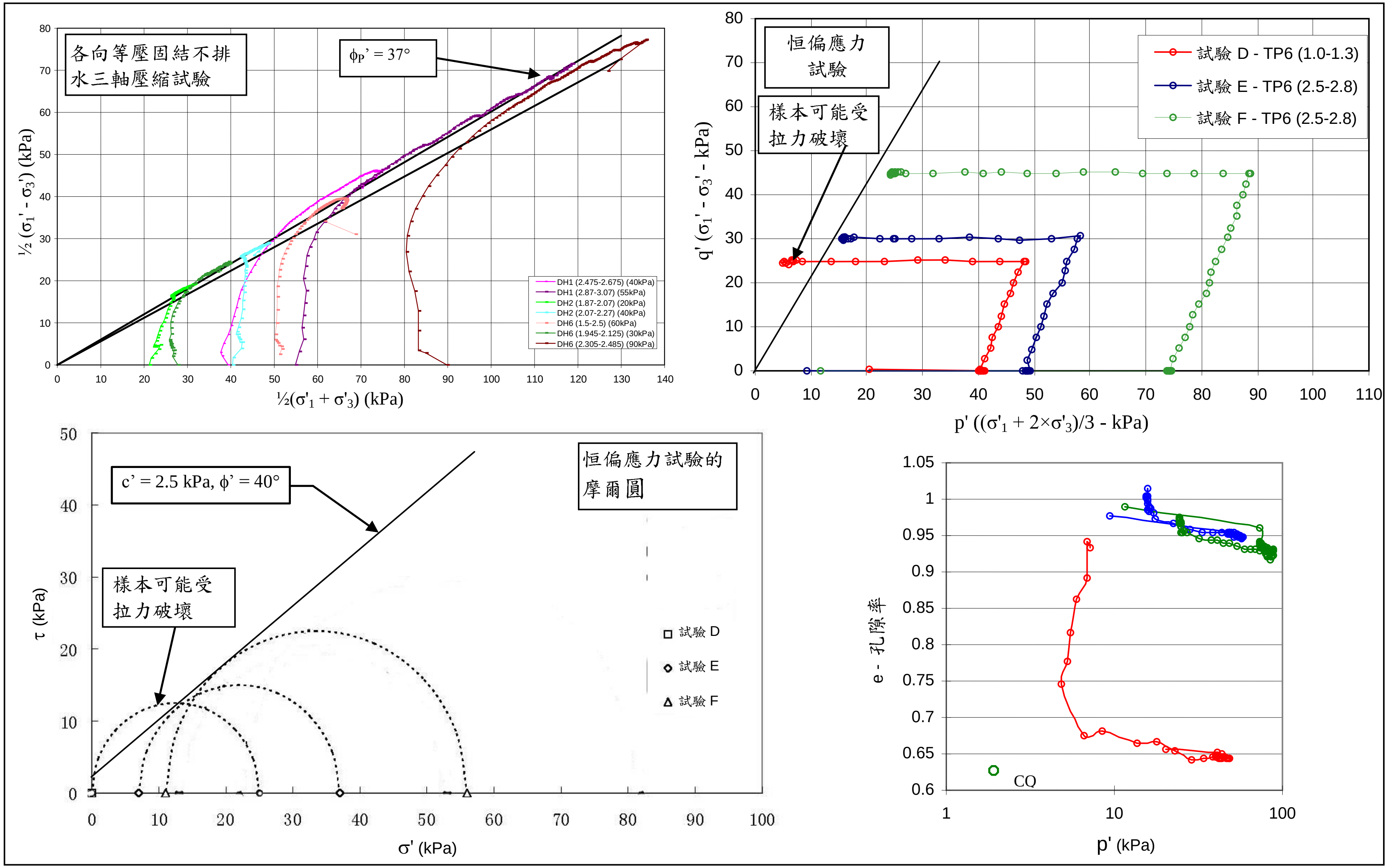


圖 16 - 坡積物的岩土特性（第二頁）

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

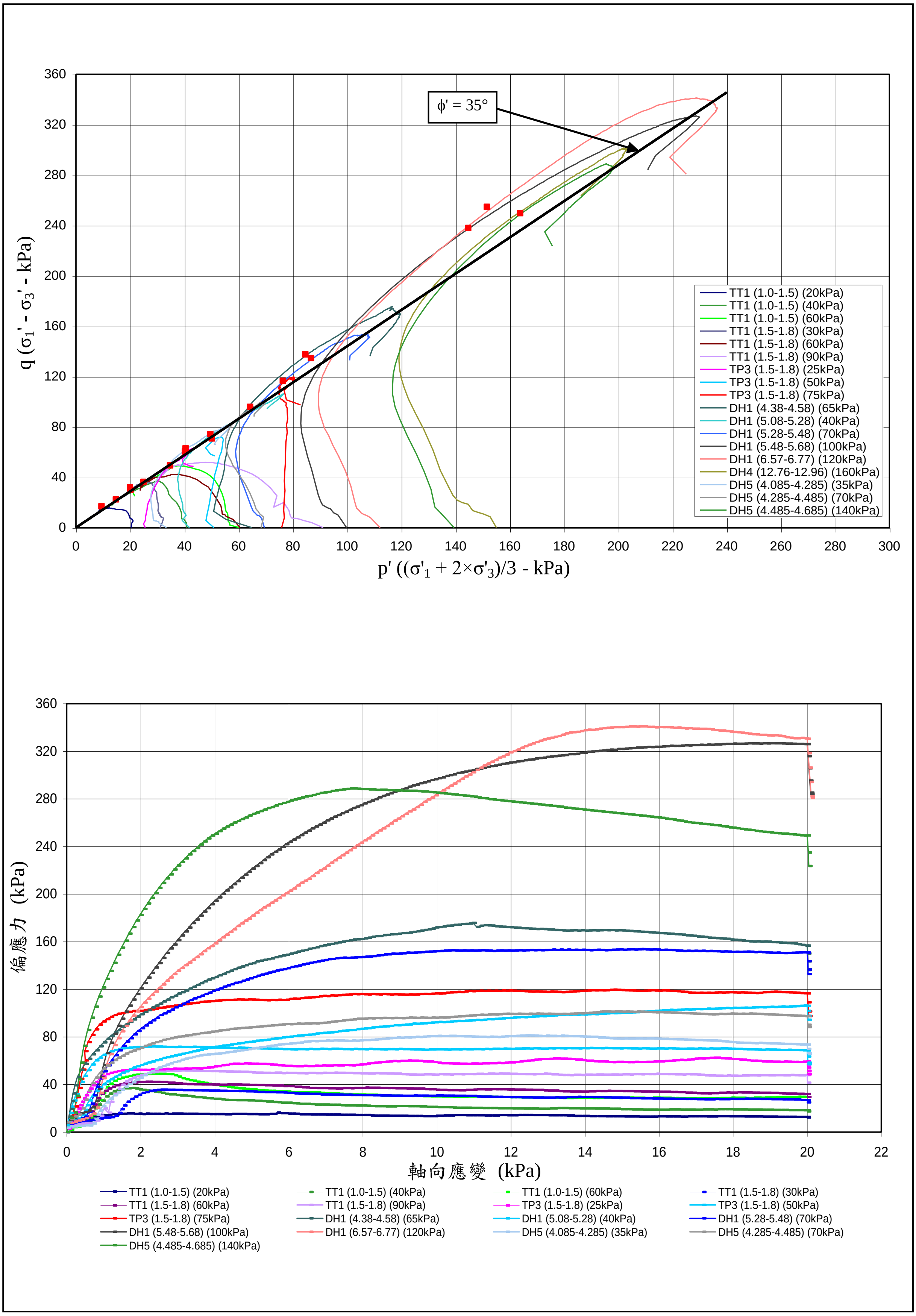


圖 17 -全風化花崗閃長岩的各向等壓固結不排水試驗的 p'-q 圖和應力-應變曲線

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

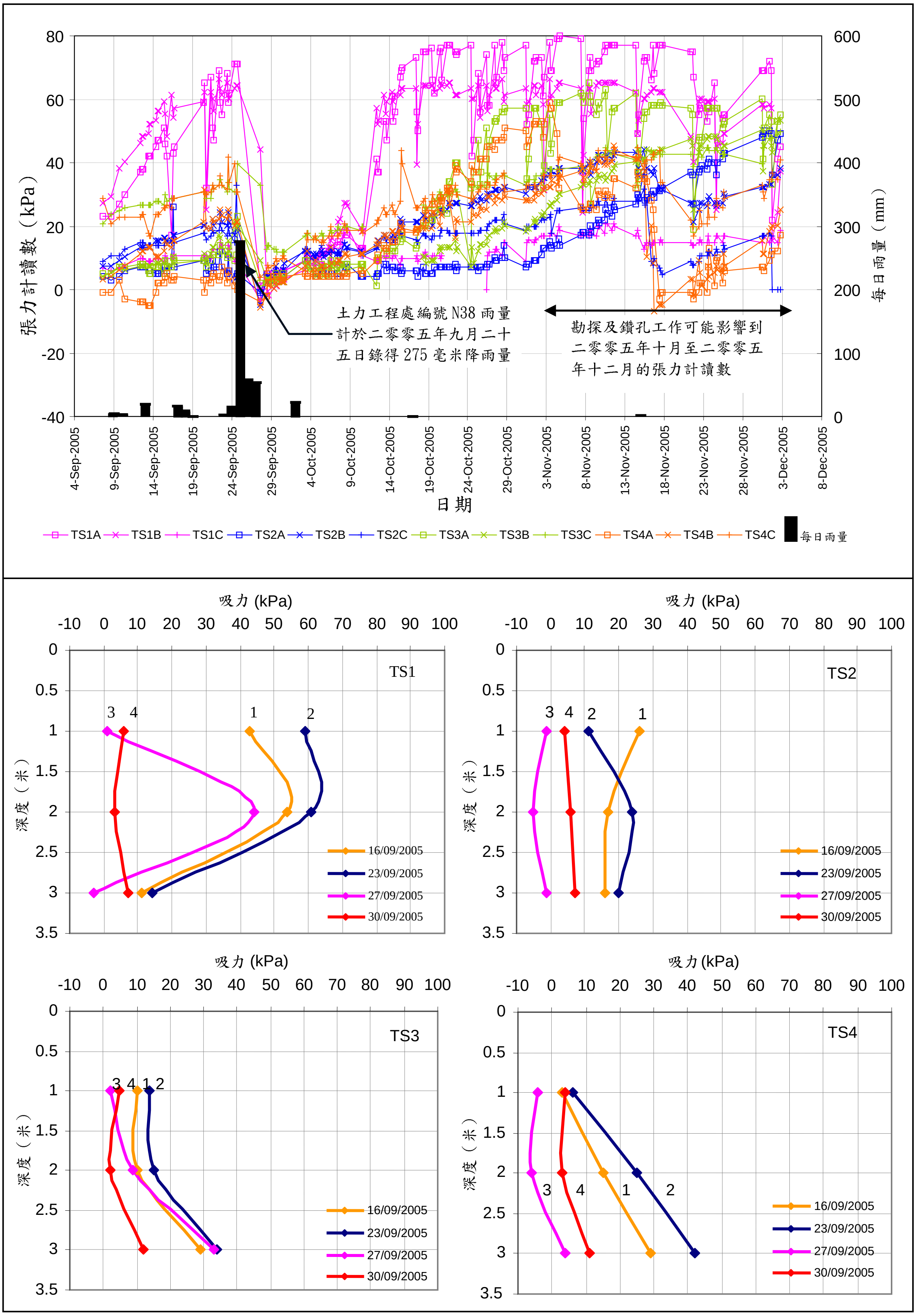
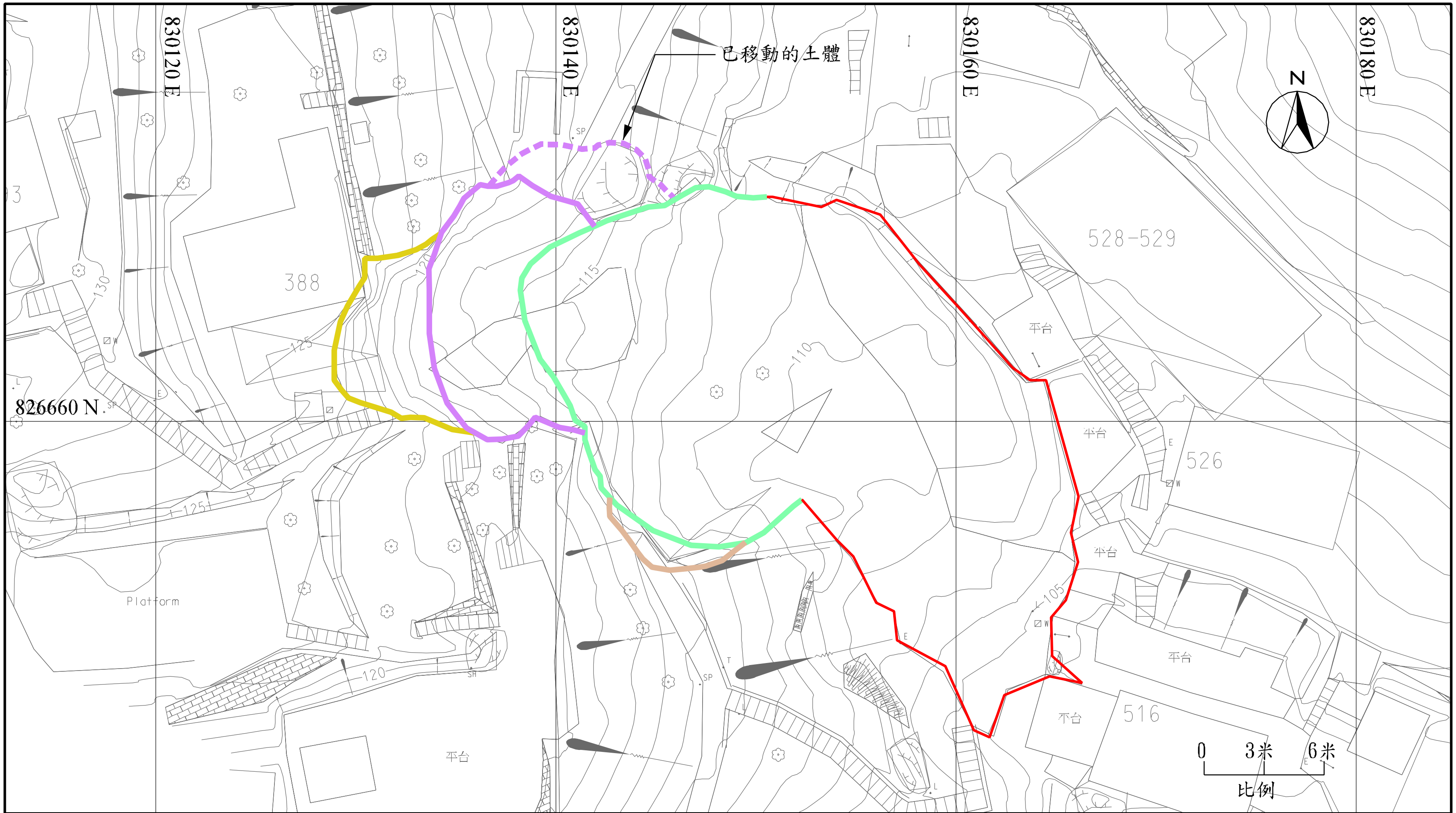


圖 18 - 張力計的讀數記錄

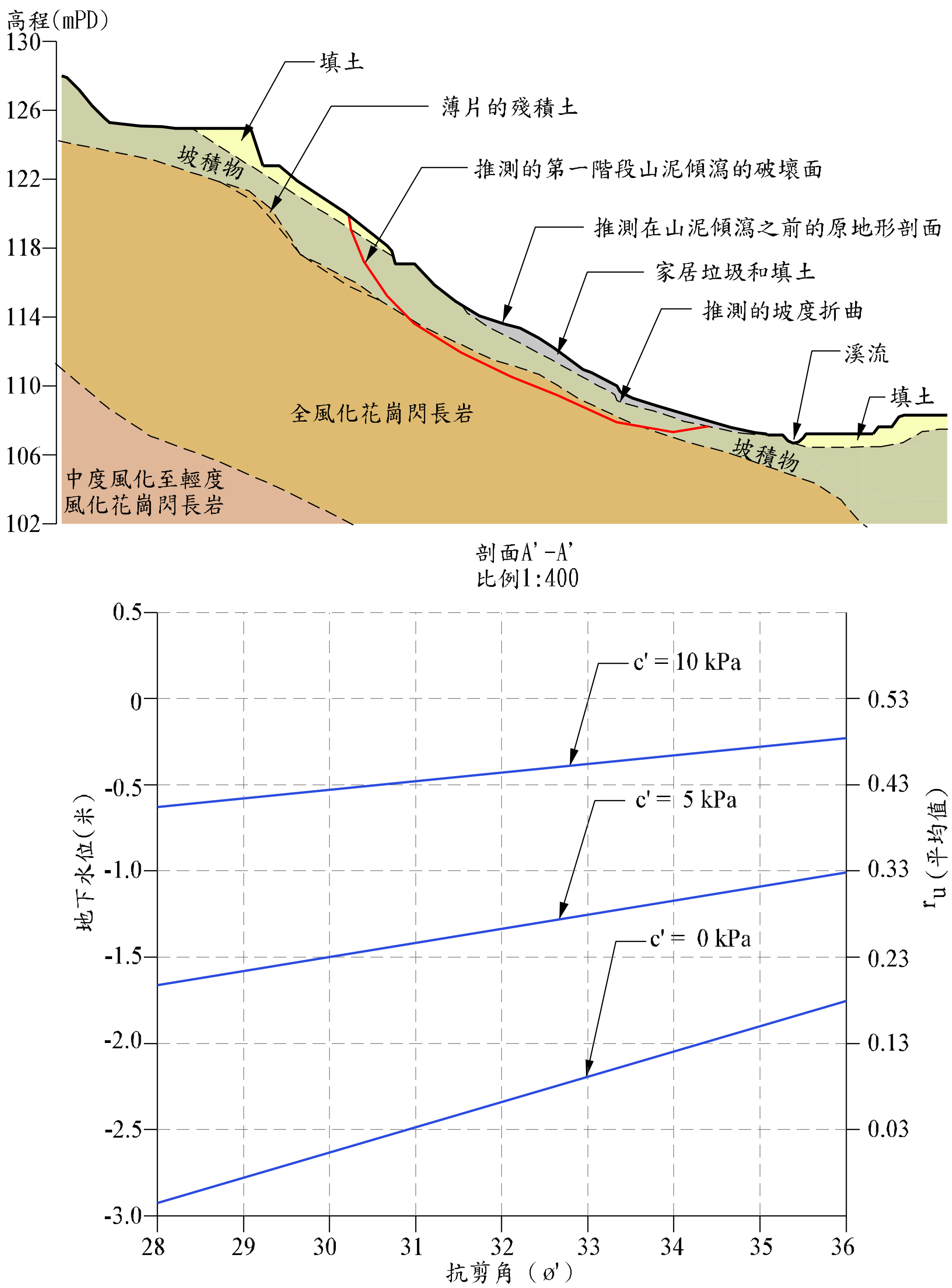
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)



圖例： 山泥傾瀉 第一階段山泥傾瀉 第二階段(主要的) 第二階段(次要的) 小路下小的崩塌

註： 底圖取自地形測量圖編號 GCS3164。

圖19 － 大致的崩塌過程

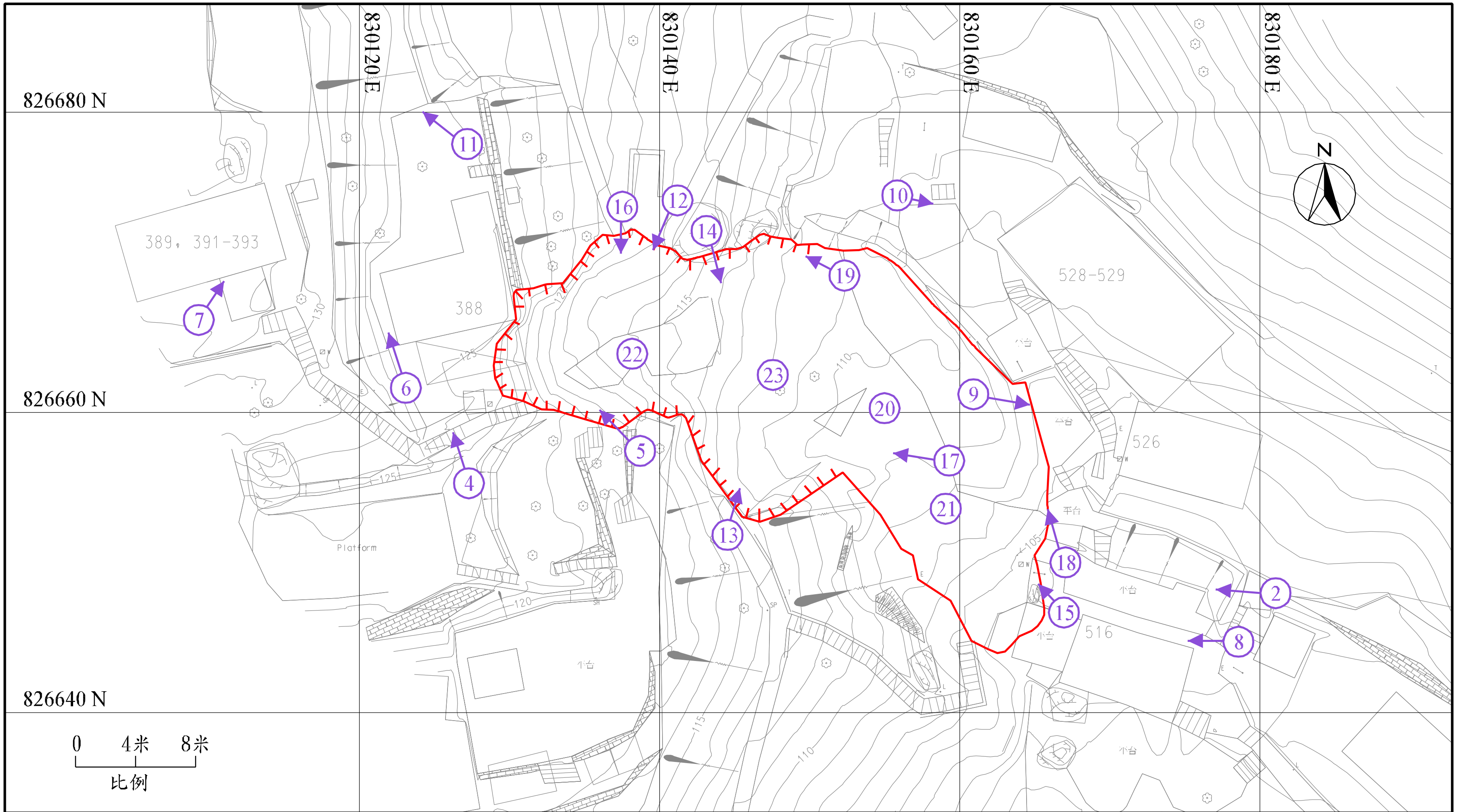


圖例 ： —— 安全系數等於1

註 ：
(1) 崩塌發生前之原地形剖面及破壞面是根據地形測量，照片記錄，山泥傾瀉後的觀察和現場勘察確定。
(2) r_u 值顯示的是相應於每個地下水位沿着破壞面的平均值。
(3) 剖面位置見圖11。

圖20 – 理論穩定性分析摘要

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)



圖例：	⑫→ 照片的位置和方向
註：	底圖取自地形測量圖編號 GCS3164。

圖21 － 照片的位置和方向

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

<u>照片目錄</u>

Table of Contents (Chinese)

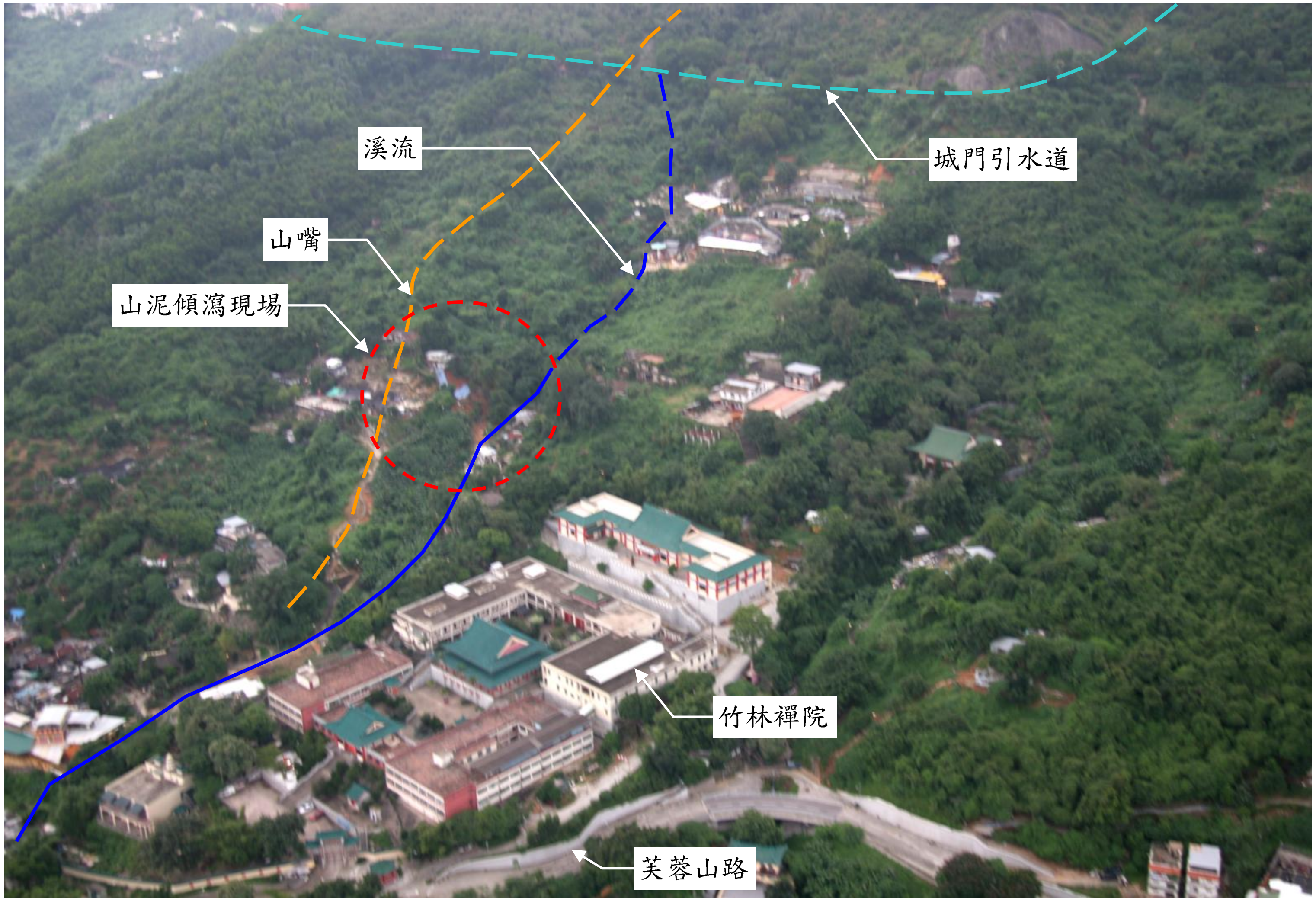
照片 1 - 二零零五年八月二十日山泥傾瀉現場的傾斜高空景像
(照片攝於二零零五年八月二十二日)

Table of Contents (Chinese) Table of Contents (Chinese) Table of Contents (Chinese) Table of Contents (Chinese)

照片 2 - 二零零五年八月二十日山泥傾瀉現場的正面景像
(照片攝於二零零五年八月二十一日)

註: 照片位置及方向見圖 21。

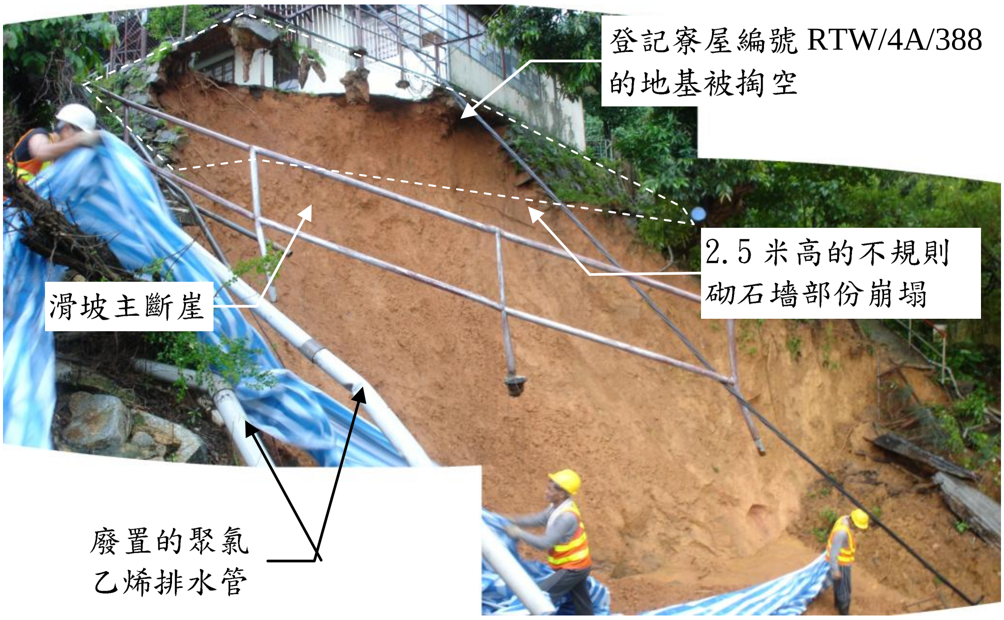
Table of Contents (Chinese)
Table of Contents (Chinese) Table of Contents (Chinese) Table of Contents (Chinese)



照片 3 - 芙蓉山村之整體外貌
(照片攝於二零零五年八月二十二日)

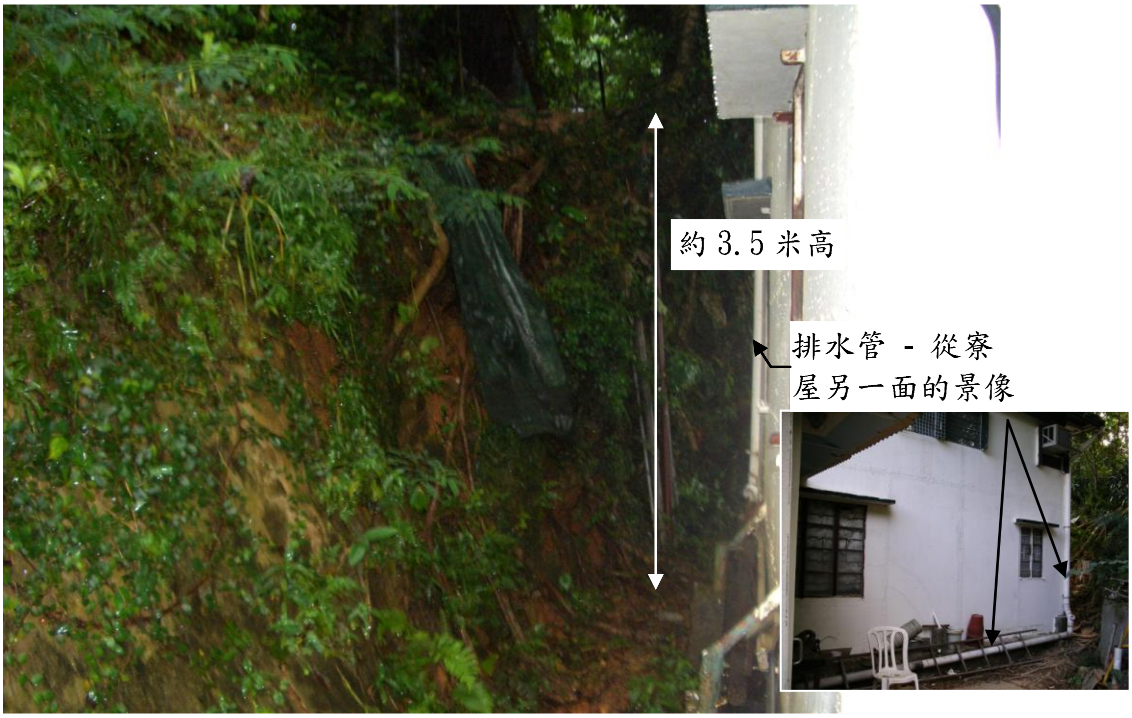
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

照片 4 - 位於滑坡斷崖上方的登記寮屋編號RTW/4A/388
(照片攝於二零零五年八月二十九日)



照片 5 - 滑坡主斷崖及地基被掏空的登記寮屋編號RTW/4A/388
(照片攝於二零零五年八月二十一日)

註: 照片位置及方向見圖 21。



照片 6 - 登記寮屋編號RTW/4A/388 後方的排水管及削坡
(照片攝於二零零五年八月二十一日)

照片 7 - 登記寮屋編號RTW/4A/389, 391-393
(照片攝於二零零五年九月十三日)

註: 照片位置及方向見圖 21。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

照片 8 - 登記寮屋編號RTW/4A/516
(照片攝於二零零五年八月二十一日)

照片 9 - 登記寮屋編號RTW/4A/526
(照片攝於二零零五年十二月五日)

註: 照片位置及方向見圖 21。

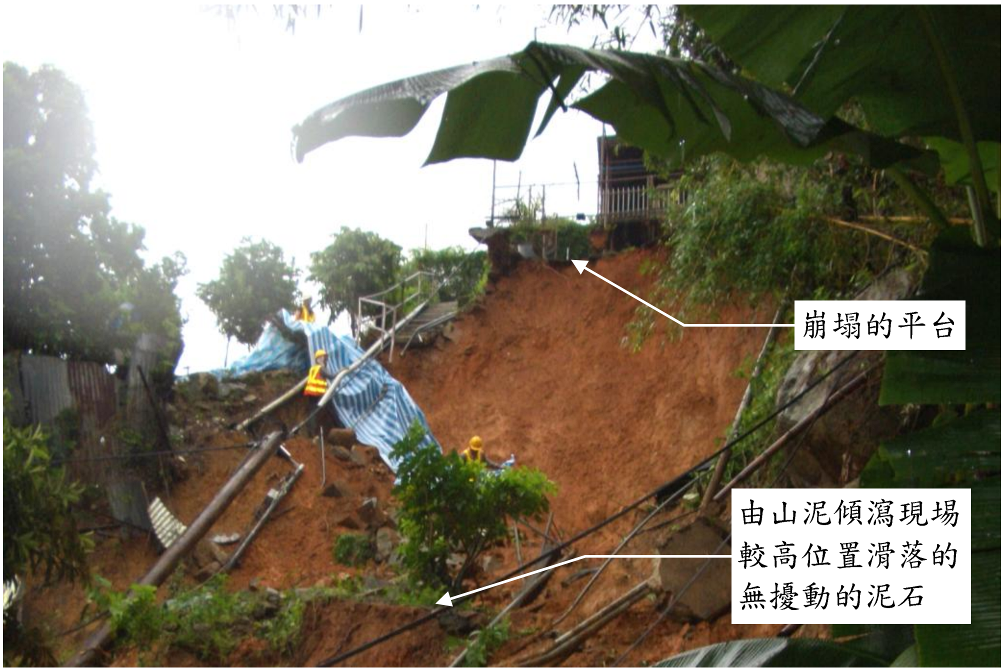
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

照片 10 - 登記寮屋編號RTW/4A/528-529
(照片攝於二零零五年十二月五日)

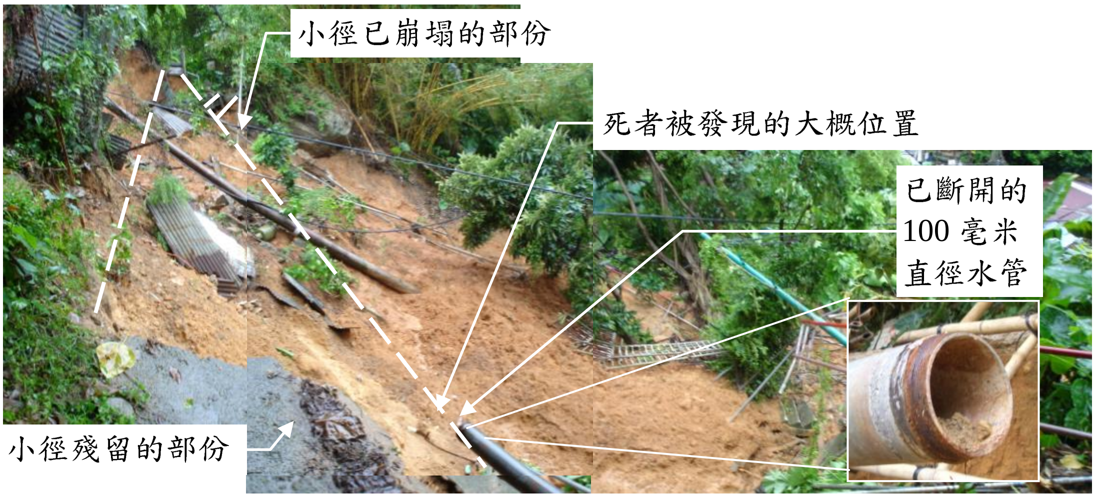
照片 11 - 伸延自登記寮屋編號RTW/4A/389, 391-393 的聚氯乙烯排水管
(照片攝於二零零五年十二月六日)

註: 照片位置及方向見圖 21。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

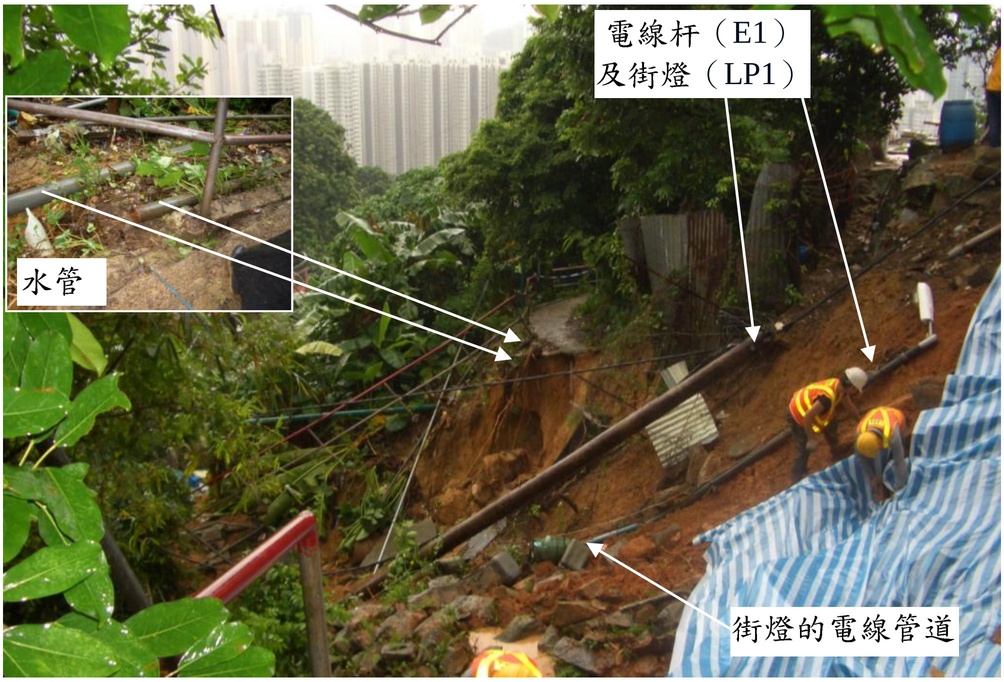


照片 12 - 山泥傾瀉主斷崖及南面斷崖
(照片攝於二零零五年八月二十一日)

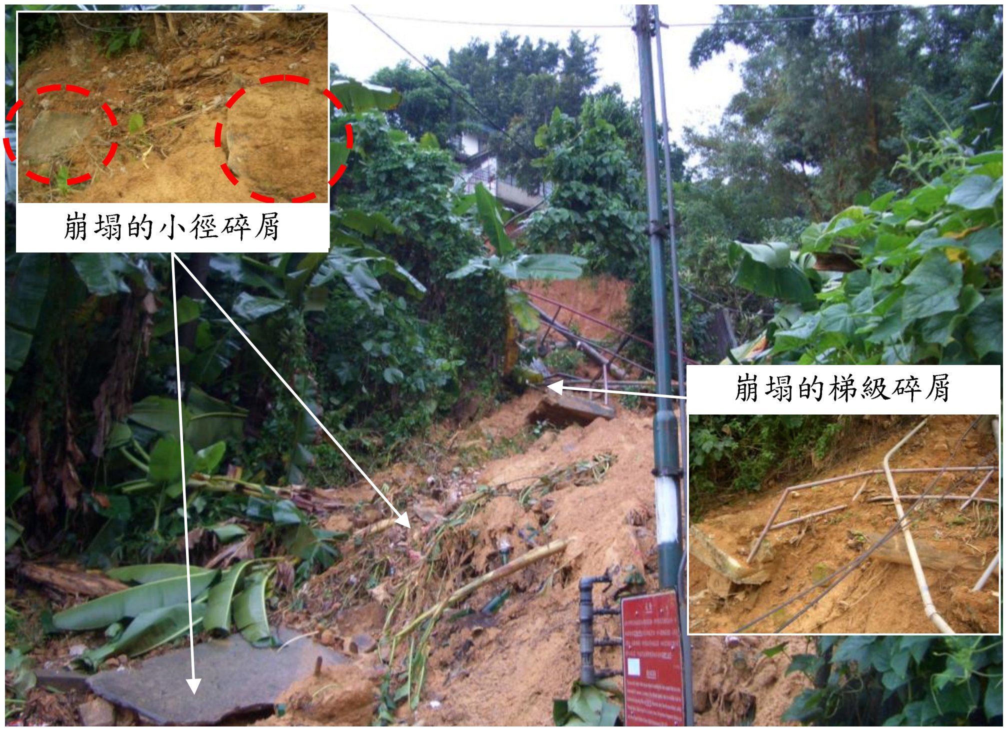


照片 13 - 崩塌的小徑及已斷開的 100 毫米直徑水管
(照片攝於二零零五年八月二十一日)

註: 照片位置及方向見圖 21。



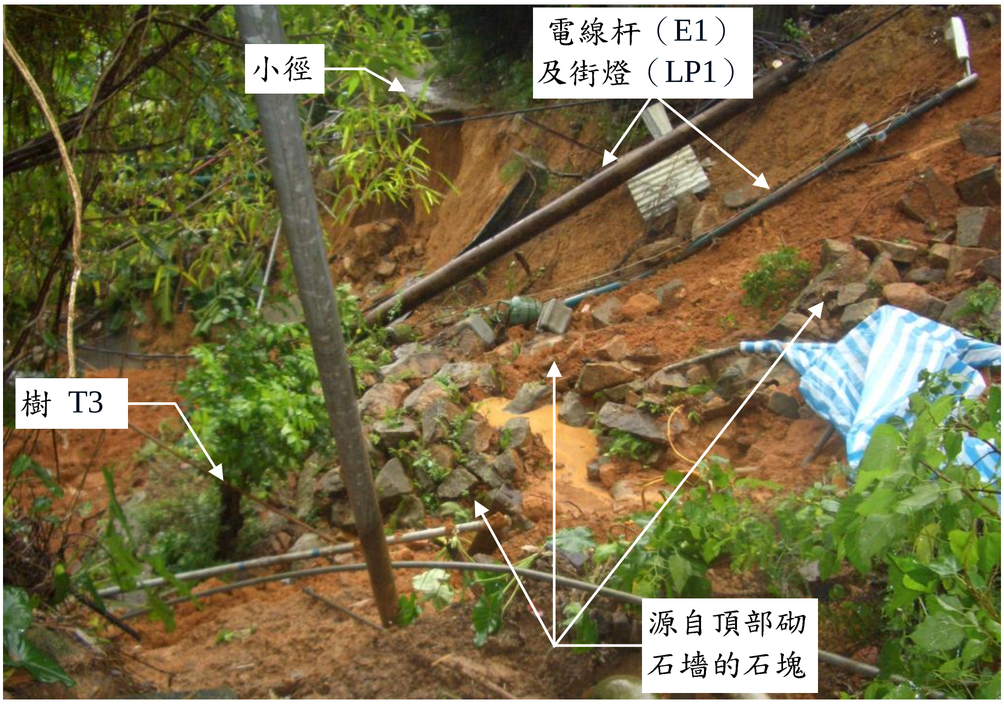
照片 14 - 損壞的公用設施
(照片攝於二零零五年八月二十一日)



照片 15 - 滑坡泥石下部近滑坡腳的景像
(照片攝於二零零五年八月二十一日)

註: 照片位置及方向見圖 21。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)



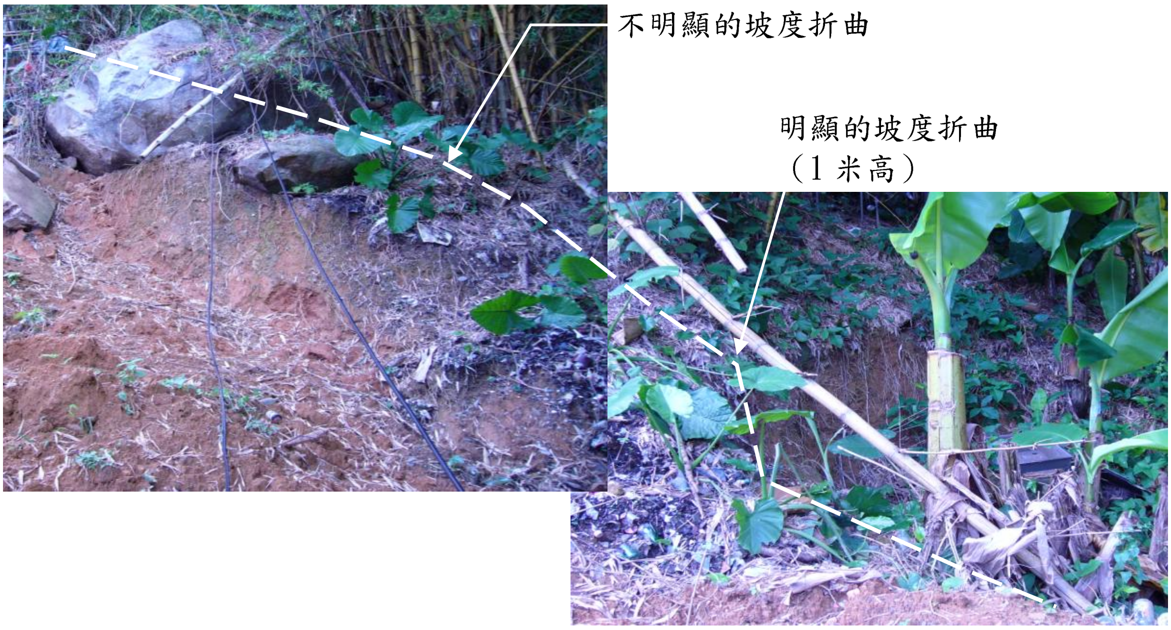
照片 16 - 滑坡泥石上部的景像
(照片攝於二零零五年八月二十一日)

照片 17 - 街燈 LP2 位於小徑欄杆的下方
(照片攝於二零零五年九月七日)

註: 照片位置及方向見圖 21。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

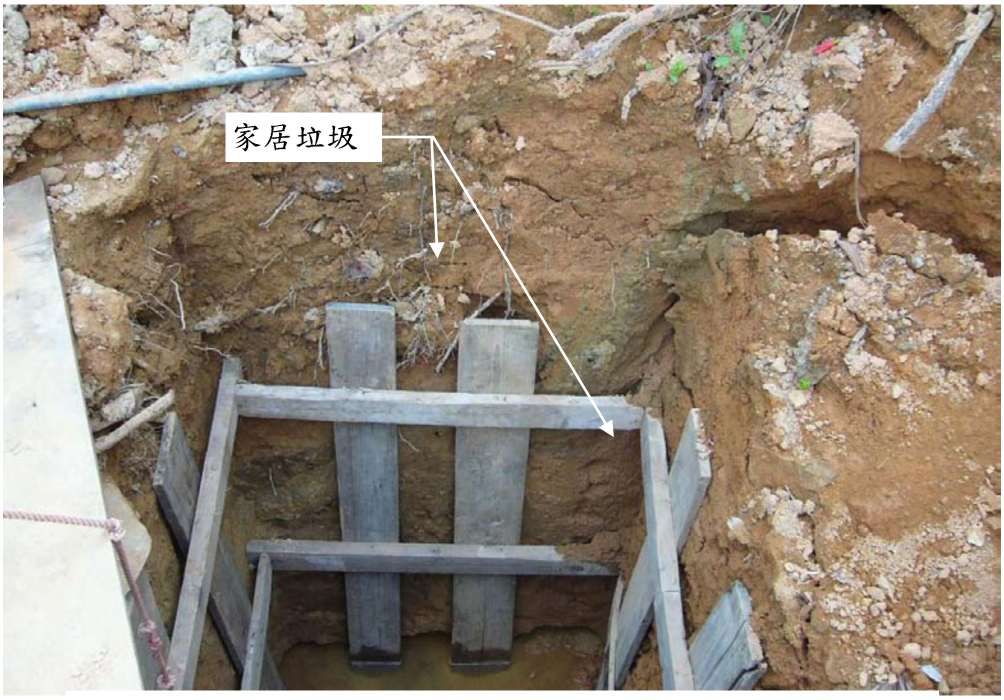
照片 18 - 家居垃圾隨著滑坡泥石一起滑動
(照片攝於二零零五年八月二十一日)



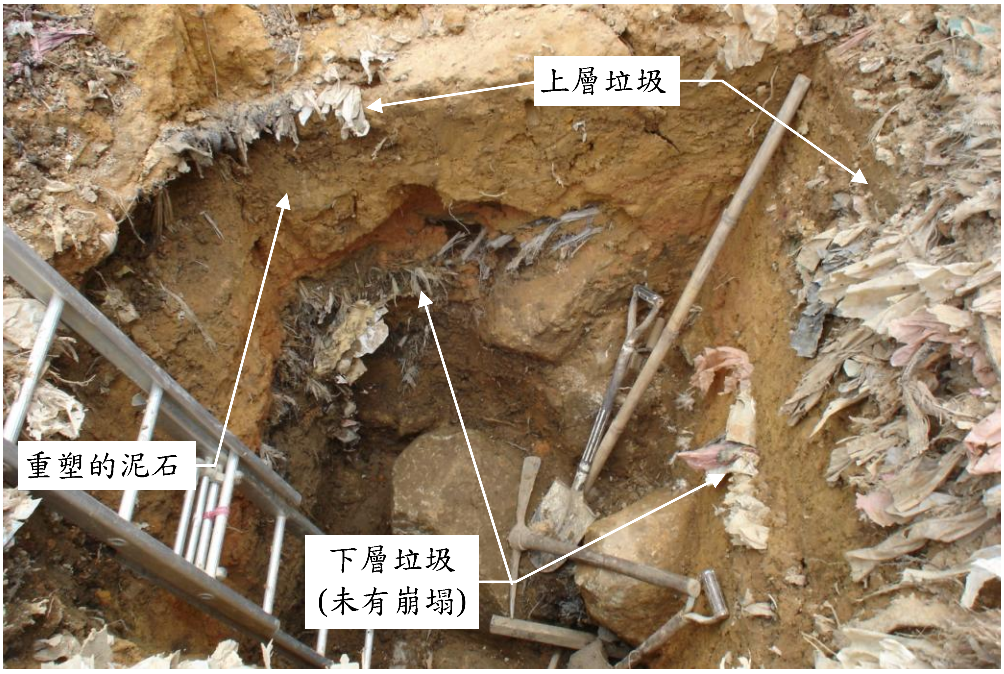
照片 19 - 在滑坡以北鄰近山坡上的坡度折曲
(照片攝於二零零五年九月十三日)

註: 照片位置及方向見圖 21。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)



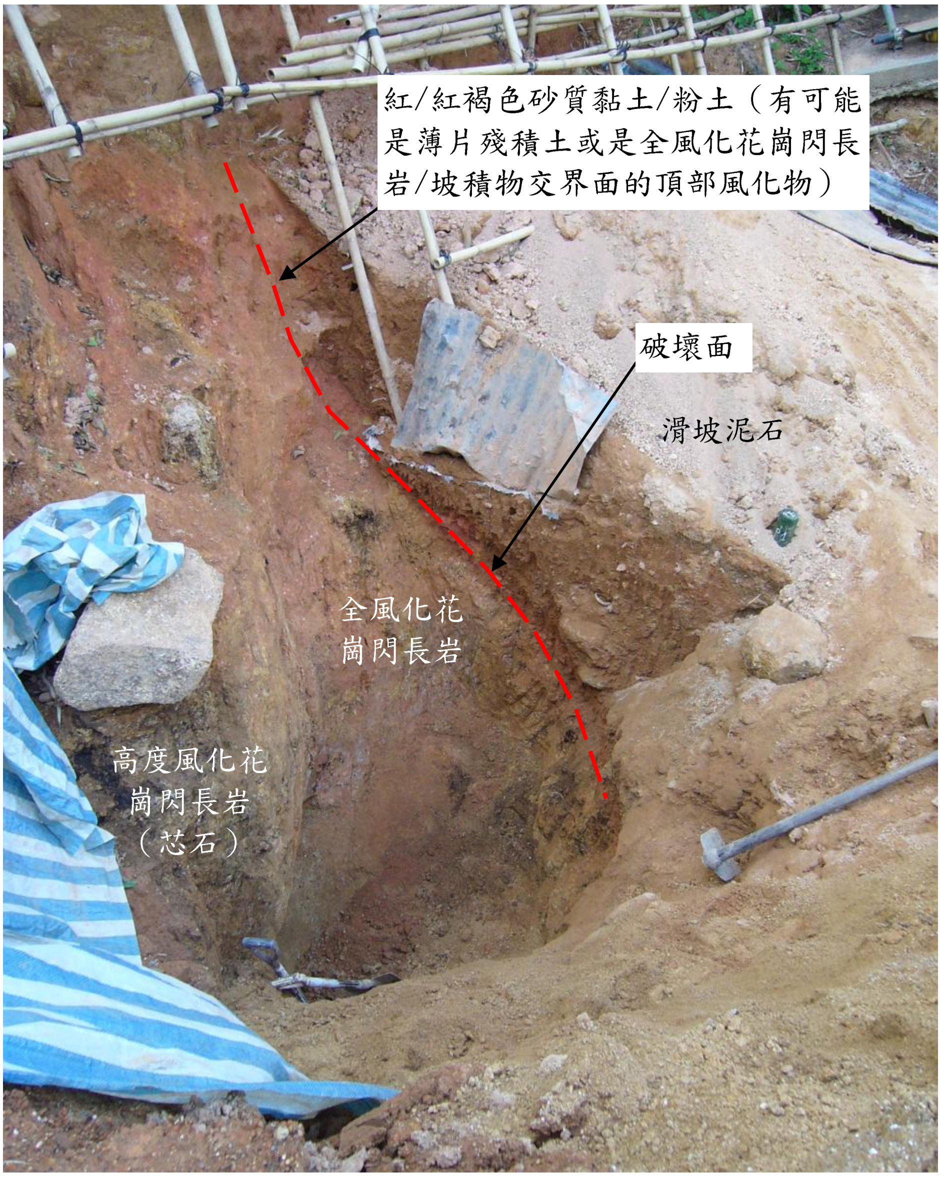
照片 20 - 探井 TP4 顯示滑坡泥石含有已變形的家居垃圾層
(照片攝於二零零五年十月十七日)



照片 21 - 探井 TP11 顯示上層及下層家居垃圾
(照片攝於二零零五年十月二十五日)

註: 照片位置及方向見圖 21。

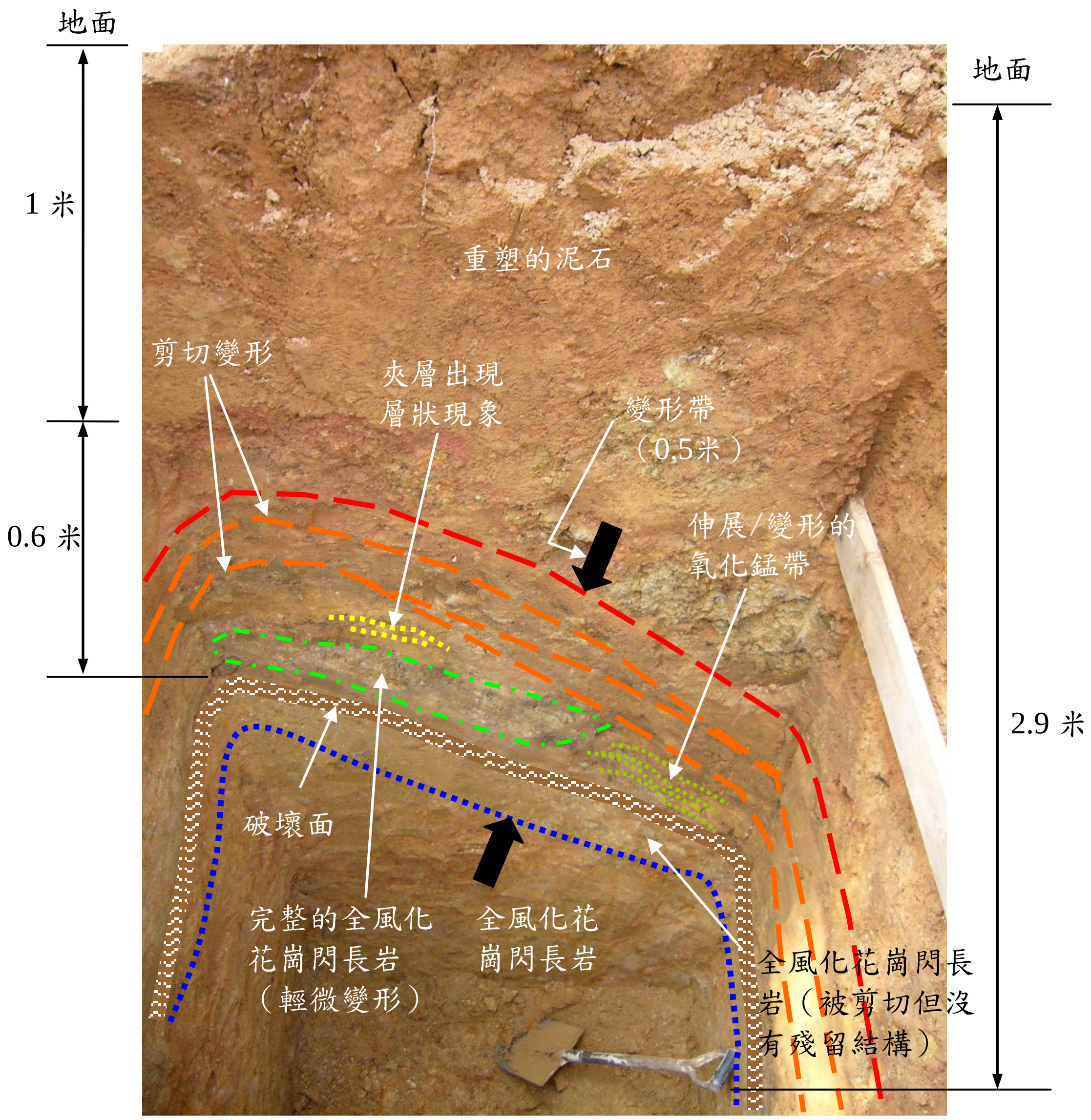
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)



照片 22 - 探槽 TT1 顯露的破壞面
(照片攝於二零零五年九月二十二日)

註: 照片位置及方向見圖 21。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)



照片 23 - 探井 TP3 顯露的破壞面及變形帶
(照片攝於二零零五年九月二十二日)

註: 照片位置及方向見圖 21。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

附錄 A

事發地點的發展歷史

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

目錄

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

備註

A1. 引言

芙蓉山村的發展歷史是根據以下資料確定的：

(a) 以往的測量圖，

(b) 一九二四年至二零零四年的航空照片，以及

(c) 土力工程處的檔案記錄。

在下文中所提及的地方和特徵載於圖 A1。

A2. 事發地點的發展歷史

現存最早的航空照片攝於一九二四年，顯示該區域爲一處天然山坡，山坡上有一南北走向的溪流將山坡分開成兩條南北走向的山嘴。爲了便於介紹，山嘴將被定義爲“西山嘴” (沿著溪流的西邊)和“東山嘴” (沿著溪流的東邊)。兩條山嘴及其兩側附近的地方均未有被人爲活動改動過。西山嘴的西側，即二零零五年八月發生山泥傾瀉的地方，比東山嘴鄰近的一側陡峭得多。在竹林禪院現址可以看到一些梯田。

航空照片，編號 Y00120-1 (5,800')

竹林禪院是始建於一九二七年，第一座寺廟在一九三二年竣工。

竹林禪院的記錄照片

在一九三七年，橫貫山泥傾瀉現場對上山坡的城門引水道經已建成。

水務署 1937 年 52 號合同的竣工平面圖航空照片，編號 Y00689 (20,000')

在一九四九年，沿著東山嘴的菩提園經已建成，竹林禪院亦已擴建。在竹林禪院以西的溪流上可以看到一處高反射區，相應爲一塊耕地和一個人造水池/堰。竹林禪院和水池之間有一個平台正在建造中。

航空照片，編號 Y2007 (5,800')

除了沿著西山嘴的西側可以看到一片墓地(G1)外，其東側似乎沒有明顯被人爲活動改動過。東山嘴普遍由零散的樹木和灌木的植被所覆蓋，而西山嘴則由少量的草和灌木的植被所覆蓋。

在一九五四年，竹林禪院與水池之間，建於一九四九年的平台擴建了。西山嘴仍未受人爲活動影響。

航空照片，編號 Y02729-30 (29,200')

到一九六三年可以發現，菩提園、竹林禪院和水池東面的平台上的建築物進一步擴建，其中包括興建小型的建築物、削坡、擋土牆和連接的小路。

航空照片，編號 Y09036-37 (3,900'), Y09120-21 (8,000')

一條橫跨二零零五年八月滑坡現場的小路(FP1)已可以看到，小路與現在的路線相似，並通往滑坡現場以北剛建成不久的平台。平台上可看到幾所已建成的建築物。這條小路沒有被鋪築且比現的在要窄一點。平台東面較上的位置新建了一墓地。在小路 FP1 的下方有一處明顯的高反射區，可能是由於行人從小路 FP1 往返溪流附近的水池而引致局部的侵蝕。

編號 RTW/4A/516 寮屋(寮屋的位置見圖 2)已經在沿著溪流東面；緊靠水池北側的地方建成。

在小路 FP1 以上，西山嘴較高的山坡，大致被樹木覆蓋著。小路 FP1 以下及溪流以西的山坡則覆蓋著灌木和少量分散的樹。

在一九六四年，沿著小路 FP1 下方的山坡可以看到一處高反射區(L1)，該位置可能是由溪流的淘蝕而引起的一次局部不穩定或曾經被人工開挖。高反射區 L1 的西側和南側可以很清晰的看到包括有凸出的坡度折曲，而北側顯得比較圓滑及平緩一些。在一九六三年的航空照片上觀察到覆蓋這個位置的植被現在經已不再存在，只有反射區的下部可以看見一段連續的植被。

航空照片，編號 Y11313-14 (1,800'), Y11149-50 (1,800'), Y11276-77 (2,700')

編號 RTW/4A/514 和 RTW/4A/526 寮屋已經沿溪流的東邊建成。

在一九六七年，高反射區 L1 更加明顯。先前覆蓋著該處下部的植被經已不見了，而整個區域均很反光。由於該處的高反光度和照片缺乏對比，並未能夠從中作出更詳細的判釋。

航空照片，編號 Y13483-85 (3,900')

沿著水池的東邊建成了一所寮屋。在西山嘴的墓地 G1 的南面，亦建成了幾所寮屋。在二零零五年八月山泥傾瀉的西北面，一列梯田沿著西山嘴而建。

在一九六九年，由於有大量的寮屋(包括編號 RTW/4A/364-366 寮屋)和相關平台的興建，沿著西山嘴的西側已明顯地被人爲活動改動過。在二零零五年八月山泥傾瀉中受影響的，編號 RTW/4A/388 寮屋亦已經建成了。沒有證據顯示在這所寮屋以下的山坡有明顯的傾倒填土的跡象。

航空照片，編號 15380-82 (4,000')

沿著溪流東邊也建成幾所寮屋，包括編號 RTW/4A/513 寮

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

屋和位於編號 RTW/4A/516 寮屋東面的另外兩所寮屋。

在一九七二年，一列在一九六四年至一九六七年期間建成，位於二零零五年八月山泥傾瀉西北面的梯田的範圍進一步擴大。

航空照片，編號 2279,81 (13,000')

沿著西山嘴西側的寮屋數目顯著增加。利用一九七三年低海拔航空照片對建築物的詳細評估顯示，總共有 11 所寮屋在這個時期建成(包括編號 RTW/4A/370-372, 374, 376-379, 389, 391-393, 411 寮屋及北面的一些其他的寮屋)。寮屋之間的地方明顯比較反光，顯示地面有持續的侵蝕或者有寮屋居民進行土方/鋪築。連接小路 FP1 和編號 RTW/4A/388, 389, 391-393 寮屋的梯級經已建成。

航空照片，編號 3261-63 (5,000')

在一九七五年，溪流旁邊的一個平台上，已建成了一所自一九七三年動工的寮屋。

航空照片，編號 11794-95 (12,500')

到一九七六年，沿著溪流東邊新建成了一些寮屋，包括編號 RTW/4A/528-529 寮屋和其南面的一些寮屋；同期建成的還有菩提園西北面的一些寮屋。

航空照片，編號 15463-64 (4,000')

過往見到的高反射區 L1 大致仍可看到。該特徵的南側和北側仍然明顯，北側已被重新生長的植被遮蔽。

沿著小路 FP1 下方的山坡，可以看到幾處有小量的堆積物。這些可能是回填物料或是局部的侵蝕。但以這航空照片的高度，並不能有效地斷定。

小路(FP2)從小路 FP1 延伸出來，連接在溪流東面；編號 RTW/4A/528-529 寮屋北面的另外一間寮屋。

到了一九七七年，過往位於沿著小路下方山坡的侵蝕或回填物料範圍經已被植被覆蓋而不再明顯。但是，可以看到有可能是一處局部侵蝕的一段線狀高反射區，伸延進高反射區 L1 的頂部。

航空照片，編號 19734-35 (4,000')，20070-71 (4,000')

在一九七八年，沿著小路 FP1 下方的山坡，可以看到小範圍的高反射區，這些可能是局部回填的填土或家居垃圾。

航空照片，編號爲 24061-62 (4,000')

在編號 RTW/4A/528-529 寮屋的北面建成了一片寮屋群。

在小路 FP1 和 FP2 的路口新建成了垃圾收集站(RCP)。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

到了至一九七九年，溪流的東邊已發展爲密集的寮屋群。

航空照片，編號 27492,94 (4,000')

在一九八零年，垃圾收集站下方的山坡，可以看到有一處高反射區。這些有可能是局部的回填的填土或家居垃圾。

航空照片，編號 32966-67 (4,000')

在一九八二年，沿著小路 FP1 下方的山坡，可以看到反射區擴大。該區域似乎是用作放置鬆散物質(可能爲填土或家居垃圾)的場地。

航空照片，編號 43124-25 (3,000'), 43859-60 (2,500')

小路 FP1 下方的一片山坡已被用作種植蕉樹。

到一九八四年，先前在一九八零年和一九八二年的航空照片識別出的高反射區已被重新生長的植被所遮蔽。從小路 FP1 向下通往溪流的一段梯級經已建成。

航空照片，編號 56548-49 (4,000')

在一九八七年，小路 FP1 下方的山坡可以看到一處局部的反射區，其範圍與最初在一九八零年觀察到的相似，並且在一九八八年的航空照片中依然清晰可見及反光。

航空照片，編號 A09886-87 (4,000'), A10493-94 (4,000'), A10503-04 (4,000')

在一九九一年，位於小路 FP1 下方山坡的高反射區顯著擴大。

航空照片，編號 A27540-41 (4,000')

有一所寮屋(原本建於一九七二年，在編號 RTW/4A/376-379 寮屋的東面)已被拆除。

到一九九二年，先前在一九九一年可以看到的高反射區已被植被遮蔽。

航空照片，編號 A30483-84 (5,000'), A32637-38 (4,000')

在一九九三年至一九九五年間的航空照片中，沒有發現重大的變化。

到一九九六年，沿著溪流的寮屋普遍已開始被清拆。

航空照片，編號 A35973-74 (4,000'), CN5647-48 (10,000'), A38141,52 (5,000'), CN9556-57 (10,000'), CN12369-70 (10,000') A14217-18 (4,000'), A15816-178 (4,000')

到一九九八年，溪流範圍內的寮屋經已被大量清拆，只剩下幾所分散的寮屋。沿著西山嘴的寮屋亦有部份被清拆，只留下空置的平台。

航空照片，編號 A48357-58 (4,000')

受二零零五年八月山泥傾瀉影響的範圍經已完全被植物所遮蔽。

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

Table of Contents (Chinese)

在一九九九年，沿著小路 FP1 下方的山坡，可以看到有一處高反射區。該區域與一九七八年觀察得的反射區位置相若。

在二零零零年至二零零四年間的航空照片中，沒有發現重大的變化。

航空照片，編號
CN28065-66 (5,500')
CW31688-89 (7,000')
CW32673-74 (4,000')
RW01544-45 (4,000')
CW42645-46 (4,000')
CW47196-97 (4,000')
CW49880-81 (8,000')
CW57011-12 (4,000')
CW59195-96 (4,000')

Table of Contents (Chinese)

A3. 過往的評估

二零零五年八月山泥傾瀉事件沒有涉及任何已登記的斜坡，在滑坡範圍內或附近的地方過往亦沒有展開任何工程或研究。

A3.1 非發展性清拆計劃

根據政府爲那些處於有即時及明顯危險或容易遭到山泥傾瀉威脅並已登記的寮屋居民提供安置的政策，從八十年代中期開始，土力工程處依照非發展性清拆(NDC)計劃進行研究，以劃定各寮屋區和確定需要清拆的寮屋建築物。研究包括利用地形分類測繪、航空照片判釋(API)和參考滑坡傷亡的記錄，以確定潛在滑坡災害的地區。在作出實地視察後，土力工程處會確定需要清拆的寮屋。因斜坡安全理由而建議清拆的寮屋是由土力工程處提出，而地政總署(Lands D)和房屋署(HD)則負責爲寮屋居民提供清拆和安置。

土力工程處 Instruction No. 2/89, Non-Development Clearance and Restoration Works in Squatter Areas

Table of Contents (Chinese)

題目爲 “Squatter Clearance Studies for Tung Yeung, Tse Mei, Fuk Tak New and Ling Nam New (Upper) village”的研究方法綱領

在 NDC 計劃下，土力工程處在一九八五年勘察了芙蓉山村。在一九八五年十二月三十日，土力工程處向房屋署建議因斜坡安全理由而需要清拆的寮屋(圖 A2)。受二零零五年八月山泥傾瀉影響；編號 RTW/4A/388, RTW/4A/516, RTW/4A/526 和 RTW/4A/528-529 寮屋均位於 NDC 勘察範圍內，但當時並沒有被建議清拆。

土力工程處備忘錄，參考編號 GCMd 2/E1/RA4 (W)（15）號 一九八五年十二月三十日

Table of Contents (Chinese)

地政總署和房屋署在編號 TW 15/87 清拆計劃下，展開了清拆和安置工作，並於一九八九年十一月完成。一共有 43 所寮屋被清拆。

房屋署備忘錄，參考編號 TW/C 32/3/93 (98)號，一九八九年十一月三十日

一九九二年五月，土力工程處對過往在 NDC 計劃下勘察過的新界寮屋區，進行重新勘察的工作。在一九九二/九三年度 NDC 重新勘察計劃下，芙蓉山村的實地勘察工作於一九九二年十月進行。在一九九二年十一月十二日，土力工程處向房屋署建議因斜坡安全理由而需要清拆的寮屋(圖 A2)。受二零零五年八月的山泥傾瀉事件影響；編號 RTW/4A/388, RTW/4A/516, RTW/4A/526 和 RTW/4A/528-529 寮屋在此次重新勘察中被建議清拆。

土力工程處 AR 1/93 號報告：Re-inspection of Squatter Villages in the New Territories: July 1992 to June 1993 Executive Summary 一九九三年八月

土力工程處備忘錄，參考編號 GCMd 4/13/ RA11 II (26) 一九九二年十一月十二日

清拆和安置是由地政總署和房屋署負責，並在一九九三年七月期間，展開了編號 TW 8/92 清拆計劃。房屋署一共篩選出 290 所需要清拆的寮屋，並且爲這些家庭提供居所安置。在此次清拆計劃期間，約有 60 所沒有在一九九二年間被土力工程處建議清拆的寮屋，亦以"其他理由" (即保安原因，管理方面)被納入 NDC 計劃中清拆。在一九九四年十一月，房屋署建議在編號 TW18/94 清拆計劃中，清拆編號 RTW/4A/389, 391-393 寮屋(圖 A2)。清拆和安置在一九九三年至一九九六年間進行。

房屋署備忘錄，參考編號 TW/C 1/7/83 (190) 一九九三年六月一日

房屋署備忘錄，參考編號 TW/C 1/7/93 (79) 一九九四年十一月二十九日

編號 TW 8/92 清拆計劃在一九九五年四月二十六日完成(圖 A3）。總共有 20 個家庭拒絕接受安置，並堅持在原地繼續居住，其中包括受二零零五年八月山泥傾瀉事件影響；編號 RTW/4A/388, RTW/4A/389, 391-393, RTW/4A/516, RTW/4A/526 和 RTW/4A/528-529 寮屋的居民。這些寮屋一直到二零零五年八月二十日發生山泥傾瀉事件前仍沒有被清拆。芙蓉山村的一些居民指出，編號RTW/4A/389, 391-393 寮屋在事發時被一些並非在芙蓉山村居住的癮君子所使用。

房屋署備忘錄，參考編號 TW/C 7/3/93 III (114) 一九九五年三月二十二日

房屋署備忘錄，參考編號 HD(C) NTW 7/7/VI 二零零五年十二月二十二日

在二零零一年九月，土力工程處在二零零一至二零零二年度勘察計劃(溪流附近)下，重新勘察了芙蓉山村溪流附近的區域。重新勘察顯示，除了在一九九二年被土力工程處建議清拆的寮屋外，沒有其他寮屋需要清拆。

土力工程處備忘錄，參考編號 GCMd 4/13/ 11 sf9(S) (2) 二零零一年十一月三十日

A3.2 <u>地區岩土研究計劃</u>

在研究範圍內相關的岩土工程資料已被土力工程處編撰成地區岩土研究計劃(GASP)報告 II，新界中部(土力工程處，一九八七）。資料是以比例爲 1：20 000 的地圖顯示，作爲區域性評估和策略性規劃的用途。工程地質圖顯示山泥傾瀉現場爲淺水灣組粗粒凝灰岩。按岩土因素劃分的土地用途圖(GLUM)顯示，山泥傾瀉附近的山坡屬於第 II 級地區(即中等岩土規限的地區)，而沿著山泥傾瀉現

地區岩土研究計劃報告 II，新界中部 (土力工程處，一九八七)

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

場附近溪流的地區則識別為第 III 級地區(高岩土規限的地區)。一般性限制和工程評估圖(GLEAM)將研究範圍內的山坡歸類為“潛在發展區域”。自然地理限制圖(PCM)顯示，雖然山泥傾瀉現場附近的溪流旁邊的山坡被歸類為“限制發展地域”，研究範圍內的開闊山坡是沒有分類的。

A4. 過往的不穩定性

研究範圍內過往的不穩定性歷史，是翻查相關檔案資料而確定的(圖 6 和 A4)。

NTLI, 擴大版 NTLI, LLD, 土力工程處的山泥傾瀉資料庫

根據土力工程處的山泥傾瀉資料庫、山體滑坡目錄(NTLI)、大型滑坡資料庫(LLD)和山體滑坡目錄擴大版的資料顯示，在二零零五年八月山泥傾瀉現場及鄰近的地區並沒有任何山泥傾瀉記錄。

根據土力工程處的山泥傾瀉資料庫，芙蓉山村以往總共有 30 次山泥傾瀉事件記錄(見表 A1 和圖 A4)，其中的 14 次位於二零零五年八月山泥傾瀉現場的 150 米半徑範圍內(圖 6)。這 14 次山泥傾瀉事件主要發生在人造斜坡上，崩塌體積介乎 0.5 立方米到 50 立方米之間，大部分山泥傾瀉均影響了寮屋，有些甚至引致相關的寮屋需要永久性遷離。距離最近的山泥傾瀉(事件編號為 MW87/8/29)是位於小路 FP2(見第 A2 部分)下方的小型崩塌，該崩塌發生在距離山泥傾瀉現場東北面約 20 米的溪流旁邊，崩塌體積約為 3 立方米。

A5. 參考書目

土力工程處 (一九八七) Geotechnical Area Studies Programme - Central New Territories. GASP Report No. II，土力工程處，香港，165 頁及 4 張地圖。

土力工程處 (一九九二) Non-development Clearance Programme, 1992 Re-inspection Programme Fu Yung Shan. Drawing No. GCMd 92/39，土力工程處，香港。

土力工程處 (一九九三) Re-inspection of Squatter Villages in the New Territories: July 1992 to June 1993 Executive Summary. Report No. AR 1/93，土力工程處，香港，15 頁及 2 張地圖。

King, J.P. (一九九九) Natural Terrain Landslide Study - The Natural Terrain Landslide Inventory. 土力工程處，香港，127 頁。(土力工程處第 74 號報告)。

表目錄

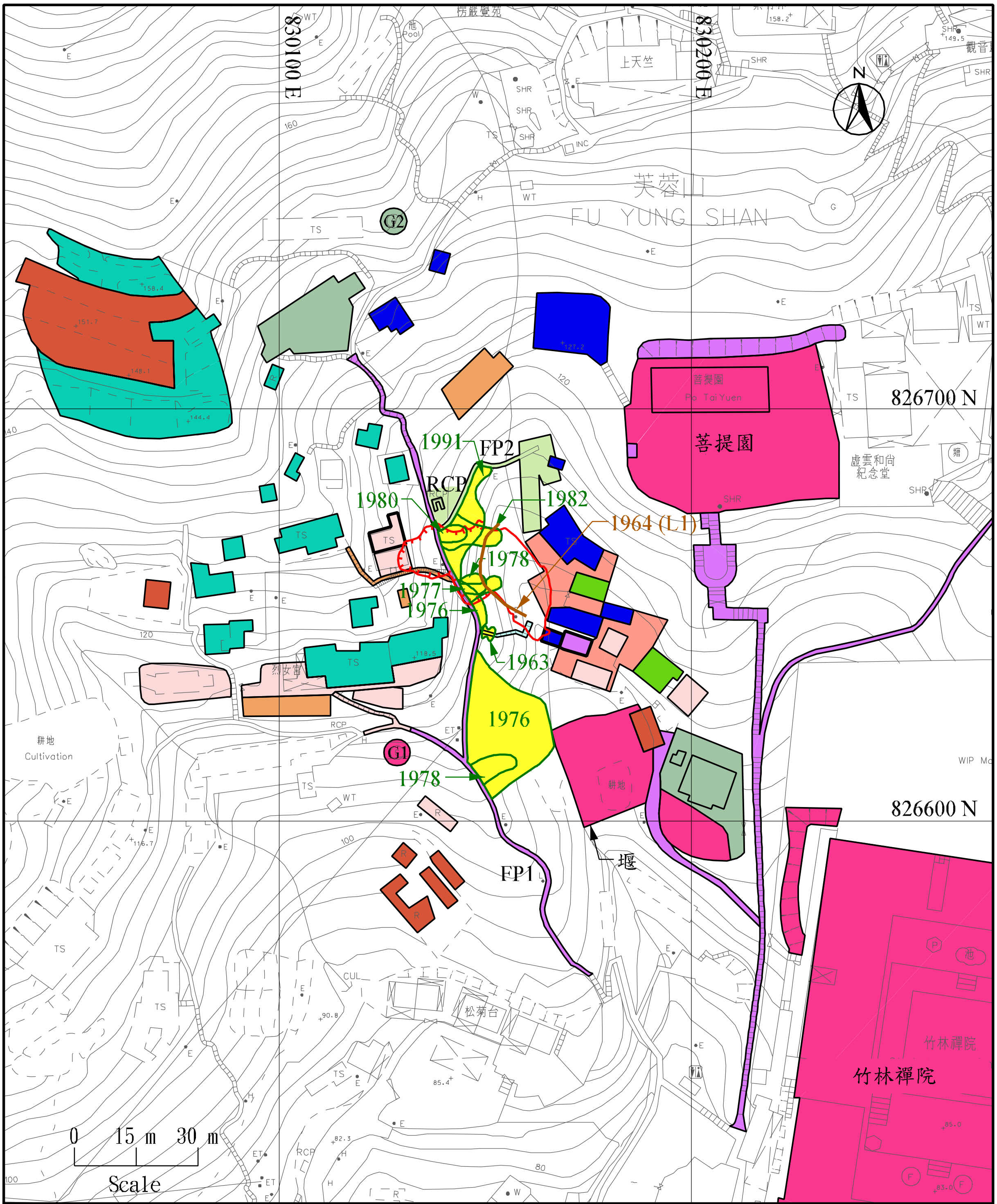
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

表 A1 - 土力工程處的山泥傾瀉資料庫內關於芙蓉山村以往的山泥傾瀉報告

事件編號	崩塌形式	相關斜坡	崩塌體積 (立方米)	影響
NT82/55	山泥傾瀉	削土坡	輕微 (<50)	兩所寮屋需要永久性遷離
NT82/238	滾石	削土坡	輕微 (<50)	一所寮屋需要永久性遷離
NT82/240	山泥傾瀉	削土坡	~40	引水道被堵塞
NT82/8/36	擋土牆倒塌, 侵蝕	擋土牆， 天然溪流	較大(>50)	二十所寮屋需要永久性遷離
NT82/9/5	山泥傾瀉	削土坡	~5	兩所寮屋需要永久性遷離
MW87/8/28	山泥傾瀉	削土坡	3	一所寮屋和通道受影響
MW87/8/29	侵蝕	小路下的山坡	3	小路受影響
MW88/7/1	地面下陷	削土坡	0	一所寮屋需要永久性遷離
MW89/5/61A	山泥傾瀉	削土坡	2	通道受影響
MW89/5/61B	山泥傾瀉	削土坡	1	通道受影響
MW89/5/66	山泥傾瀉	削土坡	0.5	一所寮屋需要永久性遷離
MW92/5/63	山泥傾瀉	削土坡	2	一所寮屋受影響
MW92/5/69	山泥傾瀉	削土坡	2.5	兩所寮屋需要永久性遷離
MW93/6/15	擋土牆倒塌	擋土牆	2	一所寮屋需要臨時疏散
MW93/6/16	山泥傾瀉	削土坡	1.5	小路受影響
MW93/6/17	山泥傾瀉	小路下的山坡	45	小路受影響
MW93/9/6	山泥傾瀉	天然山坡	1	兩所寮屋需要永久性遷離
MW94/7/33	山泥傾瀉	削土坡	15	公路受影響
MW94/8/44	山泥傾瀉	削土坡	2	一所寮屋需要永久性遷離
MW97/5/9	山泥傾瀉	削土坡	3	公路受影響
MW97/5/34	山泥傾瀉	削土坡	35	通道受影響
MW97/7/102	山泥傾瀉	削土坡	10	兩所寮屋需要永久性遷離
MW97/7/103	山泥傾瀉	削土坡	4	一所寮屋需要永久性遷離
MW97/8/15	山泥傾瀉	削土坡	10	公路受影響
MW2001/6/45	山泥傾瀉	小路下的山坡	2	小路受影響
2002/06/0038	山泥傾瀉	削土坡	1	小路受影響
2003/10/0198	山泥傾瀉	削土坡	0.5	小路受影響
2005/06/0181	山泥傾瀉	削土坡	100	一所寮屋受影響
2005/07/0251	山泥傾瀉	填土坡	8	小路受影響
2005//8/0362 (二零零五年八月山泥傾瀉)	山泥傾瀉	小路下的山坡	400	一人喪生，四所寮屋需要永久性遷離

圖目錄

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)



圖例：

二零零五年八月的山泥傾瀉

1963 擾動區域（在一九六三年航空照片上可見的侵蝕、填料/家居垃圾的堆積）

G1 墓地

光禿的土體（在一九六四年航空照片上可見）

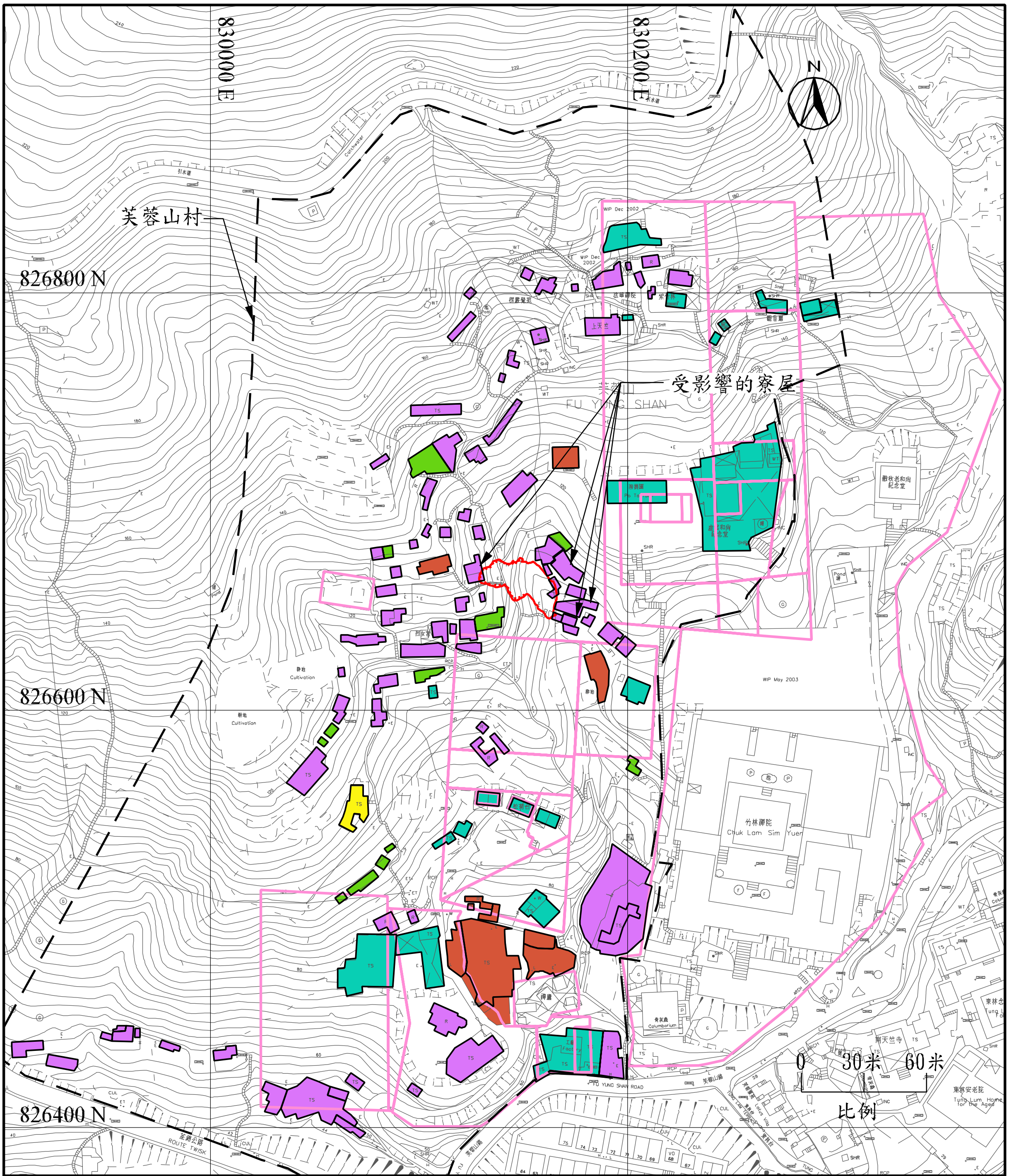
發展情況

1949之前	1967	1976
1954 - 1963	1969	1978
1963	1972	1979
1964	1973	1984

註：　底圖取自二零零四年三月編號 7SW-11C 測量圖（比例1:1000）。

圖A1 － 事發地點歷史

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)



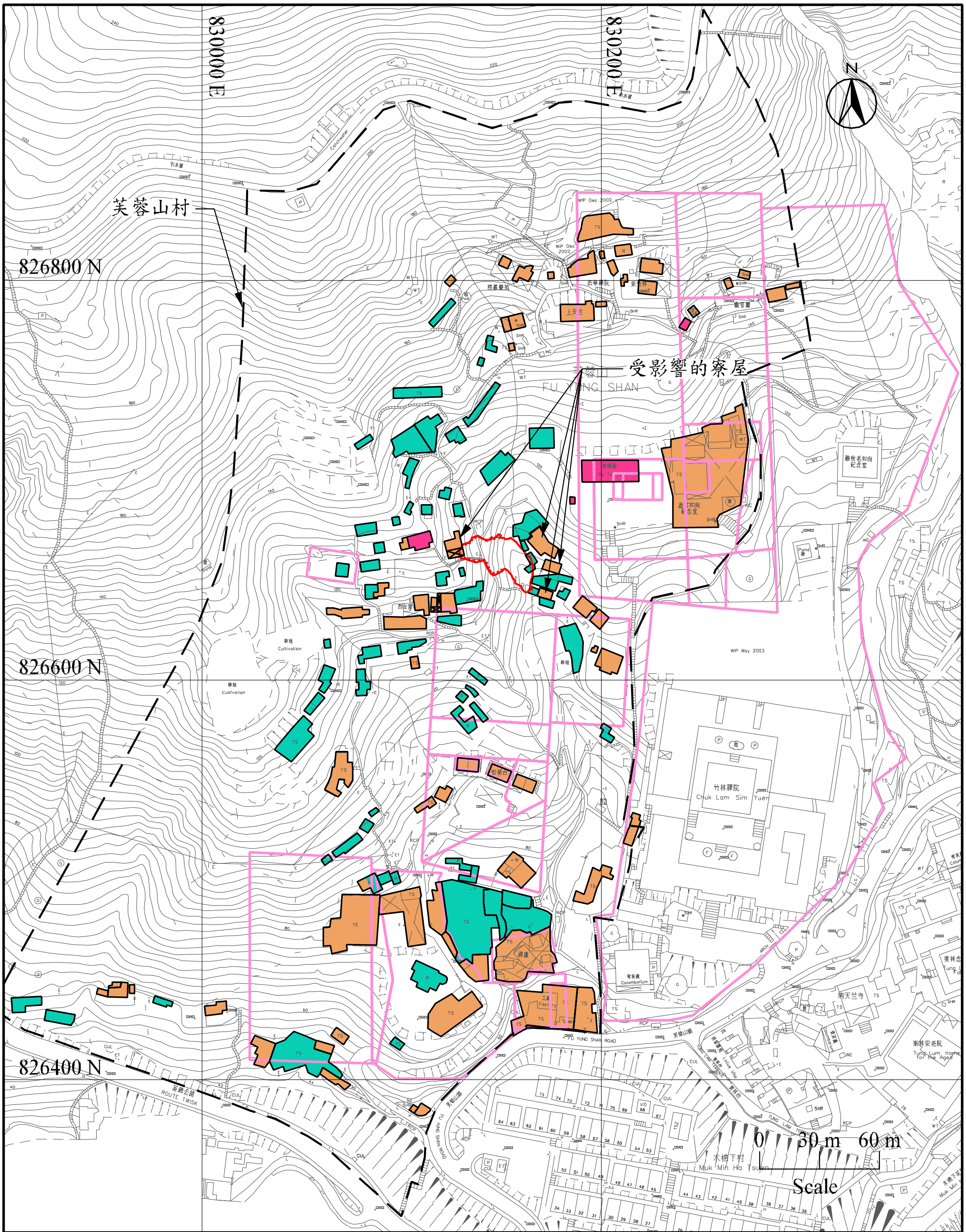
圖例：

- 二零零五年八月的山泥傾瀉
- 私人土地
- 一九九三年六月山泥傾瀉之後被建議永久性的遷離的建築物
- 土力工程處於一九八五年提出的非發展性清拆建議（於編號TW15/87清拆計劃下執行）
- 土力工程處於一九九二年提出的非發展性清拆建議（於編號TW8/92清拆計劃下執行）
- 房屋署於一九九四年提出的非發展性清拆建議（於編號TW18/94清拆計劃下執行）
- 現存的建築物在二零零五年八月的山泥傾瀉前未有被建議清拆

註： 底圖取自二零零四年三月編號 6SE-15D, 6SE-20B, 7SW-11C及7SW-16A測量圖（比例1:1000）。

圖A2 - 非發展性清拆建議

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)



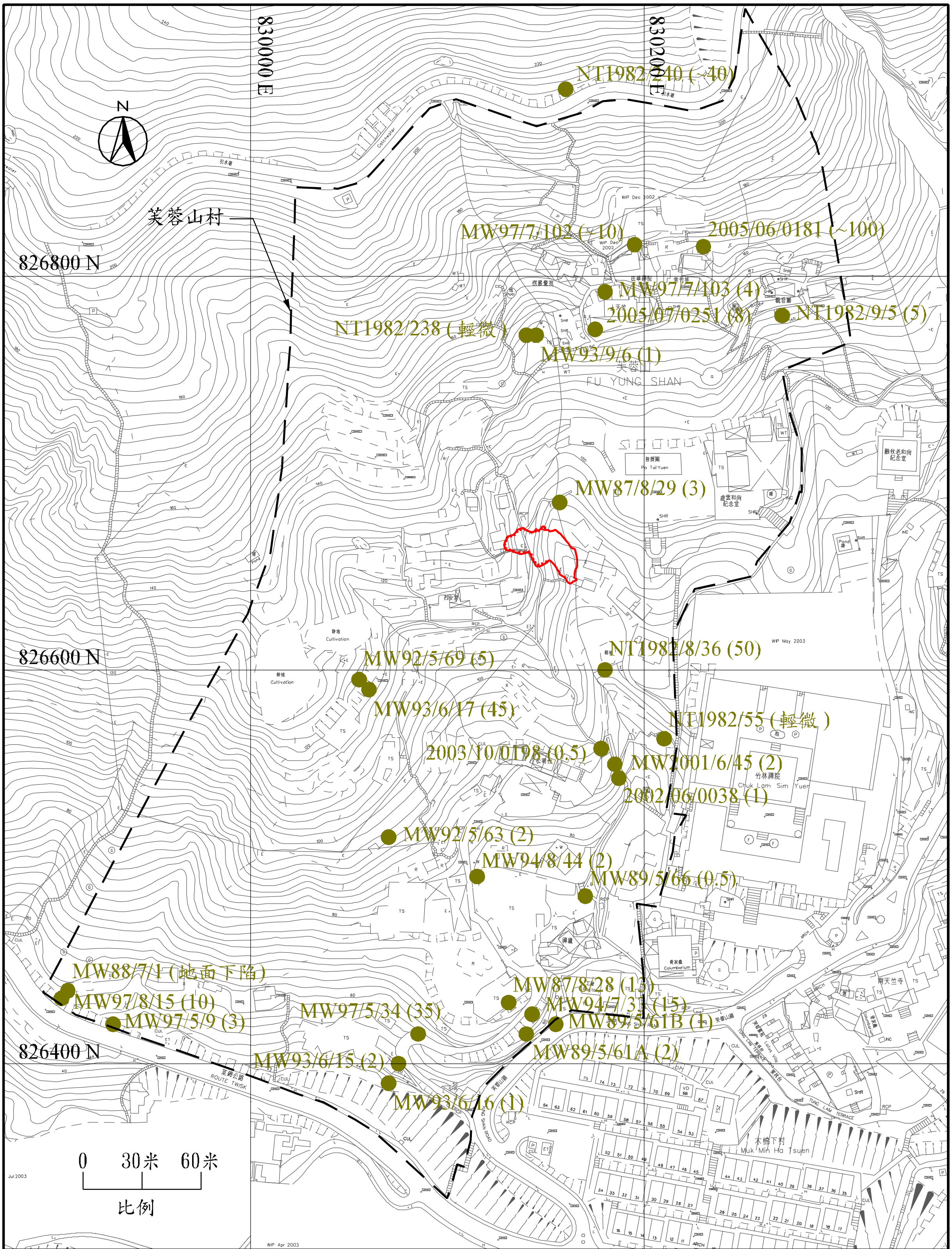
圖例：

- 二零零五年八月的山泥傾瀉
- 私人土地
- 二零零五年八月山泥傾瀉前已遷徙/清拆的寮屋/建築物
- 二零零五年八月山泥傾瀉前仍被使用的寮屋/建築物
- 二零零五年八月山泥傾瀉之前仍未清拆但沒有居住迹象的寮屋/建築物

註： 底圖取自二零零四年三月編號 6SE-15D, 6SE-20B, 7SW-11C及7SW-16A測量圖（比例1:1000）。

圖A3 － 二零零五年八月山泥傾瀉前寮屋的清拆情況

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)



圖例：

二零零五年八月的山泥傾瀉

MW92/5/63 (2) 山泥傾瀉事件編號MW92/5/63 其崩塌體積為2立方米

註： 底圖取自二零零四年三月編號 6SE-15D, 6SE-20B, 7SW-11C及7SW-16A測量圖（比例1:1000）。

圖A4 － 芙蓉山村以往的山泥傾瀉報告

Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)
Table of Contents (Chinese)

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

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

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

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

Writing to
Publications Sales Section,
Information Services Department,
Room 402, 4th Floor, Murray Building,
Garden Road, Central, Hong Kong.
Fax: (852) 2598 7482

or
- Calling the Publications Sales Section of Information Services Department (ISD) at (852) 2537 1910
- Visiting the online Government Bookstore at http:// www.bookstore.gov.hk
- Downloading the order form from the ISD website at http://www.isd.gov.hk and submitting the order online or by fax to (852) 2523 7195
- Placing order with ISD by e-mail at puborder@isd.gov.hk

讀者可採用以下方法購買土力工程處刊物(地質圖及免費刊物除外)：

書面訂購
香港中環花園道
美利大廈4樓402室
政府新聞處
刊物銷售組
傳真: (852) 2598 7482

或
- 致電政府新聞處刊物銷售小組訂購 (電話：(852) 2537 1910)
- 進入網上「政府書店」選購，網址為 http://www.bookstore.gov.hk
- 透過政府新聞處的網站 (http://www.isd.gov.hk) 於網上遞交訂購表格，或將表格傳真至刊物銷售小組 (傳真：(852) 2523 7195)
- 以電郵方式訂購 (電郵地址：puborder@isd.gov.hk)

1:100 000, 1:20 000 and 1:5 000 geological maps can be purchased from:

Map Publications Centre/HK,
Survey & Mapping Office, Lands Department,
23th Floor, North Point Government Offices,
333 Java Road, North Point, Hong Kong.
Tel: (852) 2231 3187
Fax: (852) 2116 0774

讀者可於下列地點購買1:100 000、1:20 000及1:5 000地質圖：

香港北角渣華道333號
北角政府合署23樓
地政總署測繪處
電話: (852) 2231 3187
傳真: (852) 2116 0774

Requests for copies of Geological Survey Sheet Reports and other publications which are free of charge should be directed to:

For Geological Survey Sheet Reports which are free of charge:
Chief Geotechnical Engineer/Planning,
(Attn: Hong Kong Geological Survey Section)
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5380
Fax: (852) 2714 0247
E-mail: jsewell@cedd.gov.hk

For other publications which are free of charge:
Chief Geotechnical Engineer/Standards and Testing,
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5346
Fax: (852) 2714 0275
E-mail: florenceko@cedd.gov.hk

如欲索取地質調查報告及其他免費刊物，請致函：

免費地質調查報告:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
規劃部總土力工程師
(請交:香港地質調查組)
電話: (852) 2762 5380
傳真: (852) 2714 0247
電子郵件: jsewell@cedd.gov.hk

其他免費刊物:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
標準及測試部總土力工程師
電話: (852) 2762 5346
傳真: (852) 2714 0275
電子郵件: florenceko@cedd.gov.hk

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

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 302 p. (English Version), (Reprinted, 2011).

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1	Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2007).
Geoguide 2	Guide to Site Investigation (1987), 359 p. (Reprinted, 2000).
Geoguide 3	Guide to Rock and Soil Descriptions (1988), 186 p. (Reprinted, 2000).
Geoguide 4	Guide to Cavern Engineering (1992), 148 p. (Reprinted, 1998).
Geoguide 5	Guide to Slope Maintenance, 3rd Edition (2003), 132 p. (English Version).
岩土指南第五冊	斜坡維修指南，第三版(2003)，120頁(中文版)。
Geoguide 6	Guide to Reinforced Fill Structure and Slope Design (2002), 236 p.
Geoguide 7	Guide to Soil Nail Design and Construction (2008), 97 p.

GEOSPECS

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

GEO PUBLICATIONS

GCO Publication No. 1/90	Review of Design Methods for Excavations (1990), 187 p. (Reprinted, 2002).
GEO Publication No. 1/93	Review of Granular and Geotextile Filters (1993), 141 p.
GEO Publication No. 1/2006	Foundation Design and Construction (2006), 376 p.
GEO Publication No. 1/2007	Engineering Geological Practice in Hong Kong (2007), 278 p.
GEO Publication No. 1/2009	Prescriptive Measures for Man-Made Slopes and Retaining Walls (2009), 76 p.
GEO Publication No. 1/2011	Technical Guidelines on Landscape Treatment for Slopes (2011), 217 p.

GEOLOGICAL PUBLICATIONS

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

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

TECHNICAL GUIDANCE NOTES

TGN 1	Technical Guidance Documents