REVIEW OF THE 20 AUGUST 2005 DEBRIS FLOOD AT LO WAI, TSUEN WAN

GEO REPORT No. 212

Maunsell Geotechnical Services Limited

GEOTECHNICAL ENGINEERING OFFICE

CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT

THE GOVERNMENT OF THE HONG KONG

SPECIAL ADMINISTRATIVE REGION

REVIEW OF THE 20 AUGUST 2005 DEBRIS FLOOD AT LO WAI, TSUEN WAN

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PREFACE

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

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

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

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FOREWORD

This report presents the findings of a review of the debris flood that occurred some time between 4:15 p.m. and 5:00 p.m. at Lo Wai, Tsuen Wan on 20 August 2005. The debris flood was probably triggered by two major landslides (Incident No. 2005/08/0338) on slope No. 7SW-A/CR134, which is situated immediately above the section of the Shing Mun Catchwater north of Lo Wai. Four other slopes Nos. 7SW A/F76, 7SW A/F77, 7SW A/F38 and 7SW A/CR132 located along the debris trail were caused to fail (Incidents Nos. 2005/08/0348, 2005/08/0402, 2005/08/0528 and 2005/08/0417). The incident also resulted in temporary evacuation of 118 residents and 84 visitors to the temples. A section of Lo Wai Road was temporarily closed.

The key objectives of the review were to document the facts about the debris flood and associated landslides, present relevant background information and establish the probable causes of the debris flood and associated landslides. The scope of the review comprised site reconnaissance, desk study and engineering analysis.

The report was prepared as part of the 2005 Landslide Investigation Consultancy for landslides occurring in Kowloon and the New Territories in 2005, for the Geotechnical Engineering Office, Civil Engineering and Development Department, under Agreement No. CE 15/2004 (GE). This is one of a series of reports produced during the consultancy by Maunsell Geotechnical Services Limited.

L.J Endicott

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Agreement No. CE 15/2004 (GE)
Study of Landslides Occurring in Kowloon
and the New Territories in 2005 -
Feasibility Study

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1. INTRODUCTION

Between 4:15 p.m. and 5:00 p.m. on 20 August 2005 when the Landslip Warning and Amber Rainstorm Warning had been in effect for more than 19 hours and 7½ hours respectively, two landslides (Incident No. 2005/08/0338) occurred on slope No. 7SW-A/CR134. The slope is situated immediately above a section of the Shing Mun Catchwater, which is located to the north of Lo Wai, Tsuen Wan (Figure 1). The landslide debris substantially blocked the catchwater channel and caused the water to back up. Consequently, two overflow weirs upstream of the landslides spilled large quantities of water into two limbs of a natural streamcourse intersecting the catchwater (Figure 1 and Plate 1).

As the flow travelled downstream, it undercut severely the stream bed and side slopes Nos. 7SW-A/F76 and 7SW-A/F77 close to the outlets of the overflow weirs of the streamcourse and entrained loose materials (there were also reports that a portion of slope No. 7SW-A/F76 failed prior to the debris flood). The flow, entraining large amounts of debris, developed into a debris flood, which undermined or damaged a number of squatter structures near the streamcourse and destroyed a pier of a footbridge across the streamcourse.

An access road intercepted the debris flood at about 226 m below the overflow weirs. The debris flood blocked the cross-road drain and overtopped the access road where it branched out. The debris flood branches later combined and travelled towards Lo Wai Road. After travelling for some 800 m from the catchwater, the debris flood finally dissipated its remaining energy at Lo Wai Road where a large amount of debris was deposited (Figure 2 and Plate 2). Slopes Nos. 7SW-A/F38 and 7SW-A/CR132 situated along the debris flood trail were also significantly eroded.

As a result of the incident, five vehicles, including a taxi at Lo Wai Road, were trapped by the debris at various locations along the debris flood. A footbridge across the streamcourse and both lanes of Lo Wai Road were temporarily closed. Five squatter structures were recommended for permanent and compulsory evacuation. According to the Fire Services Department (FSD) Incident Report, the incident also resulted in temporary evacuation of 118 local residents and 84 visitors to the nearby temples.

Following the incident, Maunsell Geotechnical Services Limited (MGSL), the 2005 Landslide Investigation Consultant for Kowloon and the New Territories, carried out a review of the landslide incident for the Geotechnical Engineering Office (GEO), Civil Engineering and Development Department (CEDD), under Agreement No. CE 15/2004 (GE).

This report documents the facts about the debris flood and the associated landslides, findings of a desk study and pertinent site observations made by MGSL. The scope of the review does not include any ground investigation.

2. THE SITE

2.1 Site Description

2.1.1 General

A 400 m long section of the Shing Mun Catchwater is situated approximately 500 m north of Lo Wai Village (Figure 1) in Tsuen Wan at an elevation of about 202 mPD. The two

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overflow weirs (SMOF-12 and SMOF-13), which allowed large amount of discharge into two limbs of a natural streamcourse during the 20 August 2005 debris flood incident, are located within this section of the catchwater (Figure 3).

The streamcourse downstream of the catchwater runs in a southwesterly direction and is approximately 330 m long. Hilltop Country Club is located about 100 m to the south of the streamcourse and Sheung Kok Shan Village is situated on the north bank of the streamcourse. The downstream end of the streamcourse is connected to two 600 mm diameter subsurface drainage pipes at about 130 mPD maintained by the Home Affairs Department (HAD), which run under the Western Monastery immediately to the west of the downstream end. Another temple, Yuen Yuen Institute, is situated about 300 m to the west of the streamcourse (Figure 3).

A 600 mm diameter cross-road drain and a 1.1 m wide by 0.8 m high culvert are present along the streamcourse. The cross-road drain passes beneath an access road at about 149 mPD, which runs from an open car park northeast of the Western Monastery to the south. The access road connects to Lo Wai Road, which runs along the northern boundary of Lo Wai Village.

2.1.2 Shing Mun Catchwater

According to the records from the Water Supplies Department (WSD), the entire Shing Mun Catchwater is about 9 km long and is located on the hillside of Tai Mo Shan. It runs from Ha Fa Shan to the west to the Shing Mun Reservoir to the east. It collects storm water from Tai Mo Shan through direct runoff or by intercepting natural streamcourses above the catchwater. Controlled intake dams are located at the interception points of the major natural streamcourses to control the amount of water entering the catchwater. Overflow weirs are located along the catchwater. The size of the catchwater channel varies. At chainage M6500 (i.e. about 6.5 km from the Shing Mun Reservoir) near Route Twisk, the cross-sectional area of the catchwater channel is about 11 m² while at the outfall to the Shing Mun Reservoir the cross-sectional area of the catchwater channel is approximately 16 m². A 3.5 m wide road runs beside the catchwater to provide vehicular access.

Slope No. 7SW-A/CR134 is situated immediately above the section of the Shing Mun Catchwater north of Lo Wai and about 2 km from the Shing Mun Reservoir. The slope is about 50 m long, with a soil cut portion above the catchwater channel wall (Plate 3). The maximum heights of the soil cut portion and the channel wall are 7 m and 3.5 m respectively. The soil cut portion is inclined at about 55° and was covered with chunam. The sidewall of the catchwater channel is inclined at approximately 65°. Natural terrain is situated above the soil cut, with an average inclination of about 20°. The natural terrain is covered with dense vegetation comprising grass and shrubs.

Overflow weirs SMOF-12 and SMOF-13, which are upstream of slope No. 7SW-A/CR134, are located at chainages M2300 and M2360 respectively. These two weirs are openings, each about 9 m wide and 0.6 m high, located on the downhill side of the catchwater (Plate 4). The catchwater channel between these two overflow weirs and slope No. 7SW-A/CR134 is an open trapezoidal channel, with a depth of 3.2 m and top and base widths of 6 m and 3.3 m respectively.

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Four controlled intake dams are located upstream of slope No. 7SW-A/CR134, at chainages M3078, M6557, M6664 and M6704 respectively. The catchment areas above these intake dams are substantial, ranging from approximately 1.1 km² to 2.3 km².

2.1.3 Streamcourse

The streamcourse has a west and southwest limb connected to the spillways immediately below the two catchwater overflow weirs. The two limbs are typically about 4 m wide and about 55 m to 70 m long, joining downstream to the streamcourse. The upper portions of these limbs have gradients of approximately 36°, which reduce to about 9.5° near the confluence. The total drop in elevations from the invert of the overflow weirs to the bed of the confluence is about 27 m.

The streamcourse is about 3 to 4 m wide and has an overall gradient of about 9° and a horizontal bend of about 50º approximately 120 m downstream of the overflow weirs. Two registered fill slopes (Nos. 7SW-A/F76 and 7SW-A/F77) which are maintained by the Drainage Services Department (DSD), form the banks of the upper part of the streamcourse (Figure 3).

Slope No. 7SW-A/F76 was about 80 m long, up to 5 m high and inclined at an angle of 35° whereas slope No. 7SW-A/F77 was about 168 m long and up to 4 m high, with a slope angle of 35°. The surfaces of the two slopes are covered with grass, shrubs and banana trees. Sheung Kok Shan Village, which includes some squatter structures, is located at the crest of slope No. 7SW-A/F77. Some squatter structures are also located at the crest of slope No. 7SW-A/F76.

Approximately 190 m downslope of the overflow weirs is a steel footbridge (at about 166 mPD) crossing the streamcourse that provides access to Lung Mo Temple. The footbridge was partly supported by a cement-rendered brick pier near the southern end of slope No. 7SW-A/F77. About 40 m further downstream, the streamcourse reaches an access road and flows through a 600 mm diameter cross-road drain which is maintained by HAD. An open car park is situated to the west of the cross-road drain and to the northeast of Western Monastery. The car park is roughly rectangular in plan, being about 50 m by 18 m. Slope No. 7SW-A/F38, which is about 10 m high and inclined at an angle of 35°, is situated below the southeast corner of the open car park. The slope was covered with grass and shrubs. The maintenance responsibility of slope No. 7SW-A/F38 rests with the Lands Department (Lands D) and the owners of private Lot No. 1186 in DD 453. At the toe of slope No. 7SW-A/F38 is an open area of approximately 270 m² at an elevation of about 131 mPD.

Beyond the cross-road drain, the streamcourse continues for about 75 m in open channel and connects to a culvert that passes underneath the front yard of village house No. 200, just to the northeast of Western Monastery. Two 600 mm diameter subsurface drainage pipes are connected to the outlet of the culvert on the other side of the front yard. Both pipes run towards Western Monastery and connect to another culvert that runs north to south beneath the monastery. Records for this culvert that are kept by the Buildings Department were relocated for micro-filming and unavailable for inspection during the course of the study.

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2.1.4 Access Road and Lo Wai Road

The access road, which is about 3 m to 9 m wide, runs from the open car park to Lo Wai and is about 330 m long. The upper part of the access road is aligned northeast-southwest up to a bend near the southeast corner of Western Monastery, beyond which it is aligned north-south. The overall gradient of the access road is approximately 7°. At the junction of the streamcourse and the access road, the access road is about 9 m wide and 1.5 m above the stream bed. Slope No. 7SW-A/CR132, which is about 5 m high and inclined at an angle of about 60°, is situated below the access road just to the south of Western Monastery. The slope was covered by thin vegetation on the northern portion and chunam on the southern portion. The maintenance responsibility for slope No. 7SW-A/CR132 rests with the Lands D. The access road connects to Lo Wai Road, which is an approximately 7 m wide two-lane carriageway.

2.2 Regional Geology

According to Hong Kong Geological Survey 1:20,000 Solid and Superficial Geology Map Sheet 7 – Sha Tin (GCO, 1986), slope No. 7SW-A/CR134 above the Shing Mun Catchwater is underlain by fine ash to coarse ash tuff, tuff-breccia and tuffite, while the streamcourse below the catchwater is underlain by coarse ash crystal tuff. An area of fill overlying the coarse ash crystal tuff is present at the location of Hilltop Country Club (Figure 4).

3. SITE HISTORY AND PAST INSTABILITY

3.1 Site History

The history of site development has been determined from an interpretation of the available aerial photographs, together with a review of the relevant documentary information and site observations. Detailed observations from aerial photograph interpretation (API) are summarized in Appendix A.

Construction of Shing Mun Catchwater was completed in 1936 and the associated slopes, including slope No. 7SW-A/CR134, were probably formed at the same time. Based on API, slope No. 7SW-A/CR134 was trimmed and modified between 1964 and 1982.

In 1945, the terrain below the catchwater was undeveloped. The streamcourse originated on the hillside above the catchwater and was intercepted by the catchwater at overflow weir SMOF-13 and continued along the southwest limb of its present-day course (i.e. at the upper portion of the streamcourse immediately below the catchwater). At that time, the west limb of the upper streamcourse was a tributary, which now collects discharge from overflow weir SMOF-12. Prior to construction of the catchwater in 1936, the alignment of the streamcourse was similar to its present-day alignment. It connected to another streamcourse downstream, which originated at Sam Dip Tam to the west of Lo Wai. In 1945, a footpath ran from the catchwater across the streamcourse to Lo Wai Road (Figure 5).

Extensive erosion immediately below overflow weirs SMOF-12 and SMOF-13 occurred some time between 1945 and 1963, leading to over-steepening of the slopes on

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either side of the streamcourse at the location of the present-day slopes Nos. 7SW-A/F76 and 7SW-A/F77 (see Section 3.3.2).

The area in the vicinity and beyond the crests of present-day slopes Nos. 7SW-A/F76 and 7SW-A/F77 had been used for agricultural purposes in the past. On the 1954 aerial photographs, agricultural terraces are visible for the first time beyond the crest of slope No. 7SW-A/F76 (Figure 5). After 1972, the area above the crest of slope No. 7SW-A/F77 was noted to be also used for agricultural purposes (Figure 5), and some of the terraces associated with this agricultural development are still present today. Squatter structures were constructed in parallel with the agricultural development and some of these structures were constructed very close to the streamcourse. The history of site development along the streamcourse is shown in Figure 5.

By 1954, the section of Lo Wai Road intercepting the present-day access road had been completed. The footbridge to Lung Mo Temple across the streamcourse was constructed between 1963 and 1964, and the temple was constructed between 1964 and 1969 (Figure 5).

The platform to the south of the catchwater at the present-day location of the Hilltop Country Club was formed between 1964 and 1969, together with the club access road and the slopes within the club complex (Figure 5). Examination of old survey maps indicates that the club buildings were constructed between 1977 and 1980.

In 1969, construction of the access road between the present-day location of the open car park and Lo Wai Road was completed; prior to that, the road was a cul-de-sac to Sheung Kok Shan Village. The cross-road drain beneath the access road was probably constructed at the same time and slope No. 7SW-A/CR132, which is situated below the present-day access road, was formed in 1967.

Western Monastery was constructed in about 1972 and the site formation works would have involved the construction of, *inter alia*, an approximately 70 m long culvert along the original streamcourse. Subsequently between 1994 and 2000, the monastery was redeveloped to the north in two phases and a further 25 m of the streamcourse was covered over (Figure 5).

The building of village house No. 200 to the northeast of Western Monastery was completed between 1978 and 1979 (Figure 5). Based on the 1980 survey map, the streamcourse in the front of the house at that time was in open channel. In 1985, the open area immediately to the east of the house was formed and the yard at the front of the house was extended, which involved covering an approximately 20 m section of the streamcourse leading to its present configuration.

A series of platforms at the present-day location of the open car park is visible on the 1985 aerial photographs and by 1991 the open car park, together with slope No. 7SW-A/F38, had been formed (Figure 5). Some of the area, now part of slope No. 7SW-A/F38, was previously used for agricultural proposes as seen in the 1955 survey map and the 1964 aerial photographs (Figure 5).

3.2 Squatter Clearance

As a result of the August 2005 debris flood incident, five squatter structures

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(viz. Nos. RTW/4AD/123, RTW/4AD/125, RTW/4AD/126, RTW/4AD/119 and RTW/4AD/115 as registered by the Housing Department (HD) under their 1982 Squatter Structure Survey) were recommended for permanent evacuation (viz. Category I NDC) by the GEO (Figure 6). The above five squatter structures were vacated in November 2005, as confirmed by Lands D.

Squatter structures Nos. RTW/4AD/123, RTW/4AD/125 and RTW/4AD/126 were situated at the crest of slope No. 7SW-A/F76, while squatter structure No. RTW/4AD/119 was located above the crest of slope No. 7SW-A/F77. Squatter structure No. RTW/4AD/115 was located near the southern end of slope No. 7SW-A/F77, and a pier of a footbridge. All five squatter structures are located on unallocated government land.

In the debris flood incident, squatter structure No. RTW/4AD/125 partly collapsed, squatter structure No. RTW/4AD/126 completely collapsed and squatter structure No. RTW/4AD/119 was undermined. The rear of squatter structure No. RTW/4AD/115 was damaged and the nearby pier of the footbridge was dislocated by the debris flood. The pier had taken most of the impact force of the debris flood, resulting in only minor damage to part of squatter structure No. RTW/4AD/115 (i.e. it was a 'near-miss' case).

Squatter structures Nos. RTW/4AD/119, RTW/4AD/123 and RTW/4AD/125 were previously recommended for clearance (Category 2 NDC recommendations) by the GEO under the 1992 Non-development Clearance (NDC) Re-inspection Programme (Figure 6). Based on GEO records, the Category 2 NDC was planned to be dealt with by HD under Clearance No. TW 4/94 in 1994, but only squatter structure No. RTW/4AD/119 was reported by HD in 2001 to have been cleared. However, based on post-failure observations and eye-witness accounts, squatter structures Nos. RTW/4AD/119 and RTW/4AD/125 were still occupied at the time of the 20 August 2005 incident, whereas squatter structure No. RTW/4AD/123 was in ruins and unoccupied. Squatter structure No. RTW/4AD/118, which was also recommended for clearance by the GEO under the 1992 NDC Re-inspection Programme, remained unaffected in the 20 August 2005 incident (Figure 6). The squatter structure was still occupied at the time of the incident.

Squatter structure No. RTW/4AD/115 comprised two structures that were inspected by the GEO in 2002 under the 2001-2002 NDC Inspection Programme for squatter structures near streamcourses. According to GEO file records, these structures were not recommended for clearance since they were judged to be not meeting the criteria for recommending NDC of squatter structures that are subject to potential channelised debris flow hazards from natural terrain. Both structures were occupied at the time of the 20 August 2005 incident.

3.3 Past Instability

3.3.1 Natural Terrain Landslide Inventory and Large Landslide Database

In 1995, GEO compiled the Natural Terrain Landslide Inventory (NTLI), from the interpretation of high-level aerial photographs dating from 1945 to 1994 (Evans et al, 1997; King, 1997). According to the GEO's Natural Terrain Landslide Inventory, there are no natural terrain landslides in the vicinity of slope No. 7SW-A/CR134.

The GEO's Large Landslide Database contains no records of any reported large landslides in the vicinity of slope No. 7SW-A/CR134 and Sheung Kok Shan Village, Lo Wai.

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3.3.2 Aerial Photograph Interpretation

The aerial photographic record of the site indicates that previous instability has occurred at several locations, including immediately upslope of the catchwater, the natural terrain upslope of the catchwater, and the stream banks below overflow weirs SMOF-12 and SMOF-13 (Figure 7). A list of the aerial photographs that were viewed in the study is shown in Table A1 in Appendix A.

In the natural terrain upslope of the catchwater, the 1963 aerial photographs show well-defined local topographic depressions inferred to be relict instability (Figure A1). About 40 m to the west of the streamcourse above the catchwater, a concave break in slope can be seen in the natural terrain forming a relatively steep slope. Just below this feature, several inferred small to medium sized (< 100 m³) relict landslides can be seen, and one inferred large relict landslide (approximate volume of about 500 to 1000 m³) can be seen to traverse the feature (feature R1 in Figure A1). It is also noted that a rounded convex break in slope and a sharp convex break in slope are present on the natural terrain above slope No. 7SW-A/CR134.

Immediately above the catchwater, within the cut slopes associated with its formation, several areas of instability can be deduced from aerial photographs taken between 1945 and 1976 (see Figure A1). The areas of possible instability are typically indicated by high reflectivity and shape, although the poor quality of some of the earlier photographs does not preclude the fact that some of these could be construction related. Figure A1 shows a fairly high density of small-scale instability along the catchwater, some of which have repeated (retrogressive) episodes of failures at the same locations. Based on the 1963 aerial photographs, two depressions were noted on slope No. 7SW-A/CR134 approximately at the locations of the two landslides that occurred on 20 August 2005.

Extensive erosion immediately below overflow weirs SMOF-12 and SMOF-13 occurred some time between 1945 and 1963. This resulted in over-steepening of the slopes on either side of the streamcourse at the location of the upper portions of present-day slopes Nos. 7SW-A/F76 and 7SW-A/F77 (Figures A1 and A2). In contrast, the erosion along the streamcourse above the catchwater was relatively minor. Several instances of further retrogressive erosion along the north flank of the streamcourse below overflow weir SMOF-12 can be seen in 1964, 1977, 1980 and 1997 (Figure A1).

3.3.3 GEO's Landslide Database

The GEO Landslide Database contains no records of any previous reported landslides at slopes Nos. 7SW-A/CR134, 7SW-A/F76, 7SW-A/F77, 7SW-A/F38 or 7SW-A/CR132. However, landslides have been reported in the vicinity of slopes Nos. 7SW-A/F38 and 7SW-A/CR132 (Figure 7).

Two landslides (Incidents Nos. NT82/8/37A and NT82/8/37B) occurred on the natural hillside on 16 August 1982 near the present-day location of slope No. 7SW-A/F38. The incidents involved a landslide on the northern side of the streamcourse with a failure volume of about 90 m³ and another landslide with a failure volume of about 34 m³, some 10 m southwest of the first landslide.

On 4 August 1995, another landslide (Incident No. MW95/8/1) with a failure volume

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of about 1 m³, occurred on the natural hillside about 50 m to the south of slope No. 7SW-A/CR132.

4. MAINTENANCE RESPONSIBILITY AND LAND STATUS

4.1 Slopes

According to the Slope Maintenance Responsibility Information System (SMRIS) of the Lands D, the owners of private Lot No. TW 22217 were responsible for the maintenance of slope No. 7SW-A/CR134 prior to the incident. With effect from 28 August 2005, the maintenance responsibility (MR) was transferred to the WSD following the debris flood incident.

DSD is responsible for the maintenance of slopes Nos. 7SW-A/F76 and 7SW-A/F77, and Lands D is responsible for maintaining slope No. 7SW-A/CR132. Lands D and the private owners of Lot No. 1186 in DD453 are jointly responsible for the maintenance of slope No. 7SW-A/F38.

4.2 Streamcourse

According to Environment, Transport and Works Bureau Technical Circular (Works) No. 14/2004, full scale maintenance to natural watercourses should not be necessary as most of them are self-cleansing. However, ad hoc maintenance should be carried out when necessary. According to the circular, HAD were to be responsible for natural watercourses located within village areas (in unleased and unallocated government land) such as the concerned streamcourse in Lo Wai. DSD would provide advice on potential extent of flooding risks and carry out ad hoc major engineering remedial works when needed.

HAD confirmed that they are responsible for the maintenance of the access road as part of their services to villagers in rural areas. However, no maintenance or construction records of the access road were available from HAD. Both HAD and DSD have confirmed that they have no records of the associated cross-road drains. The culvert beneath the front yard of village house No. 200 is located within leased government land (No. STT673TW) and is under the MR of the owners/licensee. According to HAD, they do not have any maintenance records of the concerned culvert.

5. PREVIOUS ASSESSMENTS AND SLOPE WORKS

5.1 GCO Catchwater Studies

In 1979, WSD and GCO commenced a joint study to investigate the stability of catchwaters and their associated slopes and make recommendations to reduce the potential risk to downhill developments. The first study report (1980) summarized the available information and recommended a phased study of all catchwaters.

In the second study report (1982), data for 48 catchwaters were collated and after screening, walkover surveys of 19 catchwaters were carried out. API and mapping were carried out on six catchwaters that were considered to present the greatest potential risks.

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Four catchwaters, including the Shing Mun Catchwater, were considered to have generally high failure consequences in several sections and were studied in detail over their entire lengths.

The second report also concluded that there were a few catchwaters, which were of concern throughout their lengths and “in terms of both cut slope condition and failure consequences, the Shing Mun catchwater is potentially the most dangerous in the territory.”

As follow-up actions, WSD carried out flooding studies of selected catchwaters and as a result nominated some slopes for inclusion into the Landslip Preventive Measures (LPM) Programme managed by the GEO. Improvement works to Shing Mun catchwater were also carried out by WSD in the 1980s. In particular, based on WSD record drawings, a controlled intake dam at Chainage M3078 (i.e. about 0.9 km upstream of slope No. 7SW-A/CR134) was constructed in 1985.

5.2 Past Developments Along Streamcourse

No information of relevance to the streamcourse and nearby squatter structures has been found in any of the Buildings Department (BD) files that have been examined to date, including file No. 4-5/9110/68, which covers the development of Western Monastery.

5.3 SIFT and SIRST Studies

In 1992, the GEO initiated a project entitled "Systematic Inspection of Features in the Territory" (SIFT). This project aimed to search systematically for slopes not included in the 1977/78 Slope Catalogue and to update information on previously registered features by studying aerial photographs together with limited site inspections. The SIFT results are as follows:

(a) In 1996, slope No. 7SW-A/CR134 was classified as SIFT Class ‘C1’, i.e. a slope that had “been formed or substantially modified before 30.6.78”.

(b) In 2003, slopes Nos. 7SW-A/F76 and 7SW-A/F77 were classified as SIFT Class ‘B1’, i.e. fill slopes that had “been formed or substantially modified before 30.6.78”.

(c) In 1996, slope No. 7SW-A/F38 was classified as SIFT Class ‘B2’, i.e. a slope that had “been formed or substantially modified after 30.6.78”.

(d) In 1996, slope No. 7SW-A/CR132 was classified as SIFT Class ‘C1’, i.e. a slope that had “been formed or substantially modified before 30.6.78”.

In July 1994, the GEO commenced a project entitled “Systematic Identification and Registration of Slopes in the Territory” (SIRST), to update the 1977/78 Slope Catalogue. The SIRST results are summarised below:

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(a) On 31 October 1996, the SIRST consultant inspected slope No. 7SW-A/CR134 and recorded that 96% of the slope surface was covered by chunam. The surface condition was assessed as being "fair". Some fine cracks were noted during inspection and the consequence-to-life category of the slope was assessed to be "3". The slope has a CNPCS score (which reflects the direct risk-to-life) of 0.46.

(b) The SIRST consultant inspected slope No. 7SW-A/F76 on 3 January 2003 and recorded that 70% of the slope surface was covered by vegetation with the rest of the surface being bare. The surface condition was assessed as "fair" and erosion was observed, although the location was not recorded. The consequence-to-life category was assessed to be "1". The slope has a CNPCS score of 1.8.

(c) The SIRST consultant inspected slope No. 7SW-A/F77 on 3 January 2003 and recorded that 60% of the slope surface was covered by vegetation with the rest of the surface being bare. The surface condition was assessed as "poor" and erosion and debris were found on the slope. The consequence-to-life category was assessed to be "1". The slope has a CNPCS score of 0.72.

(d) The SIRST consultant inspected slope No. 7SW-A/F38 on 16 October 1996 and recorded that 30% of the slope surface was covered by vegetation with the rest of the surface being bare. The surface condition was assessed as "fair" and no signs of distress were found. The consequence-to-life category was assessed to be "3". The slope has no CNPCS score.

(e) The SIRST consultant inspected slope No. 7SW-A/CR132 on 22 October 1996. The slope was registered as 7SW-A/C132 at that time. Chunam covered 80% of the slope surface and the remaining surface was covered with vegetation. The surface condition was assessed as "fair", and both cracking and disruption of chunam were found. The consequence-to-life category was assessed to be "1". The slope has a CNPCS score of 1.89.

5.4 Engineer Inspections and Routine Maintenance Inspections

The MR of slope No. 7SW-A/CR134 was recently transferred from the owners of private Lot No. TW22217 to WSD. WSD confirmed that they have no records relating to maintenance inspections/works or repair works to the slope prior to the 20 August 2005 incident.

Engineer Inspections (EIs) were carried out on slopes Nos. 7SW-A/F76 and

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7SW-A/F77 by Maunsell Consultants Asia Ltd. (consultants of DSD) in August 2004. The conditions of the vegetated surfaces on both slopes were assessed as "Good" and no signs of distress were noted. The overall condition and maintenance of both slopes were assessed as "Good". No specific maintenance works were recommended. The EIs did not recommend stability assessment of either slope in the light of their good overall condition and their relatively low CNPCS scores. Routine Maintenance Inspections (RMIs) of both slopes Nos. 7SW-A/F76 and 7SW-A/F77 were carried out in July and December 2004 by DSD. No maintenance works were recommended for either slope.

EIs were carried out on slope No. 7SW-A/CR132 by consultants of Lands D, Maunsell Fugro Joint Venture (MFJV) and MGSL, in January 2000 and December 2004 respectively. Minor routine maintenance, including removal of debris from surface channels and repair of cracks in the slope hard cover, was recommended in the January 2000 EI report. Preventive maintenance works, including installation of soil nails, improvement of slope surface protection with shotcreting and provision of surface drainage channels, were also recommended. The overall state of slope maintenance was assessed as Class "1", i.e. considered to be satisfactory in general. In the December 2004 EI, it was noted that the preventive maintenance works recommended in the January 2000 EI had not been carried out by that time due to the relatively low priority. The December 2004 EI recommended minor routine maintenance works, including removal of debris from surface channels and slope surface, removal of undesirable vegetation on the wall and repair of cracks in the slope hard cover. The December 2004 EI continued to recommend the same preventive maintenance works as those in the January 2000 EI.

RMIs were carried out on slope No. 7SW-A/CR132 by MGSL in December 2002 and December 2003 respectively. The December 2002 RMI recommended clearance of obstructions to the surface drainage channels and weepholes, removal of undesirable vegetation growth and repair of the hard surface cover. At the time of the December 2003 RMI, the maintenance works recommended in the December 2002 had not been carried out and the December 2003 RMI recommended further maintenance works of a similar nature. According to the follow-up inspections carried out for the RMIs, the maintenance works recommended in the December 2002 and December 2003 RMIs had been completed by February 2004 and February 2005 respectively.

EI was carried out on the government portion of slope No. 7SW-A/F38 by MFJV (consultants of Lands D) in May 2001. The condition of the vegetated surface was assessed as being "fair" and the overall condition of slope maintenance was assessed as "1". The EI recommended minor routine maintenance works involving regrading and hydroseeding the bare slope surface. Preventive maintenance works, including provision of surface drainage channels and removal of loose blocks, were also recommended. No EI or RMI was carried out for the private portion of slope No. 7SW-A/F38, as confirmed by the private party of concern (viz. Lot No. 1186 in DD453).

5.5 Drainage Maintenance Works

No records of maintenance works along the streamcourse have been found and HAD has been unable to locate any records relating to construction or maintenance of the cross-road drains beneath the access road, despite the access road being under HAD's MR.

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No records of maintenance of the culvert beneath the front yard of village house No. 200, which is under the MR of the lessee (STT No. STT673TW), have been found.

6. DESCRIPTION OF THE INCIDENT AND POST-FAILURE OBSERVATIONS

6.1 The 20 August 2005 Debris Flood and Associated Landslides

Source Area

The debris flood incident commenced between about 4:15 p.m. and 5:00 p.m. on 20 August 2005, when the Landslip Warning and Amber Rainstorm Warning had been in effect for more than 19 hours and 7½ hours respectively. Two landslides occurred at slope No. 7SW-A/CR134, which is situated directly above the catchwater (Incident No. 2005/8/0338). The consequential blockage of the catchwater triggered the incident (Plate 1).

The landslide debris, with an estimated total volume of about 600 m³ (300 m³ in each of the landslides), was deposited in the open catchwater channel. The channel is trapezoidal in shape, with a depth of 3.2 m and top and base widths of 6 m and 3.3 m respectively. The debris substantially blocked the catchwater channel. Based on the estimated volume of the debris and the measured size of the catchwater below the landslides, it was estimated that about 80% of the channel cross-sectional area was blocked by debris.

According to eye-witness accounts (see Section 6.2.2), overflow at catchwater weirs SMOF-12 and SMOF-13 onto the spillways below probably occurred from about 11:00 a.m. onwards on 20 August 2005. Blockage of the catchwater in the late afternoon probably led to a large amount of discharge over the weirs. The backwater profile was such that no uncontrolled overtopping of the catchwater channel occurred following the landslides at slope No. 7SW-A/CR134 (Plate 2).

Upper Trail (CH 0 to CH 226) (see Figure 2 for trail chainage)

At the time of the incident, the large amount of discharge from the overflow weirs that entered the two limbs of the streamcourse (CH 0 to CH 55) probably initiated entrainment along the beds of the two limbs and undercutting of slopes Nos. 7SW-A/F76 and 7SW-A/F77.

Downstream of the confluence of the limbs, the flows incised the drainage line, entraining more soil and boulders from the stream bed and undercut the southern portions of slopes Nos. 7SW-A/F76 and 7SW-A/F77 (CH 55 to CH 226), and developed into a debris flood. Here the heavy flows and significant turbulence scoured the base width of the streamcourse from about 3 m to 7 m and to a maximum depth of approximately 3 m (Figure 13). The depth of water in the streamcourse rose typically by about 2 m to 3 m.

The undercutting of slopes Nos. 7SW-A/F76 and 7SW-A/F77 led to a series of landslides at these slopes. The debris, including domestic refuse, tree branches and other detritus, was deposited at the slope toes. One of these landslides (Incident No. 2005/08/0402), with an estimated failure volume of 40 m³, undermined squatter structures No. RTW/4AD/119, which is situated at the crest of slope No. 7SW-A/F77. One of the

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witnesses reported that a portion of slope No. 7SW-A/F76 failed on the morning of 20 August 2005 (Incident No. 2005/8/0348), which led to the collapse of squatter structures Nos. RTW/4AD/125 and RTW/4AD/126 that were situated at the crest of slope No. 7SW-A/F76.

At chainage CH 190, the debris flood destroyed a cement-rendered brick pier which provided support to the footbridge near Lung Mo Temple. The debris flood swept the destroyed pier downstream. Squatter structure No. RTW/4AD/115 is located immediately adjacent to the original position of the footbridge pier. The structure suffered only minor damage since the pier had probably taken most of the impact force, leaving only minor damage to the squatter structure (i.e. a 'near-miss' case).

Middle Trail (CH 226 to CH 560)

The debris flood travelled along the streamcourse until it reached the access road at chainage CH 226, where the water would normally flow through a 600 mm diameter cross-road drain beneath the access road. It was estimated that the amount of debris entrained up to this point was about 1,400 m^3.

The debris flood blocked the cross-road drain and overtopped the access road. Debris, comprising cobbles and boulders, was deposited on the access road and the section of the streamcourse immediately upstream. The debris accumulated to a depth of about 0.4 m to 1.5 m and trapped two vehicles which were parked (Figure 2) at this location (Plate 5).

Beyond this location, the debris flood branched out in three directions (i.e. trifurcated), as follows:

(a) To the south and along the access road down to Lo Wai Road, the first branch of the debris flood travelled approximately 310 m before reaching Lo Wai Road at chainage CH 560. Photographs taken by a resident at around 6:30 p.m. (Plates 6 and 7) shows the debris flood laden with mud flowing along the access road. Slope No. 7SW-A/CR132, which is situated below and on the western side of the access road at chainage CH 460, was scoured by the debris flood. The volume of landside debris at this slope was estimated to be about 150 m^3.

(b) The second branch of the debris flood crossed the access road and it cascaded down to the lower section of the streamcourse before reaching the front yard of village house No. 200, where it combined with the third branch of the debris flood (see (c) below). As noted before, a culvert is located beneath the front yard of the village house and its outlet downstream of the front yard leads to two drainage pipes running beneath the Western Monastery site. The debris flood blocked the culvert upstream of the front yard of the house and overtopped, depositing domestic refuse, tree branches and other detritus onto the yard area. The

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debris flood then combined here with the first branch along the access road to the east of Western Monastery (CH 380).

(c) The third branch of the debris flood flowed to the west and across the open car park. About 0.4 m deep of debris, comprising mainly gravels, cobbles and occasional small boulders, was deposited which trapped vehicles in the car park (Plate 8). The debris flood spilled over the southwest boundary of the car park and onto the western portion of slope No. 7SW-A/F38, which is situated below the southeast corner of the car park. The debris flood scoured slope No. 7SW-A/F38, resulting in a failure volume of approximately 20 m³. Debris, which was deposited at the slope toe next to the front yard of village house No. 200, included domestic refuse, tree branches and other detritus.

Lower Trail (CH560 to CH800)

The branches of the debris flood combined just to the east of Western Monastery and continued along the access road towards Lo Wai Road. The debris reached Lo Wai Road at chainage CH 560 and dissipated its remaining energy along Lo Wai Road between chainages CH 560 and CH 800. A passing taxi was trapped in the debris at chainage CH 730 (Plate 9).

The debris flood occurred in pulses and continued probably until some time after 10:20 p.m. on the night of 20 August 2005, when WSD closed two of the intake dams at chainages Ch M6557 and M6664 along the catchwater, upstream of the overflow weirs. Three “strong” pulses were reported by the eye-witnesses during the debris flood incident.

According to FSD Incident Report, the incident resulted in the temporary evacuation of 118 local residents from Sheung Kok Shan Village and Lo Wai Village, and 84 visitors to Yuen Yuen Institute, Western Monastery and Lung Mo Temple.

6.2 Post-failure Observations

6.2.1 Source Area and Debris Trail

Following the incident, several site inspections were carried out by MGSL between 21 August 2005 and 22 September 2005.

Source Area

An overall view of the two landslide scars (A and B) at slope No. 7SW-A/CR134 is shown in Plate 10. The mapping of the two landslide scars was carried out by MGSL on 29 August 2005 and is presented in Figures 8 and 9. Based on the field mapping, landslide scar A was about 25 m wide by 11 m high and up to 1.8 m deep, with an estimated volume of about 300 m³. Scar B measured approximately 24 m wide by 12 m high and up to 2 m deep, with an estimated volume of about 300 m³. The two scars exposed extremely weak to very weak, reddish brown and yellowish brown completely decomposed tuff overlain by residual

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soil and colluvium which comprise firm, moist, reddish brown and silty clay with occasional subangular fine to coarse gravel with a combined thickness of about 2 m. Erosion pipes were noted at the backscarp and western flank of both landslides. Relict joints, which were observed in the weak to moderately week, yellowish brown, streaked black highly decomposed tuff near the toe of the scars, generally strike northeast and southeast, and are subvertical, closely spaced, extremely narrow and infilled with manganese oxide. There were no signs of seepage in either scar face at the time of inspection by MGSL. Most of the debris in the catchwater had been removed by WSD at the time of the first MGSL inspection on 21 August 2005.

MGSL observed that the spillway immediately below overflow weir SMOF-13 (Plate 4) was severely scoured and some of the masonry facing blocks to the approximately 4.5 m long spillway had been dislodged (Plate 11). The scouring was probably the result of the large amount of discharge from the weir. The scouring at the spillway below weir SMOF-12 was less severe where the masonry facing blocks remained in position (Plate 12). Part of a 1 m high masonry retaining wall which appeared to be a cascade below the spillway (about 16 m downstream of overflow weir SMOF-13) collapsed, probably due to scouring effect of the water flow. The collapse created an opening of about 1 m high and 1 m wide (Plate 13).

Upper Trail (CH 0 to CH 226)

Based on the field mapping and topographic base maps as well as topographical surveys carried out by the LIC "Stand-by" Contractor and CEDD Survey Division, MGSL has developed a longitudinal section showing the ground profile along the streamcourse (Figure 10).

The west and southwest limbs (Figure 2) of the streamcourse showed signs of severe scouring and entrainment, and the toes of slopes Nos. 7SW-A/F76 and 7SW-A/F77 were heavily eroded. Plates 14 to 17 show general views of the west and southwest limbs before and after the incident (between chainages CH 38 and CH 60). Figure 11 shows a cross-section across the two limbs of the streamcourse at chainage CH 42, where the entrainment at the base was up to about 3 m.

The banks of the southwest limb are up to 7 m high, and along the crest of the northwest bank are two landslide scarps. The scarps are approximately 5 m high consisting of colluvium with reddish brown silty clay, below which is an erosion gully. The erosion gully is approximately 2 m deep (Plates 18 and 19), and 4 m wide. Weak to moderately weak, yellowish brown highly to moderately decomposed tuff is exposed along the stream bed. Numerous large boulders have been deposited with occasional finer materials along the stream bed. There is a 2.5 m high, approximately 70° steep slope (Plate 20) in the vicinity of the spillway of the southwest limb of the streamcourse. This is likely to be natural and consists of moderately to slightly decomposed tuff.

Along the west limb of the streamcourse, a 3 m high, approximately 70° steep slope (Plate 21) is located downstream of the spillway. Yellowish brown moderately to slightly decomposed tuff with closely spaced relict joints is exposed on the slope and along the lower 2 m portion of the stream valley, and less erosion was observed within this section. Nonetheless, many boulders were left along the stream bed of the west and the southwest limbs of the streamcourse.

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Figure 12 shows the interpreted geological conditions of the two limbs where the exposed soils in the entrained streamcourse were primarily colluvium consisting of occasional subangular fine to coarse gravel. It was also revealed that the colluvium located along the streamcourse from the overflow weirs to the confluence can be separated into two to three sub-layers (Plates 18 and 19).

Slope No. 7SW-A/F76 was scoured severely at chainage CH 48 and the undercutting extended to the edge of squatter structure No. RTW/4AD/124 at the slope crest. It resulted in a 'near-miss' case (Plates 22 and 23).

Significant entrainment occurred at the confluence (Plate 24). Downstream of the confluence, the extent of entrainment of the stream bed and undercutting of slopes Nos. 7SW-A/F76 and 7SW–A/F77 was also severe. Plate 25, which was taken at chainage CH 66, shows that some boulders (maximum 2 m^3 in size) on the stream bed were displaced downstream by the debris flood. Plates 26 and 27 show views of the streamcourse before and after the incident (between chainages CH 76 and CH 92). The cross-sections at chainages CH 72 and CH 150 surveyed after the incident are presented in Figures 13 and 14 respectively. It is estimated that entrainment of the bases of the streamcourse extended to a maximum depth of about 3 m (Figure 13).

No bedrock was observed along the stream bed after the confluence point except for local areas near chainage CH 110, where a small area of bedrock was exposed at the bottom of the northwest valley side (Plate 28). At the crest of the rock exposure is a layer of dumped fill and domestic refuse (Plate 28).

The debris flood realigned the streamcourse at chainage CH 100, bypassing an existing bend and cutting into the body of slope No. 7SW-A/F77 (Figure 2).

Some of the squatter structures at the crest of slopes Nos. 7SW-A/F76 and 7SW-A/F77 were affected by the debris flood. Squatter structure No. RTW/4AD/119 at approximate chainage CH 110 was undermined (Plate 29) and consequently the structure was permanently evacuated under Category 1 NDC, as recommended by the GEO. Part of squatter structure No. RTW/4AD/125, situated at the crest of slope No. 7SW-A/F76, collapsed. A completely collapsed squatter structure No. RTW/4AD/126, which is located adjacent to the squatter structure No. RTW/4AD/125, was displaced about 10 m towards the streamcourse (Plate 30). Both squatter structures Nos. RTW/4AD/125 and RTW/4AD/126 were permanently evacuated (Category 1 NDC) as recommended by the GEO. The foundation of a retaining structure, which is about 2.5 m high and 20 m to the northwest of squatter structure No. RTW/4AD/125, was also undermined (Plate 31).

The bridge pier near Lung Mo Temple was swept approximately 10 m down along the streamcourse (Plate 32). Plates 33 and 34 show the original position of the pier. Squatter structure No. RTW/4AD/115 that was situated near the bridge pier (Plate 35) was only slightly damaged by the debris flood, with part of the foundation undermined (Plates 36 and 37). It resulted in another 'near-miss' case.

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Middle Trail (CH 226 to CH 560)

Debris comprising cobbles and boulders was deposited near the junction of the access road and the streamcourse at chainage CH 226 (Plate 5). The cross-road drain beneath the access road was completely blocked by debris and the maintenance condition of the cross-road drain prior to the debris flood incident is not known. Plate 38 shows the condition of the upstream end of the cross-road drain and Plate 39 shows the condition at the downstream end. The relatively small cross-road drain was not capable of catering for such a debris flood. A CCTV survey was carried out on 6 October 2005 to examine the condition of the drain, which was found to be clear of debris and in fair condition. The alignment of the drains from the CCTV survey are presented in Figure 15.

Debris had been deposited in the open car park, which is flat and has a parapet wall with a small upstand of about 0.3 m along its southern boundary. The debris comprised gravels, cobbles and occasional small boulders (Plate 8). It was estimated that the volume of debris deposited on the access road area at chainage CH 226 and on the open car park was approximately 450 m^3.

The western portion of slope No. 7SW-A/F38, below the car park, was washed out by the debris flood (Plate 40). The scar was about 10 m wide by 23 m long, with a maximum depth of about 1.0 m (corresponding to a volume of about 40 m^3). The debris at the toe of the slope contained domestic refuse, tree branches and other detritus. Similar debris had been deposited on the front yard of village house No. 200 (Plate 41), and the culvert beneath the front yard of the house was completely blocked. Plate 42 shows the inlet to the 1.1 m wide by 0.8 m high culvert after clearance. The two drainage pipes on the other side of the front yard were partly blocked at the time of inspection (Plate 43). A CCTV survey was carried out by LIC "Stand-by" CCTV contractor to inspect these two pipes on 6 October 2005. Both pipes are 0.6 m in diameter. One of the pipes was 10.1 m long and clear of debris during the CCTV survey. The pipe was found to be connected to a culvert running to the south and under the Western Monastery. The other pipe was however blocked by soil debris at 1.3 m and further inspection could not be carried out. The alignment of the drains from the CCTV survey are presented in Figure 15.

A washout occurred at slope No. 7SW-A/CR132 at chainage CH 460, which is below the access road to Lo Wai and to the south of Western Monastery (Plate 44). The scar was about 14 m wide by 8 m long with a maximum depth of 3 m (corresponding to a volume of about 150 m^3). A vacated village house at the slope toe was damaged (Plate 45). The area to the west of slope No. 7SW-A/CR132 was also flooded.

Lower Trail (CH560 to CH800)

Debris comprising domestic refuse, tree branches, silt and detritus was deposited on Lo Wai Road, mainly between chainages CH 720 and CH 800 where there is a slight depression in the road elevation. The debris flood event caused serious flooding in Lo Wai Village beside Lo Wai Road.

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6.2.2 Witness Accounts

Seven eye-witnesses were interviewed by MGSL after the debris flood and a summary of their statements is presented below.

(a) Mr T C Lai and his nephew, the resident of No. 6 Sheung Kok Shan Village which is situated about 50 m from the streamcourse, reported the following:

Mr Lai's nephew, a high school student on his way home at about 11:00 a.m. on 20 August 2005, noted shallow water flow along the access road. This kind of water flow was often seen during heavy rainstorms in the past but the flow was unusually muddy this time.

At around 3:00 p.m. on 20 August 2005, Mr. Lai observed heavy discharge from one of the overflow weirs (weir SMOF-12) from his house (view of weir SMOF-13 was obstructed).

Between 4:00 p.m. and 6:00 p.m on 20 August 2005, he noted two strong pulses of water flow that rushed down the access road. He believed that the cross-road drain might have been blocked and the water flow was forced to travel along the access road down to Lo Wai Road.

At about 6:30 p.m. on 20 August 2005, he inspected the access road and adjacent areas and took some photographs, which show debris comprising domestic refuse, soil and gravels near the car park and the access road. Some debris was still being washed down the access road by the floodwater and refuse had been trapped against the screen of the roadside fence.

He recalled that the streamcourse was 'rumbling' for the rest of that night. He inspected the streamcourse outside his house on the morning of 21 August 2005 and found that many boulders and debris had been deposited on the section of streamcourse opposite to his house.

Mr Lai has lived in the village for over 20 years and this was the first time that he experienced such a debris flood.

(b) Mr Lai, a resident of house No. 200, Sheung Kok Shan Village, Lo Wai, which is located downstream by the side of the access road near a side door to the Western Monastery and about 100 m from the junction of Lo Wai Road, reported the following:

He noted two pulses of large water flow coming down with debris along the streamcourse between 4:00 p.m. and 6:00

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p.m. on 20 August 2005, before he and his family were evacuated at 6:00 p.m. Debris had blocked the culvert underneath his front yard and floodwater was flowing at ground surface and across his yard.

(c) Two occupants of squatter structure No. RTW/4AD/115, Sheung Kok Shan Village, Lo Wai, reported the following:

They were evacuated from the squatter structure at about 4:00 p.m. on 20 August 2005.

On the morning of 21 August 2005, one of them noticed that the back of their squatter structure had been damaged by the debris flood.

(d) Mr and Mrs Chan, the residents of squatter structure No. RTW/4AD/125, Sheung Kok Shan Village, Lo Wai, reported the following:

A landslide occurred at the crest of slope No. 7SW-A/F76 (in front of their squatter structure) at around 10:00 a.m. on 20 August 2005. The landslide lasted for about 15 minutes. Part of their squatter structure collapsed as a result of the landslide. They escaped to the access road beside the catchwater above Lo Wai (from east of the overflow weirs SMOF-12 and SMOF-13 to slope No. 7SW-A/CR134). They noted that the water level in the catchwater was only about "one foot" below the top level of the catchwater channel and the water appeared to be muddy. No signs of a landslide at slope No. 7SW-A/CR134 were observed at the time.

Mr Chan returned to their squatter structure with the Police at around 3:00 p.m. on 20 August 2005. As Mr Chan passed the footbridge to Lung Mo Temple, he observed heavy muddy flow in the streamcourse and took a short video of the scene with his mobile phone.

According to Mr Chan, cracks were evident in the crest area of slope No. 7SW-A/F76 in the past. Voids underneath their front yard were also observed. The streamcourse had only a small amount of water flow. However, water had been seen discharging from the overflow weirs on several occasions in the past.

6.2.3 Records by Police and FSD

Two Incident Reports were received from the FSD regarding the incident. The reports indicated that the FSD first arrived on site at 4:43 p.m. on 20 August 2005 to rescue stranded people and evacuate residents and temple visitors. The FSD report also indicated that based

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on HAD's records, the incident resulted in 118 local residents and 84 visitors to the nearby temples being temporarily evacuated.

Logs were received from the Tsuen Wan Police Station, which indicated that 65 persons in total were registered and evacuated in the incident.

6.2.4 Damage Caused

A summary of the damage caused by the debris flood (other than landsliding) is presented below:

(a) some of the masonry facing blocks protecting the base of the spillway below overflow weirs SMOF-12 and SMOF-13 were dislodged;

(b) part of a 1 m high masonry retaining wall below the spillway of overflow weir SMOF-13 collapsed, leaving an opening of about 1 m high by 1 m wide;

(c) two vehicles (one lorry and one private car) were trapped at the open car park and another two vehicles (two vans) parked along the access road were also trapped;

(d) squatter structure No. RTW/4AD/119 of Sheung Kok Shan Village above slope No. 7SW-A/F77 was undermined;

(e) squatter structure No. RTW/4AD/115 of Sheung Kok Shan Village near the footbridge was damaged;

(f) squatter structures Nos. RTW/4AD/125 and RTW/4AD/126 above slope No. 7SW-A/F76 partially and completely collapsed respectively;

(g) a cement-rendered brick pier providing partial support to the footbridge leading to Lung Mo Temple was swept away by the debris flood;

(h) a vacated village house at the toe of slope No. 7SW-A/CR132 was damaged; and

(i) a passing taxi was trapped in the debris that was travelling down Lo Wai Road.

6.3 Actions Taken by various Government Departments

6.3.1 Water Supplies Department

WSD inspected the Shing Mun Catchwater on the afternoon of 20 August 2005. A WSD inspection team passed the section of Shing Mun Catchwater above Lo Wai twice when they carried out their inspection between 3:00 p.m. and 4:35 p.m. on 20 August 2005. No

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landslide or irregularity along this section of the catchwater was reported. However, it is not certain if there were discharges at the overflow weirs SMOF-12 and SMOF-13 at the time.

According to WSD, WSD received a referral from the Customer and Technical Enquiry Centre regarding the debris flood incident at 7:15 p.m. on 20 August 2005. At 9:00 p.m., WSD arrived on site and noted that water was discharging from the overflow weirs SMOF-12 and SMOF-13. No overland flow was observed. At that time, the four controlled intake dams along the Shing Mun Catchwater and upstream of the overflow weirs (at chainages M6704, M6664, M6557 and M3078 respectively) were functioning properly (i.e. allowing water to enter the catchwater).

At 10:20 p.m. on 20 August 2005, WSD closed two of the controlled intake dams at chainages M6557 and M6664 near Route Twisk (i.e. about 4370 m and 4480 m upstream of the landslides at slope No. 7SW-A/CR134 respectively) to prevent water from entering the catchwater at these locations. Following this operation, the discharge at the overflow weirs SMOF-12 and SMOF-13 gradually reduced. WSD's contractor removed the landslide debris from the catchwater between 11:30 p.m. on 20 August 2005 and 4:00 a.m. the following morning.

6.3.2 Drainage Services Department

On 21 August 2005, DSD inspected the affected areas along the streamcourse below the overflow weirs. Shotcrete protection was subsequently applied to the failure scars on slopes Nos. 7SW-A/F76 and 7SW-A/F77 as well as other affected areas along the streamcourse.

6.3.3 Geotechnical Engineering Office of Civil Engineering and Development Department

At approximately 5:00 p.m. on 20 August 2005, the GEO Emergency Team was informed by FSD that large quantities of muddy water were flowing down the hillside towards Lo Wai.

The inspection engineer, who arrived on site at about 6:00 p.m. on 20 August 2005, reported that muddy water was still flowing along the access road and was "up to his knees".

The inspection engineer drove along the catchwater access road from Route Twisk near Tso Kung Tam, Tsuen Wan, to the landslides at slope No. 7SW-A/CR134. He noted that although landslide debris had substantially blocked the catchwater channel, water was overtopping the debris to continue downstream. At the same time, water was backing up in the channel and substantial quantities were cascading from the overflow weirs into the streamcourse limbs below. No overland flow could be seen.

The two landslides at slopes Nos. 7SW-A/F76 and 7SW-A/F77 below the overflow weirs were not inspected at that time. After inspection of slope No. 7SW-A/CR134, the inspection engineer returned to the temporary command centre at Lo Wai and WSD was informed of the situation at the catchwater by telephone.

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The GEO inspection engineer returned to the landslides at slope No. 7SW-A/CR134 with a WSD inspection team at about 8:45 p.m. On the way to the scene, it was observed that the Controlled Intake Dam at chainage M3078 allowed water from the upslope catchment to enter the catchwater.

The situation at the above Controlled Intake Dam remained unchanged at about midnight when the GEO inspection engineer left the site.

7. ANALYSIS OF RAINFALL RECORDS

Rainfall data were obtained from GEO automatic raingauge No. N03, which is the nearest raingauge to the study area and is located about 1.2 km to the south at Tsuen Wan Treatment Works, Shing Mun Road (Figure 1). The raingauge records and transmits rainfall data at 5-minute intervals via a telephone line to the Hong Kong Observatory and the GEO.

According to the eye-witness accounts and records from WSD, the debris flood commenced between about 4:15 p.m. and 5:00 p.m. on 20 August 2005, when the Amber Rainstorm and Landslip Warnings were in effect. The warnings had been in effect since the evening of 19 August 2005.

The daily rainfall recorded by raingauge No. N03 over the month preceding the incident, together with the hourly rainfall readings for the period of 18 to 21 August 2005, are presented in Figure 16. The rainstorm commenced on the afternoon of 18 August 2005 and intense rainfall was recorded until the evening of 20 August 2005. The maximum 24-hour and 48-hour rolling rainfall before the incident was 425.5 mm and 538 mm respectively. The maximum 1-hour rolling rainfall was recorded as 46 mm between 10 a.m. and 11 a.m. on 20 August 2005 (Table 1).

Table 1 presents the estimated return periods for the maximum rolling rainfall for various durations recorded by raingauge No. N03 with reference to historical rainfall data at the Hong Kong Observatory in Tsim Sha Tsui (Lam & Leung, 1994). The results show that the 31-day rolling rainfall of 1236 mm before the incident was the most severe, with a corresponding return period of about 61 years, whilst for other rainfall durations of between 4 hours and 15 days, the corresponding return periods range from 3 years to 38 years. Return periods for rainfall durations less than 2 hours are less than 2 years.

The return periods were also assessed based on the statistical parameters derived by Evans & Yu (2001) for rainfall data recorded by raingauge No. N03 between 1984 and 1997. The return periods of the 24-hour and 48-hour rainfall were about 25 years and 29 years respectively. It is noted that the estimated return periods of the August 2005 rainstorm based on rainfall data at raingauge No. N03 are similar to those estimated by the historical rainfall data at the Hong Kong Observatory, except for the long duration rainfall.

The maximum rolling rainfall for the August 2005 rainstorm has been compared with the past major rainstorms between 1983 and 2004 recorded by raingauge No. N03, which came into operation in June 1983 (Figure 17).

The maximum rolling rainfall for the August 2005 rainstorm is comparable to the most severe rainstorms recorded between 1983 and 2003 for rainfall durations of more than 12 hours.

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8. DIAGNOSIS OF THE PROBABLE CAUSES OF THE LANDSLIDES AND THE DEBRIS FLOOD

8.1 Site Setting

At the time of the incident, the four controlled intake dams upstream of the overflow weirs at chainages M3078, M6557, M6664 and M6704 were operating under normal condition, allowing water to enter the catchwater.

According to the eye-witness accounts, the water level in the subject section of the catchwater, which is an open trapezoidal channel, on the morning of 20 August 2005 prior to the landslides at slope No. 7SW-A/CR134 was only about 0.3 m below the top level. The relatively high water level was probably due to the prolonged rainfall. This could also be an indication that the catchwater might have reached its design capacity.

Slope No. 7SW-A/CR134, located directly above the catchwater, had a record of past instability as observed in the 1963 aerial photographs. The assignment of the maintenance responsibility of this cut slope by SIMAR to a private party prior to the debris flood incident meant that WSD did not previously include slope No. 7SW-A/CR134 in their slope maintenance programme since the SIMAR determination in 1999. This 10.5 m high feature comprised an old (pre-1977) cut that was formed without any geotechnical input.

Overflow weirs SMOF-12 and SMOF-13 were surveyed as part of the present study and the cross-sections are presented in Figures 18 and 19 respectively. The invert levels of the openings are at 201.59 mPD and 201.62 mPD for weirs SMOF-12 and SMOF-13 respectively, which are a short distance below the top level of the catchwater channel that typically varies between 202.25 mPD and 202.35 mPD (Figures 20 and 21).

The streamcourse, which connects to the spillways below the overflow weirs, had little water flow under normal conditions. Before the incident, the bed of the streamcourse comprised mainly colluvium with some large boulders. The API indicates that the natural terrain above the catchwater has been fairly active in the geological past in terms of mass wasting (e.g. landslides or erosion), and that colluvial deposits were likely to have accumulated in depressions and channels in the lower foothills prior to the catchwater construction. The upper parts of slopes Nos. 7SW-A/F76 and 7SW-A/F77 are located in these areas and field mapping observed that different layers of colluvium are exposed in the flanks of the slopes. Prior to the incident, both slopes were vegetated with no hard surface protection. It is possible that the upper parts of slopes Nos. 7SW-A/F76 and 7SW-A/F77 alongside the streamcourse were formed by natural erosion/scouring of the relatively loose colluvium due to previous discharges from the overflow weirs between 1945 and 1963 according to API (Section 3.3.2).

Field mapping revealed that the colluvium located along the streamcourse from the overflow weirs to the confluence of the two limbs can be separated into two to three sub-layers (Plates 18 and 19), indicating that previous occurrence of instability probably took place prior to the 2005 debris flood. This also corroborates the evidence from API.

In the lower parts of slopes Nos. 7SW-A/F76 and 7SW-A/F77 down the streamcourse, the adjacent stream bed probably restricted erosion due to the more frequent prevalence of rock in the streamcourse and the stream banks.

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The cross-road drain at the intersection of the streamcourse and access road (chainage CH 226), and the culvert underneath the front yard of village house No. 200 had no preventive or mitigation measures against possible blockage (such as a grating).

8.2 Probable Causes of the Landslides and the Debris Flood

The large amount of discharge at overflow weirs SMOF-12 and SMOF-13 was likely to have been a consequence of significant blockage of the downstream catchwater channel by landslide debris from the major failures of slope No. 7SW-A/CR134. Landslide debris contributed to reduce the water-carrying capacity of the catchwater, which was probably near or at its design capacity, causing the water to back up. The crest levels of the catchwater below slope No. 7SW-A/CR134 are higher than the invert levels of the overflow weirs (Section 8.1). This level difference means that at the time of the incident, the water level probably rose significantly within the catchwater, causing additional discharge at the overflow weirs but not overtopping the catchwater channel between the slope and the weirs. This is consistent with the field observations made on 20 August 2005 by the GEO. Based on the as-built records for the catchwater, the overflow weirs SMOF-12 and SMOF-13 have substantial overflow capacities of 6.8 m^3/s and 7.8 m^3/s respectively.

The major landslides at slope No. 7SW-A/CR134 that occurred on 20 August 2005 were probably triggered by infiltration due to the heavy and prolonged rainfall. The apparent assignment of this slope by SIMAR to a private owner prior to the landslide meant that no improvement works or maintenance were undertaken on the slope, which was probably a contributory factor to the failure.

The orientation of the exposed relict joints is such that the major landslides are not structurally controlled. Failure was probably caused by water ingress through direct infiltration and subsurface recharge from the uphill area, due to heavy and prolonged rainfall, leading to wetting up of the ground mass, reduction of soil suction and development of positive groundwater pressure.

The heavy flows from the overflow weirs into the upper limbs of the streamcourse probably built up momentum as a result of the steepness of the streamcourse limbs (in the order of 35°), and the substantial drop in head of about 27 m between the invert levels of the overflow weirs and the level of the stream bed at the confluence of the streamcourse limbs. The stream bed and slopes Nos. 7SW-A/F76 and 7SW-A/F77 comprised loose colluvium that was susceptible to entrainment and undercutting by the flow. As shown in the longitudinal section presented in Figure 10, the depth of entrainment increased along the limbs of the streamcourse.

The merging of the heavy flows from the two limbs probably resulted in a highly turbulent surge at the confluence, thus increasing the erosive power of the debris flood. As the surge travelled further downstream, it probably developed into a debris flood with considerable momentum and erosive power. The domestic refuse and other wastes, probably dumped into or near the streamcourse (possibly by the squatters in the vicinity) also provided another source of material that was easily swept by the debris flood. The undercutting of slopes Nos. 7SW-A/F76 and 7SW-A/F77 by the significant water flows probably initiated retrogressive landsliding at the slopes. The high momentum and significant erosive power of

the debris flood were manifested by the straightening of a bend along the streamcourse (Section 6.2.1).

The width of the streamcourse increases in the vicinity of Lung Mo Temple, allowing the debris flood to spread resulting in deposition of some of the cobbles and boulders. Complete blockage of the cross-road drain beneath the access road by washed debris and refuse caused the debris flood to overtop the access road and branch out. This relatively flat area also allowed spreading of the debris flood and further deposition of cobbles and boulders (Plate 5).

One of the branches of the debris flood travelled along the access road and downward to Lo Wai Road. Due to the continuous fall of the access road towards Lo Wai Road, the debris flood did not slow down at this locality. Slope No. 7SW-A/CR132 is situated below a bend on the access road at approximate chainage CH 460. Some of the debris flood spilled over slope No. 7SW-A/CR132 and contributed to the slope failure through erosion by concentrated surface water flow.

Another branch of the debris flood flowed across the car park, which is flat. The upstand of the boundary parapet wall probably allowed the debris flood to pond before spilling over its southern boundary. The debris flood eroded the western portion of the non-engineered fill slope No. 7SW-A/F38 while cascading down from the car park. No compaction records for slope No. 7SW-A/F38 could be found and the degree of compaction is unknown. The open area at the toe of this slope provided another flat area for deposition of debris. The velocity of the debris flood passing over the car park and the open area at the toe of slope No. 7SW-A/F38 probably started to reduce.

The debris flood continued along Lo Wai Road, where the remaining debris was deposited on a slightly depressed section of the road (Plate 9).

Three strong pulses of debris flood activity were reported to have taken place on 20 August 2005. Two occurred between 4:00 p.m. and 6:00 p.m. and the third at around 8:00 p.m. The earlier two pulses may be related to the relatively intense rainfall between 3:00 p.m. and 4:00 p.m. and between 5:00 p.m. and 6:00 p.m. respectively (Figure 16). However, there was no obvious increase in rainfall intensity prior to the third pulse both from the hourly rainfall data and from the 15-minute rainfall data. The last pulse could have resulted from a ‘dam break’ at a certain point along the streamcourse, where partial blockage had developed. Such a possible ‘dam break’, if it did occur, could be located at a narrow section along the streamcourse as shown in Figure 2 (see also Plate 46).

8.3 Mobility of the Debris Flood

The continuous recharge from the overflow weirs into a vulnerable natural streamcourse that is susceptible to scouring and entrainment led to high mobility of the debris flood. Based on Lands D’s survey map (1:1000), the debris flood travelled about 800 m, with a travel angle (i.e. the angle between the distal end of the debris and the invert of overflow weir No. SMOF-12) of about 8°.

The narrow streamcourse channel probably contributed to maintain the high mobility and velocity of the debris flood. Most of the entrainment took place in the upper part of the

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streamcourse below the weirs. The velocity of the debris flood fluctuated as it passed over different terrain and as a result, debris of varying composition was deposited in the flatter or more gently inclined sections along the trail. The thicknesses of debris deposited at the intersection of the streamcourse and access road (chainage CH 226) and at the front yard of house No. 200 (chainage CH 310) were up to about 1.5 m and 2 m respectively. The maximum thickness of debris deposited at Lo Wai Road where the taxi was trapped, was about 0.3 m.

9. DISCUSSION

The major failure at the source area on slope No. 7SW-A/CR134 had negligible direct consequence-to-life but due to the knock-on effects triggered by the slope failure, major havoc resulted to the structures along the streamcourse and the developed area below the hillside following the development of a debris flood. The indirect consequence-to-life as well as the social and economic consequences were considerable. The havoc has occurred under the normal operating conditions of the catchwater whereby the large amount of discharge was released through the overflow weirs into the natural streamcourse below pursuant to the design intent.

The debris flood was the result of a series of related events:

(a) the two major landslides at slope No. 7SW-A/CR134 immediately above the catchwater during heavy rainfall;

(b) blockage of the catchwater flow by the landslide debris, causing large amount of discharge at the two upstream overflow weirs SMOF-12 and SMOF-13;

(c) entrainment and erosion of the connecting streamcourse, providing the source of materials to the debris flood; and

(d) blockage of the cross-road drain and culvert along the streamcourse, causing the debris flood to overtop and branched out to the access road and to Lo Wai Road.

There are a number of key contributory factors to these events, as follows:

(a) the heavy rainfall, with a critical return period of 1 in 61 years for the long-duration rainfall, triggered the two landslides at slope No. 7SW-A/CR134 which has a history of instability (Section 3.3.2);

(b) lack of slope maintenance prior to the landslides;

(c) despite its considerable cross-sectional area (15 m^2), the open catchwater channel was vulnerable to blockage by debris from major landslides occurring above it (it was estimated that 80% of the catchwater channel cross-section

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area was blocked by the debris from the two landslides on slope No. 7SW-A/CR134);

(d) slopes Nos. 7SW-A/F76 and 7SW-A/F77 on either side of the streamcourse which connects to the overflow weirs SMOF-12 and SMOF-13, comprised mainly loose colluvium and had no hard surface protection. Hence, they were susceptible to scouring. The eroded materials from the slopes probably increased the erosive power of the floodwater and allowed the floodwater to trigger a debris flood;

(e) the domestic refuse along the streamcourse provided a source of readily erodible materials to the debris flood and contributed to the blockage of the cross-road drain and culvert; and

(f) the cross-road drain and culvert were not capable of catering for the large amount of discharge from the overflow weirs. No preventive or mitigation measures against blockage, such as gratings, were provided for these drainage facilities, and they were susceptible to blockage.

10. CONCLUSIONS

It is concluded that the debris flood that occurred at Lo Wai on 20 August 2005 was the result of a series of events at the section of Shing Mun Catchwater and along the streamcourse below the catchwater overflow weirs, which were triggered by the two major landslides on a cut slope (No. 7SW-A/CR134) uphill of the catchwater.

The landslides were probably triggered by heavy and prolonged rainfall. Lack of slope maintenance was probably a contributory factor to the landslides. The resulting blockage of the catchwater channel by the landslide debris caused the water in the catchwater to back up, resulting in large amount of discharges at the two upstream overflow weirs. The large amount of discharges through the catchwater overflow weirs caused significant scouring of a streamcourse that was susceptible to erosion, which led to the development of a debris flood.

The overall site setting was adverse in that a slope failure some 800 m above Lo Wai Village could, through a series of knock-on effects, lead to major havoc and significant social consequences to the developed area below.

It was fortuitous that there were only minor damages caused by the debris flood to several squatter structures and the foundation to a footbridge along the streamcourse. Many of the squatter structures along the streamcourse were subject to NDC recommendations but some of the inhabitants had opted to remain and hence these people continue to be exposed to the risk of debris flows and debris floods, which may be triggered by a large amount of discharge from the catchwater overflow weirs.

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Table 1 - Maximum Rolling Rainfall at GEO Raingauge No. N03 for Selected Durations Preceding the Landslides on 20 August 2005 and Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years)	
			Based on Lam & Leung (1994)	Based on Evans & Yu (2001)
5 Minutes	7.5	10:55 a.m. on 20 August 2005	< 2	< 2
15 Minutes	20.0	11:00 a.m. on 20 August 2005	< 2	< 2
1 Hour	46.0	11:05 a.m. on 20 August 2005	< 2	< 2
2 Hours	87.0	11:05 a.m. on 20 August 2005	< 2	2
4 Hours	132.0	11:50 a.m. on 20 August 2005	3	3
12 Hours	270.0	2:35 p.m. on 20 August 2005	8	15
24 Hours	425.5	3:55 p.m. on 20 August 2005	19	23
48 Hours	538.0	3:35 p.m. on 20 August 2005	28	26
4 Days	600.5	4:00 p.m. on 20 August 2005	19	16
7 Days	700.5	4:00 p.m. on 20 August 2005	26	24
10 Days	786.0	4:00 p.m. on 20 August 2005	31	20
12 Days	859.0	4:00 p.m. on 20 August 2005	38	20
15 Days	859.0	4:00 p.m. on 20 August 2005	23	11
31 Days	1236.0	4:00 p.m. on 20 August 2005	61	11

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).
(4) According to the eye-witnesses accounts, the landslide occurred at about 4:00 p.m. on 20 August 2005 when the Amber Rainstorm Warning and Landslip Warning was in effect..
(5) The nearest GEO raingauge to the site is raingauge No. N03 located about 1.2 km to the south.

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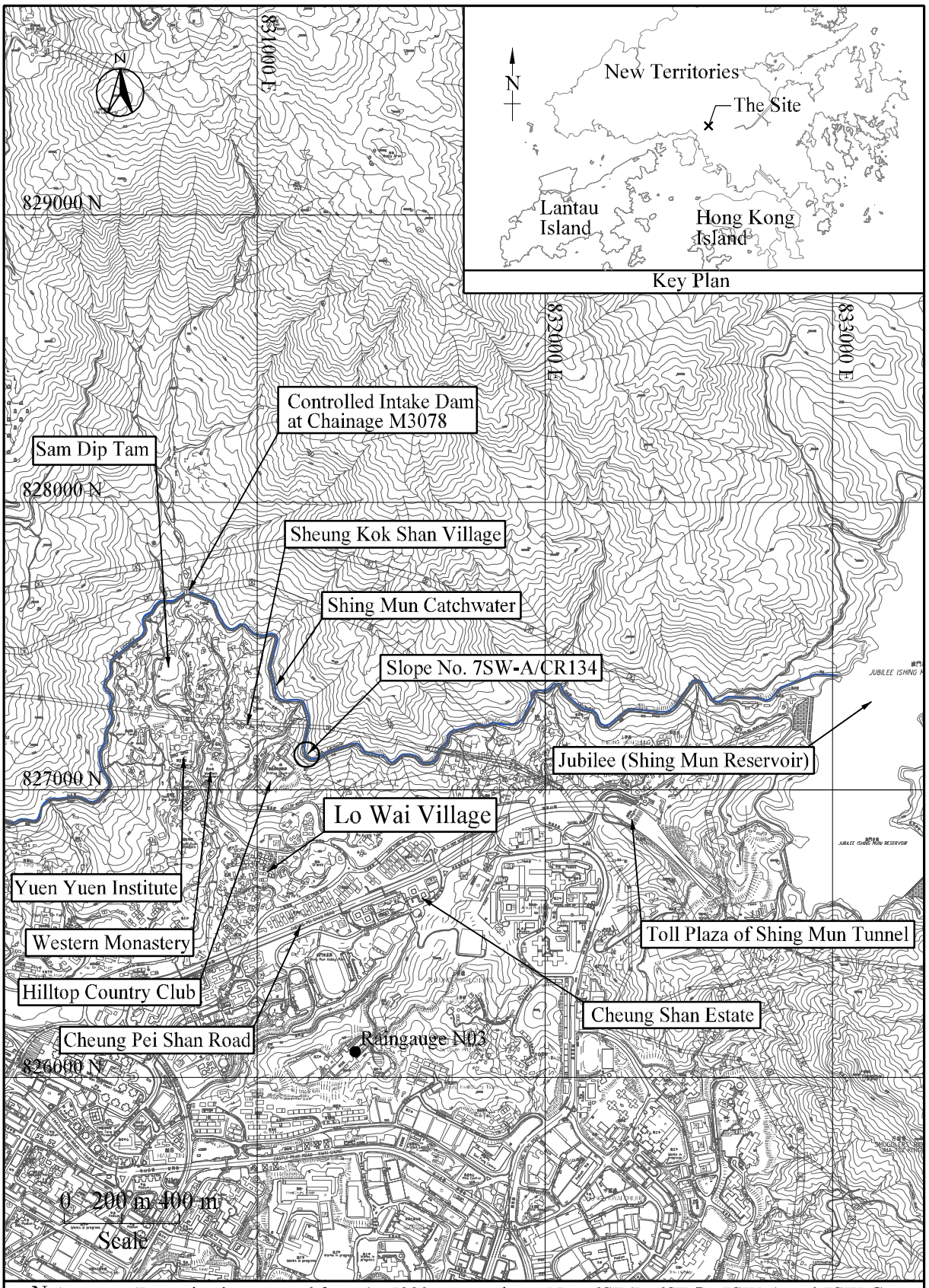

Note : Base plan is extracted from 1 : 5000 survey sheets Nos. 6SE-B, 6SE-D, 7SW-A and 7SW-C dated March 2004.

Figure 1 - Location Plan

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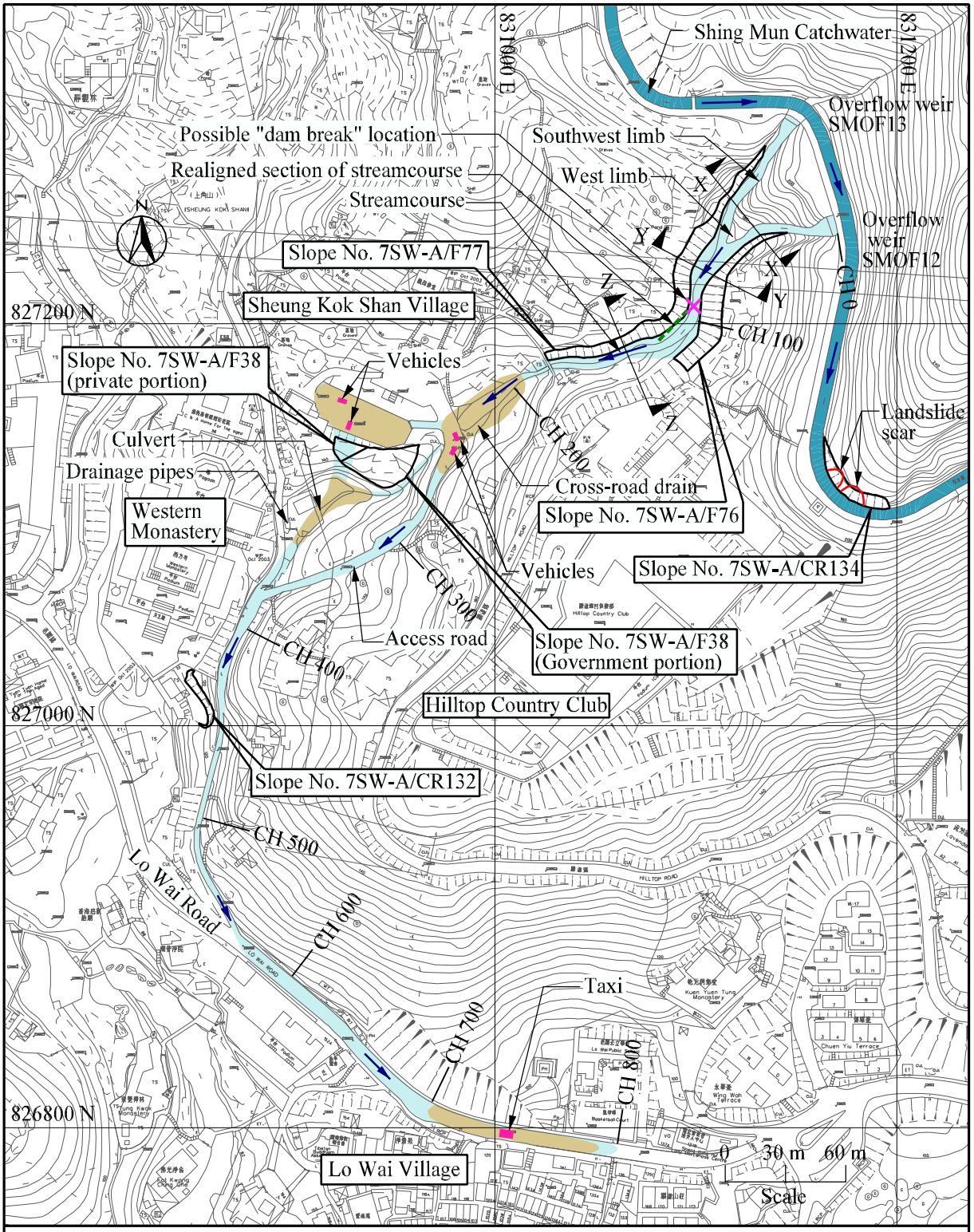

Legend :

- Flow direction
- Main areas of debris deposition
- Vehicle / taxi trapped by debris
- Debris Flood Trail
- Shing Mun Catchwater

Note : Base plan is extracted from 1 : 1000 survey sheets Nos. 7SW-11B and 7SW-11D dated March 2004.

Figure 2 - Debris Flood Trail

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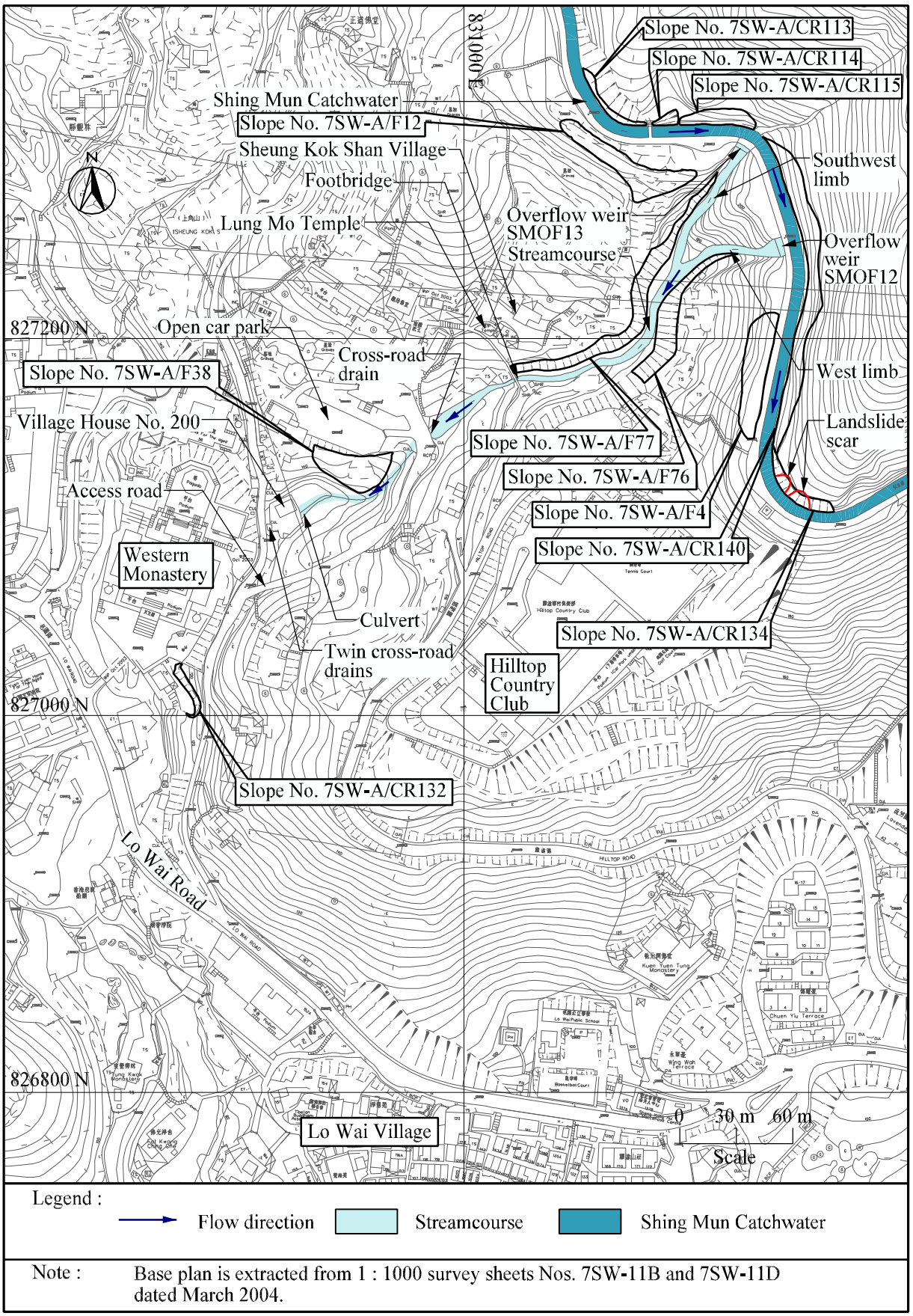

Note : Base plan is extracted from 1 : 1000 survey sheets Nos. 7SW-11B and 7SW-11D dated March 2004.

Figure 3 - Site Layout Plan

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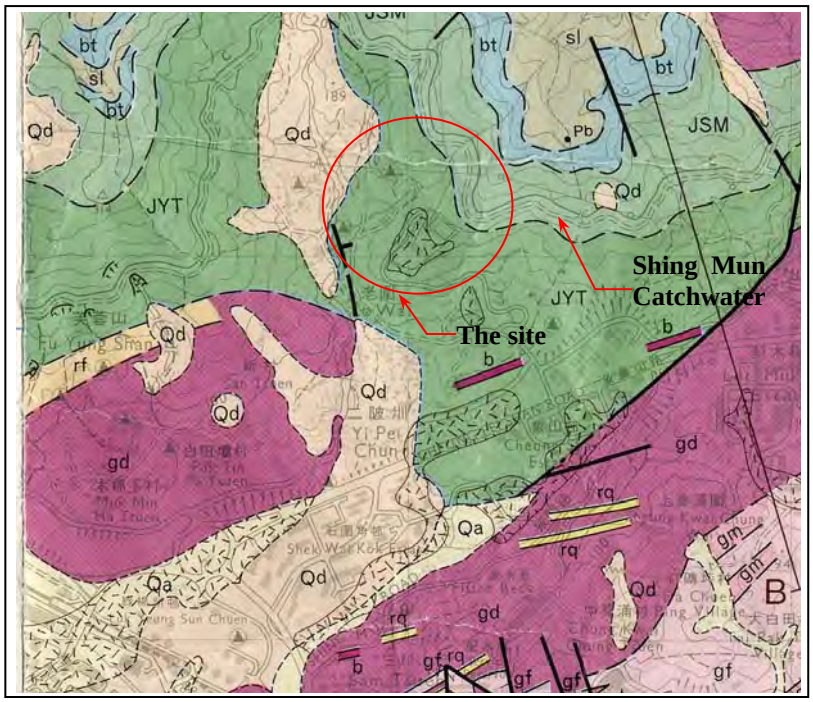

N

0m 1000 m

Scale

LEGEND:

SUPERFICIAL DEPOSITS

Qa	Clay/silt, sand and gravel (Alluvium)	Qd	Sand, gravel, cobbles and boulders in clay/silt matrix (Debris Flow Deposits)
	Fill		

SOLID GEOLOGY

b	Basalt	JYT	Crystal tuff with hornblende
rq	Quartzphyric rhyolite	JSM	Crystal and lithic tuff, tuff-breccia and tuffite
bt	Block-bearing tuff and tuffite	sl	Siltstone and mudstone
rf	Feldsparphyric rhyolite	gd	Granodiorite
gm	Medium-grained granite	gf	Fine-grained granite

GEOLOGICAL LINES

- Geological boundary, superficial deposits
- Geological boundary, solid rock
- 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 No. 7, 1:20 000 scale (GCO, 1986)

Figure 4 - Regional Geology

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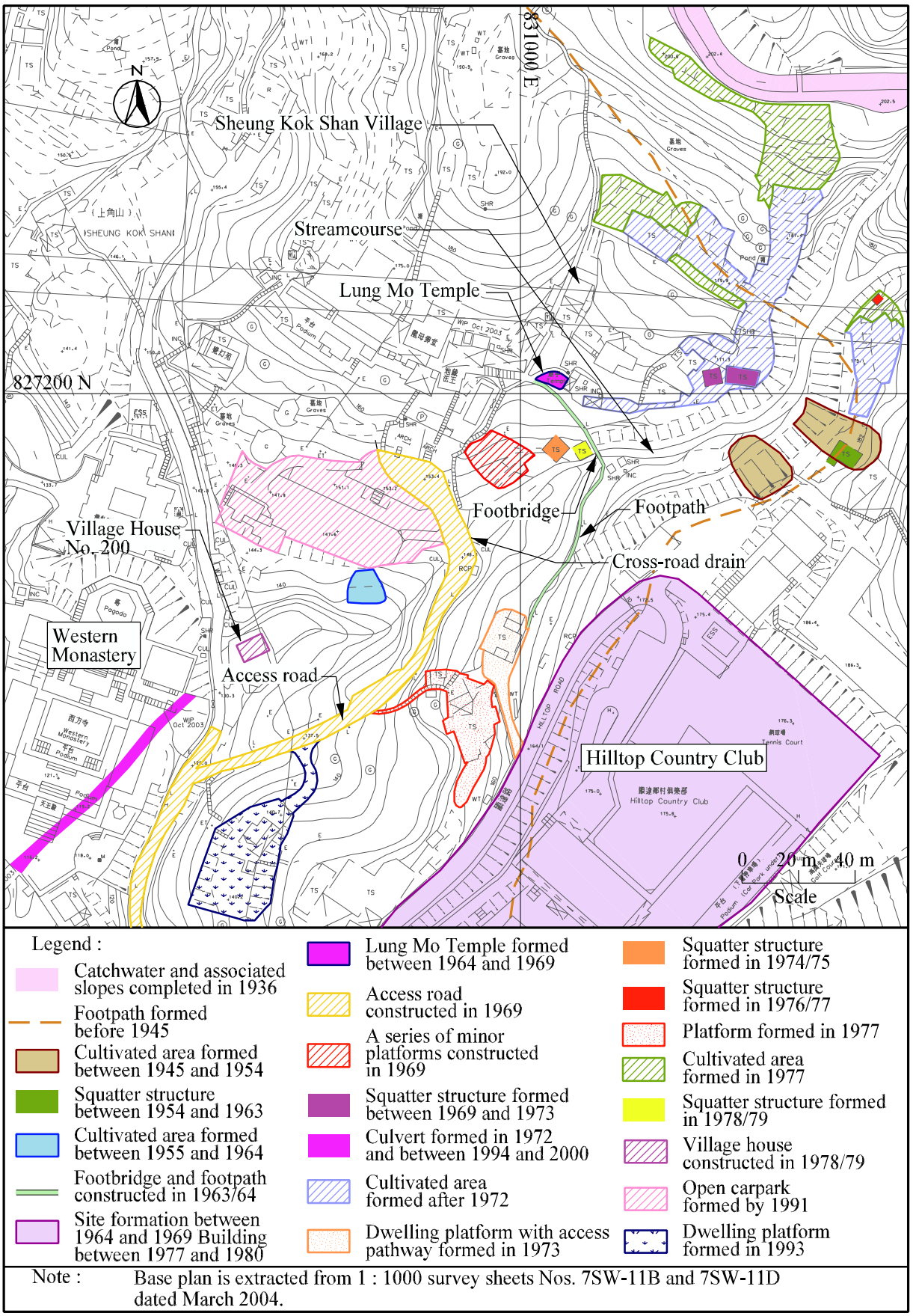

Figure 5 - Site History

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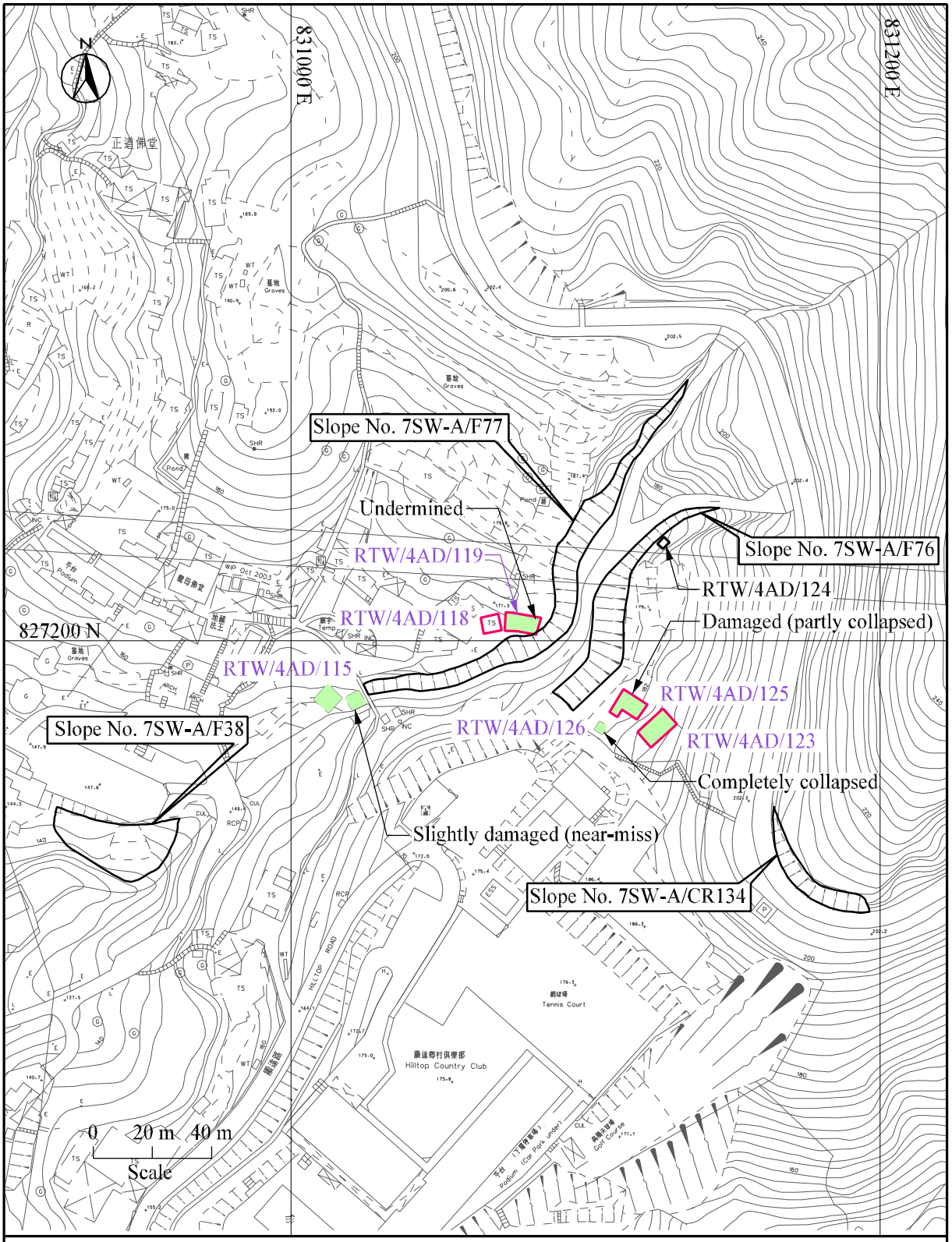

Legend :	Squatter structures recommended for NDC Cat. 1 Clearance after the 20 August 2005 Debris Flood Incident		Squatter structures recommended for NDC Cat. 2 Clearance under 1992 NDC Re-inspection Programme
Note :	Base plan is extracted from 1 : 1000 survey sheet No. 7SW-11B dated March 2004.		

Figure 6 - Squatter Structures and Recommendations for Non-development Clearance

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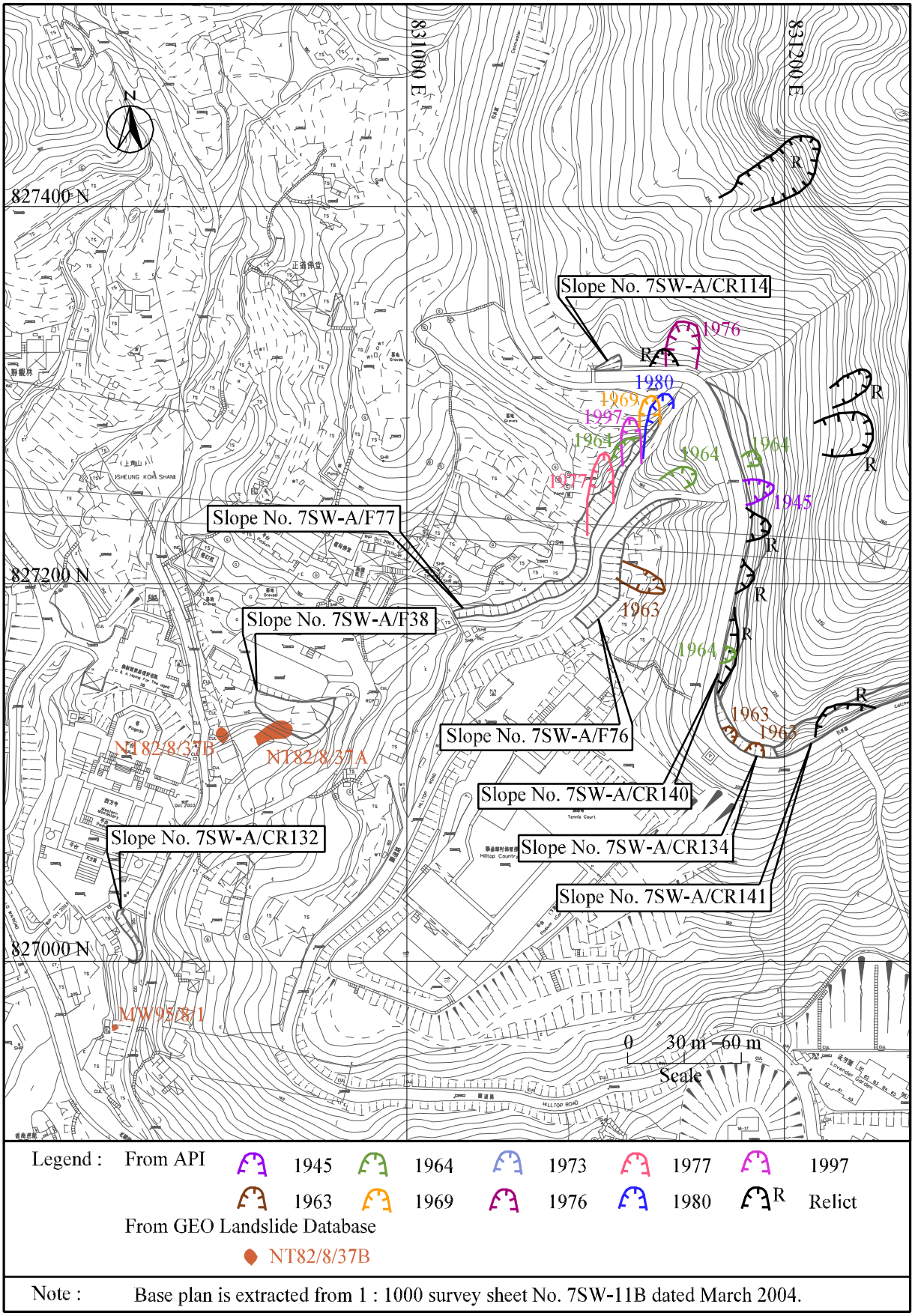

Figure 7 - Past Instabilities

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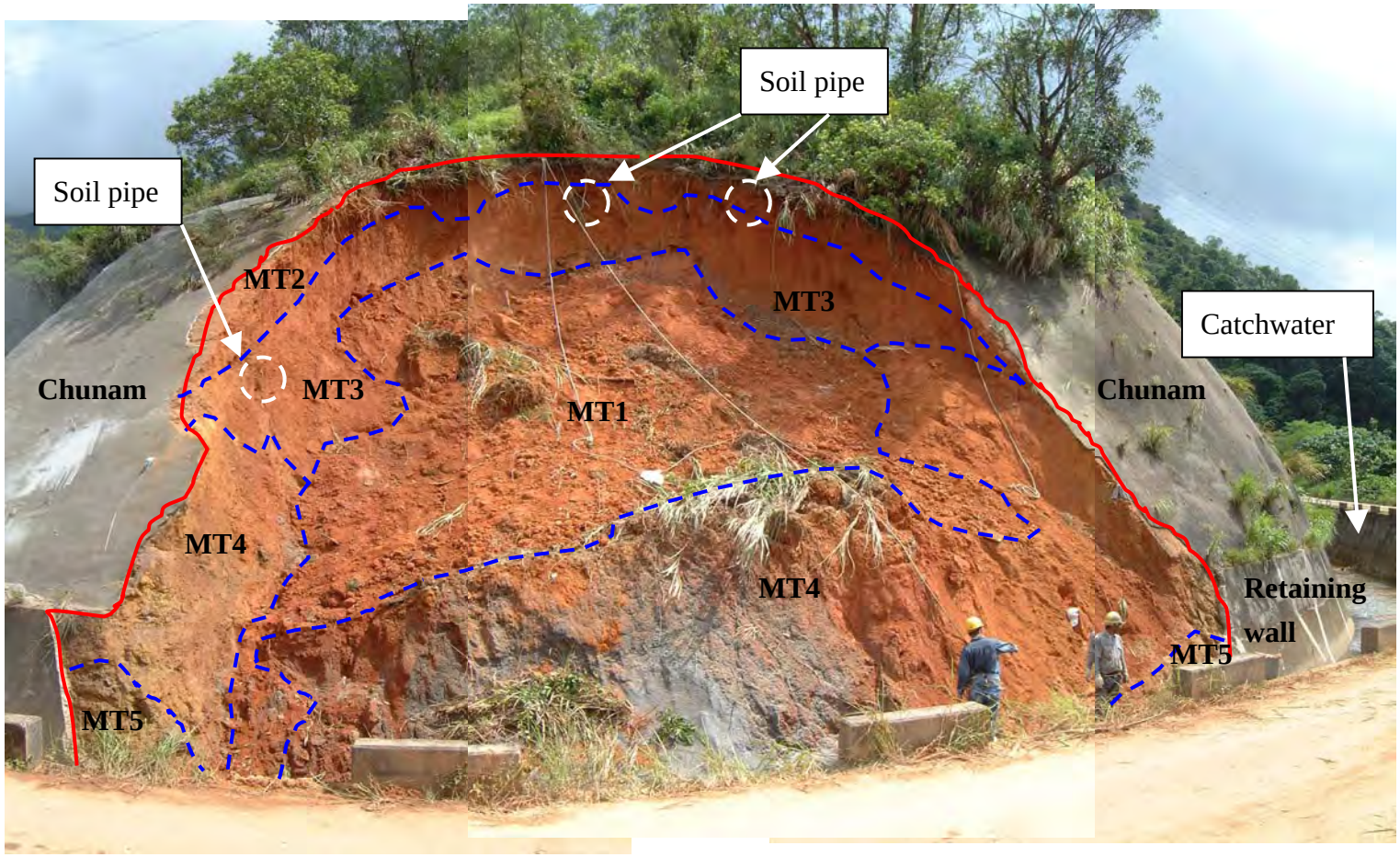
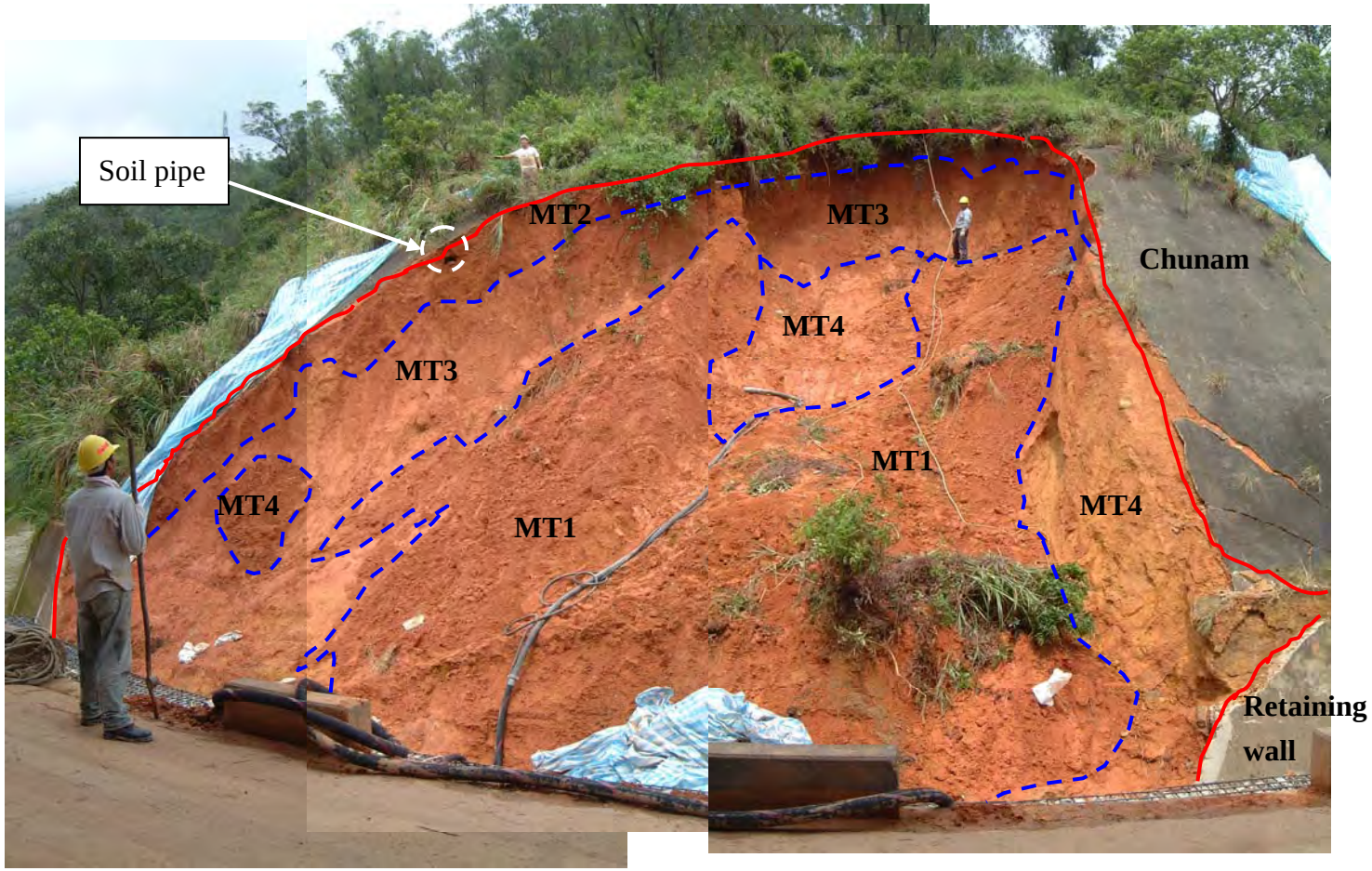


Legend :

MT1	Soft, moist, reddish brown, silty CLAY with occasional subangular fine to coarse gravel, roots, grasses and brushes (LANDSLIDE DEBRIS)	
MT2	Firm, moist, reddish brown, silty CLAY with occasional subangular fine to coarse gravel (COLLUVIUM)	
MT3	Firm, moist, reddish brown, silty CLAY (RESIDUAL SOIL)	
MT4	Extremely weak to very weak, reddish brown and yellowish brown, completely decomposed TUFF (Stiff, clayey SILT with relict manganese infilled joints)	
MT5	Weak to moderately weak, yellowish brown, streaked black, highly to moderately decomposed TUFF, closely spaced relict joints, infilled with manganese	

Figure 8 - Field Mapping of Landslide Scar A at Slope No. 7SW-A/CR134



Legend :

MT1	Soft, moist, reddish brown, silty CLAY with occasional subangular fine to coarse gravel, roots, grasses and brushes (LANDSLIDE DEBRIS)	MT3	Firm, moist, reddish brown, silty CLAY (RESIDUAL SOIL)
MT2	Firm, moist reddish brown, silty CLAY with occasional subangular fine to coarse gravel (COLLUVIUM)	MT4	Extremely weak to very weak, reddish brown and yellowish brown, completely decomposed TUFF (Stiff, clayey SILT with relict manganese infilled joints)

Figure 9 - Field Mapping of Landslide Scar B at Slope No. 7SE-A/CR134

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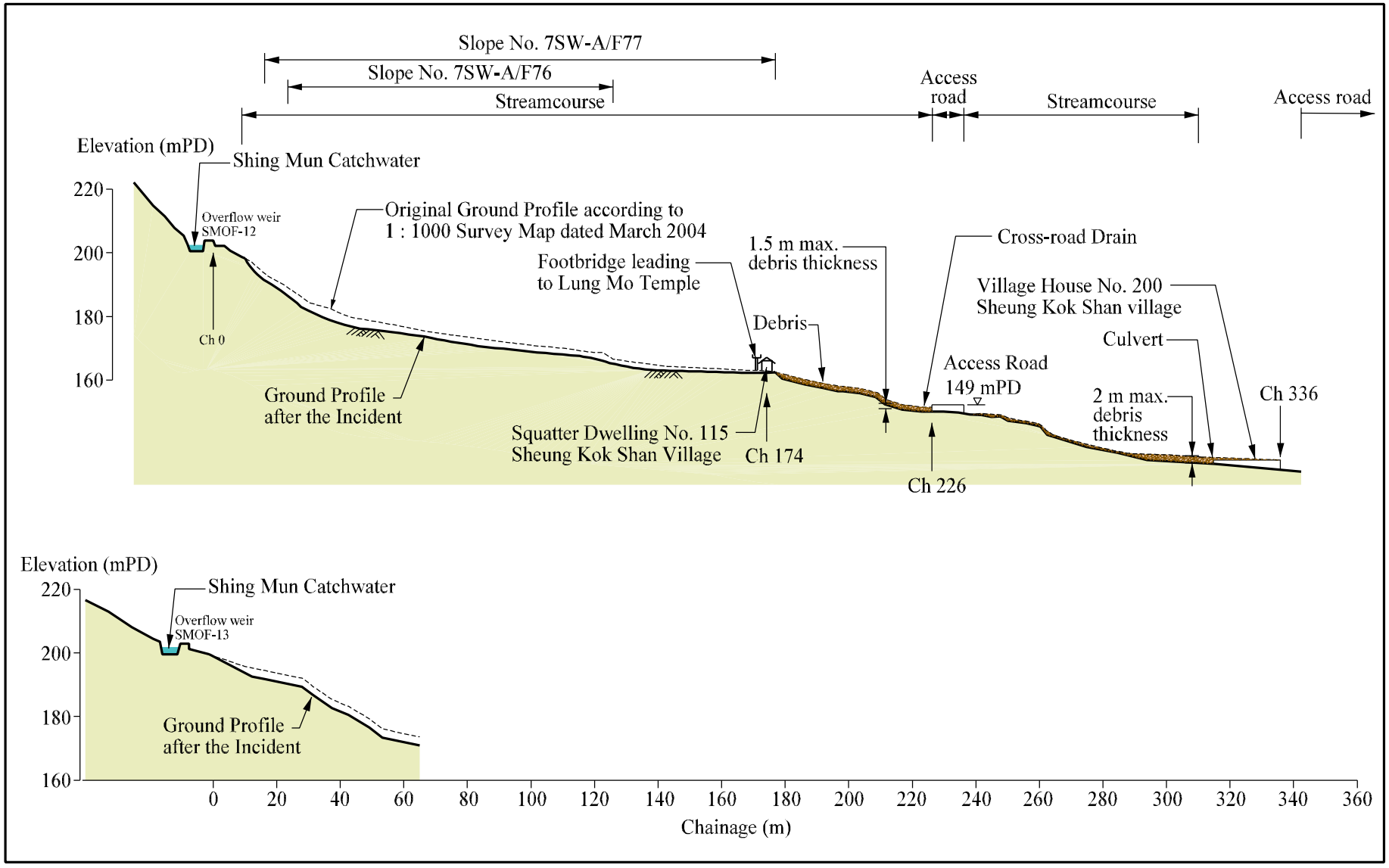


Figure 10 - Longitudinal Section of Streamcourse

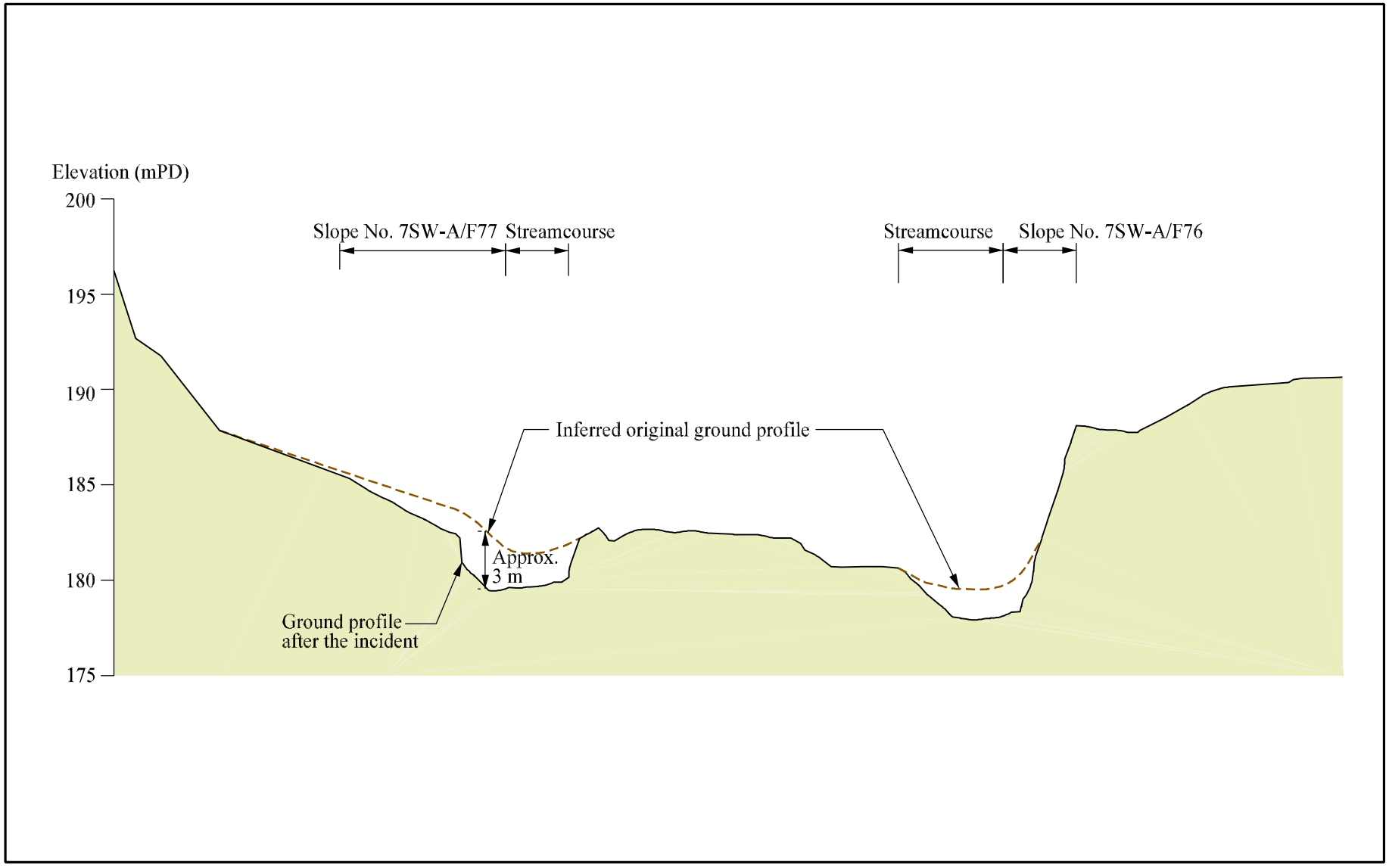


Figure 11 - Cross-section X-X at Approximate Chainage CH 42 before and after 20 August 2005 Incident

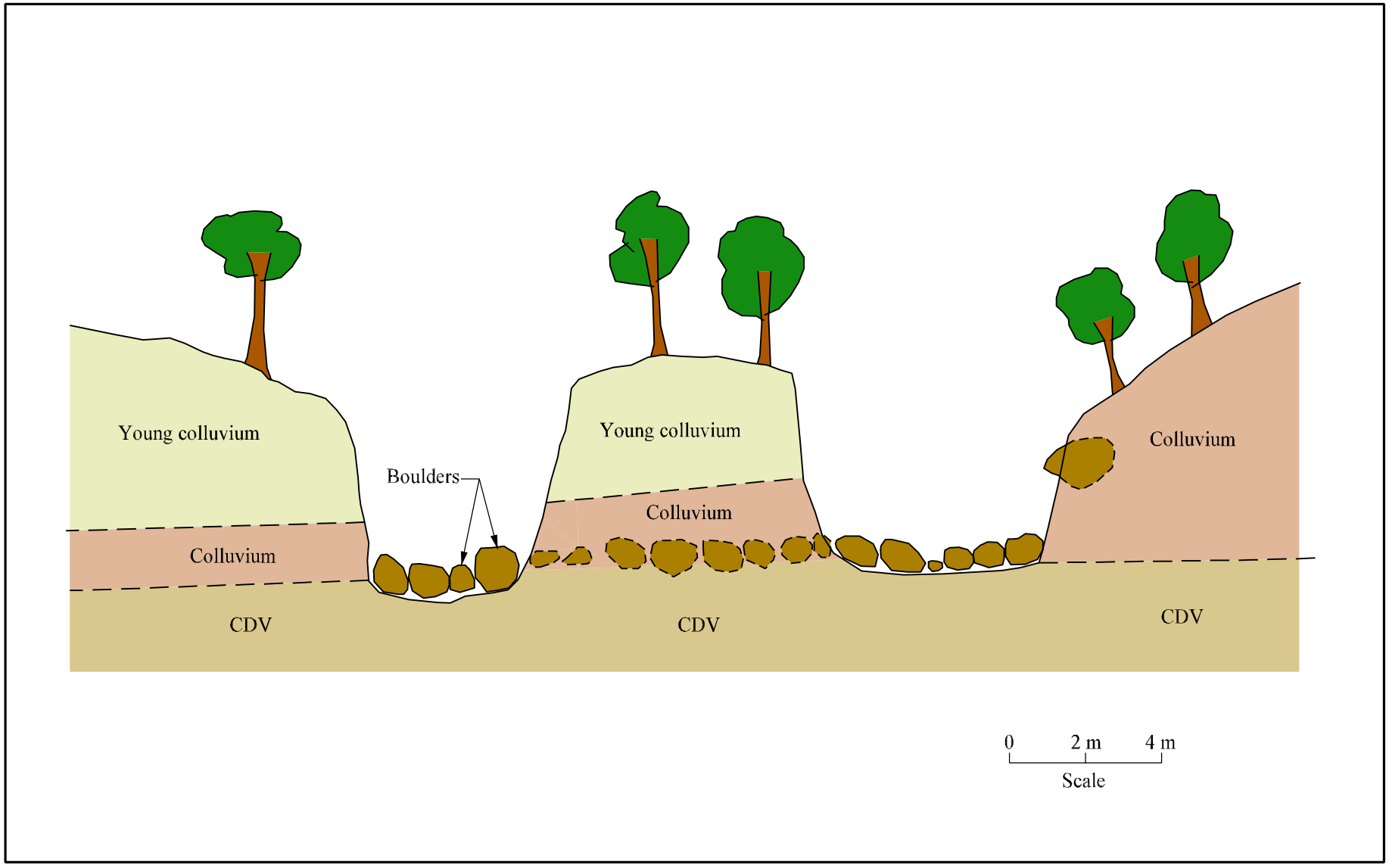


Figure 12 - Geological Section of Two Limbs of Streamcourse

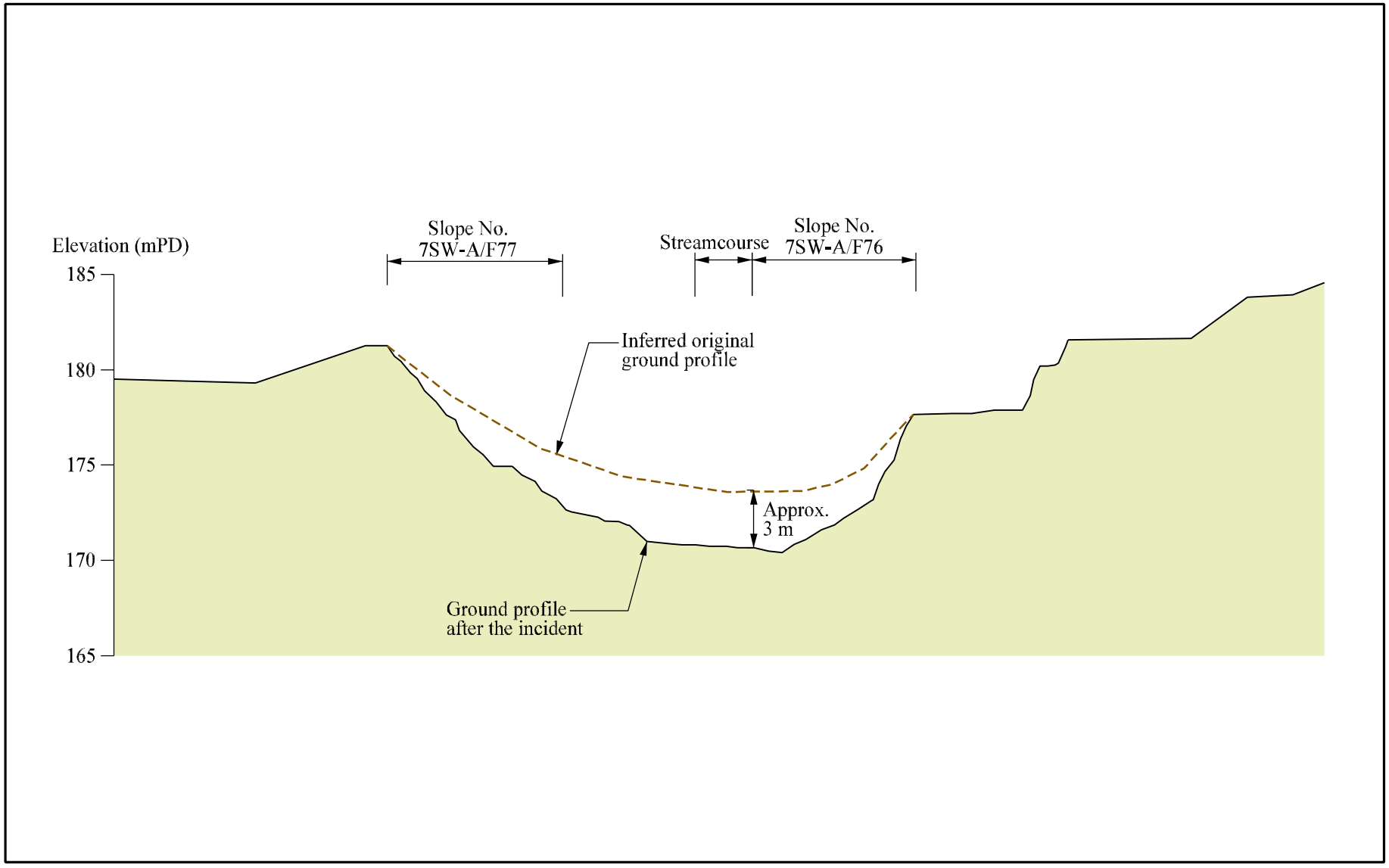


Figure 13 - Cross-section Y-Y at Approximate Chainage CH 72 before and after 20 August 2005 Incident

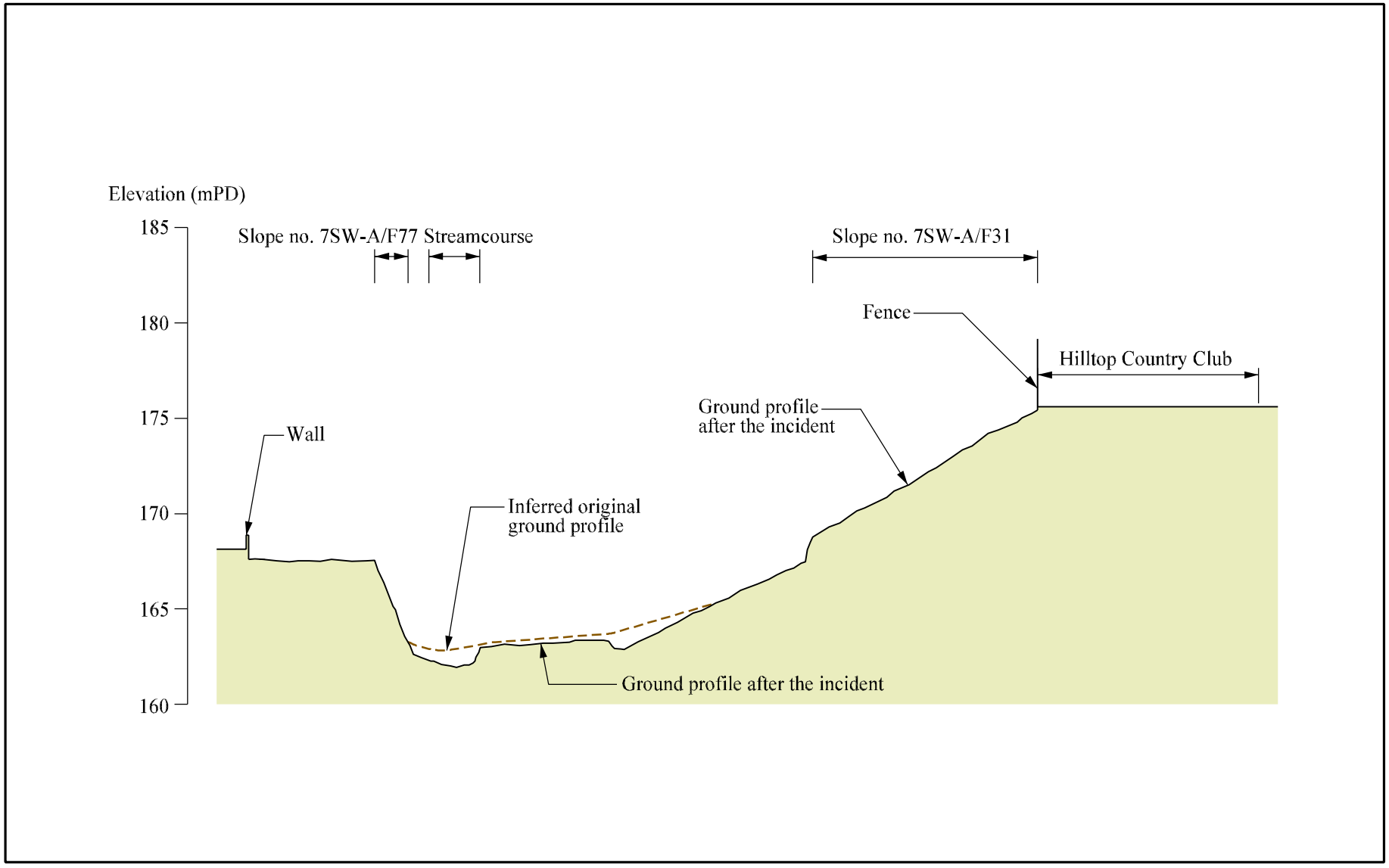
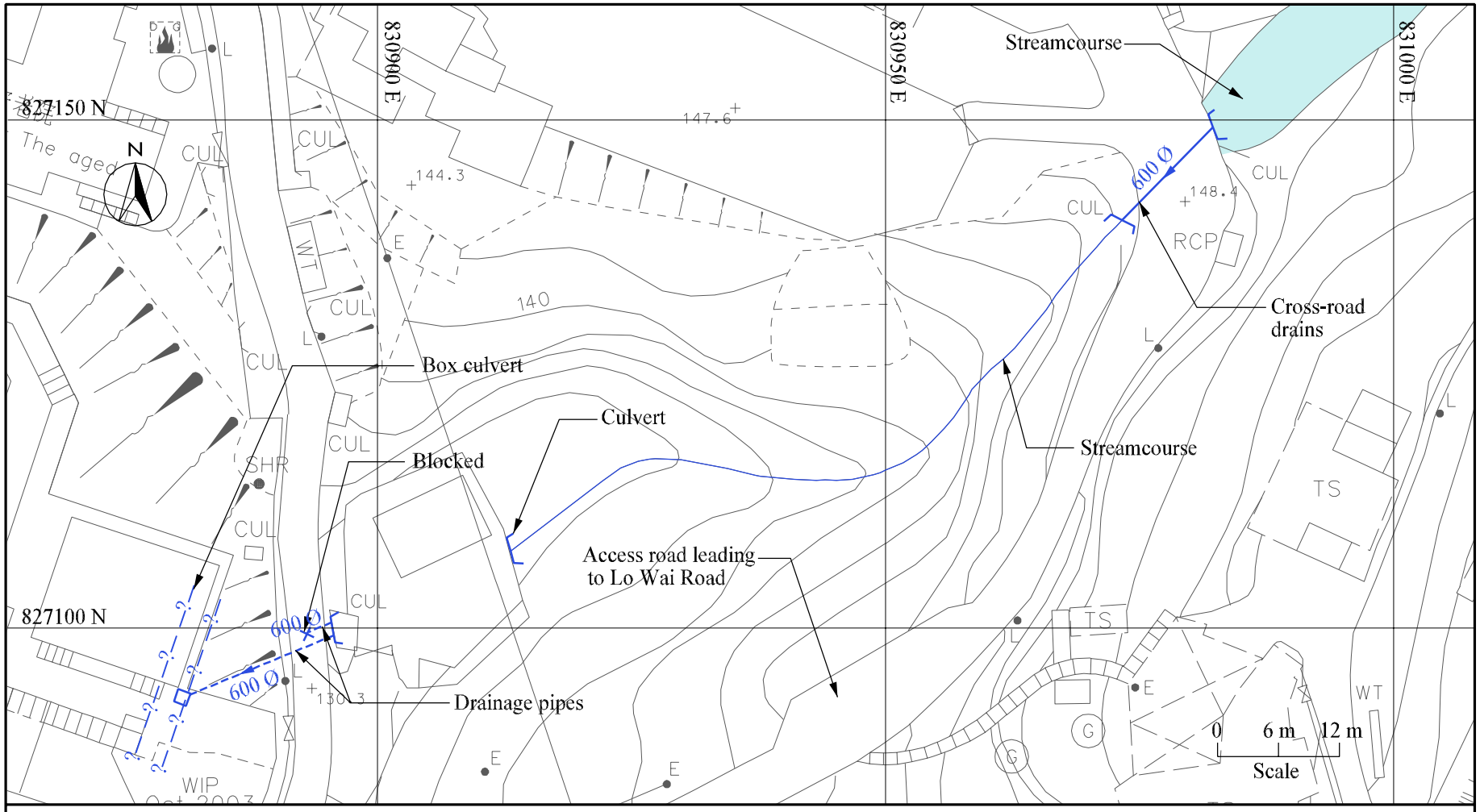


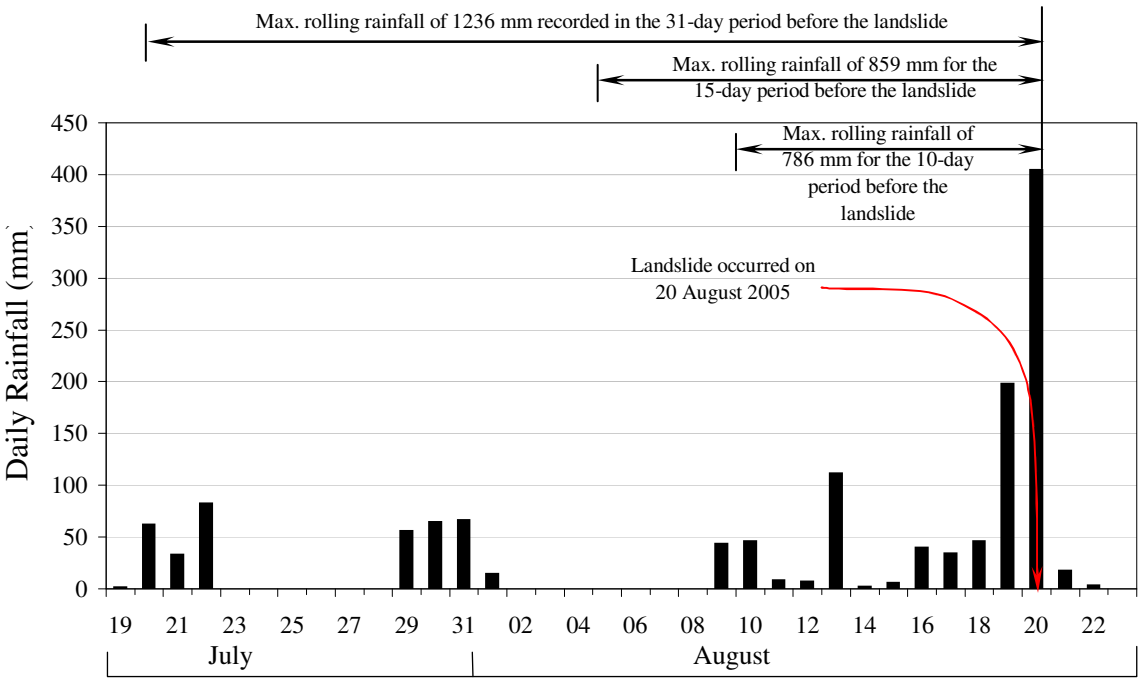
Figure 14 - Cross-section Z-Z at Approximate Chainage CH 150 before and after 20 August 2005 Incident



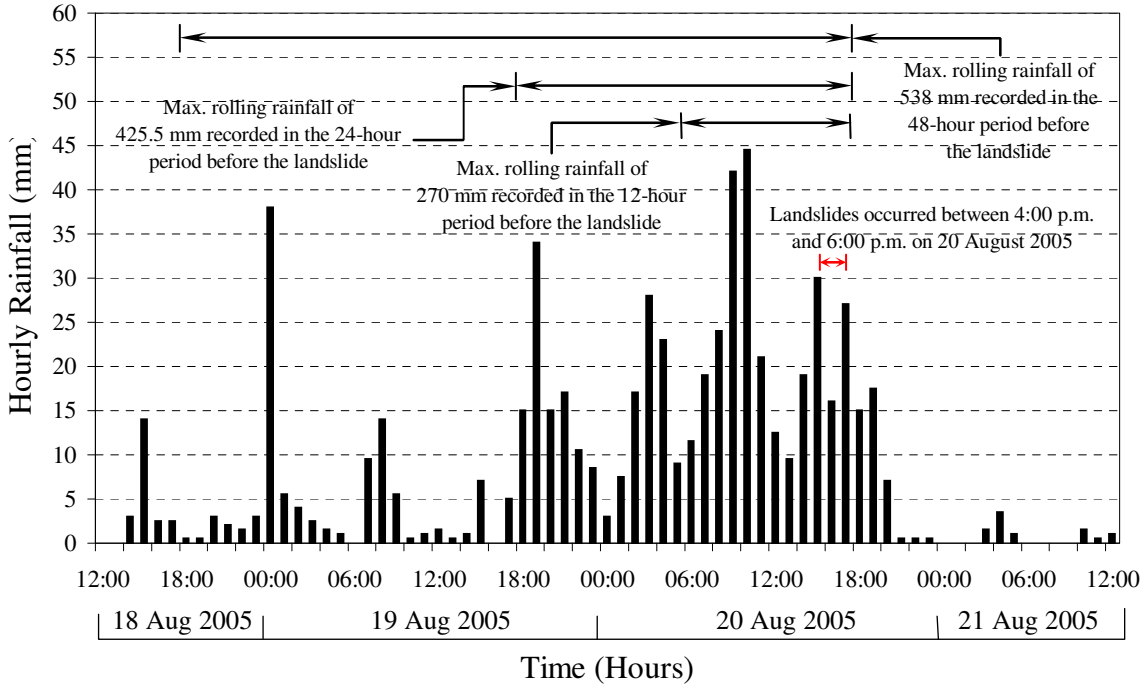
Legend : Crossroad drain Outlet / inlet Drainage pipe

Note : Base plan is extracted from 1 : 1000 survey sheet No. 7SW-11B dated March 2004.

Figure 15 - Alignments of Cross-road Drains and Drainage Pipes by CCTV Survey



(a) Daily Rainfall Recorded at GEO Raingauge No. N03 between 19 July 2005 and 23 August 2005



(b) Hourly Rainfall Recorded at GEO Raingauge No. N03 between 18 August 2005 and 21 August 2005

Figure 16 - Daily and Hourly Rainfall Recorded at GEO Raingauge No. N03

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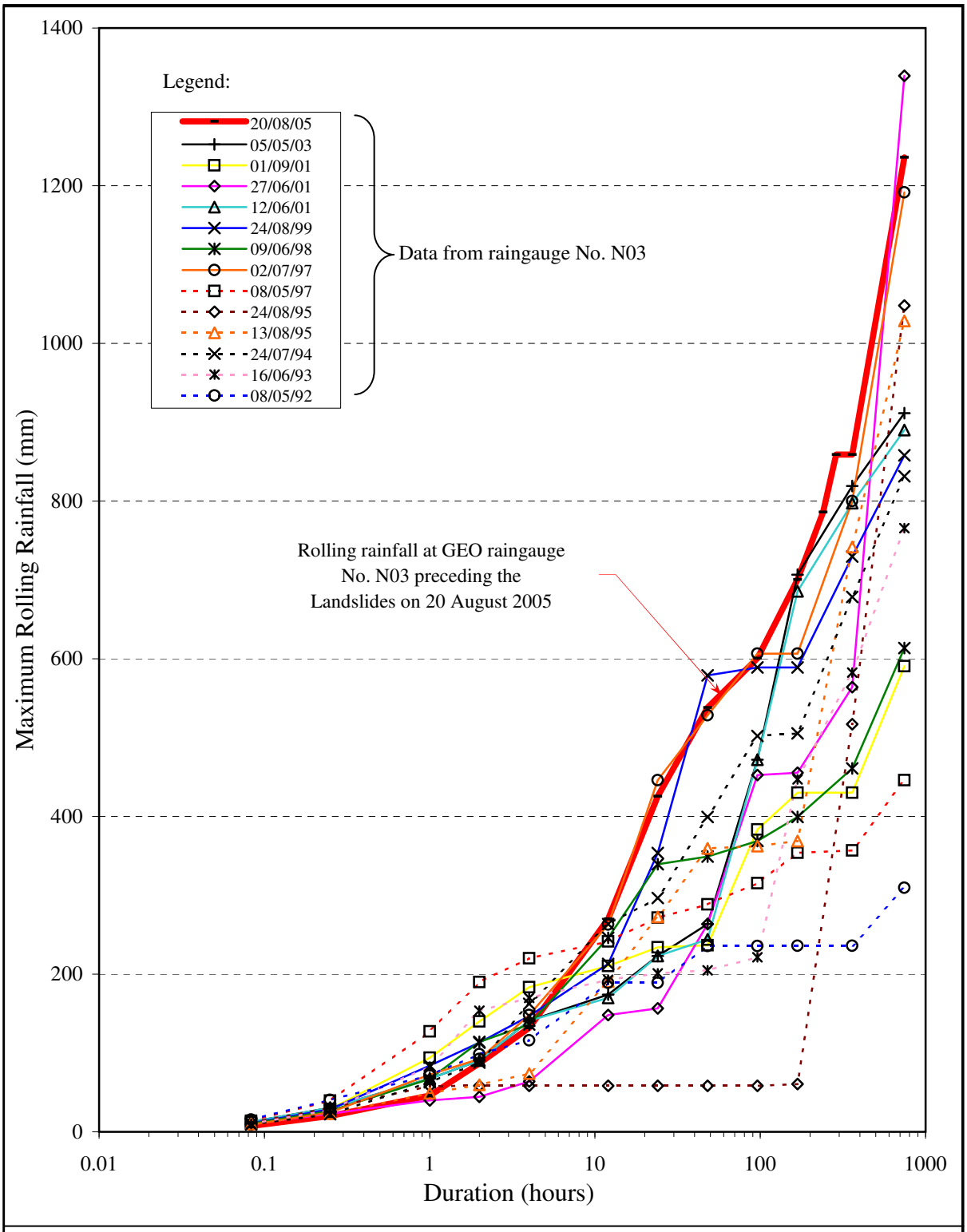

Notes: (1) Rainfall data based on 5-minute readings from GEO raingauge No. N03 (about 1.2 km to the south of the site).

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

Figure 17 - Maximum Rolling Rainfall for Previous Major Rainstorms at GEO Raingauge No. N03

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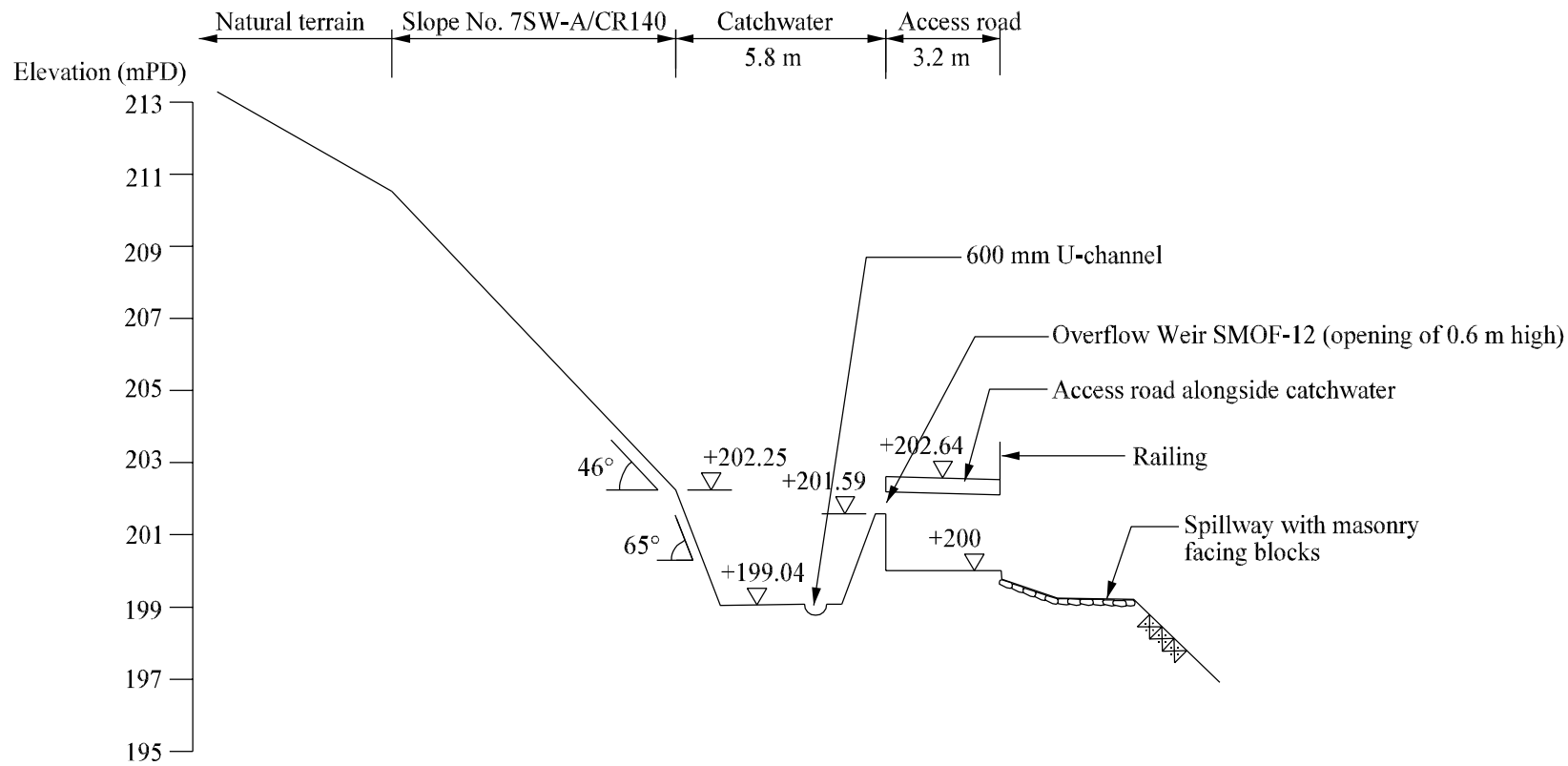
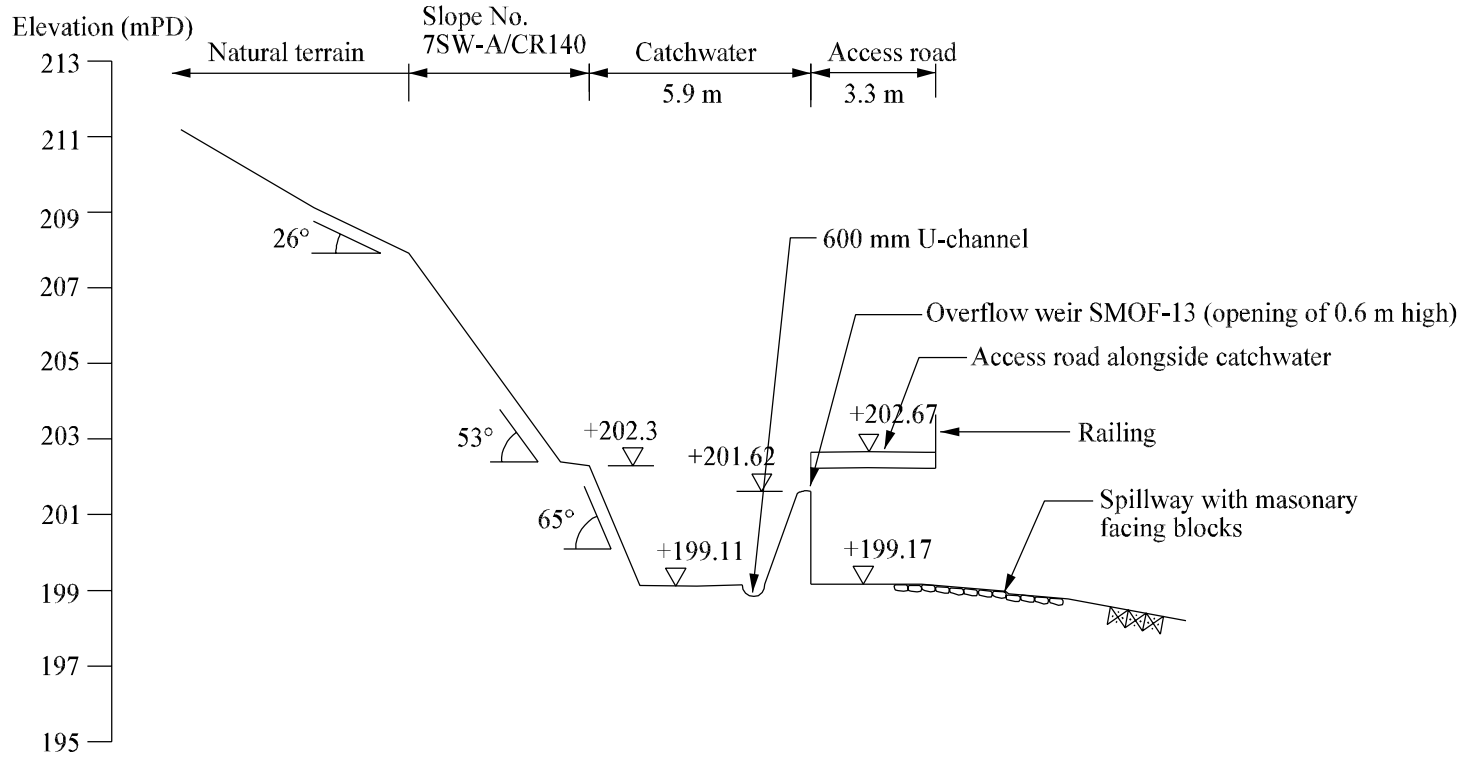


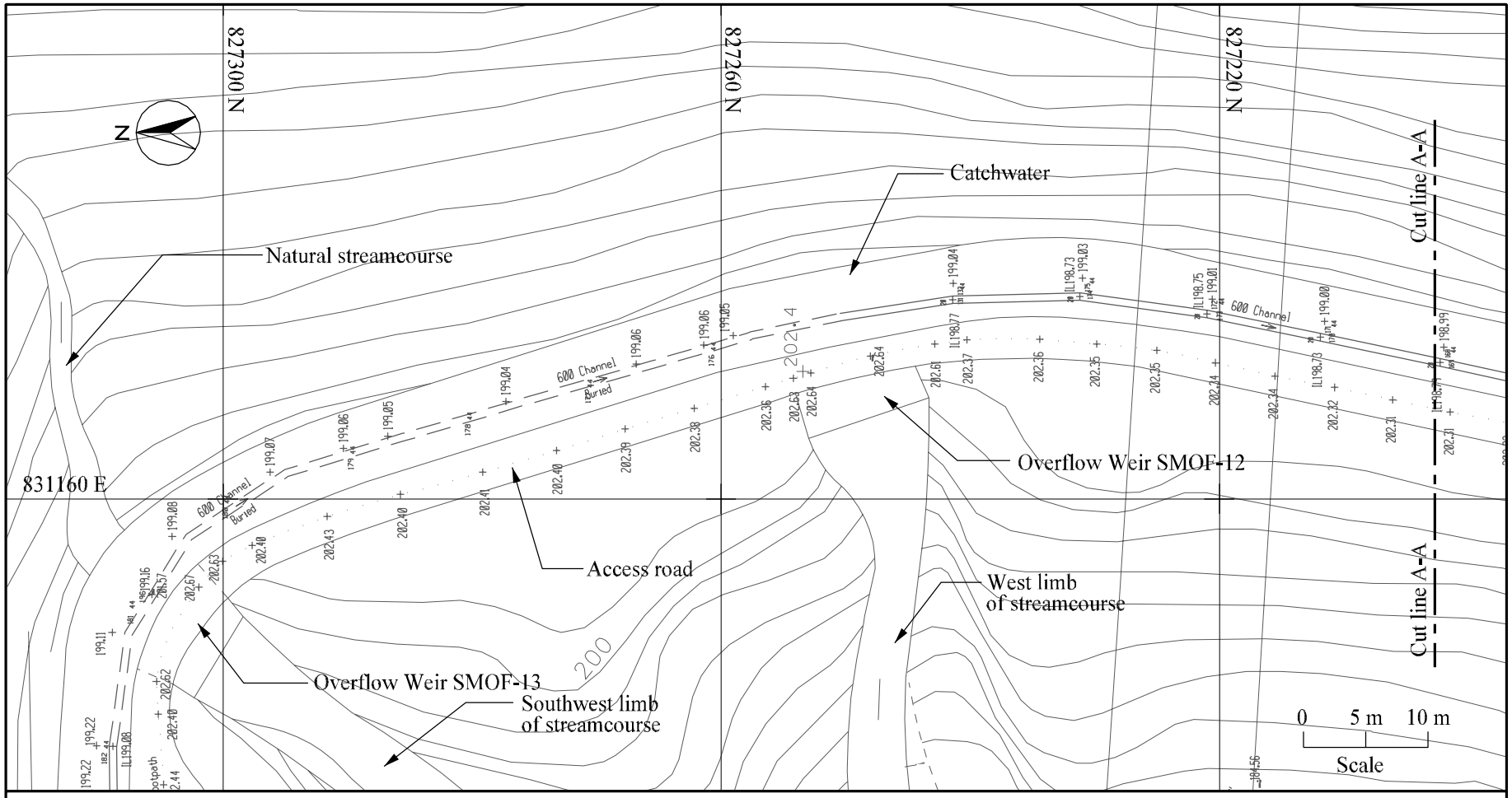
Note : All levels in mPD.

Figure 18 - Cross-section of Overflow Weir SMOF-12



Note : All levels in mPD.

Figure 19 - Cross-section of Overflow Weir SMOF-13

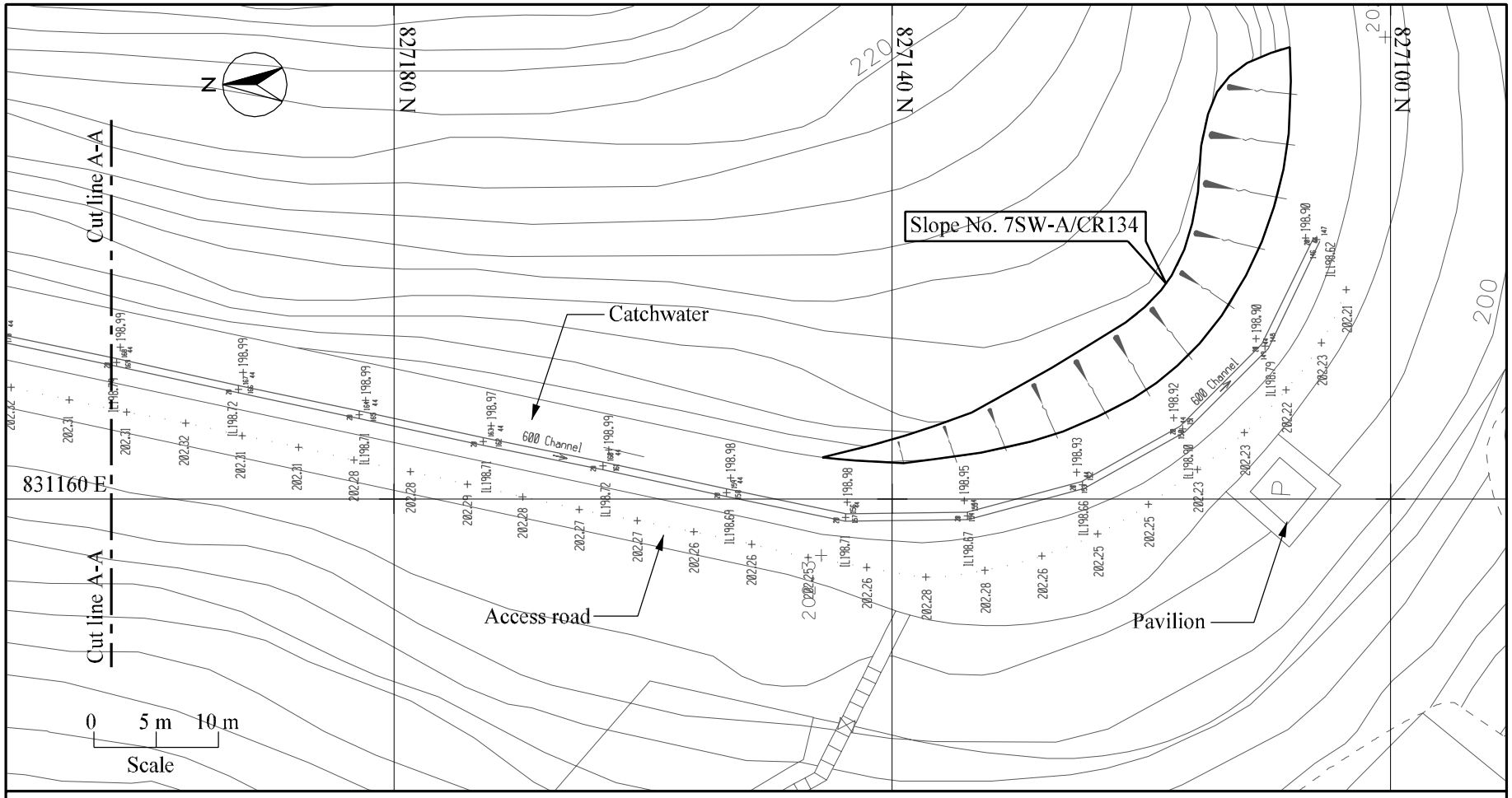


Legend :

+ Spot level in mPD

Notes : (1) Base plan is extracted from 1 : 1000 survey sheet No. 7SW-11B dated March 2004.
(2) Spot levels were measured by LIC "Stand-by" Contractor in September 2005.

Figure 20 - Spot Levels at Bottom of Catchwater and Access Road (Sheet 1 of 2)

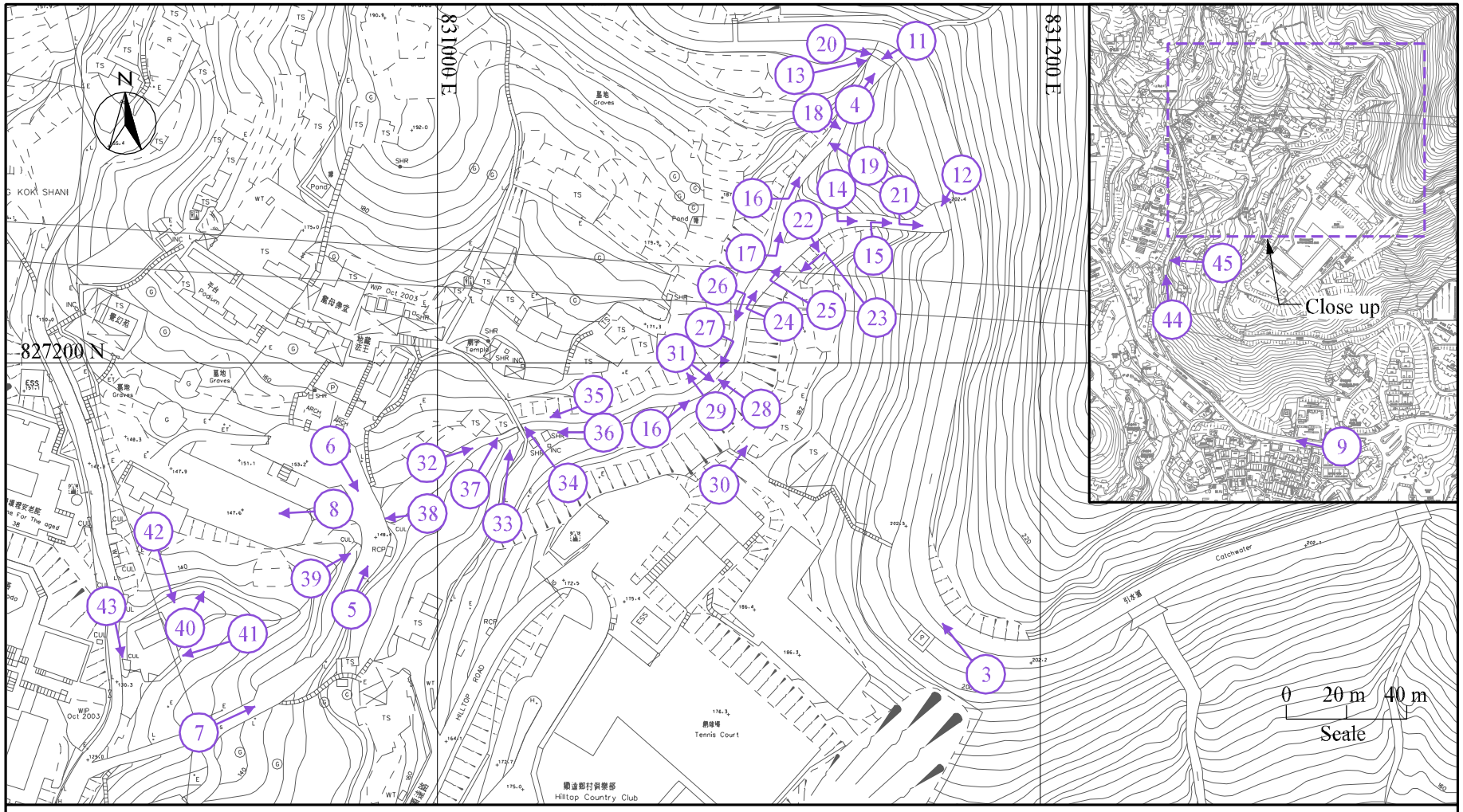


Legend :

+ Spot level in mPD

Notes : (1) Base plan is extracted from 1 : 1000 survey sheet No. 7SW-11B dated March 2004.
(2) Spot levels were measured by LIC "Stand-by" Contractor in September 2005.

Figure 21 - Spot Levels at Bottom of Catchwater and Access Road (Sheet 2 of 2)



Legend : 22 → Location and direction of photograph

Note : Base plan is extracted from 1 : 1000 survey sheet No. 7SW-11B dated March 2004.

Figure 22 - Locations and Directions of Photographs Taken

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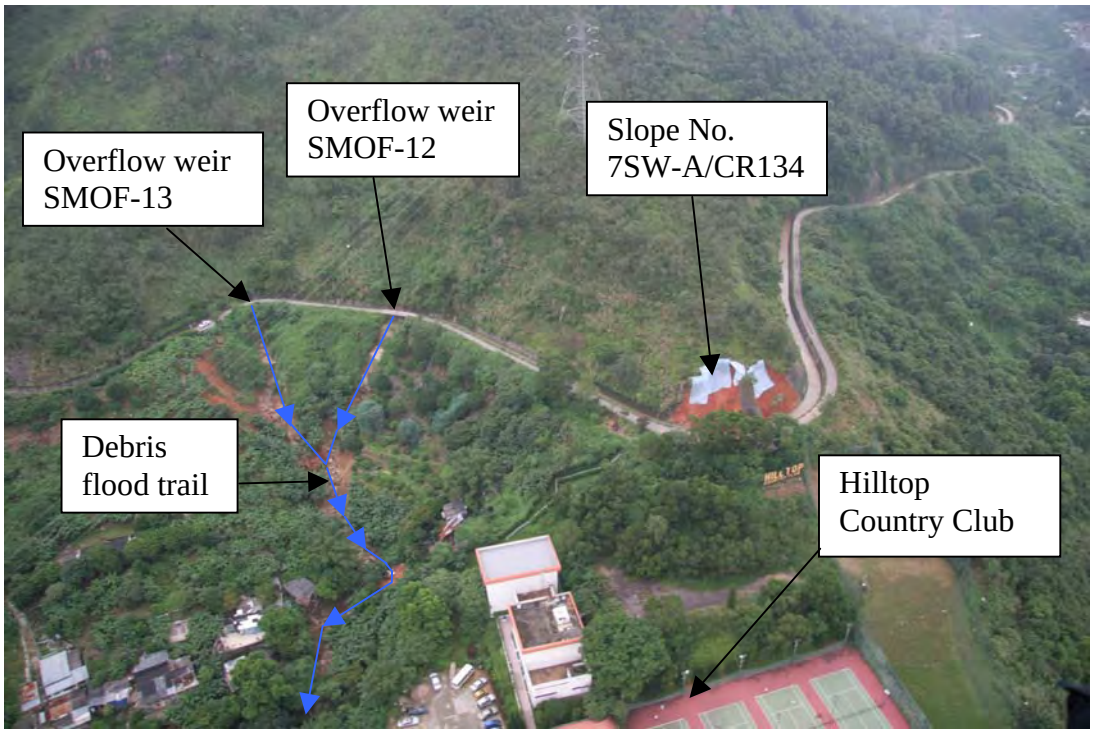

Plate 1 - Oblique Aerial View of Shing Mun Catchwater
and Landslides at Slope No. 7SW-A/CR134
(Photograph taken on 22 August 2005)

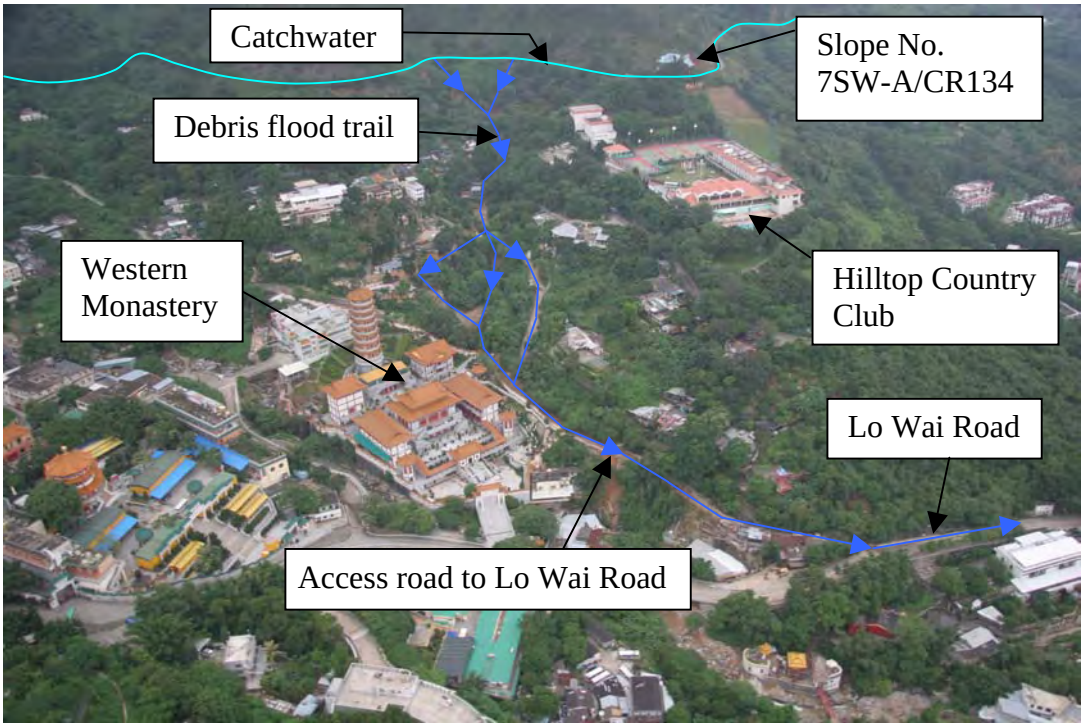

Plate 2 - Oblique Aerial View of the Debris Flood Trail
(Photograph taken on 22 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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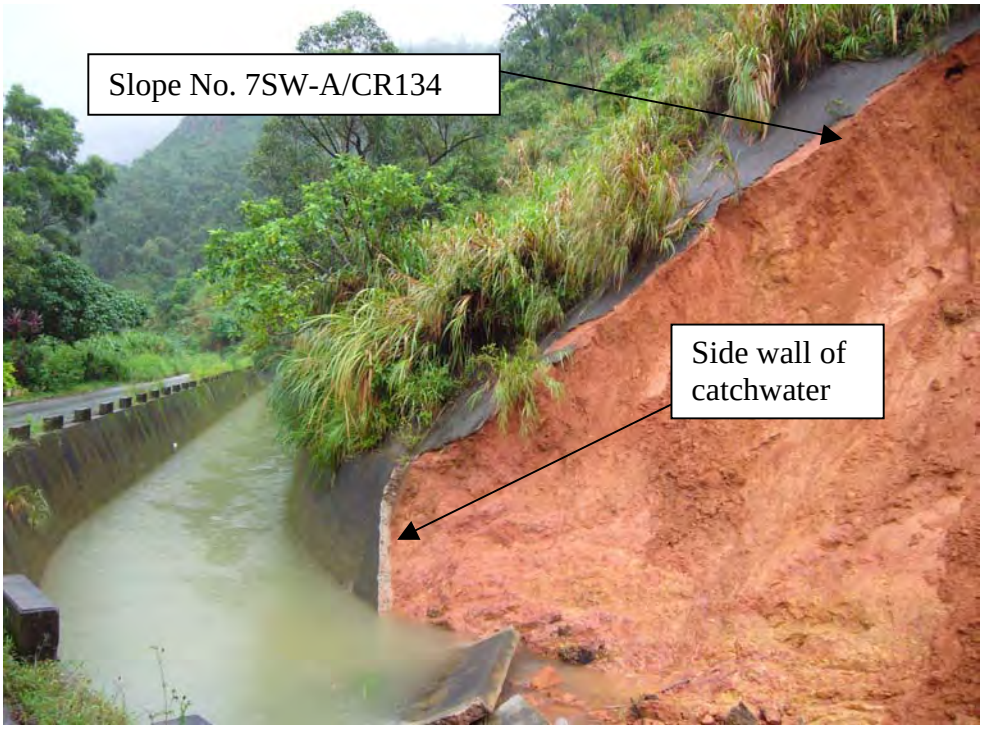

Plate 3 - Sidewall of Catchwater and Slope No. 7SW-A/CR134
(Photograph taken on 22 August 2005)

Plate 4 - General View of Overflow Weir SMOF-13
(Photograph taken on 25 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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Plate 5 - Debris Deposited on Access Road Leading to Lo Wai Road
(Photograph taken on 21 August 2005)

Plate 6 - Debris Flood Overtopped the Access Road
(Photograph taken by local resident on 20 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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Plate 7 - Debris Flood Flowing along Access Road towards Lo Wai Road
(Photograph taken by local resident on 20 August 2005)

Plate 8 - View of Debris Deposited on the Open Car Park
(Photograph taken on 21 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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Plate 9 - Taxi Trapped by Debris Deposited on Lo Wai Road
(Photograph taken on 20 August 2005 - Ming Pao Daily News)

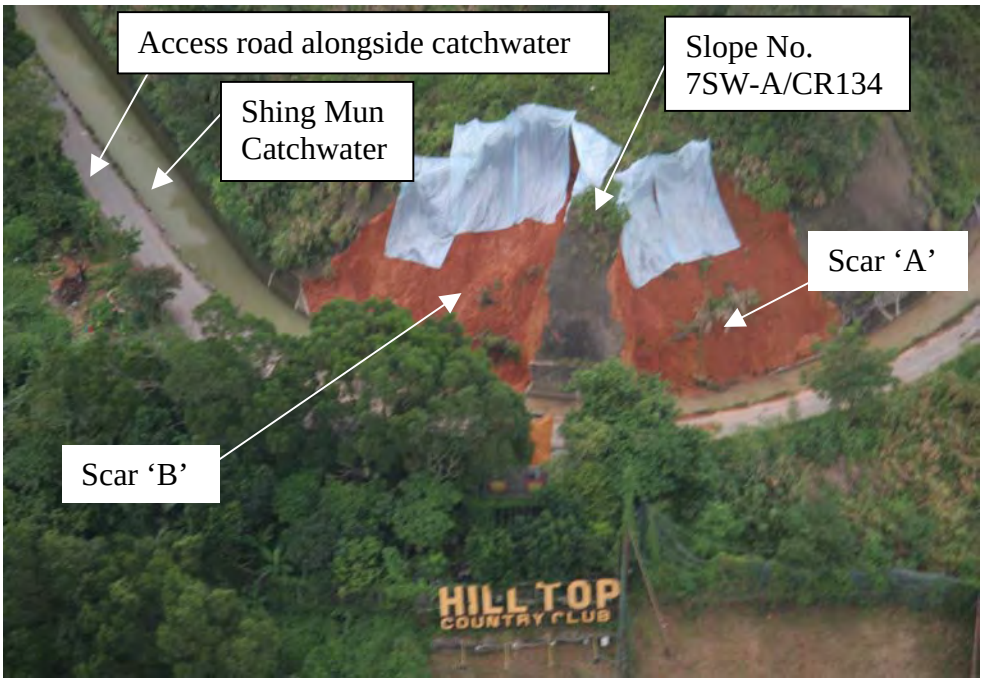

Plate 10 - Oblique Aerial View of Landslides
on Slope No. 7SW-A/CR134
(Photograph taken on 22 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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Plate 11 - Dislodged Masonry Facing Blocks at Spillway below Overflow Weir SMOF-13 (Photograph taken on 25 August 2005)

Plate 12 - Masonry Facing Blocks at Spillway below Overflow Weir SMOF-12 (Photograph taken on 25 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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Plate 13 - Collapse of Part of a Masonry Wall below the Spillway (Below Overflow Weir SMOF-13) (Photograph taken on 25 August 2005)

Plate 14 - View of West Limb of the Streamcourse at Approximate Chainage CH 38 before the Incident (Photograph taken on 1 September 2004)

Note: See Figure 22 for locations and directions of photographs taken.

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Plate 16 - View of Southwest Limb of the Streamcourse at Approximate Chainage CH 48 before the Incident (Photograph taken on 31 August 2004)

Note: See Figure 22 for locations and directions of photographs taken.

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Plate 17 - View of Southwest Limb of the Streamcourse at Approximate Chainage CH 60 after the Incident (Photograph taken on 25 August 2005)

Plate 18 - Erosion Gully in Southwest Limb with Different Layers of Colluvium (Photograph taken on 25 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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Plate 20 - Highly to Moderately Decomposed Tuff Exposed below the Spillway of the Southwest Limb (Photograph taken on 25 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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Note: See Figure 22 for locations and directions of photographs taken.

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Plate 23 - View of Crest of Slope No. 7SW-A/F76 Adjacent to Squatter Structure No. RTW/4AD/124 at Approximate Chainage CH 48 before the Incident (Photograph taken on 1 September 2004)

Plate 24 - View of Confluence of Streamcourse Limbs (Photograph taken on 25 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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Plate 25 - Erosion of Slopes Nos. 7SW-A/F76 and 7SW-A/F77 Caused by Debris Flood at Approximate Chainage CH 66 (Photograph taken on 25 August 2005)

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Note: See Figure 22 for locations and directions of photographs taken.

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Plate 27 - View of Streamcourse at Approximate Chainage CH 92 after the Incident (Photograph taken on 22 September 2005)

Plate 28 - Refuse Deposited on Highly to Moderately Decomposed Tuff at Approximate Chainage CH 110 (Photograph taken on 25 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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Note: See Figure 22 for locations and directions of photographs taken.

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Plate 31 - Foundation of a Retaining Structure Exposed
(Photograph taken on 25 August 2005)

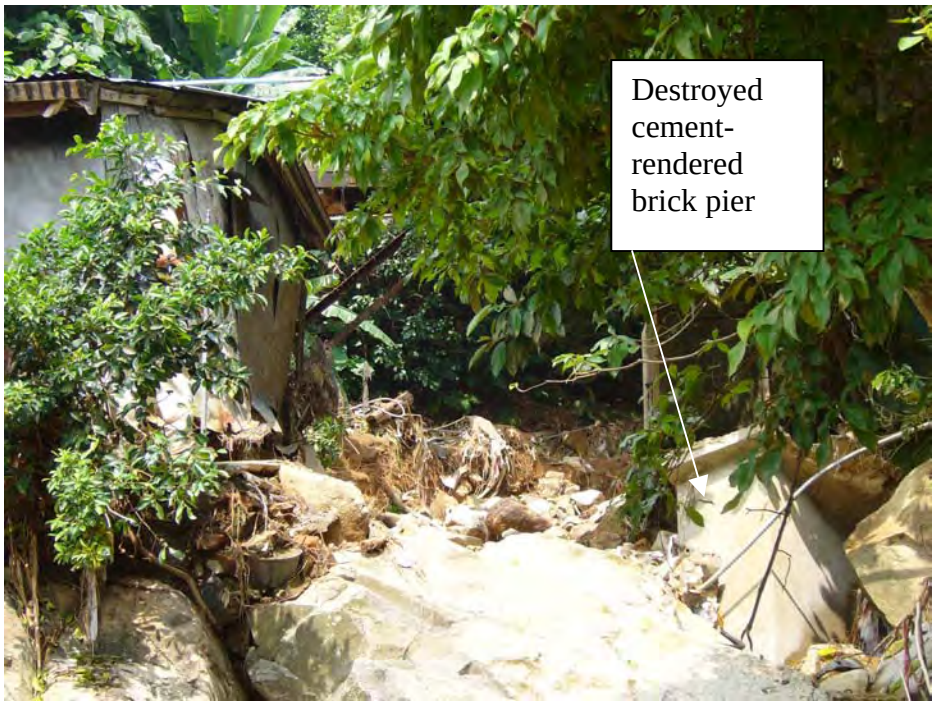

Plate 32 - View of Destroyed Brick Pier Located
Approximately 10 m Downstream of Footbridge
(Photograph taken on 25 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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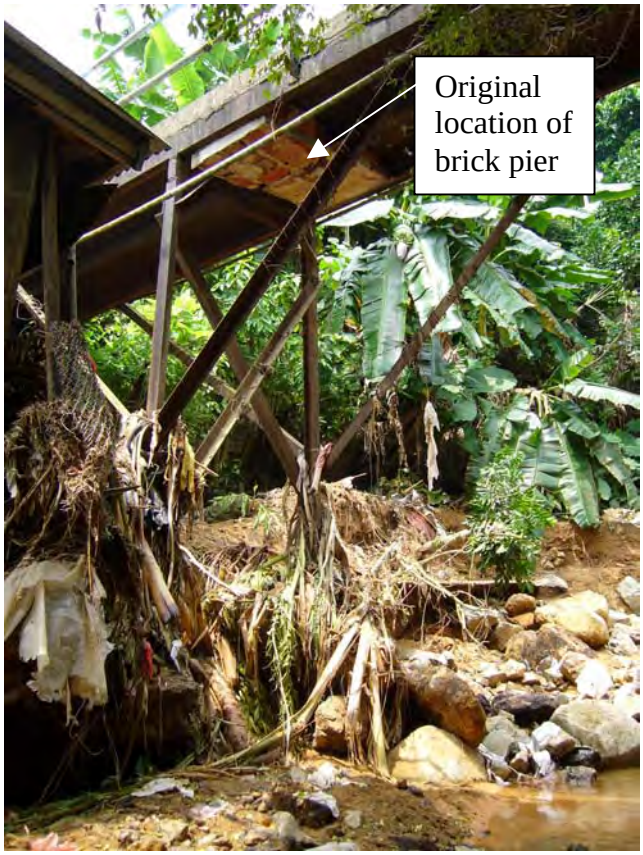

Plate 33 - Original Location of Destroyed Cement-Rendered Brick Pier Providing Partial Support to Footbridge across Streamcourse (Photograph taken on 25 August 2005)

Plate 34 - View of Footbridge and Squatter Structure No. RTW/4AD/115 before the Incident (Photograph taken on 31 August 2004)

Note: See Figure 22 for locations and directions of photographs taken.

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Plate 35 - View of Squatter Structure No. RTW/4AD/115 and Footbridge (Photograph taken on 25 August 2005)

Plate 36 - View of Damage Caused by Debris Flood to Rear of Squatter Structure No. RTW/4AD/115 (Photograph taken on 22 September 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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Plate 37 - View of Debris Deposition and Undermining of Squatter Structure No. RTW/4AD/115 (Photograph taken on 25 August 2005)

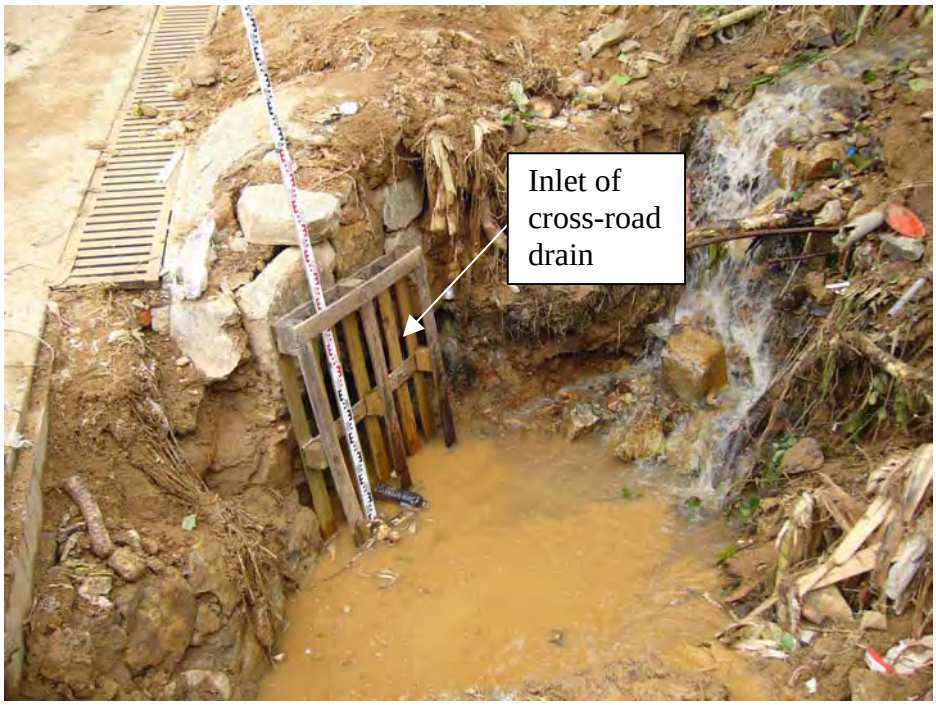

Plate 38 - View of Blocked Cross-road Drain (After Clearance) (Photograph taken on 25 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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Plate 39 - View of Outlet from Cross-road Drain beneath the Access Road
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Plate 40 - View of Landslide at Slope No. 7SW-A/F38 (Photograph taken on 25 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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Plate 41 - View of Debris and Refuse Deposited in Front Yard of Village House No. 200 (Photograph taken on 21 August 2005)

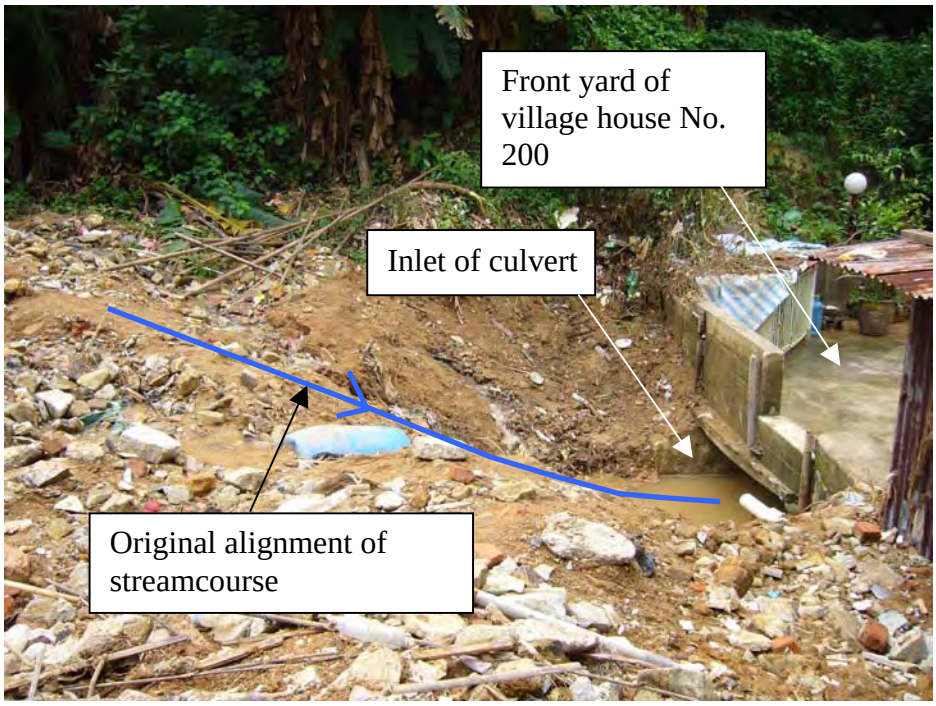

Plate 42 - View of Inlet to Culvert beneath Village House No. 200 (After Clearance) (Photograph taken on 25 August 2005)

Note: See Figure 22 for locations and directions of photographs taken.

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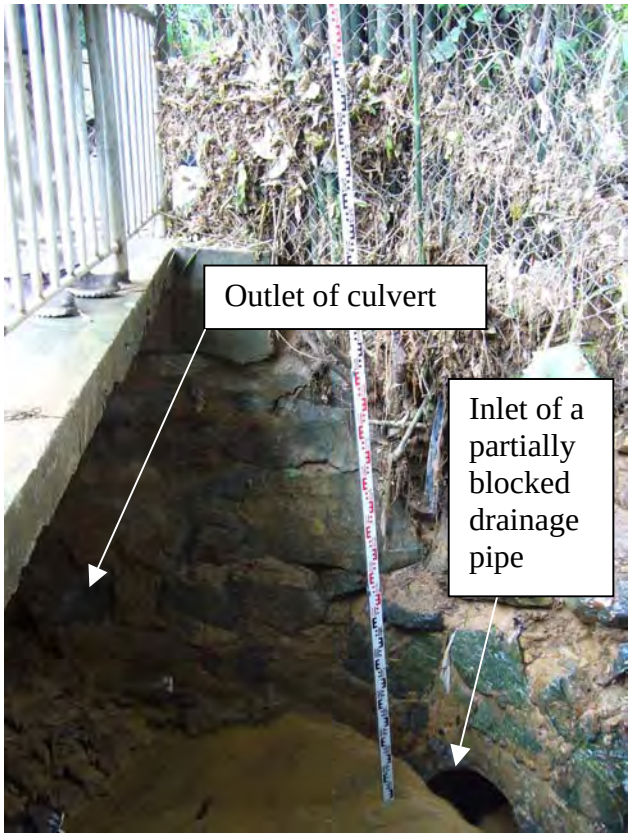

Plate 43 - Inlet of Drainage Pipe near the Front Yard of Village House No. 200 (Photograph taken on 25 August 2005)

Plate 44 - View of Landslide at Slope No. 7SW-A/CR132 (Photograph taken on 20 August 2005)

Note: See Figure 22 for locations and directions of photos taken.

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Plate 45 - A Vacated Village House at the Toe of Slope No. 7SW-A/CR132 was Damaged (Photograph taken on 25 August 2005)

Plate 46 - Possible Location of 'Dam Break' (Photograph taken on 25 August 2005)

Note: See Figure 22 for locations and directions of photos taken.

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APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

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A1. DETAILED OBSERVATIONS

This appendix sets out the detailed observations made from an interpretation of aerial photographs taken between 1924 and 2004. The main observations of the API are shown in Figures A1 and A2.

YEAR	KEY OBSERVATIONS
1924	Single, poor quality high-altitude photograph. Catchwater system has not yet been constructed, with the general study area comprising agricultural terraces and vegetated terrain.
1945	The catchwater and its associated access road have been constructed along the central study area some time between 1924 and 1945. Associated with the construction of the catchwater, several cut slopes including slopes Nos. 7SW-A/CR134, 7SW-A/CR141 and 7SW-A/CR113 can be observed along the upslope side of the catchwater (Figure 1). The extent of these slopes does not correspond exactly to the present-day slope extent suggesting that subsequent modification has occurred. Other slopes that have been constructed along the upslope side of the catchwater are difficult to clearly delineate because of a lack of image resolution. The main catchment streamcourse (Figure A1) which descends the hillside opposite overflow weir SMOF-13 is intercepted by the catchwater and discharges into the catchwater system. The hillslope terrain downslope from the catchwater appears to generally comprise natural vegetated terrain, locally modified by scattered graves. No significant erosion of the terrain downslope from the catchwater is evident in the 1945 aerial photographs. Several areas of high reflectivity or over-steepening can be seen just above the catchwater. It is difficult to ascertain with any certainty if these areas are related to instability or catchwater construction.
1954	Areas of high reflectivity, interpreted as erosion and corresponding to areas of localised over-steepening, can be observed immediately downslope from the catchwater adjacent to overflow weirs SMOF-12 and SMOF-13. An area of over-steepening and relatively high reflectivity can be observed at the south end of slope No. 7SW-A/CR140. It is difficult to ascertain with any certainty the nature and age of this probable erosional feature. Lo Wai Road together with its associated bridge has been constructed across the lower study area. The access road leading to the lower catchment area has not been constructed. However, a minor path can be observed extending in a similar alignment as the subsequently constructed road.

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YEAR	KEY OBSERVATIONS
1963	Good quality, low-altitude photographs. Much of the geomorphological mapping details in Figure A1 have been derived from these photographs. The catchwater can be clearly observed and overflow weirs SMOF-12 and SMOF-13 can be clearly seen. The terrain upslope from the catchwater broadly corresponds to the upper reaches of a well-defined perennial streamcourse channel which drains the main catchment above the site. The natural hillslope terrain on the western side of the streamcourse generally consists of south-facing sideslopes drained by several southwards draining ephemeral streamcourses. Narrow, locally steep terrain can be observed within the upper terrain defined by sharp breaks in slope and corresponding to areas of exposed rock outcrop. This break in slope is coincident with a change in geology from coarse ash tuff to block-bearing tuff. A large depression is evident in this area of exposed rock outcrop and appears to correspond to a substantial relict landslide feature (denoted as R1 in Figure A1). The landslide scar is clearly defined by sharp lateral breaks in slope, with the downslope trail indistinct from the general downslope ephemeral streamcourse channel. Localised accumulations of hummocky colluvial deposits can be identified within the downslope streamcourse channel (denoted as C1 in Figure A1), and adjacent to the main streamcourse (C2 and C3). Another area of locally over-steepened terrain can be observed immediately upslope from the catchwater channel at the location of slope No. 7SW-A/CR115 and is inferred to be an area of shallow rock outcrop. The natural hillslope terrain above the catchwater on the eastern side of the streamcourse generally consists of west-facing side slopes drained by several discontinuous ephemeral streamcourse channels. Just above the catchwater, two small depressions denoted by R2 and R3 in Figure A1. Both appear to represent relict landslides. Both features are laterally defined by sharp convex breaks in slope, with no evidence of associated downslope debris. A convex break in slope traverses across the middle hillside and just below this, two concave depressions can be seen which are also inferred to be relict landslides (R4 and R5). Further areas of over-steepening and breaks in slope are evident along the south-facing slopes in the east of the study area. These features are likely to have been formed by the continued erosion and weathering of the terrain immediately downslope from the main spurline by the heads of numerous, pre-existing ephemeral drainage channels. Two small landslide scars can be observed above the catchwater at the location of slope No. 7SW-A/CR134.

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YEAR	KEY OBSERVATIONS
1963 (Cond't)	The terrain immediately downslope from the two overflow weirs appears to contain further lobes or fans of colluvium which have deposited on more gentle sloping terrain in the foothill area. The terrain immediately below the overflow weirs has been further affected by extensive erosion and scouring. Sharply defined convex breaks in slope delineate the upper extent of active erosion with areas of high reflectivity clearly evident immediately downslope from the head of these scarp-like features. The areas of high reflectivity are inferred to be eroded material, probably localised deposits of colluvium derived from weathering of the upslope terrain and accumulated within local depressional areas. The scarp-like features are located at approximately the same location as the upper areas of present-day slopes Nos. 7SW-A/F76 and 7SW-A/F77. The extent of erosion visible in these aerial photographs highlights the dramatic change in erosion evident since 1945 following construction of the catchwater. Differentiation between the extent of erosion evident from the 1954 and 1963 aerial photographs has been made for comparative purposes. The extent of additional erosion and over-steepened terrain evident from these aerial photographs is denoted as areas E3 and E4 in Figure A2. Some localised excavation is evident along the southern bank of the streamcourse channel which appears to be related to localised construction of agricultural terrace platforms. The area affected by localised excavation is denoted as E5 (Figure A2). Construction of the platform area for the Hilltop Country Club has commenced, together with the formation of associated access roads, fill and cut slopes. Immediately to the southwest of the recently excavated terrain, minor dwelling structures together with agricultural terraces are visible. The agricultural terraces all appears to have been constructed on areas of shallow gradient terrain or at locations that appear to have been locally modified by minor excavation. However, one of these areas appears to have been formed by localised excavation and filling and corresponds to the northern end of slope No. 7SW-A/F31 (denoted as F1 in Figure A2).
1964	Good quality, low-altitude and high-altitude aerial photographs. The terrain immediately downslope from the two overflow weirs SMOF-12 & SMOF-13 appears to have been affected by continued erosion, undercutting and failure. The terrain along the northern flank of the streamcourse channel has been clearly affected by slumping of the over-steepened scarp, possibly due to the continued undercutting of the terrain by the downslope streamcourse channel. The debris from the failure is visible extending into the shallower gradient streamcourse channel immediately downslope. A second significant failure is visible affecting the terrain located between the two overflow weirs, with the failure also likely to have been caused by the continued undercutting by the downslope streamcourse channel. The debris from the failure

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YEAR	KEY OBSERVATIONS
1964 (Cond't)	can also be observed extending into the shallower gradient terrain within the downslope streamcourse depression. A recent landslide or erosion-related feature can be observed immediately upslope from the catchwater channel adjacent to overflow weir SMOF-12. Minor slumping of the southern, upper portion of slope No. 7SW-A/CR140 can be observed. Slope No. 7SW-A/CR134 appears to have been recently trimmed and modified. A squatter platform together with an area of agricultural terraces (denoted as M3 and M4 in Figure A2) has been recently constructed immediately to the west of the narrow bridge (M2). Excavated agricultural terraces are visible within the lower catchment area (M5) in the terrain immediately above the main streamcourse channel and corresponding to where slope No. 7SW-A/F38 has been subsequently constructed. The hillslope terrain upslope from these well-defined agricultural terraces has been generally modified for the construction of small scattered agricultural terraces and large graves.
1967	Good quality, low flight single aerial photograph precludes detailed stereoscopic interpretation. Area covered only includes the area south of slope No. 7SW-A/CR134. Dark lines traversing the face of slope No. 7SW-A/CR134 may possibly indicate the presence of seepage and surface water flow across the slope. Cut slope No. 7SW-A/CR132 appears to be currently under construction (M6a).
1969	Construction of the Hilltop Country Club platform and associated cut and fill slope has ceased, with unplanned vegetative growth now evident on the artificial slope faces. The areas affected by erosion and failure in 1964 generally re-vegetated, although some of the source area remains exposed and bare. An access road is under construction along the lower foothill area and extending across the main catchment streamcourse channel. The extent of the road as evident in the 1969 aerial photographs is denoted as M7 in Figure A2. A cut slope is evident along the northern side of the access road, immediately downslope from the minor dwelling platform previously identified at area M4. A culvert has been constructed to allow passage of water below the access road at the location where it traverses the streamcourse channel (M8). A minor structure (M9) has been constructed at the southern end of the narrow bridge (M2) extending across the main streamcourse channel.

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YEAR	KEY OBSERVATIONS
1969 (Cond't)	Excavation of a series of minor platforms (M10) along the lower footslope terrain immediately adjacent to the main streamcourse channel, has been undertaken. No dwellings or structures are evident on these recently formed benches.
1972	Area covered only includes the area to the south of the southern overflow weir SMOF-12. The area downslope from the catchwater affected by significant erosion in 1964, appears to have fully re-vegetated.
1973	Agricultural terraces have been constructed along the flanks of the main streamcourse channel, downslope from the catchwater (M11). A recently constructed minor dwelling platform together with an associated access pathway (M12) is visible immediately along the downslope flank of Hilltop Road. A large area of apparent fill material associated with the excavation of the platform is visible along the downslope side of the platform area (M13). A minor excavated platform and supporting retaining wall, has been constructed along the southern side of the main catchment streamcourse. The retaining wall can be observed extending out into the main streamcourse channel. Slope No. 7SW-A/CR134 appears to have been reconstructed and resurfaced.
1974	No significant changes can be observed.
1975	No significant changes can be observed. A minor dwelling (M15) appears to have been constructed at approximately the same location as that of a structure affected by the 2005 debris flood.
1976	An area of high reflectivity can be observed within the location of slope No. 7SW-A/CR115. The cause of this reflectivity cannot be determined due to the high flight height and lack of stereoscopic coverage. No other significant changes can be observed.
1977	Construction of the Hilltop Country Club is underway. The area of over-steepened terrain located along the northern flank of the main streamcourse channel downslope from the overflow weir SMOF-12 has apparently been substantially trimmed to create a wider, less steep streamcourse section. The purpose of this trimming cannot be clearly discerned but is likely to relate to expansion of the shallow gradient terrain within the immediate proximity of the streamcourse channel for extended agricultural purposes. The squatter structure (M15) can now be clearly identified.

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YEAR	KEY OBSERVATIONS
1977 (Cond't)	A squatter structure can also be observed (M16) on a recently excavated platform area (M17) immediately upslope from the narrow bridge (M2). The terrain now occupied by agricultural terraces has now extended considerably (M18). A landslide scar can now be observed in slope No. 7SW-A/CR115. Further erosion is evident in the earlier failure scars near the confluence of overflows from weir SMOF-12 and weir SMOF-13. A wide platform area has been recently constructed along the downslope side of the catchment access road at location M19. Further excavation and construction works are visible at location M20 and correspond to the formation of a platform for residential occupation (including associated cut slope construction).
1978	No significant changes can be observed.
1979	A second squatter structure (M21) can be clearly identified at approximately the same location as that of a structure affected by the 2005 debris flood. Further excavation and localised trimming appears to be underway within the area of over-steepened terrain along the northern flank of the main streamcourse, located immediately downslope from the northern overflow weir SMOF-13. The location corresponds to the northernmost section of the over-steepened terrain area previously identified within the 1954 aerial photographs. A building (M22) has been constructed within the lower section of the streamcourse channel in an area previously occupied by scattered agricultural terraces.
1980	Construction of the Hilltop Country Club has almost been completed. The northern flank of the upper section of the streamcourse located immediately downslope from the northern overflow weir SMOF-13, appears highly reflective and is assumed to be some instability. The upper section of slope No. 7SW-A/CR115 remains reflective, suggesting continued erosion of the over-steepened upper section. The area of terrain trimmed in 1977 is now occupied by a banana plantation.
1981	Slope No. 7SW-A/CR113 has been reconstructed and resurfaced. The slope surface appears highly reflective. The area of terrain downslope from weir SMOF-13 remains reflective and may be a result of the reconstruction of the weir and outlet slopes. No other significant changes can be observed.

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YEAR	KEY OBSERVATIONS
1982	Slope No. 7SW-A/CR134 has been reconstructed and resurfaced. The northern overflow weir SMOF-13 appears to have been reconstructed or modified, with the overflow section clear from any vegetative obstruction. Erosion of the streamcourse channels located downslope from both overflow weirs SMOF-12 and SMOF-13 can be observed. Further failure of the area corresponding to instability in 1964 can also be observed. The density of vegetation growth within the upper section of the main streamcourse channel has increased significantly.
1983	Continued erosion along the streamcourse channels located downslope from both overflow weirs SMOF-12 and SMOF-13 can be observed. No other significant changes can be observed.
1984	No significant changes can be observed.
1985	The hillslope terrain downslope from the catchwater has now become occupied by increased agricultural terracing. The terrain along the southern flank of the streamcourse has been cleared and appears to have been locally trimmed (M23) for probable agricultural purposes. A series of platforms (M24) have been formed within the western study area and generally correspond to the location of the carpark facility affected by the 2005 debris flood. A ramp is visible connecting the platform area to the main access road. Further minor structures have been constructed on the platform constructed in association with building M21. The platform structure (M25) can be clearly observed extending eastwards into the lower streamcourse channel area. The building structure previously observed at location M16 has been removed.
1986	No significant changes can be observed.
1987	Slope No. 7SW-A/CR114 has been reconstructed and resurfaced. The slope surface appears highly reflective. No other significant changes can be observed.
1988	No observable changes of significance.
1989	No observable changes of significance.

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YEAR	KEY OBSERVATIONS
1990	No observable changes of significance.
1991	Platform area M24 and M26 are now being utilized for car parking purposes. The alignment of the ramp leading to the platform area is consistent to the alignment of the main streamcourse channel. Slope No. 7SW-A/F38 appears to have been constructed between 1989 and 1991.
1992	No observable changes of significance.
1993	A platform has been recently constructed for a residential dwelling (M27) and the excavated materials deposited along the southern flank of the main streamcourse channel (M28).
1994	No observable changes of significance.
1995	No observable changes of significance.
1996	The terrain upslope from the catchwater has been affected by extensive hillfire that have removed all vegetation cover. No other observable changes of significance.
1997	Further failure of the terrain along the northern flank of the main streamcourse channel emerging from overflow weir SMOF-13 has been observed. The location appears to correspond to that of the landslides in 1964. The landslide trail appears highly reflective indicative of its recent occurrence.
1999	No observable changes of significance.
2000	The area previously affected by landsliding in 1997 has partially re-vegetated.
2001	No observable changes of significance.
2002	No observable changes of significance.
2003	No observable changes of significance.
2004	Area affected by recurrent landsliding remains partially bare from vegetative re-growth. Over-steepened terrain indicates that continued failure at this location is likely.

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Table A1 - List of Aerial Photographs (Sheet 1 of 2)

Date Taken	Altitude (ft)	Photograph Number
1924	11100 & 12500	Y121, Y131-32
10 November 1945	20000	Y689-91
18 November 1954	29200	Y2730-31
26 February 1963	8000	Y9121-23
31 January 1963	3900	Y9177-79
11 December 1964	2700	Y11349-51
14 December 1964	12500	Y12989-90
13 May 1967	3900	Y13485
1969	3000	Y15420-21
3 October 1972	13000	2279
20 February 1973	5000	3261-62
29 October 1973	2000	5513, 5519
20 November 1974	12500	9577-79
19 December 1975	12500	11751, 11794
29 January 1976	4000	13270
23 November 1976	12500	16520
6,12 December 1977	4000	19735-36, 20071
10 January 1978	12500	20705-06, 20730-31
3 October 1979	4000	27492
29 November 1979	10000	28169
13 November 1980	4000	32965-66
27 October 1981	10000	39183-84
27 November 1981	4000	40077
28 July 1982	3000	43126-28
10 October 1982	10000	44593-94
24 January 1983	20000	47109, 47112
1 December 1983	20000	51589-90
20 October 1984	4000	56545
2 October 1985	4000	67581-82
4 October 1985	15000	A2689-90
24 September 1986	5000	A6622
21 December 1986	10000	A8129, A8131
5 January 1987	20000	A8426
13 July 1987	4000	A9887-89
4 October 1987	4000	A10492
10 October 1988	4000	70351-52
16 January 1988	10000	A12043
3 June 1988	20000	A13437-38

Note: All aerial photographs are in black and white except for those prefixed with CN, CW or RW.

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Table A1 - List of Aerial Photographs (Sheet 2 of 2)

Date Taken	Altitude (ft)	Photograph Number
11 December 1989	4000	A20045-46
4 December 1990	20000	A24504, A24607
1 October 1991	4000	A27540-41
13 May 1992	4000	A31167
11 November 1992	10000	A33304
2 November 1993	4000	A35974-75
6 May 1994	5000	A38140-41
24 November 1995	10000	CN12369
21 December 1995	20000	CN13228
12 June 1996	4000	CN14206-07
14 November 1996	5000	CN15814
27 December 1996	10000	CN16402
29 January 1997	20000	CN16572-73
1 November 1997	10000	CN19060
3 February 1999	20000	CN22270, CN22272
8 February 1999	4000	CN22682
9 December 1999	8000	CN25102
16 February 2000	20000	CN26064-65
14 September 2000	5500	CN28065-66
15 February 2001	8000	CN29823-24
1 March 2001	20000	CN29973-74
31 May 2001	4000	CW31301
18 June 2001	7000	CW31688-89
4 July 2001	8000	CS1130
13 September 2001	4000	CW32755
25 September 2001	19000	CW34176, CW34205
20 November 2001	8000	CW35606, CW35672
18 February 2002	20000	CW38683-84
21 January 2002	16000	RW825
15 August 2002	4000	CW42607-08
9 October 2002	8000	CW44934, CW44987
25 October 2002	4000	RW1474-75
11 May 2003	4000	CW47259-60
26 November 2003	4000	CW53584
20 April 2004	4000	CW57021
5 October 2004	4000	CW60176-77, CW61061-62
Note: All aerial photographs are in black and white except for those prefixed with CN, CW or RW.		

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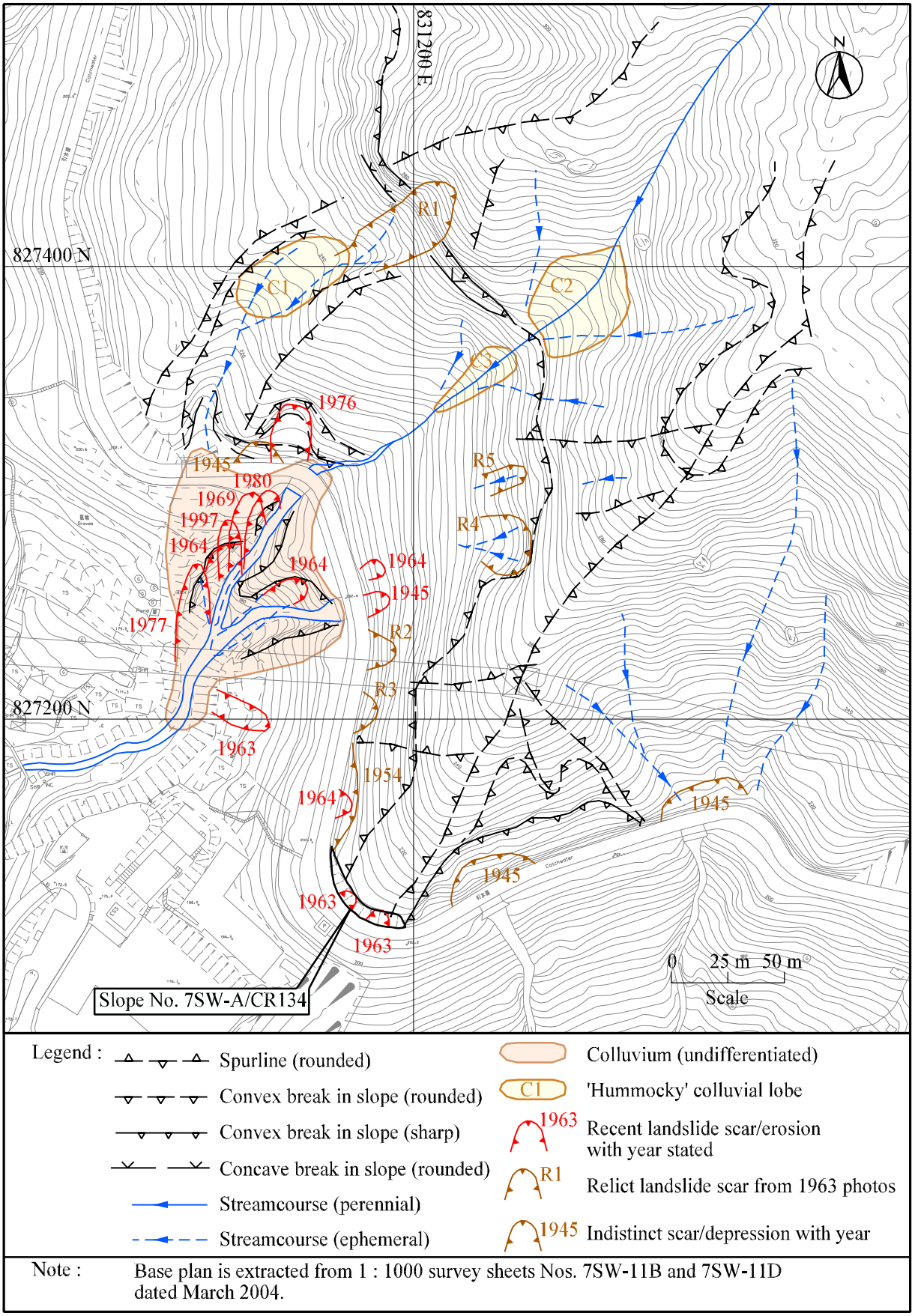

Figure A1 - Past Instabilities and Geomorphology

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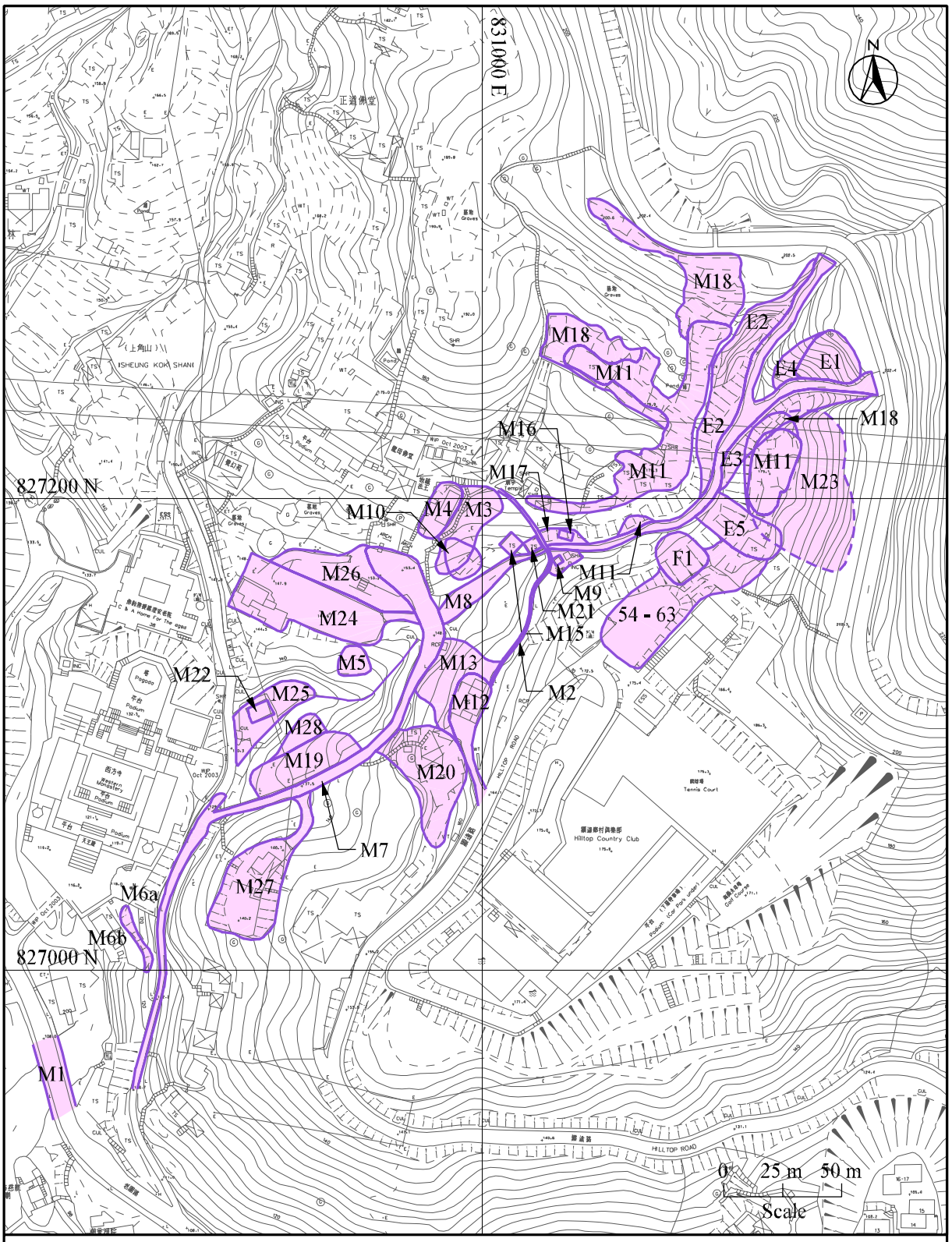

Legend : M27 Developed area No. M27 referred to the API report

54 - 63 Developed in 1954 - 1963

Note : Base plan is extracted from 1 : 1000 survey sheets Nos. 7SW-11B and 7SW-11D dated March 2004.

Figure A2 - Site Development

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

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

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GEOTECHNICAL MANUALS

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

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1	Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 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.

GEOSPECS

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

GEO PUBLICATIONS

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

GEOLOGICAL PUBLICATIONS

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

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

TECHNICAL GUIDANCE NOTES

TGN 1	Technical Guidance Documents