REVIEW OF THE 24 JUNE 2005 LANDSLIDE ON SLOPE NO. 7SW-C/CR564 TO THE NORTH OF TZE CHUK LAM FU YUNG SHAN, TSUEN WAN

GEO REPORT No. 266

Halcrow China Limited

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

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This report is largely based on GEO Landslide Study Report No. LSR 1/2009 produced in April 2009

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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 in print. These include guidance documents and results of comprehensive reviews. They can also be downloaded from the above website.

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

Y.C. Chan
Head, Geotechnical Engineering Office
May 2012

FOREWORD

This report presents the findings of a review of a landslide (Incident No. 2005/06/0181) which occurred on slope No. 7SW-C/CR564 and an adjoining sloping ground to the north of Tze Chuk Lam, Fu Yung Shan, Tsuen Wan on 24 June 2005. The incident involved the failure of an approximately 5.5 m high slope portion and a 2 m high masonry toe wall, with a total failure volume of about 100 m^3. The failed mass hit a squatter structure at the slope toe, broke two columns of the structure and piled up against the rear wall which was severely damaged. A portion of a flimsy squatter structure at the crest of the sloping ground in the western end was undermined. Both the squatter structures were evacuated as a result of the incident. No casualties were involved.

The key objectives of this review were to document the facts about the incident and to present relevant background information and pertinent site observations made under this review. The scope of the review does not include any ground investigation or detailed diagnosis of the causes of the incident. Recommendations for follow-up actions are reported separately.

This is one of a series of reports produced during the landslide investigation consultancy by Halcrow China Limited for the Geotechnical Engineering Office, Civil Engineering and Development Department, under Agreement No. CE 53/2006 (GE).

Gerry Daughton
Project Director
Halcrow China Limited

Agreement No. CE 53/2006 (GE)
Study of Landslides Occurring in Kowloon and the New Territories in 2007 – Feasibility Study

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1. INTRODUCTION

On 24 June 2005, a landslide incident (Incident No. 2005/06/0181) occurred on slope No. 7SW-C/CR564 and the adjoining sloping ground to the north of Tze Chuk Lam, Fu Yung Shan, Tsuen Wan (Figure 1). The exact time of the incident is not known, but it was reported to have occurred before 7:50 a.m., when an Amber Rainstorm Warning was in effect. The incident involved the failure of an approximately 5.5 m high slope portion and a 2 m high masonry toe wall, with a total failure volume of about 100 m^3. The failed mass hit a squatter structure at the slope toe, broke two columns of the structure and piled up against the rear wall which was severely damaged. In addition, a portion of a flimsy squatter structure at the crest of the sloping ground in the western end was undermined. Both squatter structures were evacuated as a result of the incident. No casualties were reported.

Halcrow China Limited (HCL) carried out a review of the landslide incident for the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department (CEDD) under Agreement No. CE 53/2006 (GE).

This review report documents the facts about the incident, and presents relevant background information and pertinent site observations made under this review. The scope of the review does not include any ground investigation or detailed diagnosis of the probable causes of the incident.

2. THE SITE

2.1 Site Description

The landslide occurred on slope No. 7SW-C/CR564 and the adjoining sloping ground to the north of Tze Chuk Lam, Fu Yung Shan, within the boundary of Lot 1204 in DD 453. A site plan showing the location of the landslide, together with the approximate boundary of the lot, is shown in Figure 1. A general view of the landslide is presented in Plate 1.

The sloping ground is predominantly a soil cut of about 5 m in length with a 2 m high toe wall. The slope portion has a maximum height of about 3 m and is inclined at about 50^o to the horizontal. The slope is covered with four rubble packed terraces, each about 600 mm in height. The toe wall comprises random rubbles with concrete finishing and has a face angle of about 80^o.

Slope No. 7SW-C/CR564 adjoins the sloping ground to the east and is L-shaped in plan. This slope is about 12 m long with a maximum height of about 7 m, comprising a 5 m high soil cut and a 2 m high toe wall. The soil cut portion is generally inclined at about 50^o to the horizontal. The eastern (west-facing) portion of the slope is covered with vegetation, while the western (south-facing) portion is covered with four rubble packed terraces, each about 600 mm to 800 mm in height (Plate 2). Light vegetation is growing on these terraces. The toe wall also comprises random rubbles with concrete finishing and has a face angle of about 80^o.

A single-storey squatter structure No. RTW/4A/465 is located about 1 m to 2 m from the toe of the slopes. Above the sloping ground, there is a concrete footpath of about 1.5 m to 2 m in width leading to a flimsy squatter structure at the western end of the slope crest

(Figure 2), while beyond the crest of the eastern portion of slope No. 7SW-C-CR564 is a natural hillside. There are no surface drainage provisions on, or in the vicinity of the slopes.

2.2 Geological Setting

Sheet 7 of the Hong Kong Geological Survey (HKGS) 1:20 000 scale map series HGM20 (GCO, 1986) indicates that the solid geology at the landslide site comprises crystal tuff with hornblende at the northern portion and a dyke of feldsparphyric rhyolite at the southern portion (Figure 3). Much of the solid geology is indicated as being overlain by quaternary debris flow deposits.

2.3 Maintenance Responsibility

Both slope No. 7SW-C/CR564 and its adjoining sloping ground fall entirely within Lot 1204 in DD 453 (Figure 4) and are under the maintenance responsibility of the registered lot owner.

2.4 Water-carrying Services

Based on the information provided by the utility undertakers together with field observations made after the landslide, there are no buried water-carrying services on, or above the subject slopes.

3. SITE HISTORY AND PAST SLOPE INSTABILITIES

3.1 Site History

The development history of the site has been established from a review of aerial photographs and available relevant documentary records (Figure A1). A detailed account of the aerial photograph interpretation (API) is presented in Appendix A. Salient aspects of the key observations are summarised below.

As seen from the earliest available aerial photographs taken in 1924, the Shing Mum Catchwater to the north of the 24 June 2005 landslide location had not yet been constructed. The site was part of a south-facing lightly vegetated hillside with occasional fields.

By 1945, the Shing Mun Catchwater is seen to have been built. The subject slopes are still seen to be a lightly vegetated hillside, which was truncated by two northwest to southeast trending drainage lines, about 100 m on either side of the June 2005 landslide location. Prominent areas of vegetation clearance (possibly for agricultural use) are visible above (and to the north of) the site.

By 1954, slope No. 7SW-C/CR564 were formed and a structure (possibly a single-storey building) is observed to have been constructed in front (to the south). Some building structures are identifiable about 30 m to the west of the slope.

By 1963, slope No. 7SW-C/CR564 is seen to be more defined. The slope surface appears to be predominantly bare with occasional vegetation and a toe wall is identifiable. The hillside around the location of the June 2005 landslide was moderately vegetated with what appears to be mature trees. A drainage line is identifiable about 30 m to the west of the June 2005 landslide and runs in a northwest to southeast direction. A northwest to southeast trending spur line is also evident about 50 m to the northeast of the June 2005 landslide. Boulder fields are visible on the hillside north and northwest of the landslide site. Two possible relict landslides are identifiable on the hillside about 70 m northwest of the landslide site (shown in red in Figure A2).

In the 1964 aerial photographs, vegetation clearance is visible at the eastern portion of slope No. 7SW-C/CR564 and an extension of the building structure at the slope toe had been constructed. Sizeable boulders are identifiable on the hillside to the north of the June 2005 landslide location. By 1973, a possible landslide is evident on the hillside about 50 m to the northwest of the June 2005 landslide location. The scar appears to be bare (shown in blue in Figure A2 and Plate A3).

Between 1974 and 1986, little change is observed other than a general increase in vegetation density in the area around the location of the June 2005 landslide. In the 1988 and 1991 aerial photographs, prominent areas of vegetation clearance (possibly for development) are observed about 30 m to the northwest of the 2005 landslide location. A platform is identifiable in the 1991 photographs about 10 m to the west and a path is seen to be traversing the hillside just north of the location of the June 2005 landslide (Figure A1). However, little change to the 2005 landslide site is observed.

Between 1992 and 1998, the vegetation clearance to the northwest was on going and is seen to be greater in extent. In the 1995 aerial photographs, a platform is identifiable just to the north, and in the 1998 photographs, two landslides are visible to the west of the June 2005 landslide location. Both scars were covered with hard surfacing (Figure A2 and Plate A5). Between 1999 and 2003, the vegetation clearance observed since 1991 is seen to be on going but little change to the landslide site is observed.

By 2004, both the western portion of slope No. 7SW-C/CR564 and the adjoining sloping ground are observed to have been covered with hard surfacing and possible re-profiling of the slope portions is seen to have taken place. A footpath is visible along the crest of the re-profiled slope portions. The platform, observed in the 1995 photographs, was covered with hard surfacing. The hillside just north of the June 2005 landslide location appears to have been more extensively disturbed than seen in the aerial photographs of previous years (Figure A1, Plate A5 and Plate A6). By 2005, little change to the slopes is observed and the vegetation clearance north of the site was on going. By 2006, the scar of the 24 June 2005 landslide is visible and was covered with hard surfacing (Plate A7).

3.2 Past Slope Instabilities

According to the GEO's landslide database, there are no records of any past landslides on the subject slopes, but two reported landslide incidents occurred in the vicinity of the landslide site in July 1997. These incidents are located at about 50 m to the west of the June

2005 landslide, and are shown in Figure 4. Both the landslide incidents are also observable in the 1998 aerial photographs (Section 3.1).

4. PREVIOUS ASSESSMENTS

4.1 SIFT and SIRST Studies

In March 1996, under the study entitled "Systematic Inspection of Features in the Territory" (SIFT) initiated by the GEO, slope No. 7SW-C/CR564 was designated as SIFT Class 'C1' (i.e. cut slopes that have been formed or substantially modified before 30 June 1978).

In August 1996, slope No. 7SW-C/CR564 was inspected by the GEO's consultants as part of the study entitled "Systematic Identification and Registration of Slopes in the Territory" (SIRST). According to the SIRST inspection records, 70% of the slope surface was covered by vegetation and the rest of the surface was bare. The surface condition was assessed as being "fair". Partially blocked weepholes on the rubble toe wall and no surface drainage provisions were noted during the inspection. The consequence-to-life category of the slope was assessed to be "1" and the corresponding CNPCS score was 9.59.

4.2 Stage 1 Study by GEO

In August 1996, a Stage 1 Study of slope No. 7SW-C/CR564 was carried out by the Mainland West Division of the GEO. According to the study report, neither signs of seepage, nor signs of distress were reported; however, an Engineer Inspection of the slope was recommended.

4.3 Non Development Clearance (NDC) Recommended by GEO

In October 1993, slope No. 7SW-C/CR564 was assessed by the GEO to be "especially vulnerable to landslips in times of heavy rainfall" under the 1992 NDC Re-inspection of squatter structures in Fu Yung Shan, Tsuen Wan, and the registered squatter structure (No. RTW/4A/465) at the slope toe was considered to be "liable to become dangerous as a result of landslips in times of heavy rainfall". A Closure Order of the squatter structure, among three others (i.e. Nos. RTW/4A/471, RTW/4A/479 and RTW/4A/494 as shown in Figure 4) within the lot, was recommended by the GEO to the Buildings Department (BD). The Closure Order was issued by the District Court on 14 April 1994.

Despite the issue of the Closure Order, the occupiers of the squatter structures strongly insisted to stay in the property. On 22 January 1996, a Dangerous Hillside (DH) Order No. DH 5/NT/96/C was served by the BD on the registered owner of Lot 1204 in DD 453 for the repair and maintenance of six slopes and walls, including slope No. 7SW-C/CR564. The registered owner was ordered to carry out an investigation and submit to the BD any necessary design for remedial works for the slopes on or before 22 May 1996 for approval. The DH Order became in default after 22 May 1996.

4.4 Geotechnical Design Submission

In October 1999, the defaulted investigation and design of stabilization works, as well as site monitoring of the condition of the slopes, as required by the DH Order were assigned to Greg Wong & Associates Ltd (GWAL) by the BD under Agreement No. CE 62/95. In July 2000, GWAL submitted a geotechnical report entitled "Proposed Stabilization Works for Fu Yung Shan Phase 1" to the BD for approval. This submission covered four slopes, wholly or partly within the lot, and was approved by the BD in September 2000.

On 12 December 2000, GWAL submitted to the BD another geotechnical report (GWAL, 2000) entitled "Proposed Stabilization Works for Fu Yung Shan Phase 2", covering two other slopes wholly within the lot, including slope No. 7SW-C/CR564 which was referred to as "Feature D". According to the report, site-specific ground investigation comprising three trial pits was carried out at slope No. 7SW-C/CR564. The ground investigation revealed that the cut slope comprised completely decomposed coarse ash tuff, overlain by colluvium. The profile of the slope was represented by two cross-sections (Section 1-1 and Section 2-2). Section 1-1 cut through the location of the 24 June 2005 landslide (Figure 5) and was shown as a 40^{o} to 48^{o} cutting in colluvium with a 1.5 m high toe wall.

In the geotechnical design, the proposed minimum required factor of safety (FoS) was 1.4. In the stability analysis of Section 1-1, the assumed ground model consisted of colluvium with the 1.5 m high toe wall treated as slope surfacing. Shear strength parameters of $c' = 4$ kPa and $\phi' = 34^{o}$ were adopted for colluvium. A groundwater level at about one third of the slope height was assumed in the stability analysis.

The results of the stability analysis indicated that in order to achieve the minimum FoS of 1.4, three rows of 10 m long soil nails (at horizontal spacing of 1.5 m and vertical spacing of 2 m) were required. Both the slope and the toe wall were proposed to be covered with reinforced sprayed concrete with weepholes. The GEO did not have any adverse comments on the design submission, and on 9 February 2001, the BD approved the proposed works subject to the provision of Category III qualified site supervision.

Between November 2000 and March 2003, the registered lot owner's solicitor made several requests to the BD to withhold the commencement of the approved stabilization works to the slopes within the lot, on the ground that the registered owner had started legal proceedings against the occupants of the squatter structures for recovery of the ownership. After seeking technical advice from both GWAL and the GEO, the BD withheld the commencement of the works until the end of December 2003, subject to the condition that "there should be no unforeseen deterioration in the condition of the slopes in the interim, e.g. due to exceptionally severe rainstorms or human interference".

In December 2003, the registered lot owner's solicitor further requested the BD to continue withholding the approved slope stabilization works until the end of March 2004. In consideration of this request, the BD required the registered lot owner to undertake site monitoring of the slopes on the lot and to appoint an Authorized Person (AP) to carry out the site monitoring in the period of extension. However, up to the time of the 24 June 2005 landslide, an AP had not been appointed by the lot owner. The site was monitored by GWAL during this period.

4.5 Observations during Site Inspections

In late December 2003, the Housing Department (HD) noted unauthorized slope excavation and retaining wall construction at the location of the 24 June 2005 landslide during a routine patrol of the squatters, and commented that "the activities might result in potentially dangerous slope and threatening the safety of residents nearby". The unauthorized site activities noted by the HD were subsequently referred to GWAL in February 2004, via GEO and BD.

In early March 2004, GWAL inspected the site, including slope No. 7SW-C/CR564. It was observed that concrete surfacing had been applied to slope No. 7SW-C/CR564, and a rubble facing retaining wall and the soil portion of the adjoining sloping ground (Figure 4 and Plate 2). Some minor site formation works, including hard surfacing and slope re-profiling, had taken place at two other unregistered slopes to the northwest of the location of the 24 June 2005 landslide (Figure 4). According to GWAL, the above works were carried out probably between December 2003 and January 2004 by an occupant of the squatter structures on the lot. Following the inspection, GWAL recommended that weepholes be provided for the newly applied concrete surfacing of slope No. 7SW-C/CR564 and the adjoining sloping ground, as well as provision of proper surface protection and conducting an investigation for the above two unregistered slopes. However, there is no record available to indicate that the recommended works had been completed. According to the file records of the BD, GWAL continued to undertake site monitoring until December 2004.

5. THE 24 JUNE 2005 LANDSLIDE AND POST-FAILURE OBSERVATIONS

5.1 Description of the Incident

According to the incident report prepared by the GEO, the landslide occurred on slope No. 7SW-C/CR564 and its adjoining sloping ground to the north of Tze Chuk Lam, Fu Yung Shan, Tsuen Wan on 24 June 2005 before 7:50 a.m., when an Amber Rainstorm Warning was in effect. The incident was reported by the Fire Services Department to the GEO at 11:20 a.m. on 24 June 2005. The exact time of the incident is not known. The incident involved the failure of an approximately 5.5 m high slope portion and a 2 m high masonry toe wall, with a total failure volume of about 100 m^3. The failed mass hit a squatter structure at the slope toe, broke two columns of the structure and piled up against the rear wall which was severely damaged. A portion of a flimsy squatter structure at the crest of the sloping ground in the western end was undermined. No casualties were reported as a result of the incident.

Urgent repair works, comprising trimming of the failure surface and provision of hard surface protection with weepholes, had been implemented to remove the immediate and obvious danger. In mid July 2005, the two squatter structures affected by the landslide were permanently evacuated at the recommendation of the GEO.

5.2 Post-failure Observations of the Landslide Site by MGSL

Maunsell Geotechnical Services Limited (MGSL), the Landslide Investigation Consultants for Kowloon and the New Territories for the GEO under Agreement

No. CE 15/2004 (GE), first inspected the landslide site on 29 June 2005 at about 3:00 p.m. Key observations made by MGSL are presented below and in Figure 6.

The debris from the landslide scar of about 18.6 m (W) by 13.4 m (L) by 2.3 m (D) hit the squatter structure at about 2 m from the slope toe, broke two columns of the structure and piled up against the rear wall with a corresponding travel angle of about 35^{o} (Figure 7 and Plate 3). The debris was observed to be largely saturated and comprised loose, yellowish brown, slightly silty, fine to coarse sand with many angular to sub-angular fine to coarse gravel, cobble and some boulder sized rock fragments, fragments of concrete surfacing and sections of the collapsed masonry wall (Plate 1 and Plate 4). The debris buried the toe portion of the masonry wall and the basal surface of rupture could not be determined on site. It was inferred that the surface of rupture was possibly along the interface of fill and underlying colluvium/in-situ soil (Figure 7).

The main scarp of the landslide was about 2 m high and was inclined at about 60^{o} to the horizontal below a concrete footpath along the crest of the landslide site (Plate 5). Part of the concrete footpath collapsed and a 'smooth' surface was observed at the remaining concrete above the scarp (Plate 6). This 'smooth' surface appeared to be a joint of the concrete footpath. The materials exposed at the scarp comprised mostly fill and localised colluvium (Plate 6). The fill had been placed onto the slope crest for the construction of the footpath, as observed in the 2004 aerial photographs, on which no surface drainage provisions could be observed. The pre-existing ground profile of the landslide site was inferred at about 50^{o} with reference to the previous topographical survey records (Figure 5 and Plate 2). Broken pieces of concrete surfacing were observed below the main scarp, suggesting the original slope surface had been covered with concrete. There were no weepholes identified on the broken pieces of the surfacing (Plates 3, 5 and 8). The remaining portion of the masonry toe wall was observed to be about 1.7 m to 2 m high and less than 0.5 m thick. Concrete finishing was observed to have detached from the wall surface and no weepholes were seen (Plate 7). Two rows of rubble packed terraces (each about 600 mm high) were observed to have displaced above the failed toe wall (Plate 8). These terraces were probably constructed between December 2003 and January 2004 (Section 4.5).

As a result of the displacement of the failed groundmass, a portion of a flimsy squatter structure at the western end of the backscarp had been undermined, and construction waste comprising broken bricks, rock fragments and pieces of plastic bags, was observed at the underside of the structure (Plate 10). At the toe of the landslide, the rear wall of the squatter structure was severely damaged, two columns of the wall were broken and steel window frames were distorted (Plate 3).

5.3 Inspection of the Landslide Site by HCL

HCL inspected the landslide site on 3 December 2007 and in late 2008. At the time of inspection, slope No. 7SW-C/CR564 and the adjoining sloping ground were covered with sprayed concrete with weepholes at about 1.5 m centres. It appeared that the sprayed concrete was applied as an urgent repair measure to the 24 June 2005 landslide (Plate 11 and Plate 12). Based on the field measurements, there have not been any significant changes to the ground profile of the slopes since the 24 June 2005 incident (Plates 1 & 11 and Plates 4 & 12), except for the slope toe, where a more gentle profile was observed (probably resulting

from the removal of the collapsed toe wall). The collapsed rear wall of the squatter structure at the slope toe was also observed to have been removed and replaced with a canopy comprising steel corrugated cladding supported by steel tubular vertical posts (Plate 13). During the inspections, no signs of seepage or distress were observed on the slopes.

6. ANALYSIS OF RAINFALL RECORDS

Rainfall data were obtained from the nearest the GEO automatic raingauge (No. N38), which is located at Po Leung Kuk Lee Shing Pik College, about 1.3 km to the west of the landslide site (Figure 1). This 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 landslide incident report prepared by the GEO, the landslide incident occurred on 24 June 2005 before 7:50 a.m., when an Amber Rainstorm Warning was in effect.

The daily rainfall for the 31-day period before the incident and the hourly rainfall between 23 and 24 June 2005 are presented in Figure 8. The records show that 89 mm of rainfall was recorded on 23 June 2005, the day before the incident. On the day of the incident, the record of the hourly rainfall shows that a total of 137.5 mm of rainfall was recorded from midnight to 7:50 a.m.

The return period for the rainfall recorded at raingauge No. N38 preceding the landslide was estimated based on historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994). The maximum rolling rainfall for various durations was derived and is given in Table 1. The result shows that the 15-day rolling rainfall of 806 mm before the incident was the most severe, with a corresponding return period of 16 years, whilst for the other rainfall durations, the return periods range from 2 years to 12 years.

The return periods were also assessed based on the statistical parameters derived by Evans & Yu (2001) for rainfall data recorded by raingauge No. N38. It is noted that the estimated return periods of the 24 June 2005 rainstorm based on rainfall data at raingauge No. N38 are generally similar to those estimated by the historical rainfall data at the Hong Kong Observatory, except for the rainfall durations of 1 hour, 15 days and 31 days.

A comparison of the maximum rolling rainfall of the 24 June 2005 rainstorm with those of the past major rainstorms between 2000 and 2004 recorded by raingauge No. N38 since November 1999, when it became operational, is presented in Figure 9. The maximum rolling rainfall of the 24 June 2005 rainstorm is the most severe rainstorm recorded since 2000 for rainfall durations of more than 12 hours and less than 15 days.

7. DISCUSSION

The 24 June 2005 incident involved the failure of slope No. 7SW-C/CR564 and the adjoining sloping ground. The incident occurred during prolonged and heavy rainfall with a return period of 16 years. The close correlation between the heavy rainfall and the time of the landslide suggests that the failure was rain-induced.

Previous assessments by GWAL in 2000 indicated that slope No. 7SW-C/CR564 was

substandard and slope upgrading works were necessary to ensure its stability. The stability condition of slope No. 7SW-C/CR564 and the adjoining sloping ground was exacerbated by the unauthorized works carried out in late 2003 to early 2004. These unauthorized works, comprising the construction of a series of rubble packed terraces and placement of fill materials overlying the slope and adjoining ground at an angle of about 60° to the horizontal, were not constructed to the required safety standards. This was probably a key contributory factor to the failure as evidenced by the landslide which mainly involved the newly placed fill materials.

The landslide was probably triggered by water ingress during heavy rainfall through direct infiltration and subsurface seepage, resulting in the build-up of transient groundwater pressure within the soil mass. Rainfall analyses suggest that the medium-term rainfall (i.e. between 12 hours and 15 days) preceding the 2005 landslide was the most severe, as compared to the previous rainstorms since 2000. In addition, the surface of the unauthorized fill materials, as well as the rubble packed terraces, was covered by hard surfacing without weepholes. This impermeable layer might have prevented the dissipation of water pressure within the soil mass.

8. REFERENCES

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LIST OF TABLES

Table 1 - Maximum Rolling Rainfall at GEO Raingauge No. N38 for Selected Durations preceding the Landslide on 24 June 2005 and Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period (Hours) (see Note 4)	Estimated Return Period (Years) (see Note 3)	
			A	B
5 minutes	12.5	06:30 hours on 24 June 2005	<2	3
15 minutes	31.0	06:35 hours on 24 June 2005	3	3
1 hour	81.5	06:45 hours on 24 June 2005	9	4
2 hours	95.5	07:00 hours on 24 June 2005	<3	<3
4 hours	116.0	07:45 hours on 24 June 2005	2	<3
12 hours	137.5	07:50 hours on 24 June 2005	<2	<2
24 hours	191.5	07:40 hours on 24 June 2005	<2	<2
2 days	264.0	07:50 hours on 24 June 2005	2	2
4 days	455.5	07:50 hours on 24 June 2005	6	5
7 days	584.0	07:50 hours on 24 June 2005	10	10
15 days	806.0	07:50 hours on 24 June 2005	16	9
31 days	975.5	07:40 hours on 24 June 2005	12	5

Notes:

(1) Maximum rolling rainfall was calculated from 5-minute rainfall data.

(2) The nearest GEO raingauge to the landslide site is raingauge No. N38 located at Po Leung Kuk Lee Shing Pik College, about 1.3 km to the west of the landslide site.

(3) Return periods were derived from Table 3 of Lam & Leung (1994) (Column A refers) and using data of raingauge No. N38 from Evans & Yu (2001) (Column B refers).

(4) For the purpose of rainfall analysis, the landslide was assumed to occur at 07:50 hours on 24 June 2005 when the Amber Rainstorm Warning was in effect.

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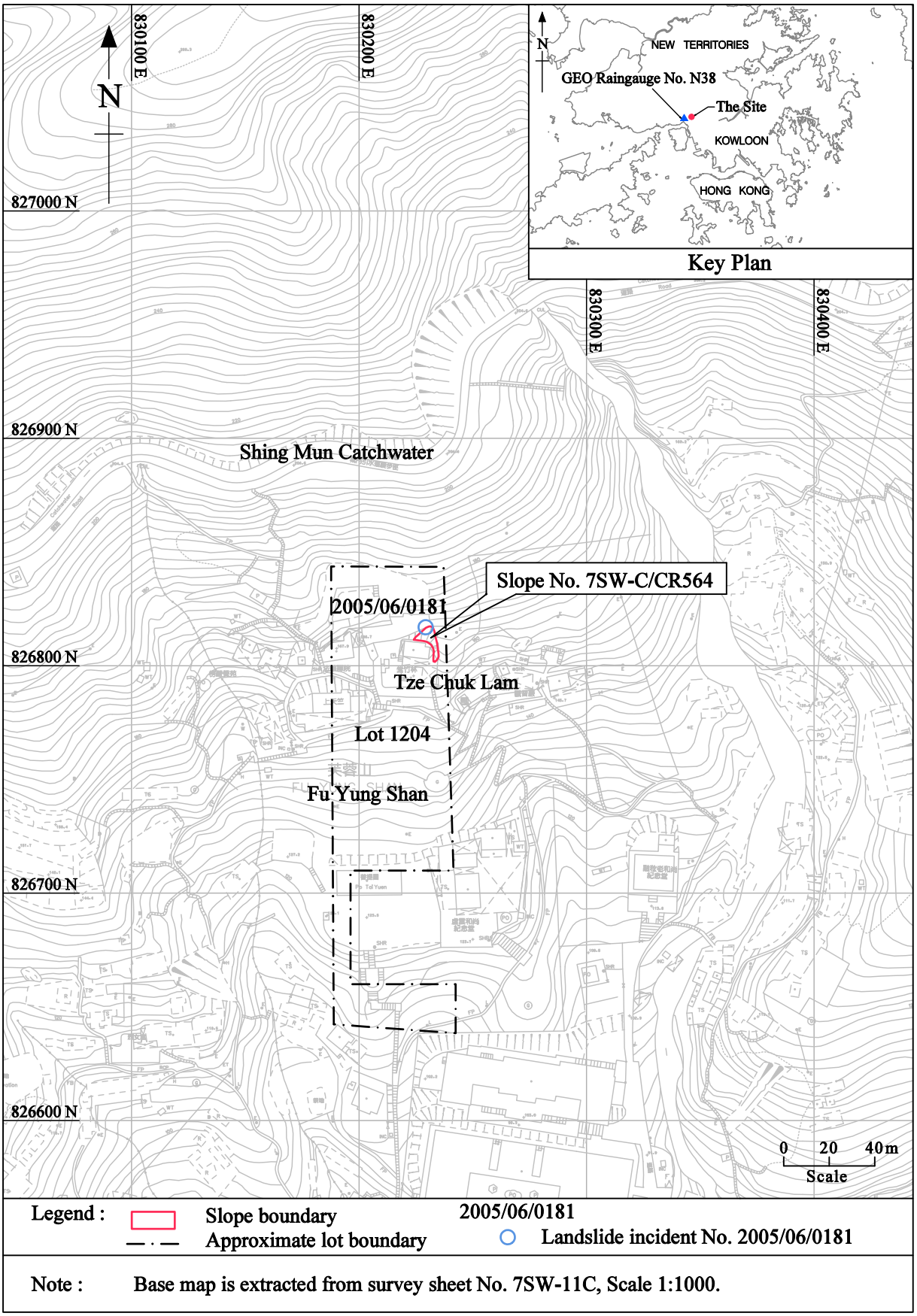

Figure 1 - Location Plan

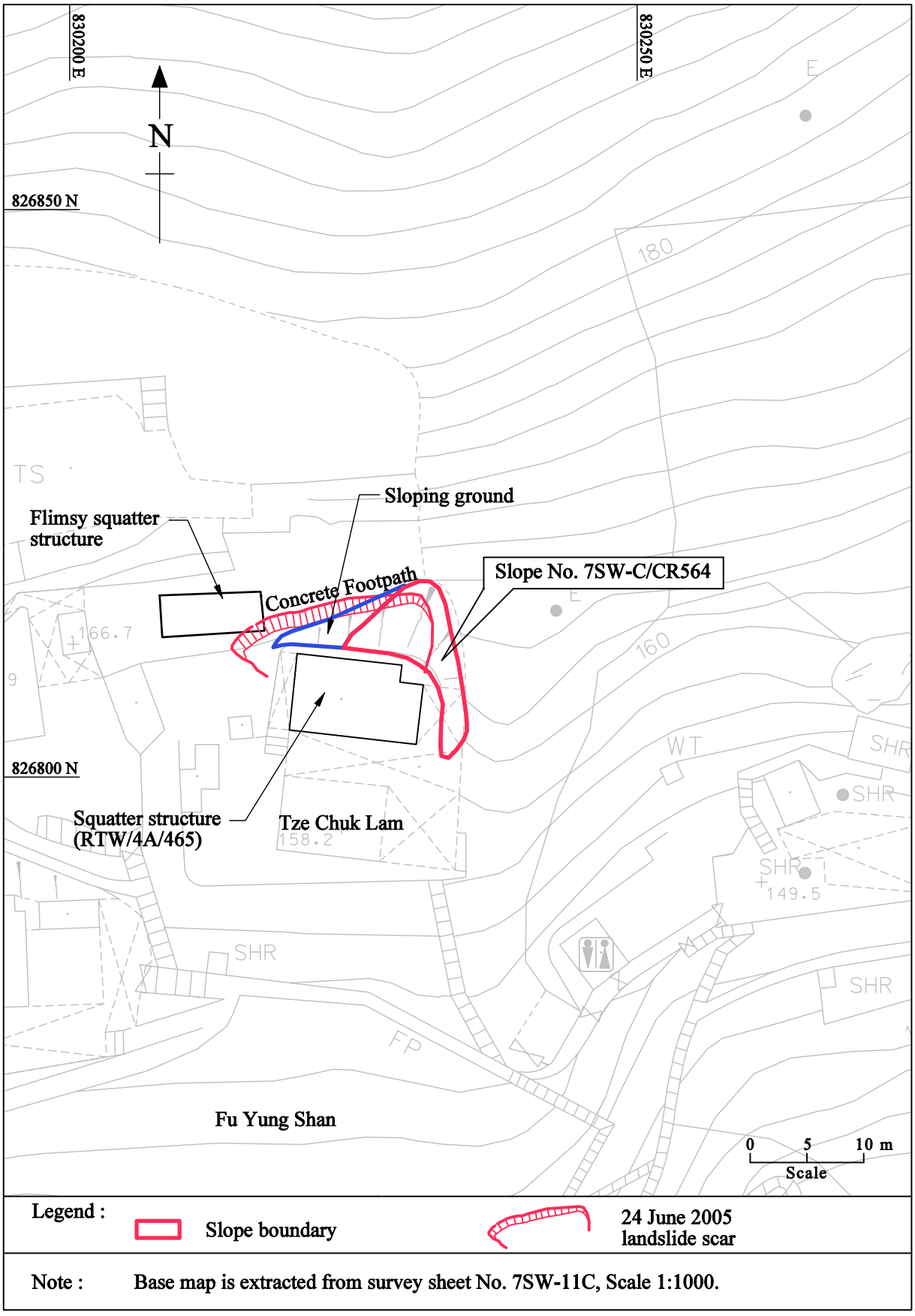

Figure 2 - Site Layout Plan

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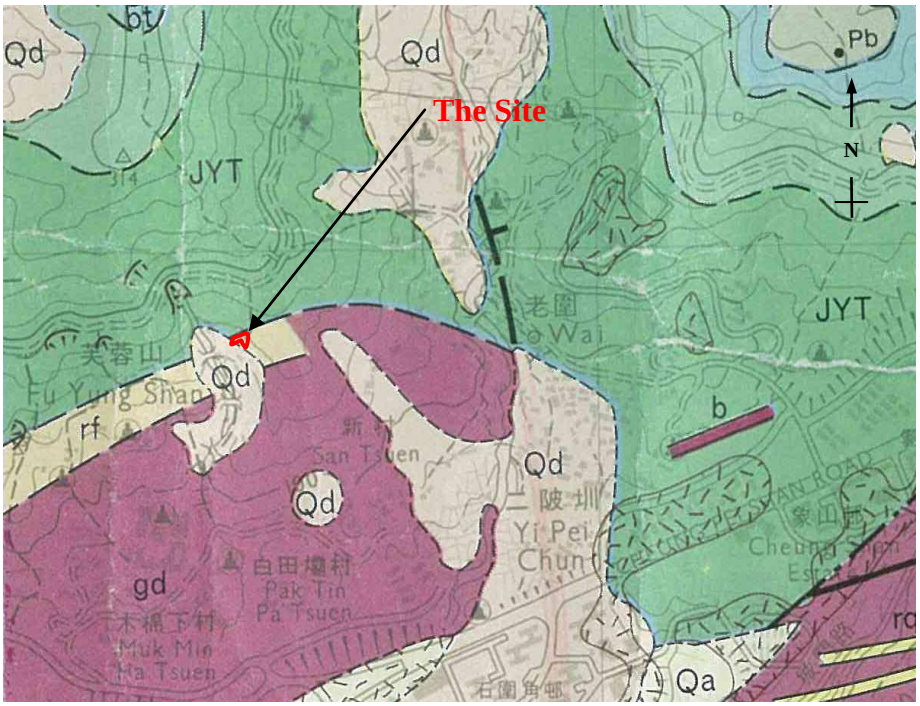


LEGEND:

SUPERFICIAL DEPOSITS

Qa	Alluvium	Qd	Debris flow deposits
Qms	Marine sand		Fill

SOLID GEOLOGY

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

GEOLOGICAL LINES

- Geological boundary, superficial deposit
- Geological boundary, solid rock (* Broken line denote uncertainty)
- Fault (* Broken line denote uncertainty)
- Photogeological lineament

MINERAL OCCURRENCE

- Pb Galena

MINERAL, FOSSIL AND MISCELLANEOUS SYMBOLS

- Landslide backscar; scarp of terraced Quaternary deposits

Note : Extracted from Hong Kong Geological Survey Map Series HGM20, Sheet No. 7, 1:20,000 scale (GCO, 1986)

Figure 3 - Regional Geology

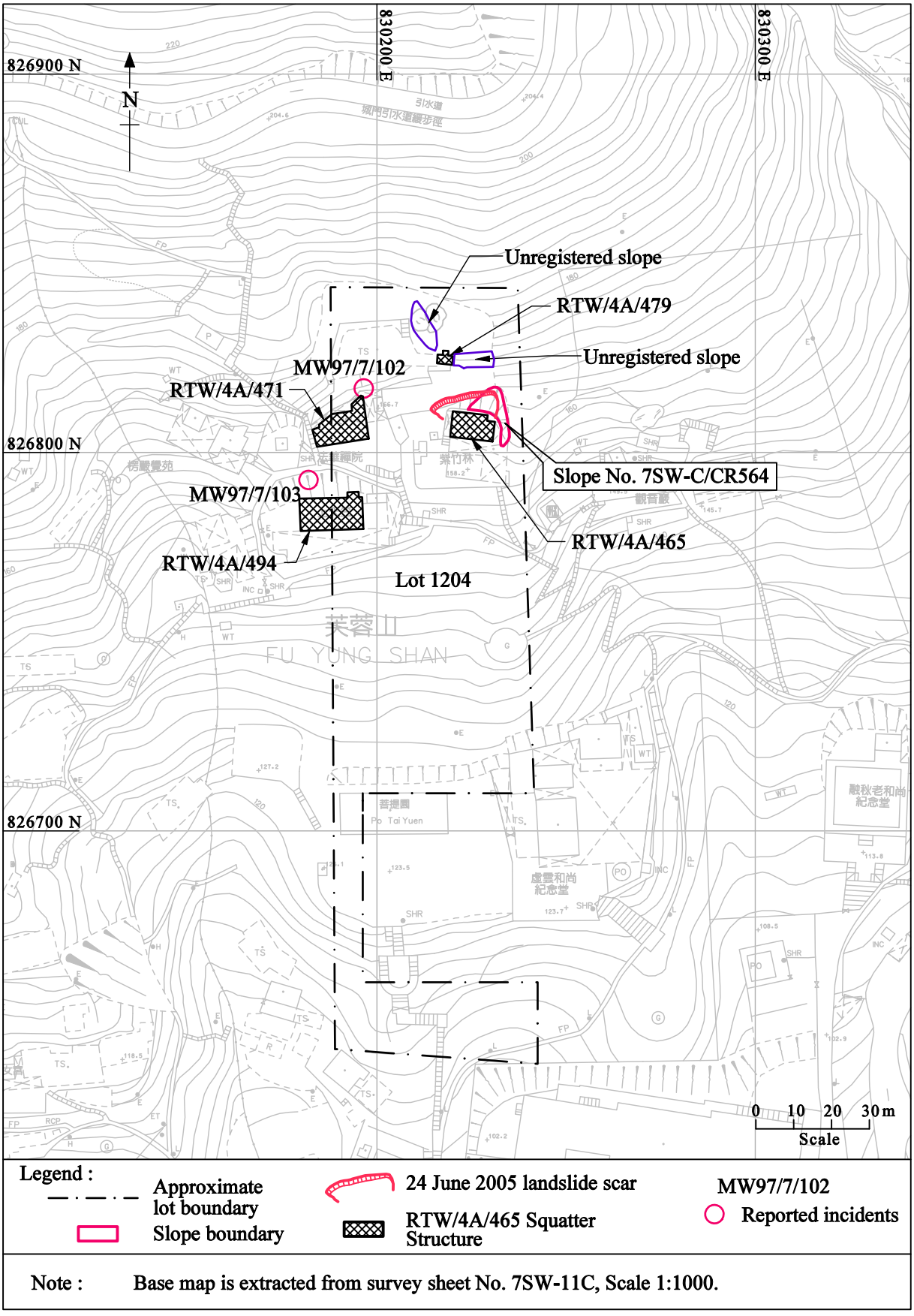
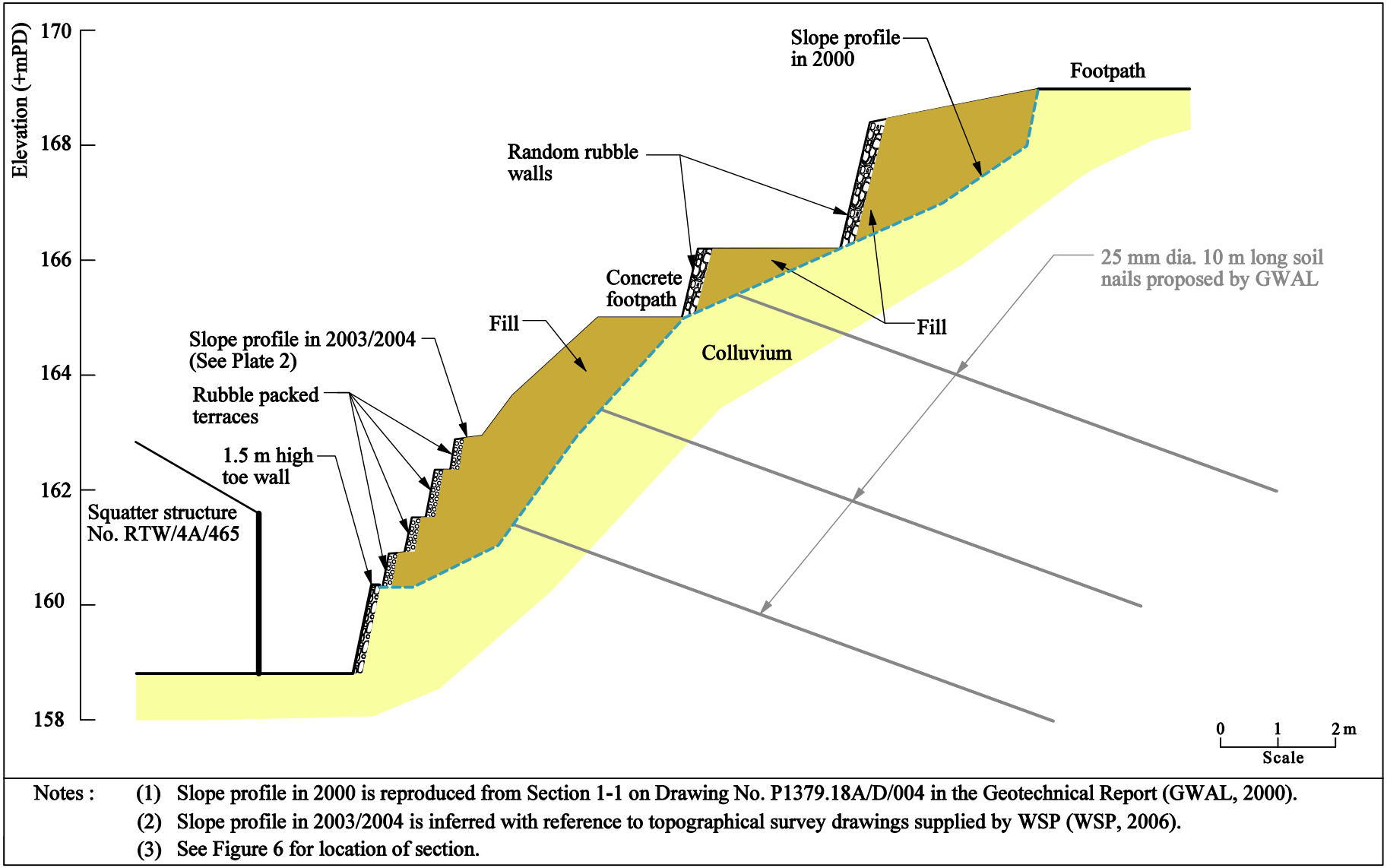


Figure 4 - Past Instabilities



Notes :
(1) Slope profile in 2000 is reproduced from Section 1-1 on Drawing No. P1379.18A/D/004 in the Geotechnical Report (GWAL, 2000).
(2) Slope profile in 2003/2004 is inferred with reference to topographical survey drawings supplied by WSP (WSP, 2006).
(3) See Figure 6 for location of section.

Figure 5 - Section A-A through Slope No. 7SW-C/CR564 prior the June 2005 Landslide

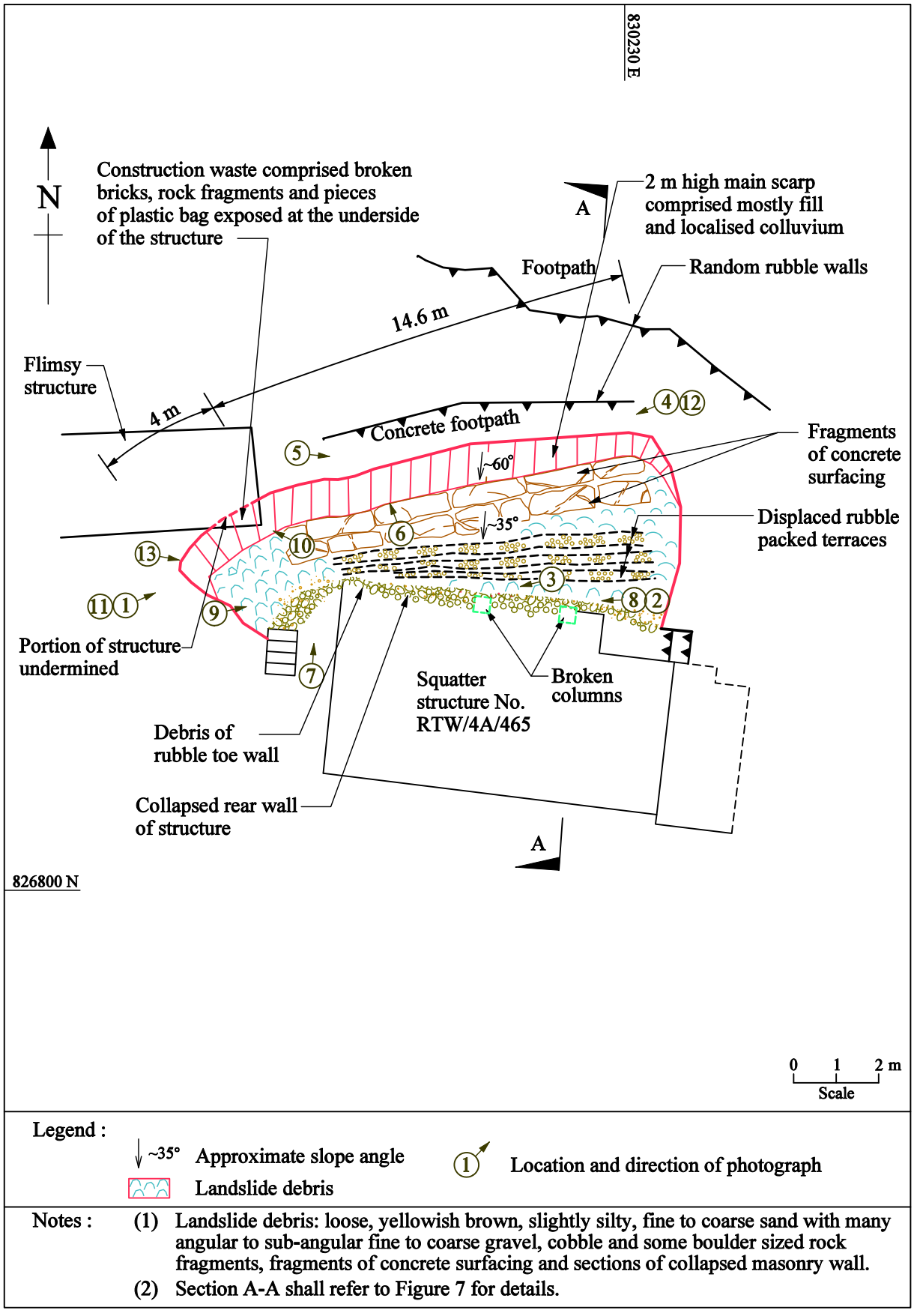
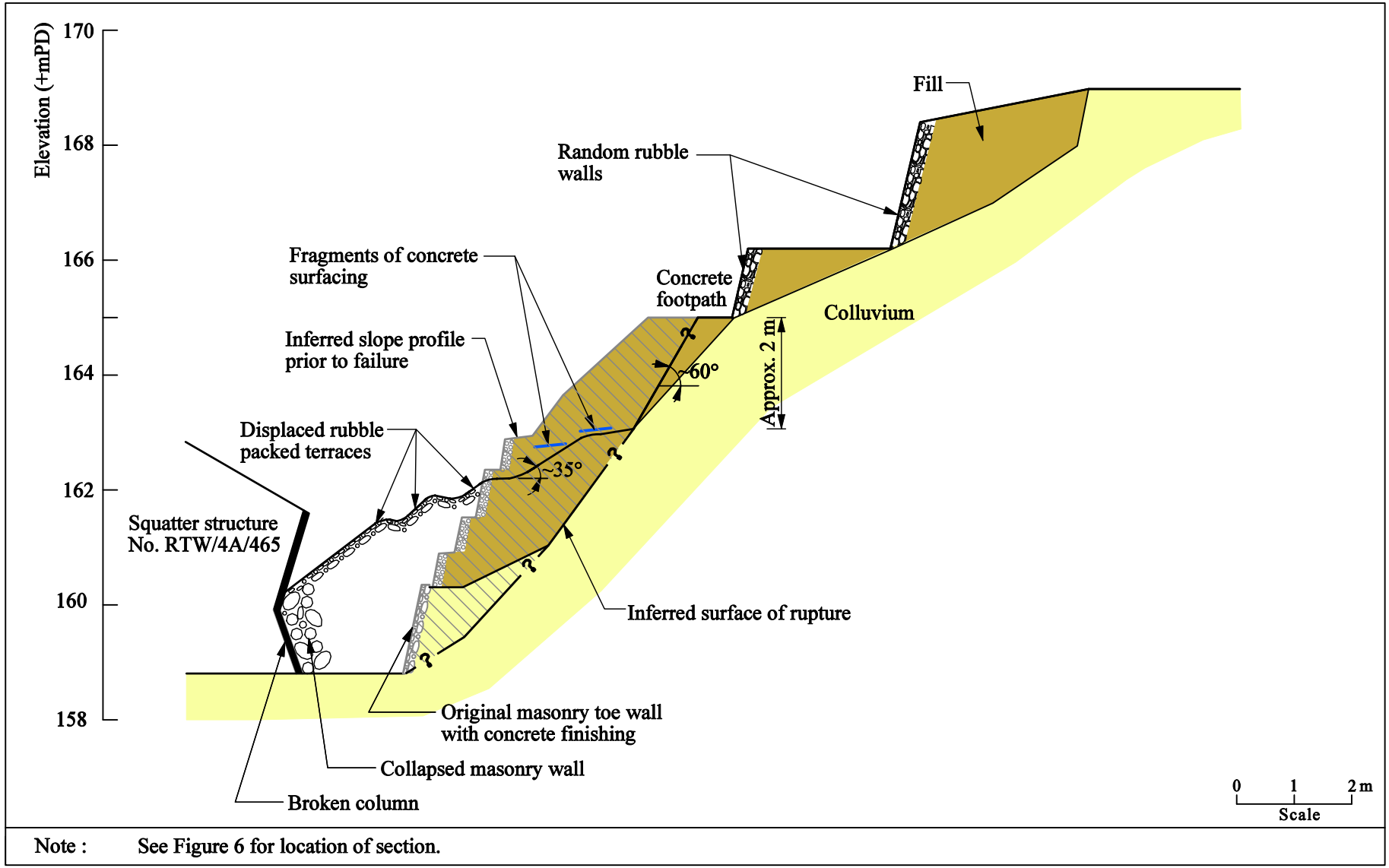


Figure 6 - Plan of the 24 June 2005 Landslide Site



Note : See Figure 6 for location of section.

Figure 7 - Section A - A through the Landslide Site

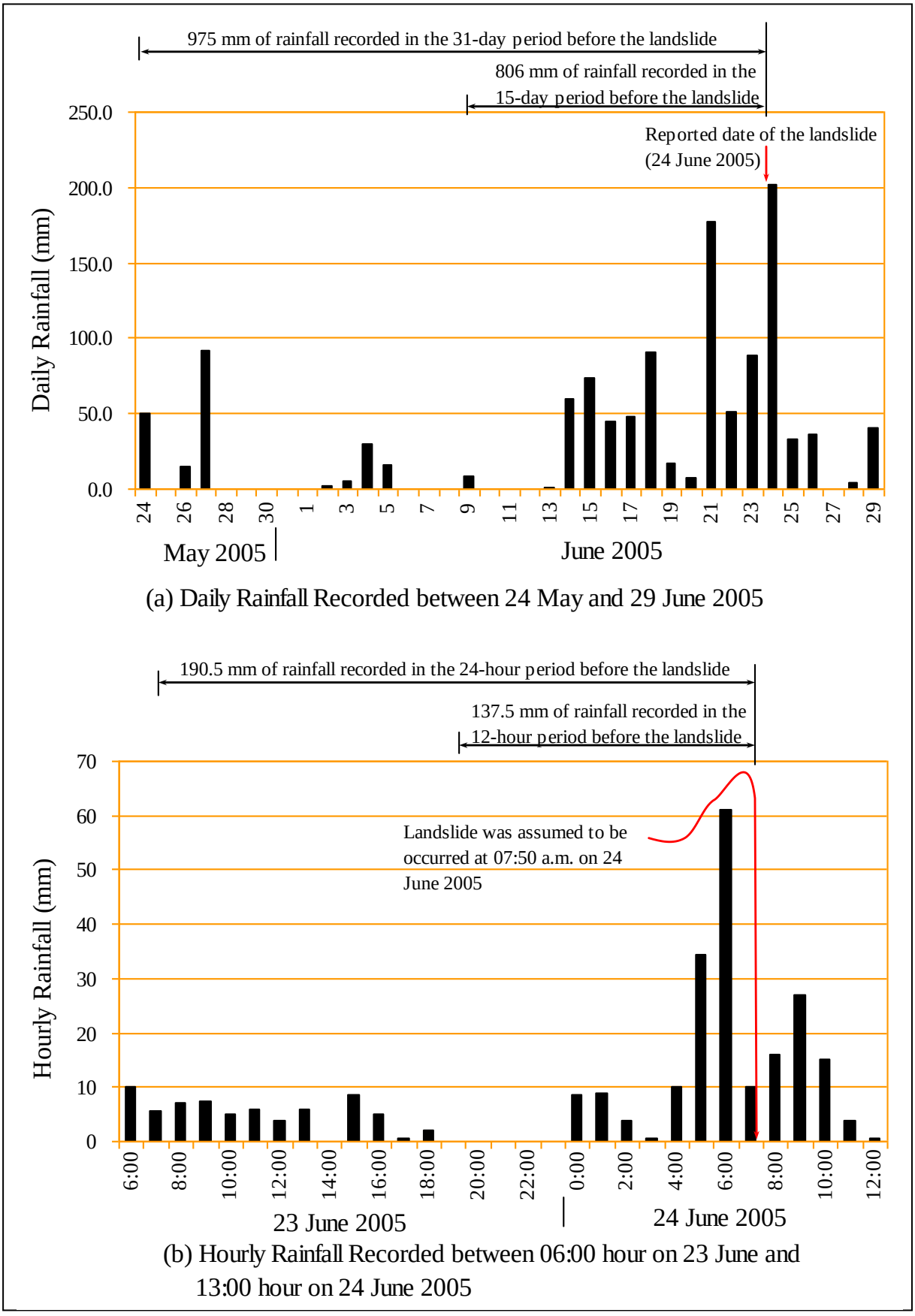


Figure 8 - Daily and Hourly Rainfall Recorded at GEO Raingauge No. N38

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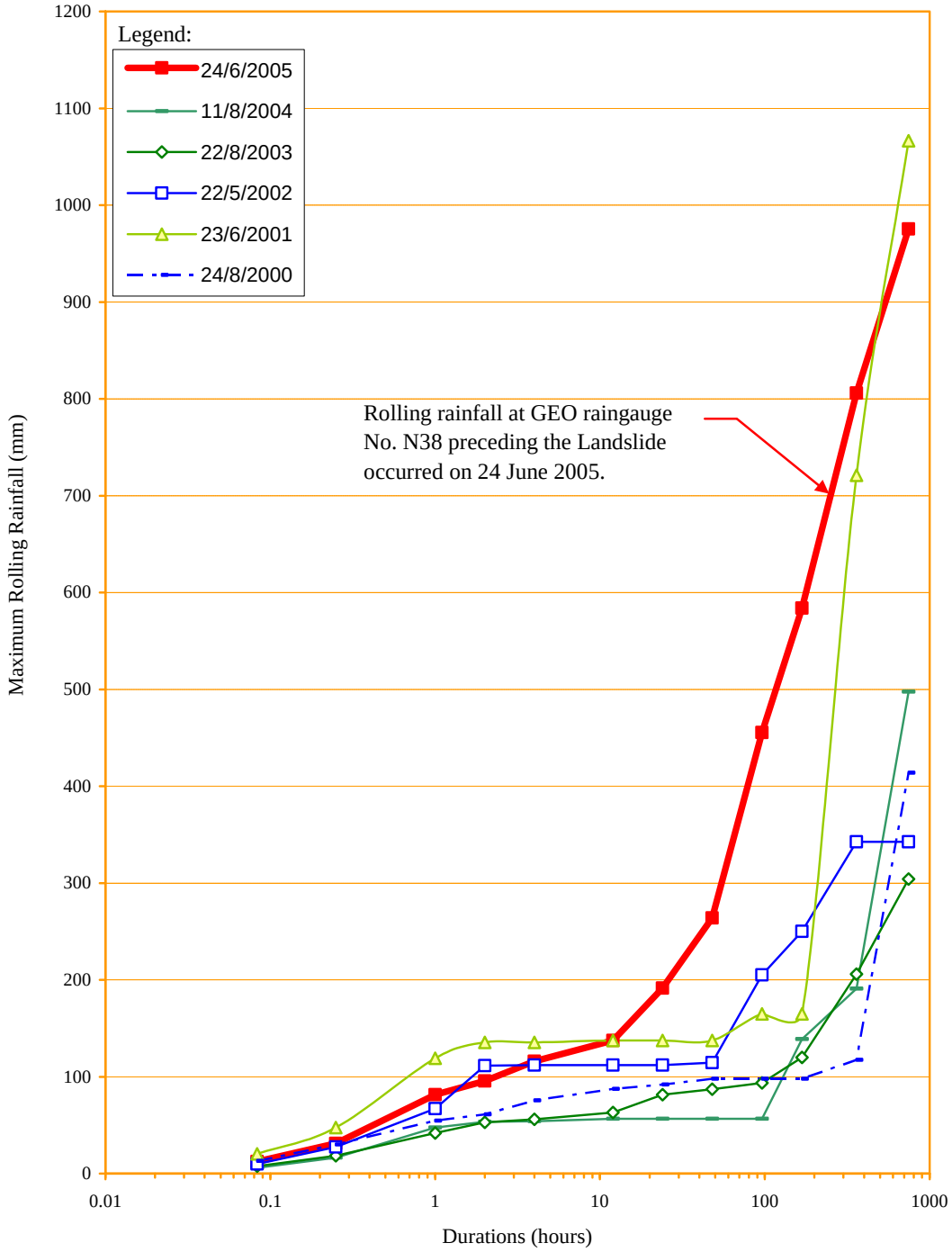

Notes:
(1) Rainfall data are 5-minute statistics from GEO raingauge No. N38 (about 1.3 km to the west of the site).
(2) Rolling rainfall of previous rainstorms calculated at GEO raingauge No. N38 since November 1999 when the raingauge became operational.

Figure 9 - Maximum Rolling Rainfall for Previous Major Rainstorms at GEO Raingauge No. N38 between 2000 and 2004

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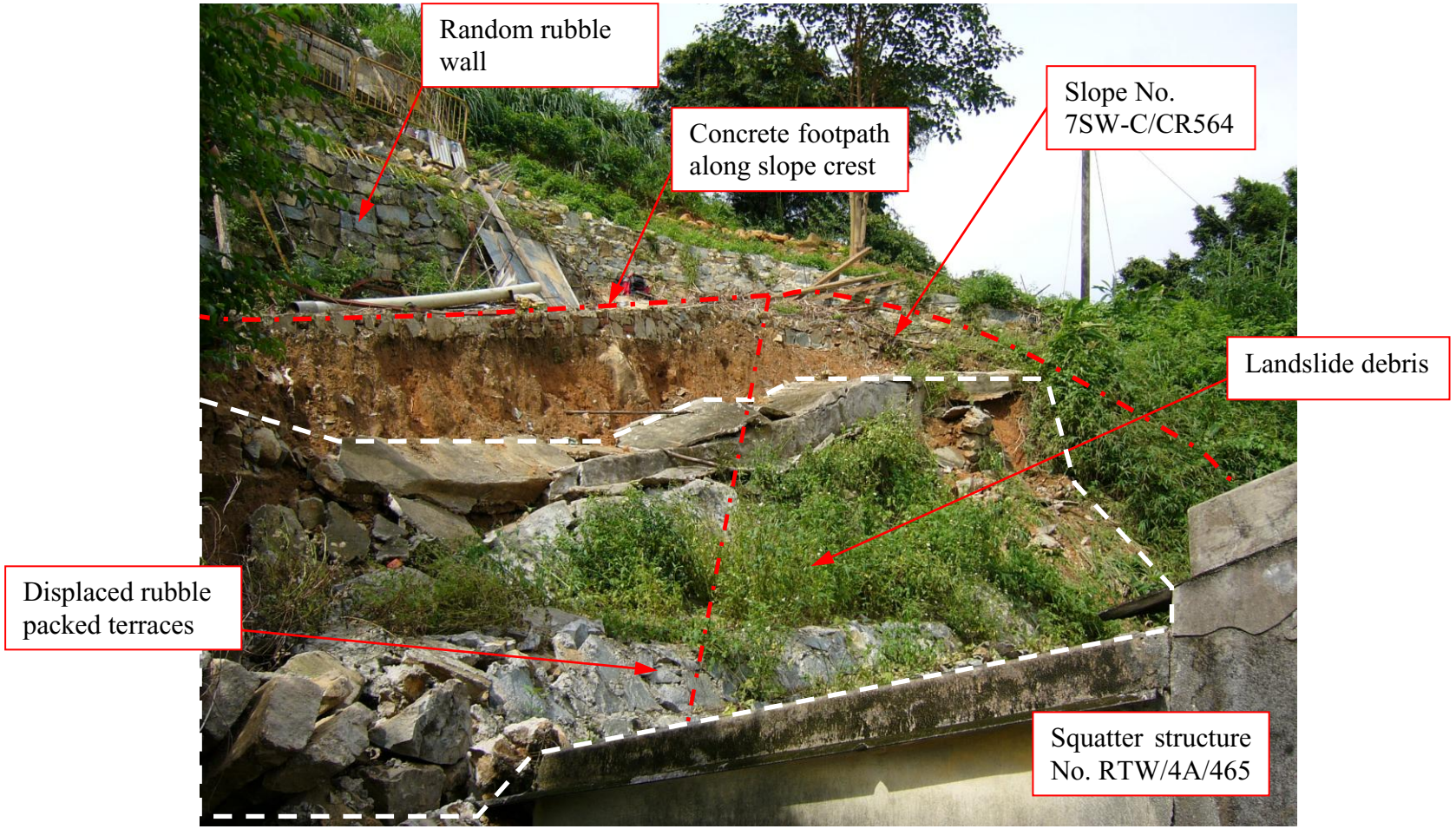

Plate 1 - General View of the Landslide from Slope Toe
(Photograph taken on 29 June 2005 by MGSL)

Note : See Figure 6 for location and direction of photograph.

Plate 2 - General View of Slope No. 7SW-C/CR564 in 2004
(Photograph taken in early March 2004 by GWAL)

Note : See Figure 6 for location and direction of photograph.

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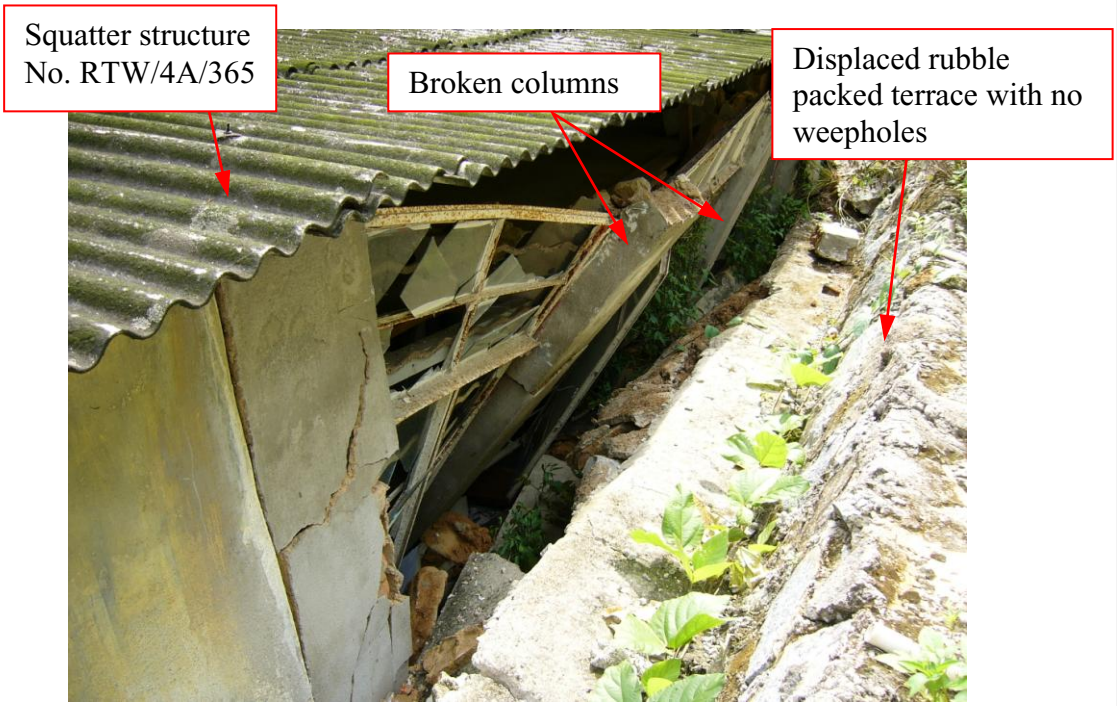

Plate 3 - Debris Piled Up against Rear Wall of Squatter Structure at Toe
(Photograph taken on 29 June 2005 by MGSL)

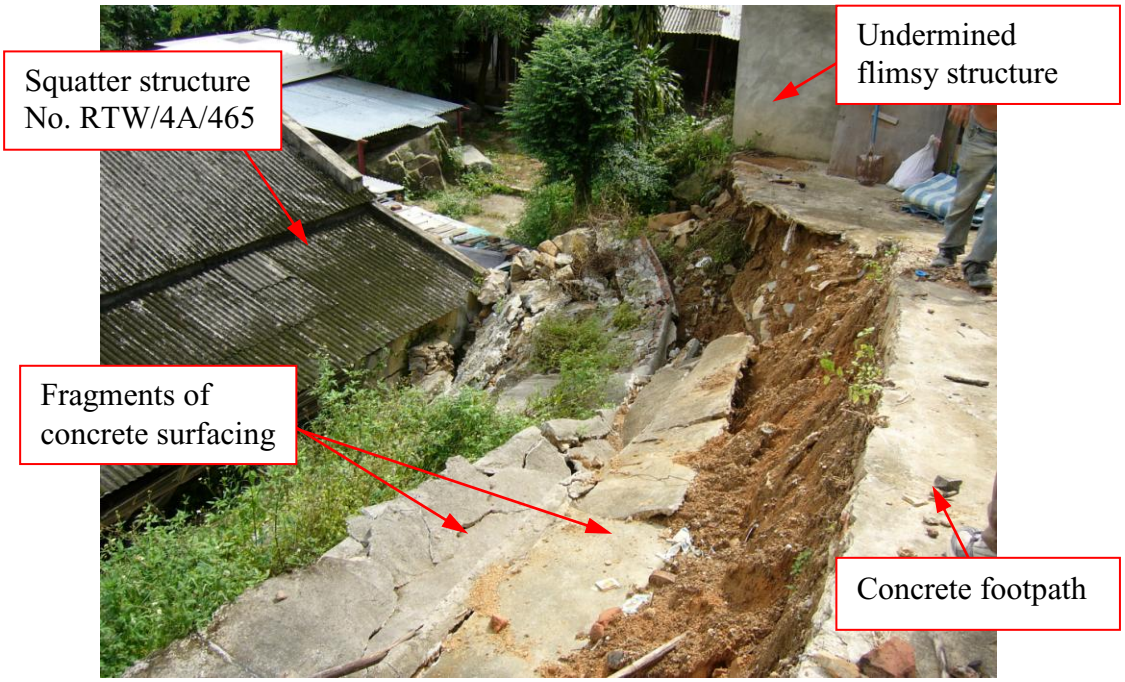

Plate 4 - General View of the Landslide from Slope Crest
(Photograph taken on 29 June 2005 by MGSL)

Note : See Figure 6 for locations and directions of photographs.

Plate 5 - View of the Main Scarp
(Photograph taken on 29 June 2005 by MGSL)

Plate 6 - Fill Materials at the Main Scarp
(Photograph taken on 29 June 2005 by MGSL)

Note : See Figure 6 for locations and directions of photographs.

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Plate 7 - Concrete Finishing of Toe Wall
(Photograph taken on 29 June 2005 by MGSL)

Plate 8 - Displaced Rubble Packed Terraces above Failed Toe Wall
(Photograph taken on 29 June 2005 by MGSL)

Note : See Figure 6 for locations and directions of photographs.

Plate 9 - View of Slope No. 7SW-C/CR564 in 1996
(Photograph taken on 23 August 1996 and extracted from GEO's Slope Information System)

Note : See Figure 6 for location and direction of photograph.

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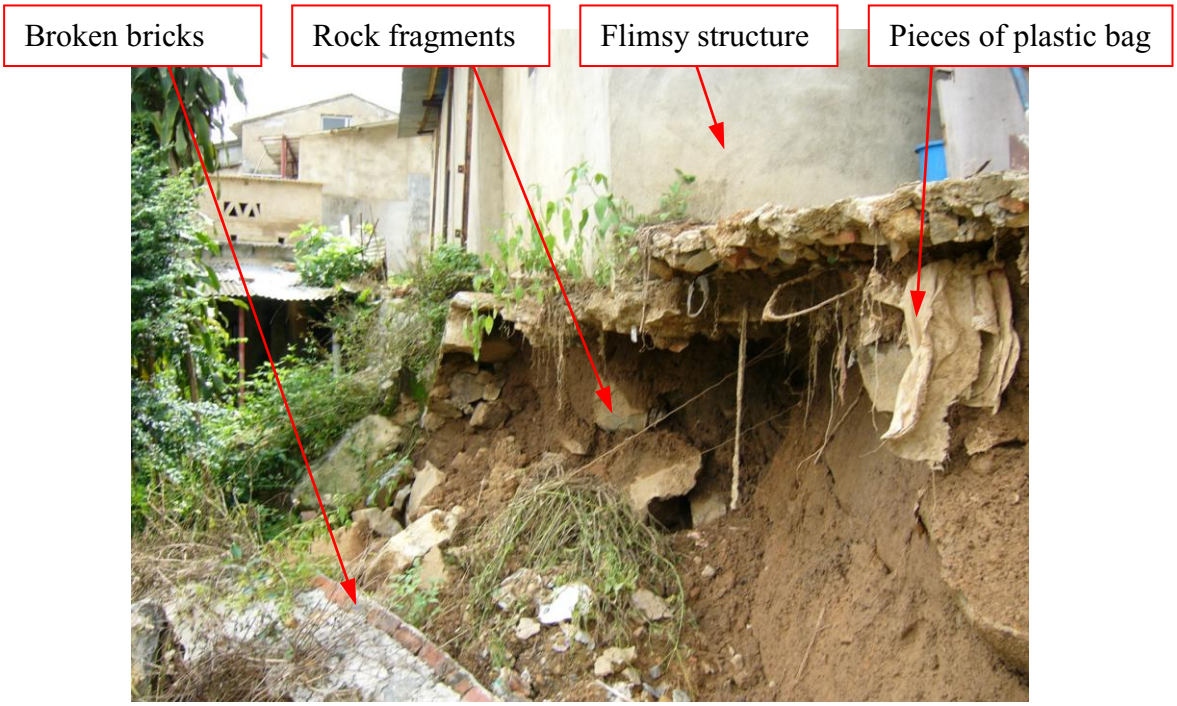

Plate 10 - Undermined Flimsy Squatter Structure
(Photograph taken on 29 June 2005 by MGSL)

Plate 11 - Eastern Portion of Slope No. 7SW-C/CR564 in 2007
(Photograph taken on 3 December 2007 by HCL)

Note : See Figure 6 for locations and directions of photographs.

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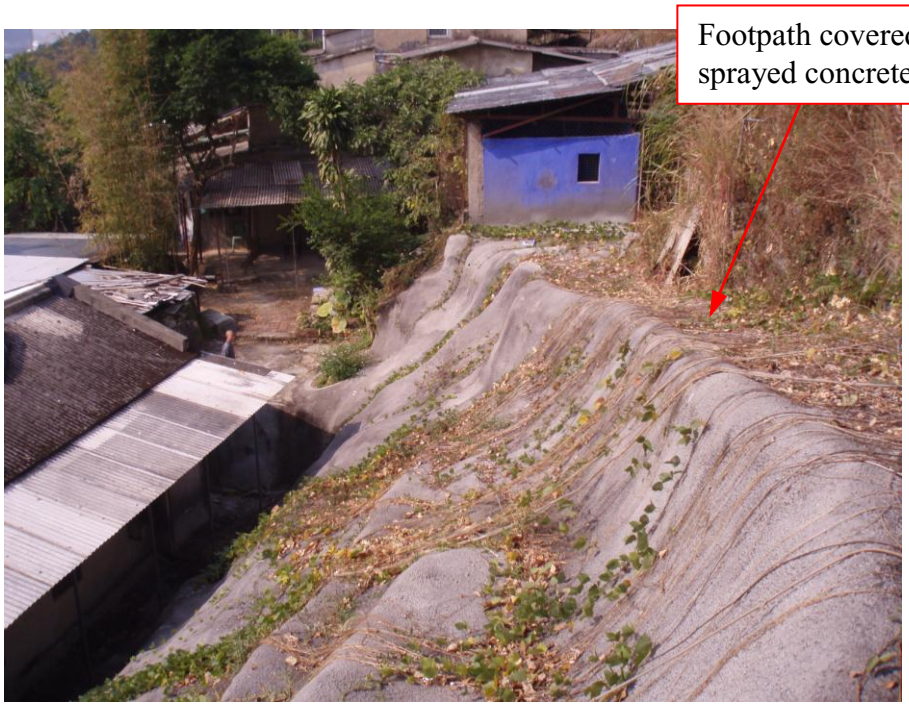

Plate 12 - Western Portion of Slope No. 7SW-C/CR564 in 2007
(Photograph taken on 3 December 2007 by HCL)

Plate 13 - Toe of Slope No. 7SW-C/CR564 in 2007
(Photograph taken on 3 December 2007 by HCL)

Note : See Figure 6 for locations and directions of photographs.

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APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

CONTENTS

A.1 DETAILED OBSERVATIONS

This report presents the findings of an aerial photograph interpretation (API) of the 24 June 2005 landslide site and the surrounding hillside. The primary aims of the API were to identify the former topographical setting of the 24 June 2005 landslide location, and to establish the development history of the concerned area.

A list of aerial photographs examined in this landslide review is presented in Table A1 and the key observations from the aerial photographs are shown in Figures A1 to A2 and Plates A1 to A7.

YEAR	OBSERVATIONS
1924	High altitude and low resolution, single photograph. Slope No. 7SW-C/CR564 had not yet been formed. The Shing Mun Catchwater to the north of the 24 June 2005 landslide location had not been formed either (Figure A1 and Plate A1). The area in the vicinity of the 24 June 2005 landslide location is seen to be a lightly vegetated hillside with occasional fields. Some light patches are observed on the hillside, indicative of possible anthropogenic activities.
1945	High altitude and moderate resolution, single photograph. The subject slopes are seen to be a lightly vegetated hillside, which was truncated by two northwest to southeast trending drainage lines, about 100 m on either side of the June 2005 landslide location. Prominent areas of vegetation clearance (possibly for agricultural use) are observed above slope No. 7SW-C/CR564. The Shing Mun Catchwater is observed to have been formed (Figure A1).
1954	High altitude and moderate resolution, single photograph. Slope No. 7SW-C/CR564 is not clearly visible but appears to have been formed. A building structure is observed to have been constructed at the toe of the slope (Figure A1 and Plate A1). Some other building structures are also observed to be present at about 30 m to the west of the slope on the lightly vegetated hillside.
1963	Low altitude and high resolution, stereo pairs. First stereo pairs available. Slope No. 7SW-C/CR564 is seen to be a cutting in a south-facing hillside and a toe wall is visible. The surface of the slope appears to be predominately bare with occasion vegetation.

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YEAR	OBSERVATIONS
	The hillside surrounding the 24 June 2005 landslide location appears to be covered with moderate vegetation. A drainage concentration is seen to be present at about 30 m to the west of the 2005 landslide site and appears to run in a northwest-southeast direction. A northwest-southeast trending spur line is also observed to be present at about 50 m to the northeast of the 2005 landslide site. Boulder fields are observed on the hillside immediate to the north of the site and at about 50 m to the northwest respectively. Two possible relict landslide scars are observed on the hillside at about 70 m to the northwest of the 2005 landslide site (Figure A2).
1964	Low altitude and high resolution, stereo pairs. Possible vegetation clearance is observed at the eastern portion of the 2005 landslide site and the hillside above is seen to be bare (Plate A2). Sizable boulders are clearly visible on the hillside just to the north of the 2005 landslide site. A path is observed to have been formed on the hillside at about 40 m to the northwest of the 2005 landslide site (Figure A1). An extension of the building structure at the toe of the 2005 landslide site is observed to have been built against the toe wall of slope No. 7SW-C/CR564.
1972	High altitude and high resolution, single photograph. No significant change to slope No. 7SW-C/CR564 is observed. A structure is observed to be formed on the hillside at about 15 m north of the 2005 landslide site (Figure A1).
1973	High altitude and high resolution, stereo pairs. No significant change to slope No. 7SW-C/CR564 is observed. A possible landslide scar is observed on the hillside at about 50 m to the northwest of the 2005 landslide site. The surface of the scar appears to be bare (Figure A2 and Plate A3).
1974	High altitude and high resolution, stereo pairs. No significant changes to slope No. 7SW-C/CR564 and its surroundings are observed.
1975	High altitude and high resolution, stereo pairs. No significant changes to slope No. 7SW-C/CR564 and its surroundings are observed.

YEAR	OBSERVATIONS
1976	Low altitude and high resolution, stereo pairs. No significant changes to slope No. 7SW-C/CR564 and its surroundings are observed.
1977	Low altitude and high resolution, stereo pairs. No significant changes to slope No. 7SW-C/CR564 and its surroundings are observed. The landslide scar observed in the 1973 aerial photographs appears to be covered with light vegetation.
1978	Low altitude and high resolution, stereo pairs. No significant changes to slope No. 7SW-C/CR564 are observed. There appears to be trimming of vegetation on the hillside immediate above the 2005 landslide site.
1979	Low altitude and high resolution, stereo pairs. No significant changes to slope No. 7SW-C/CR564 and its surroundings are observed.
1980	Low altitude and high resolution, stereo pairs. No significant changes to slope No. 7SW-C/CR564 and its surroundings are observed.
1981	Low altitude and high resolution, single photograph. No significant changes to slope No. 7SW-C/CR564 and its surroundings are observed.
1982	Low altitude and high resolution, stereo pairs. No significant change to slope No. 7SW-C/CR564 is observed. Small building structures are seen to have been erected next to the building structure below slope No. 7SW-C/CR564 (Figure A1).
1983	High altitude and high resolution, stereo pairs. No significant changes to slope No. 7SW-C/CR564 and its surroundings are observed.

YEAR	OBSERVATIONS
1984	Low altitude and high resolution, stereo pairs. No significant changes to slope No. 7SW-C/CR564 and its surroundings are observed.
1985	High altitude and high resolution, stereo pairs. No significant changes to slope No. 7SW-C/CR564 and its surroundings are observed.
1986	Low altitude and high resolution, single photograph. No significant changes to slope No. 7SW-C/CR564 and its surroundings are observed.
1988	High altitude and high resolution, stereo pairs. No significant change to slope No. 7SW-C/CR564 is observed. There appears to be disturbance to the vegetated hillside at about 30 m to the northwest of the 2005 landslide site.
1991	Low altitude and high resolution, stereo pairs. No significant change to slope No. 7SW-C/CR564 is observed. Disturbance to the vegetated hillside observed in the 1988 photographs is still visible. Site formation works are seen being carried out at about 25 m to the northwest of the 2005 landslide site (Plate A4). A platform is observed to have been formed at about 10 m west of the 2005 landslide site (Plate A4). A path is observed to have been formed at about 5 m north of slope No. 7SW-C/CR564 along the contour line, just north of the 24 June 2005 landslide location (Figures A1 and A2).
1992	Low altitude and high resolution, stereo pairs. No significant change to slope No. 7SW-C/CR564 is observed. The development above the 2005 landslide site, as observed in the 1991 photographs is seen to be on-going.
1993	High altitude and high resolution, stereo pairs. No significant change to slope No. 7SW-C/CR564 is observed. The development above the 2005 landslide site, as observed in the 1991 photographs is seen to be on-going.

YEAR	OBSERVATIONS
1994	Low altitude and high resolution, stereo pairs. No significant change to slope No. 7SW-C/CR564 is observed. The development above the 2005 landslide site, as observed in the 1991 photographs is seen to be on-going.
1995	Low altitude and moderate resolution, stereo pairs. No significant change to slope No. 7SW-C/CR564 is observed. The development above the 2005 landslide site, as observed in the 1991 photographs is seen to be on-going. As part of the development, a building structure is observed to have been built at about 25 m to the northwest of slope No. 7SW-C/CR564 (Figure A1). The hillside immediate above (north of) the 2005 landslide site is observed being modified (probably cutting activities) and the surface appears to be bare with some boulders (Plate A5). A platform is seen to have been formed just north of slope No. 7SW-C/CR564. A structure is seen being constructed on the platform as observed in the 1991 photographs, at about 10 m west of the 2005 landslide site (Figure A1).
1997	High altitude and moderate resolution, single photograph. No significant change to slope No. 7SW-C/CR564 is observed. The development above the 2005 landslide site, as observed in the 1991 photographs is seen to be on-going.
1998	Low altitude and high resolution, stereo pairs. No significant change to slope No. 7SW-C/CR564 is observed. The development above the 2005 landslide site, as observed in the 1991 photographs is seen to be on-going. Substantial development (cutting and filling works) is also observed to be on-going in the hillside to the southwest of the 24 June 2005 landslide location (Plate A5). The cutting in the hillside above the 2005 landslide site is visible and boulders are exposed. The structure at about 15 m north of the 2005 landslide site (as observed in the 1972 photograph) is seen to be demolished (Figure A1). Landslide scars (MW97/7/102 and MW97/7/103) are visible at about 40 m to the west and about 55 m to the southwest of the 2005 landslide site.

YEAR	OBSERVATIONS
	Both the landslide scars appear to be covered with hard surface cover (Figure A2 and Plate A5).
1999	Low altitude and high resolution, stereo pairs.
	No significant change to slope No. 7SW-C/CR564 is observed.
	The development above the 2005 landslide site, as observed in the 1991 photographs is seen to be on-going.
2000	Low altitude and high resolution, single photograph.
	No significant change to slope No. 7SW-C/CR564 is observed.
	The development above the 2005 landslide site, as observed in the 1991 photographs is seen to be on-going.
	The structure, which was constructed in 1995 on the platform at about 10 m west of the 2005 landslide site, is observed to have been demolished (Figure A1).
2001	High altitude and moderate resolution, stereo pairs.
	No significant change to slope No. 7SW-C/CR564 is observed.
	The development above the 2005 landslide site, as observed in the 1991 photographs is seen to be on-going.
2002	Low altitude and high resolution, stereo pairs.
	No significant change to slope No. 7SW-C/CR564 is observed.
	The development above the 2005 landslide site, as observed in the 1991 photographs is seen to be on-going.
2003	Low altitude and high resolution, stereo pairs.
	No significant change to slope No. 7SW-C/CR564 is observed.
	The development above the 2005 landslide site, as observed in the 1991 photographs is seen to be on-going.
	Removal of boulders on the hillside at about 25 m northwest of the 2005 landslide site is observed to be in progress (Figure A1 and Plate A6).
2004	Low altitude and moderate resolution, stereo pairs.
	The western portion of slope No. 7SW-C/CR564 appears to be modified;

YEAR	OBSERVATIONS
	vegetation in the slope portion appears to have been removed and the ground surface appears to be re-profiled and covered with hard surface. A footpath is seen to have been formed along the crest of the re-profiled slope portion. The platform formed in 1995 (above the footpath) also appears to be covered with hard surface (Figure A1 and Plate A6). Removal of boulders on the hillside at about 25 m northwest of the 2005 landslide site is observed to be in progress (Figure A1 and Plate A6).
2005	Low altitude and moderate resolution, stereo pairs. No significant changes to slope No. 7SW-C/CR564 and its surroundings are observed.
2006	Low altitude and high resolution, single photograph. The 24 June 2005 landslide scar is observed to have been covered with hard surface cover (Plate A7).

LIST OF TABLES

Table A1 - List of Aerial Photographs

Date of photos taken	Altitude (ft)	Photograph Number
1924	Unknown	Y00120
10 November 1945	22,000	Y00689
18 November 1954	29,200	Y02729
29 January 1963	3,900	Y09037 – Y09038
20 December1964	1,800	Y11149 – Y11150
3 October 1972	13,000	2281
20 February 1973	5,000	3262 – 3263
20 November 1974	12,500	9578 – 9579
19 December 1975	12,500	11794 – 11795
4 October 1976	4,000	15463 – 15464
6 December 1977	4,000	19733 – 19734
7 December 1978	4,000	24061 - 24062
2 October 1979	4,000	27466 – 27467
13 November 1980	4,000	32965 – 32966
19 January 1981	4,000	36324
28 July 1982	3,000	43124 – 43125
24 January 1983	20,000	47018 – 47019
20 October 1984	4,000	56547 – 56548
4 October 1985	15,000	A02691 – A02692
17 September 1986	4,000	A05701
3 June 1988	20,000	A13370 – A13371
1 October 1991	4,000	A27553 – A27554
20 October 1992	4,000	A32651 – A32652
4 October 1993	20,000	CN4426 – CN4427
8 November 1994	4,000	A39931 – A39932
26 September 1995	3,500	CN11061 – CN11062
1 November 1997	10,000	CN19060
5 March 1998	4,000	CN19496 – CN19497

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Date of photos taken	Altitude (ft)	Photograph Number
8 February 1999	4,000	CN22681 – CN22682
14 September 2000	5,500	CN28065
4 July 2001	8,000	CS01127 – CS01128
15 August 2002	4,000	CW42606 – CW42607
29 November 2003	2,500	RW03443 – RW03444
20 April 2004	4,000	CW57022 – CW57023
5 March 2005	6,000	RW04692– RW04693
19 May 2006	4,000	CW71821
Note: All aerial photographs are in black and white except for those prefixed with CN, CS, CW or RW.		

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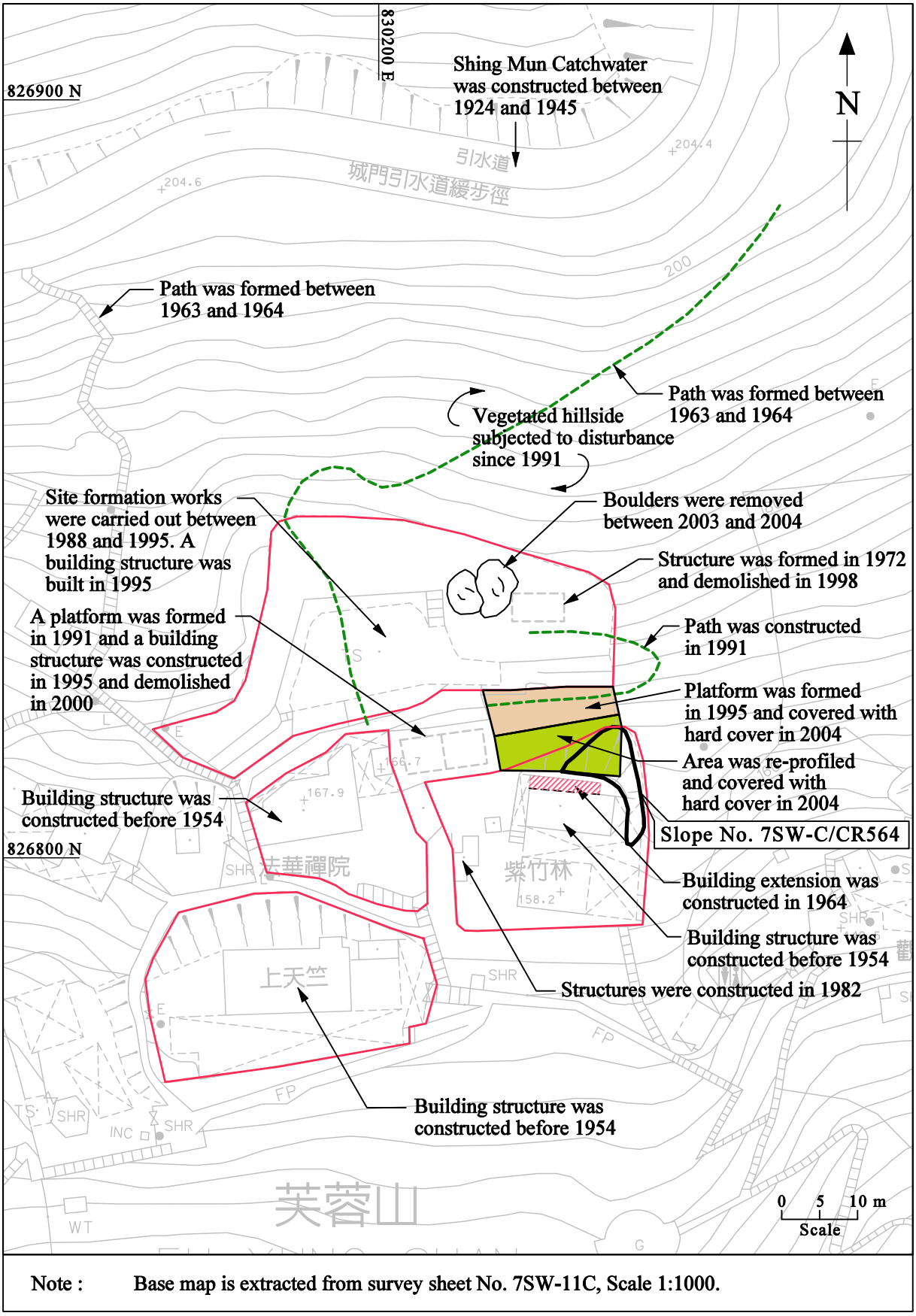

Note : Base map is extracted from survey sheet No. 7SW-11C, Scale 1:1000.

Figure A1 - Site Development History

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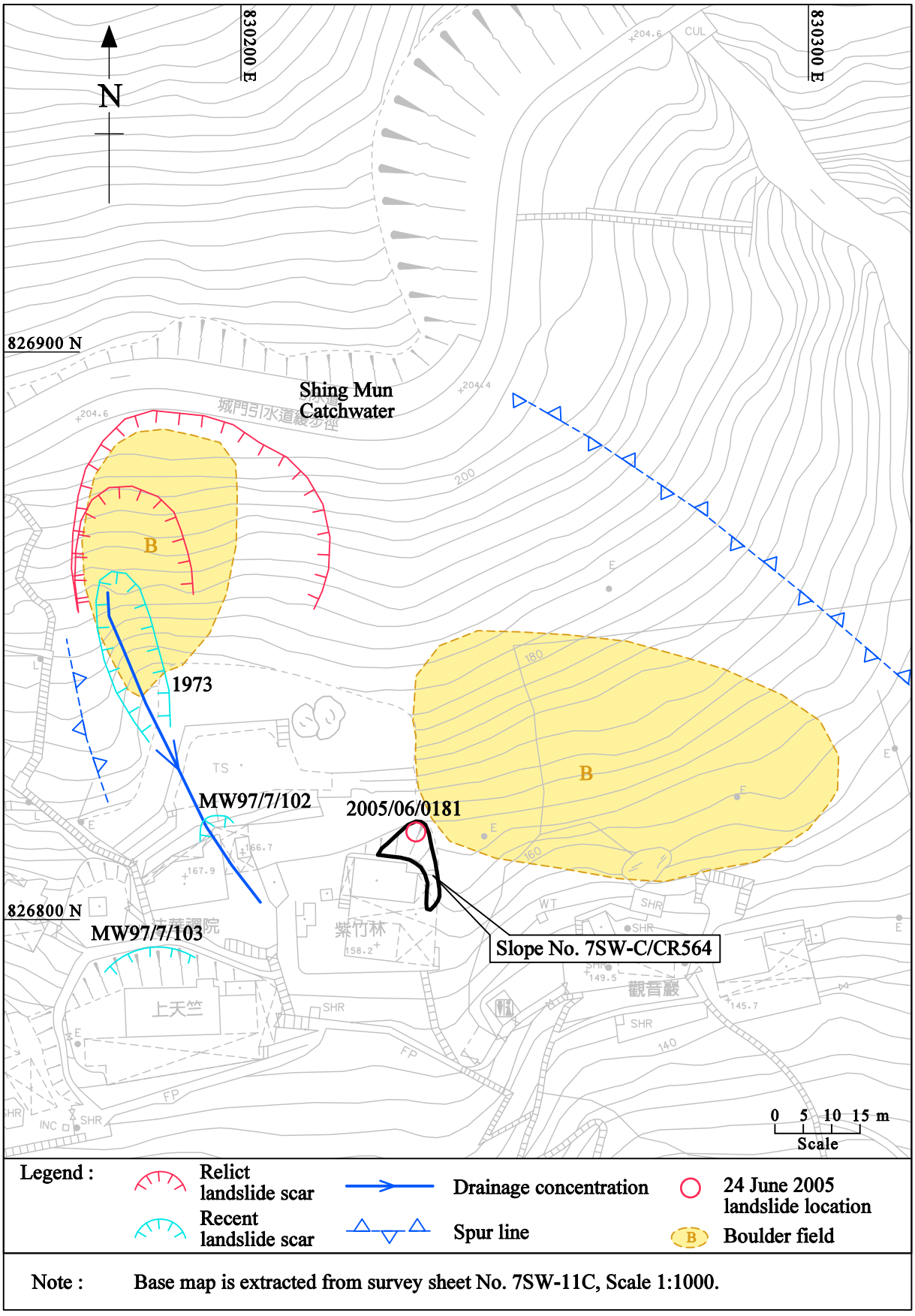

Figure A2 - API Findings

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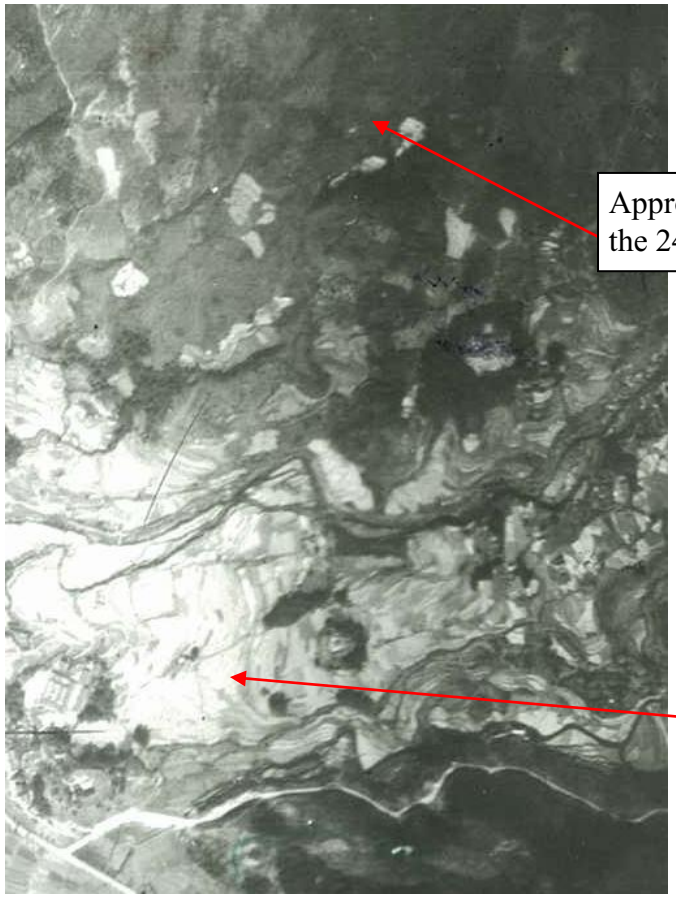

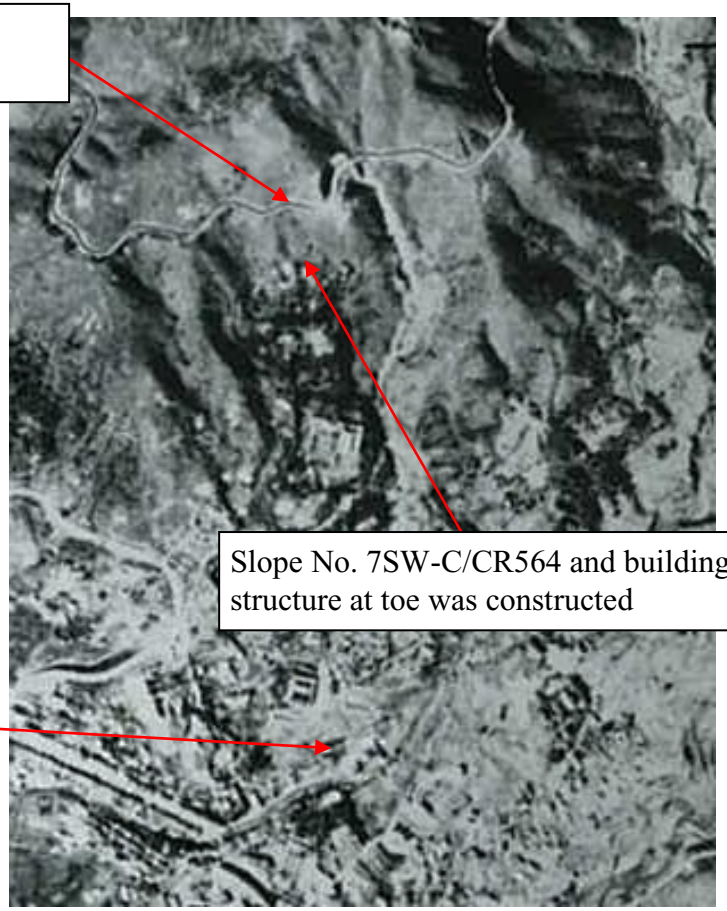

(Photograph Y00120 taken in 1924)

(Photograph Y02729 taken on 18 November 1954)

Plate A1 - Extract from 1924 and 1954 Aerial Photographs

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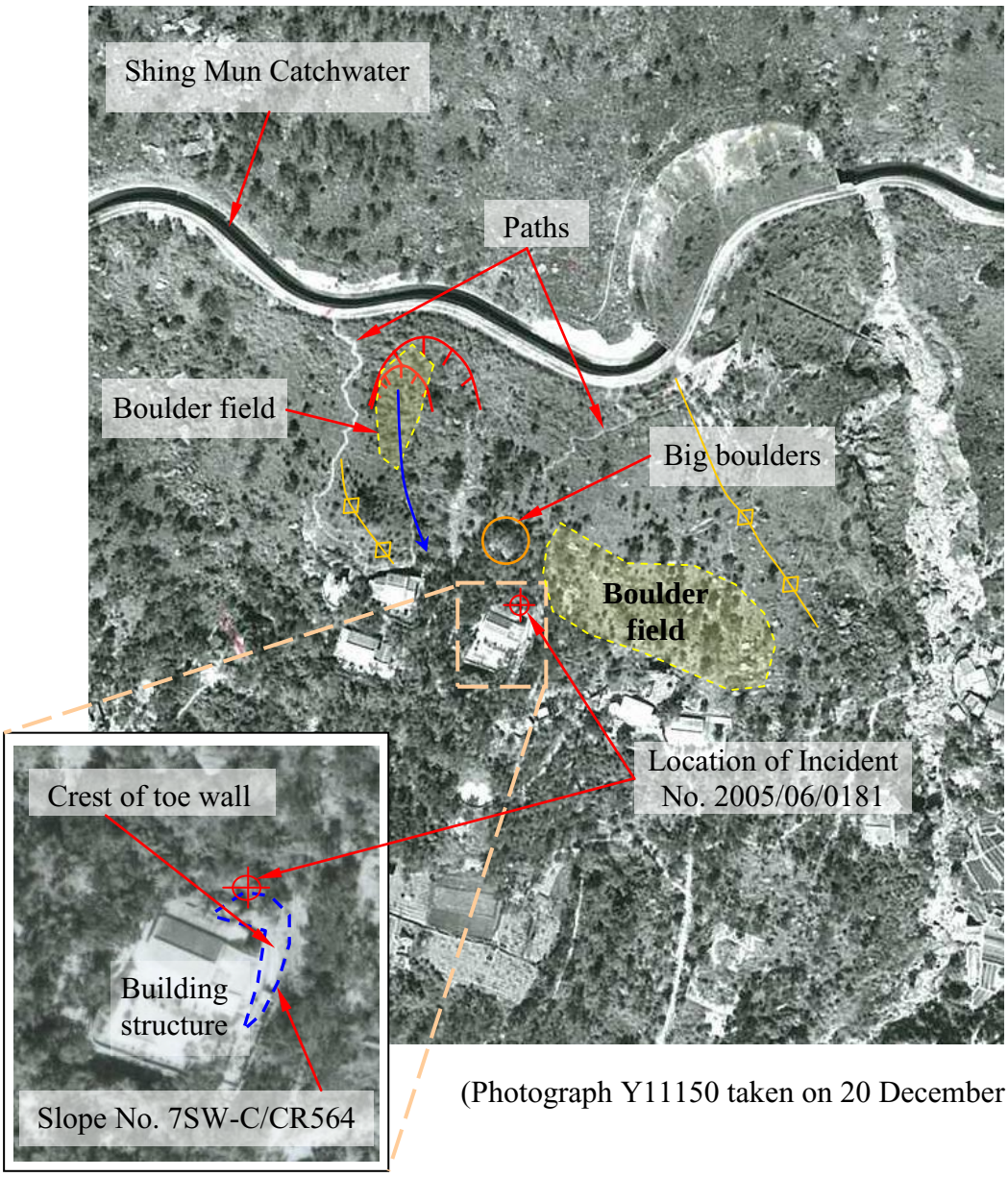

(Photograph Y11150 taken on 20 December 1964)

Legend:

Drainage concentration

Ridge line / Spur line

Relict landslide

Incident No. 2005/6/0181

Plate A2 - Extract from 1964 Aerial Photograph

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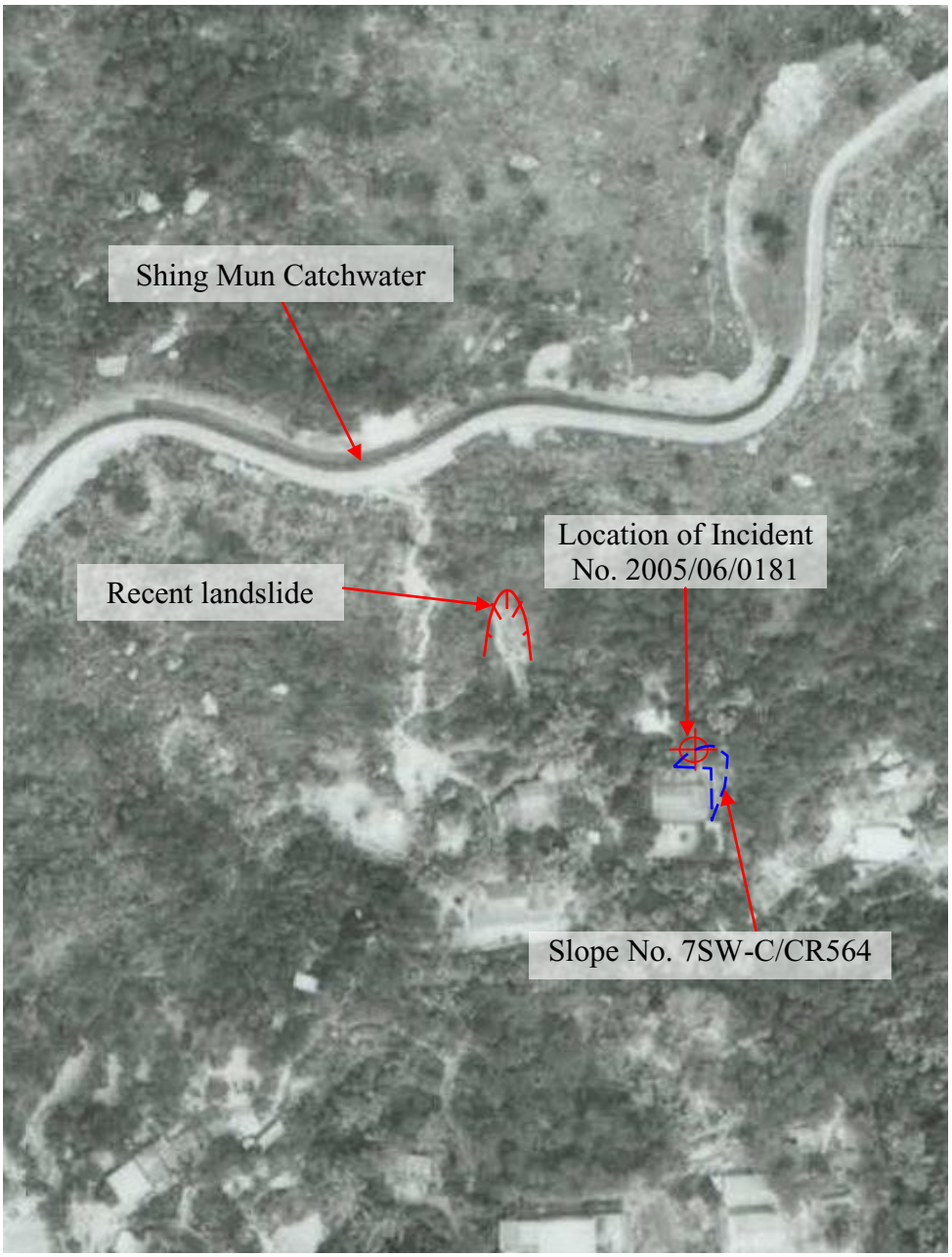

(Photograph 3263 taken on 20 February 1973)

Plate A3 - Extract from 1973 Aerial Photograph

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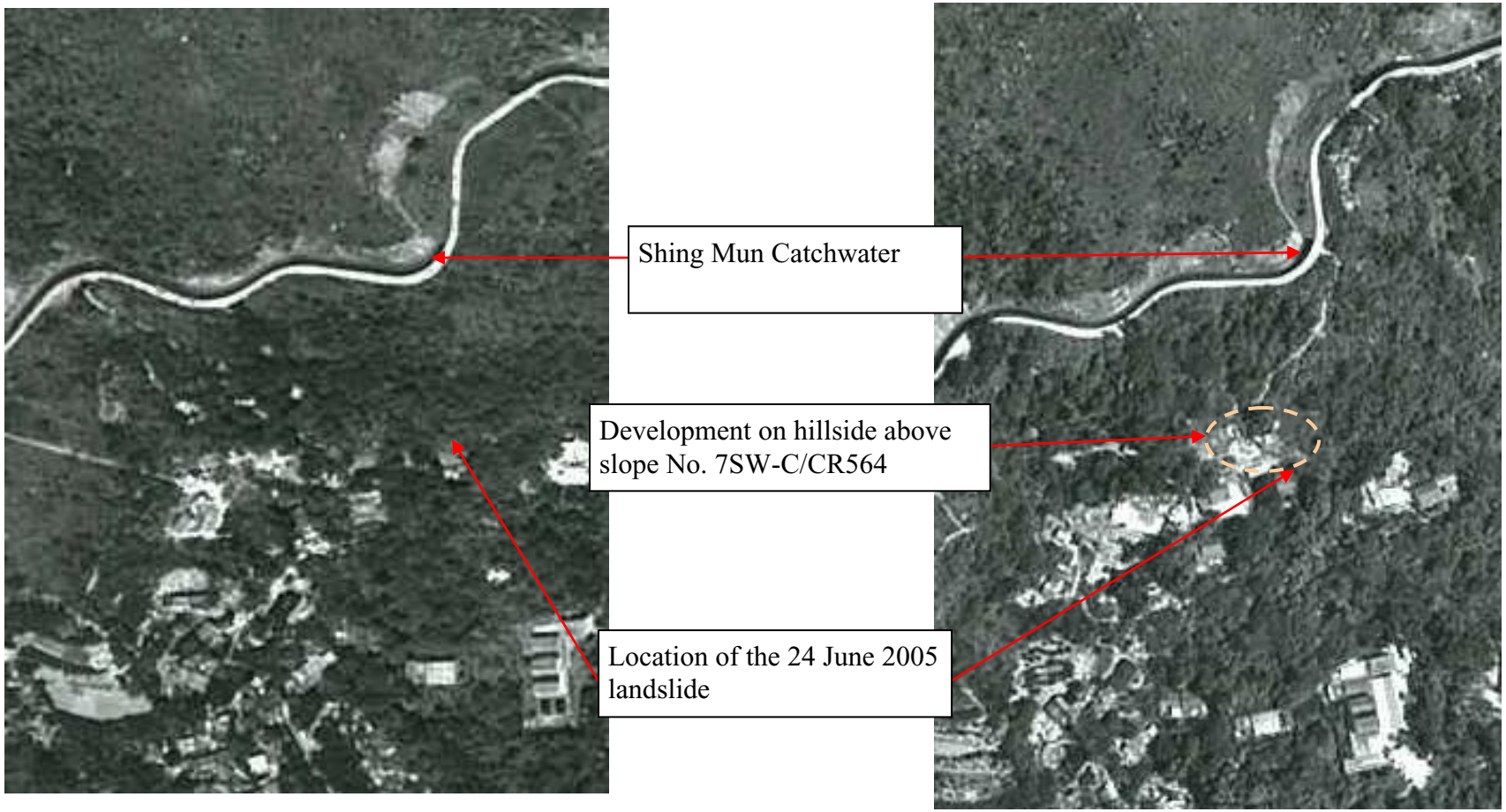

(Photograph A05701 taken on 17 September 1986)

(Photograph A27552 taken on 1 October 1991)

Plate A4 - Extract from 1986 and 1991 Aerial Photographs

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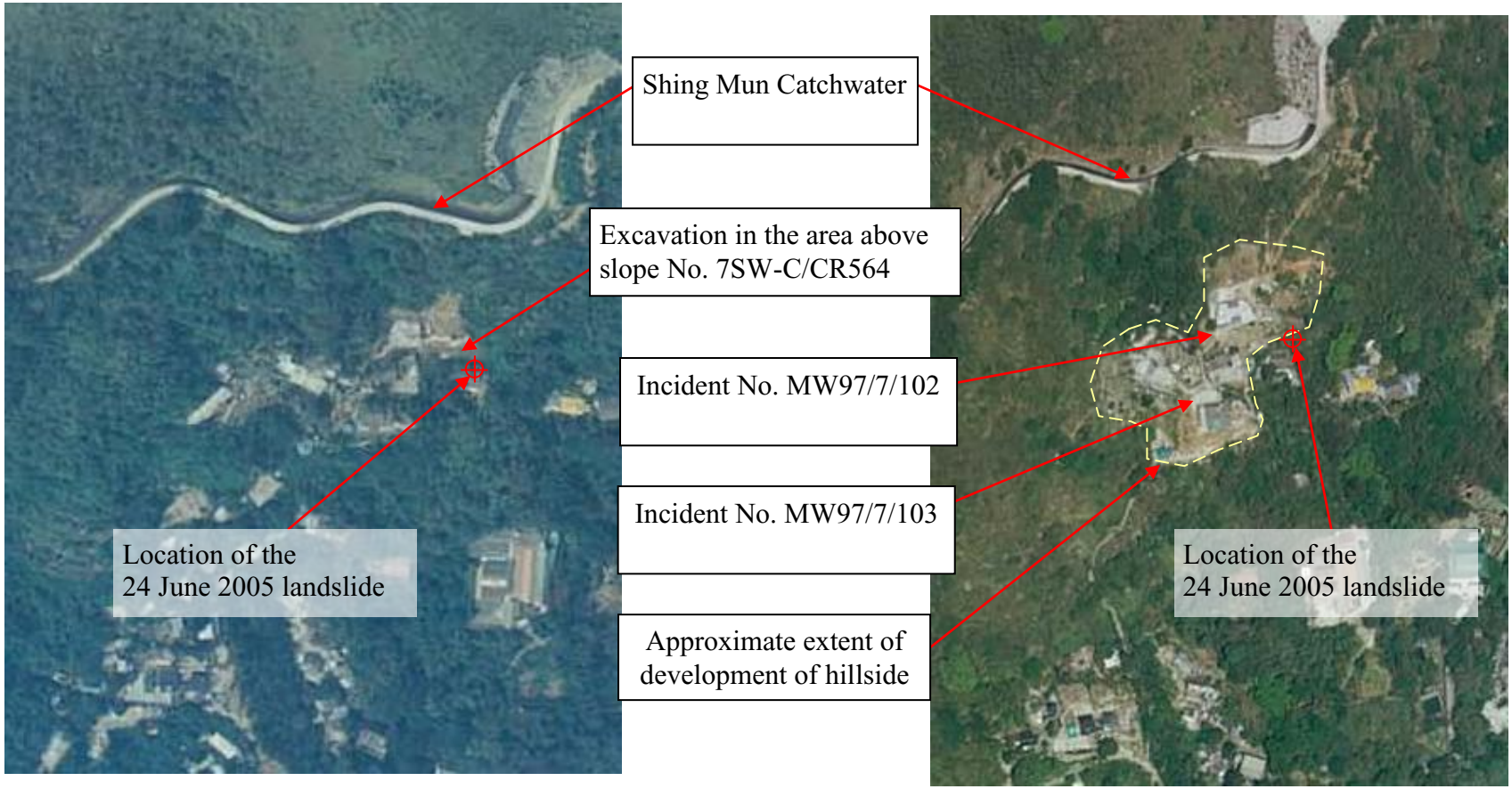


(Photograph CN11061 taken on 26 September 1995)

(Photograph CN19496 taken on 5 March 1998)

Plate A5 - Extract from 1995 and 1998 Aerial Photographs

Removal of boulders between 2003 and 2004

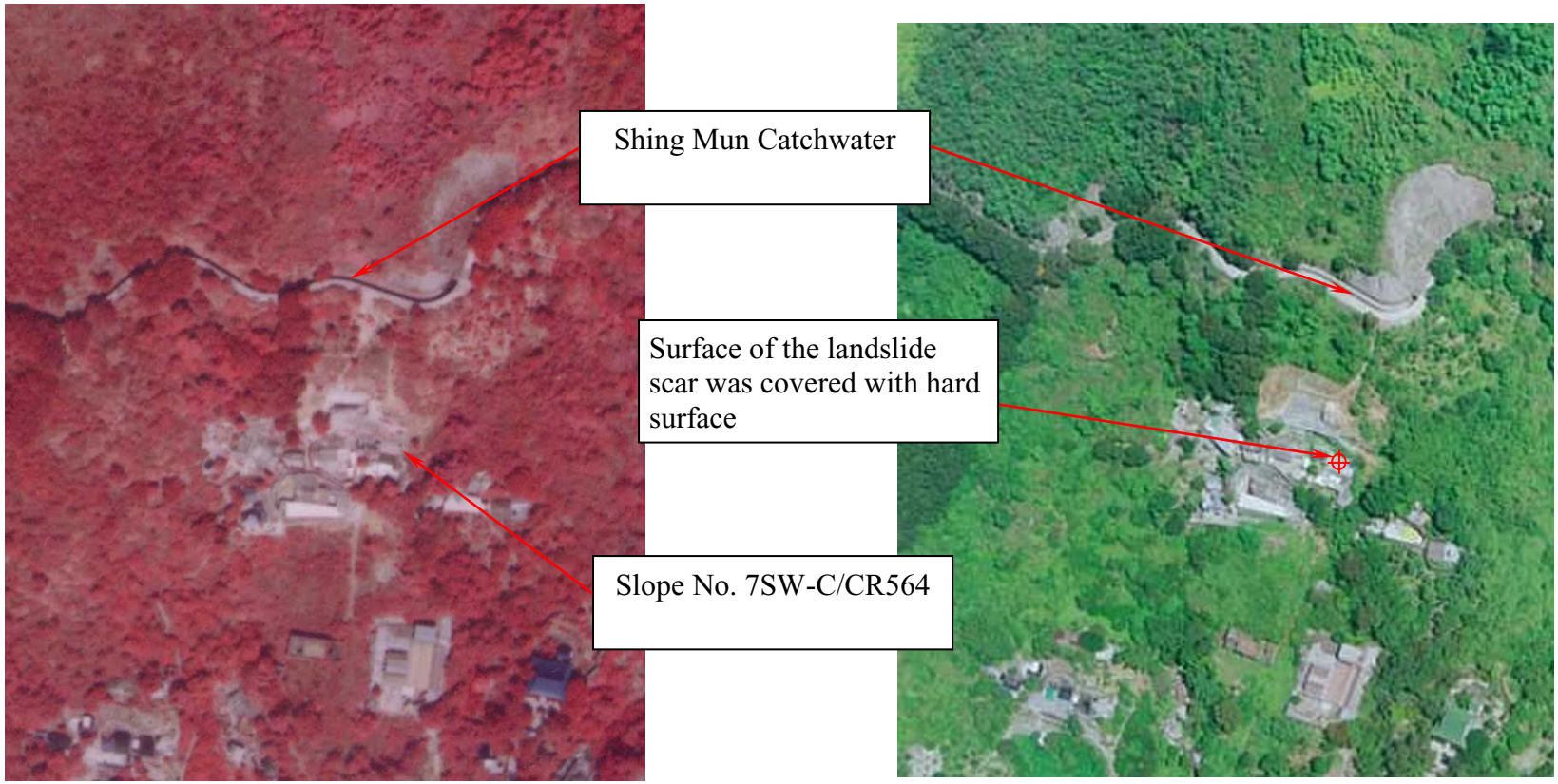
Location of the 24 June 2005 landslide

Area above slope No. 7SW-C/CR564 was re-profiled and covered with hard surface

(Photograph RW03444 taken on 29 November 2003)

(Photograph CW57023 taken on 20 April 2004)

Plate A6 - Extract from 2003 and 2004 Aerial Photographs



(Photograph RW04693 taken on 5 March 2005)

(Photograph CW71821 taken on 19 May 2006)

Plate A7 - Extract from 2005 and 2006 Aerial Photographs

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

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

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

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

Writing to
Publications Sales Section,
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Garden Road, Central, Hong Kong.
Fax: (852) 2598 7482

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

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香港中環花園道
美利大廈4樓402室
政府新聞處
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傳真: (852) 2598 7482

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

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

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

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

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北角政府合署23樓
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電話: (852) 2231 3187
傳真: (852) 2116 0774

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

For Geological Survey Sheet Reports which are free of charge:
Chief Geotechnical Engineer/Planning,
(Attn: Hong Kong Geological Survey Section)
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5380
Fax: (852) 2714 0247
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Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5346
Fax: (852) 2714 0275
E-mail: thomashui @cedd.gov.hk

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免費地質調查報告:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
規劃部總土力工程師
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電話: (852) 2762 5380
傳真: (852) 2714 0247
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電話: (852) 2762 5346
傳真: (852) 2714 0275
電子郵件: thomashui@cedd.gov.hk

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

GEOTECHNICAL MANUALS

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

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

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

GEOSPECS

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

GEO PUBLICATIONS

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

GEOLOGICAL PUBLICATIONS

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

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

TECHNICAL GUIDANCE NOTES

TGN 1	Technical Guidance Documents