SECTION 4
DETAILED STUDY OF TWO FAILURES AT LI PO CHUN UNITED WORLD COLLEGE, WU KAI SHA ON 2 JULY 1997

Halcrow Asia Partnership Ltd

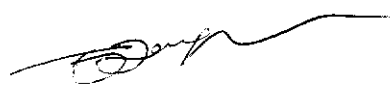
This report was originally produced in December 1998 as GEO Landslide Study Report No. LSR 25/98

FOREWORD

This report presents the findings of a study of two failures (GEO Incident Report No. ME97/8/16), one on a cut slope and the other on a fill slope, at Li Po Chun United World College, Wu Kai Sha. The failures occurred sometime between 1 and 2 July 1997. Both failures were minor and deposited debris on open space, with no significant consequence.

The key objectives of the detailed study were to document the facts about the failures, present relevant background information and establish the probable causes of the failures. The scope of the study was limited to site reconnaissance, desk study and analysis. Recommendations for follow-up actions are reported separately.

The report was prepared as part of the 1997 Landslip Investigation Consultancy (LIC), for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 68/96. This is one of a series of reports produced during the consultancy by Halcrow Asia Partnership Ltd (HAP). The report was written by Mr R J Simonds and reviewed by Dr R Moore. The assistance of the GEO in the preparation of the report is gratefully acknowledged.



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1. INTRODUCTION

Sometime between 18:00 hours on 1 July 1997 and 08:00 hours on 2 July 1997 two failures occurred, one on a cut slope and the other on a fill slope, at Li Po Chun United World College (Figure 1 and Plates 1 and 2). In both cases debris was deposited on open space. No fatalities or injuries were reported.

Following the incidents, Halcrow Asia Partnership Ltd (the 1997 Landslip Investigation Consultants), carried out a detailed study of the failures for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 68/96. This is one of a series of reports produced during the consultancy by Halcrow Asia Partnership Ltd (HAP).

The key objectives of the study were to document the facts about the failures, present relevant background information and establish the probable causes of the failures. The scope of the study was limited to site reconnaissance, desk study and analysis. Recommendations for follow-up actions are reported separately.

This report presents the findings of the detailed study which comprised the following key tasks:

(a) a review of relevant documents relating to the history of the site,

(b) analysis of rainfall records,

(c) detailed site observations and measurements, and

(d) diagnosis of the probable causes of the failures.

2. THE SITE

2.1 Site Description

The locations of the failures are shown in Figure 1. One of the failures (denoted 'A' in Figure 2), located 20 m north of Lok Wo Sha Lane, occurred on a 7 m-high old cut slope (No. 7NE-D/C44), which is inclined at about 60° to the horizontal. Prior to the failure the cut slope was unprotected and sparsely covered with vegetation (Plate 2). A trapezoidal drainage channel is located about 2 m beyond the crest of the cut slope.

The second failure (denoted 'B' in Figure 2), located to the east of an access road to Li Po Chun World College, occurred an 8 m-high fill slope, which is inclined at about 30° to the horizontal and was constructed against an old cut slope in 1996. A basketball court and tennis courts are present at the toe of the fill slope.

Prior to the failure, the fill slope and the area beyond the slope crest were covered with grass and a few isolated young trees. The drainage on the fill slope comprised 300 mm

U-channels along the toe of the slope and 4 m beyond the crest of the slope respectively (Figure 2).

According to District Lands Office, failure A occurred on unallocated Government land and failure B occurred within Sha Tin Town Lot (STTL) No. 367 (Figure 3). According to the SIMAR (Systematic Identification of Maintenance Responsibility of Slopes in the Territory) consultancy, the Lands Department is responsible for the maintenance of the section of Slope No. 7NE-D/C44 on which failure A occurred. The owners of Li Po Chun United World College are responsible for the maintenance of the portion of slope No. 7NE-D/C44, within Lot (STTL) No. 367.

2.2 Site History

The site history has been established from aerial photographs of the site spanning the period 1949 to 1997 and a review of documentary information (Tables 1 and 2).

Aerial photographs taken in 1969 show that a large quarry was located at the site which modified the existing natural terrain and created the cut slope (Figure 3). At this time there was a trapezoidal drainage channel along the crest of the cut slope. This channel appears to have been either removed or infilled sometime before 1996. A fill slope was subsequently constructed against the cut slope, between January and May 1996, except for the southern-most 25 m-long section.

The development of the college was carried out in two phases. The works under Phase I commenced in early 1991 and consisted of site formation, slope drainage provisions and construction of the main college buildings. Phase I was completed in mid-1994. Works under Phase II, which commenced in January 1996, comprised a 160 m-long and 8 m-high fill slope formed against the existing cut slope (Figure 2). Phase II was completed in May 1996.

The owners of the college appointed consultants Wong & Ouyang (HK) Ltd (W & O) to undertake design and supervision of the construction works. As part of the Phase I design, a drainage layout plan was submitted to the Buildings Department (BD) and was approved in February 1992. This plan gave the proposed drainage detail along the crest of the slope, which consisted of a 300 mm U-channel connected to an existing trapezoidal channel.

A site formation plan for the Phase II works was submitted to the GEO via BD, who commented that there was "no geotechnical objection" to the proposed site formation works "subject to Qualified Supervision" (GEO, 1995). The site formation plan was subsequently approved by BD in November 1995.

Aerial photographs taken in July 1995 show white staining on the access road above the location of failure B on the fill slope (Figure 3). It is considered likely that the staining resulted from surface water run-off down the access road.

During construction of the fill slope, movement monitoring points installed at the slope crest were checked weekly (W & O, 1996a). The monitoring records showed that there was no significant movement of the fill slope during this period.

The specification for the new fill slope, as detailed on the site formation plan, required, inter alia, that the existing cut slope be benched prior to filling and that the in-situ density of compacted fill should not be less than 95% of the maximum dry density. It would appear from weekly site records (W & O, 1996a) that a notable amount of fill was placed prior to in-situ density testing. It is also unclear from the records as to the extent of testing during fill placement. Following completion of the slope works, in-situ testing was undertaken from trial pits to an estimated depth of up to 2 m. Results show the degree of compaction ranged between 95% and 104% (W & O, 1996b).

In August 1996, W & O submitted the as-built drawings and a slope record sheet certifying that the fill slope had been completed and was "structurally safe". A copy of these documents was forwarded to the GEO who advised BD that "there is no geotechnical objection to the site formation works provided that the works have been completed in accordance with the approved plans" (GEO, 1996a).

2.3 Previous Studies

The old cut slope, against which the new fill slope was constructed, was not registered in the 1977/78 Catalogue of Slopes.

In 1992, the GEO initiated the consultancy agreement entitled "Systematic Inspection of Features in the Territory" (SIFT) which, inter alia, aims to identify and update information on slopes based on studies of aerial photographs and limited site inspection. In 1996, the SIFT study noted that "construction (was) visible" and identified the slope as a SIFT Class "C2" indicating that it was a cut slope that had been "formed or substantially modified after 30.6.78" (GEO, 1996b).

In 1994, the GEO commenced the consultancy agreement entitled "Systematic Identification and Registration of Slopes in the Territory" (SIRST) to update the 1977/78 Catalogue of Slopes and to prepare the New Catalogue of Slopes. The fill slope was inspected by the SIRST consultant in July 1997 following the landslide. The consultant reported no signs of seepage or distress but noted a partially blocked crest drain. The fill slope and the cut slope were considered as one feature and registered as cut slope No. 7NE-D/C44 in the New Catalogue of Slopes. The consultant also reported no "Inferred Past Instability" and confirmed that the slope, referred to as a cut slope with a SIFT classification of "C2", was "formed or modified post mid 78". Most of the feature is, however, a newly-formed fill slope.

W & O (1996c), the consultants appointed to design sport facilities at the site, completed a stability assessment of slope No. 7NE-D/C44 including the design of upgrading works within Lot (STTL) No. 367. There was no assessment or upgrading works on the southern most 25 m-long section of the cut slope, on which failure A occurred, as this section of slope was outside the lot boundary.

2.4 Previous Landslides

There are no records of past landslides in the vicinity of the 1997 failures in GEO's landslide database.

A landslide was identified on the 1969 aerial photographs (Table 1) on the northern part of the original cut slope (Figure 3). The landslide scar was subsequently regraded and covered by the fill slope formed in 1996.

Minor erosion was observed near the northern part of the fill slope according to aerial photographs taken in May 1997 (Figure 3).

2.5 Subsurface Conditions

The geological memoir (Addison, 1986) and Sheet 7 of the Hong Kong Geological Survey 1:20 000-scale Map Series (Geotechnical Control Office, 1986) indicate that the site is underlain by medium-grained granite. Geological sections through the cut slope and fill slope are shown in Figures 4 and 5 respectively.

At the location of failure A, adjacent surface exposures indicate that the cut slope comprised completely decomposed granite of mass weathering grade PW 0/30 (Figure 4).

A site investigation report by Lam Geotechnics Ltd (1990) included records of twelve boreholes drilled over the site of the proposed college development. Borehole No. BH10 was located about 20 m to the north of failure B (Figures 2 and 5). Groundwater assumed by W & O (1990) for the design was at a depth of about 4 m below the base of the newly-formed fill slope (Figure 5).

3. THE INCIDENTS

3.1 Time of the Failures

No eye-witnesses to the failures were identified. The caretaker at Li Po Chun United World College reported that the incidents had not occurred prior to 18:00 hours on 1 July 1997 but he observed the debris at about 08:00 hours on 2 July 1997. The precise timing of the failures is therefore unknown, although it is considered possible that they occurred sometime between 04:00 hours and 08:00 hours on 2 July 1997, during which time there was a severe rainstorm (see Section 4). A Landslip Warning was issued at 06:25 hours on 2 July 1997.

3.2 Description of the Failures

The description of the failures is based on the GEO Incident Report (No. ME97/8/6) and information provided by the college. HAP was unable to examine the failure scars or debris prior to completion of the remedial works.

The scar of failure A was reported as 3 m wide, 5 m high and about 0.5 m deep, with an estimated failure volume of about 8 m^3. The failure occurred on a 7 m-high cut slope inclined at about 60° to the horizontal. Examination of exposures in the cut slope on either side of the scarp by HAP confirmed the material to be completely decomposed granite with a mass weathering zone of PW 0/30. The failed section had no surface protection or slope drainage. The debris from the failure was deposited at the base of the slope where it blocked a catchpit and a U-channel. The geometry of the failure and the mode of debris deposition indicate that the failure was a shallow debris slide.

The GEO Incident Report noted that the scarp for failure B was 6 m-long but according to information provided by the college, failure B consisted of a 35 m-long scarp at the crest of the fill slope near to its interface with the cut slope (Figure 2). The scarp was an approximately linear feature that ran parallel to the slope crest with a height of up to about 1 m. The face of the scarp was inclined at between about 45° and sub-vertical. Some time after the failure, it appears that secondary washout of the exposed fill occurred locally below the scarp, probably as a result of surface run-off. A narrow (less than 2 m wide), thin washout trail formed down the fill slope. The debris from the washout blocked the U-channel at the toe of the slope and a thin layer of debris accumulated on the adjacent open space (Plate 1). Based on the dimensions of the scarp, the estimated failure volume was about 25 m^3.

Shortly after the incident, from information provided by the college, seepage was observed from a number of locations at the toe of the slope, but no seepage was observed on the scarp surface. It was noted during inspection by HAP on 24 February 1998 that the existing U-channel at the crest of the fill slope was partially blocked.

The general drainage layout plan for the college approved by BD in February 1992 shows a 300 mm U-channel connecting with the trapezoidal channel along the crest of the fill slope. At the time of inspection, the college caretaker informed HAP that this connecting U-channel was not present prior to the failure and had been constructed during the remedial works which were designed by W&O (Plate 5). The absence of the connecting U-channel could have promoted blockage and ponding of the crest U-channel.

The GEO Incident Report states "poor compaction" as a possible contributing cause of failure. Information provided by the college also suggested that the fill near the slope surface may not have been adequately compacted.

3.3 Follow-up Action

Following the incident, the GEO recommended a Dangerous Hillside Order be served on the owners of Lot (STTL) No. 367 (GEO, 1997) in respect of slope No. 7NE-D/C44 in November 1997.

4. RAINFALL

The nearest GEO automatic raingauge No. N09 is located at the Meteorology Laboratory at Chinese University, Sha Tin, about 4 km west of the site (Figure 7). The daily rainfall recorded between 1 June and 5 July 1997 is shown in Figure 6a. There was 1005.5 mm and 617 mm of rainfall in the 31 days and 15 days before the incidents respectively. The hourly rainfall between 29 June and 2 July 1997 is shown in Figure 6b. There was little rainfall between 18:00 hours on 1 July 1997 and 04:00 hours on 2 July 1997 which was followed by a severe rainstorm between about 04:00 hours and about 12:00 hours on 2 July 1997.

An isohyet plot of rainfall recorded during the rainstorm between 00:00 hours and 08:00 hours on 2 July 1997 is given in Figure 7.

The estimated return periods for maximum rolling rainfall for selected durations based on historical rainfall at the Hong Kong Observatory (Lam & Leung, 1994) are presented in Table 3. The maximum rolling 4-hour rainfall between 04:00 hours and 08:00 hours on 2 July 1997 was the most severe, with a corresponding return period of about 30 years.

5. PROBABLE CAUSES OF THE FAILURES

Given that HAP's study was initiated after completion of the slope repair works and that no ground investigation was carried out, the following diagnosis of the probable causes of the failures is based essentially on the findings of the desk study.

The close temporal correlation between the severe rainstorm in the morning of 2 July 1997 and the likely time of the failures indicates that intense rainfall probably triggered the landslides.

Failure A occurred on an oversteep (60°) old cut slope, which was formed in completely decomposed granite and was substandard. The failure was probably caused by infiltration of rainwater into the unprotected slope. Infiltration probably caused an increase in the degree of saturation of the near-surface soil, which resulted in loss of soil suction and reduction in shear strength leading to failure.

Failure B appears to have involved deformation near the crest of the fill slope and the development of 35 m-long scarp as a result of water ingress. The likely sources of water in the slope are:

(a) stormwater run-off from the access road above the fill slope overflowing the crest U-channel, and

(b) direct infiltration of rainfall into the slope.

Probable contributory factors to the failure could have been the presence of poorly compacted fill and inadequate surface drainage provision.

6. CONCLUSIONS

The two failures reported at Li Po Chun United World College affected an old substandard cut slope and a compacted fill slope recently formed in 1996. The failures were probably triggered by rainfall.

The cause of the minor cut slope failure is likely to have been infiltration into the unprotected oversteep soil cut formed in completely decomposed granite.

The failure on the fill slope involved deformation near the crest of the slope and secondary washout. Concentrated water ingress into the fill slope as a result of overflow from the crest U-channel was possible. The presence of poorly compacted fill could be a possible contributory factor in the failure.

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Table 1 – Summary of Site Development from Aerial Photograph Interpretation

Year	Photograph Reference No.	Altitude	Observations
1949	Y020212/3	5800 ft	The site was heavily vegetated natural hillside with low-lying agricultural terraces to the east and a small sea inlet from Tolo Harbour to the west.
1963	Y08730/1	3900 ft	Several depressions possibly minor excavations evident along the crest-line of the natural terrain.
1969	Y15703/4/5	-	A large quarry had developed over the site. The natural terrain had been significantly modified and a cut slope had been formed with an access road along the crest. The quarry was apparently not active and rows of young trees had been planted as part of a restoration scheme. A landslide was present in the cut slope, however no debris was evident at the toe of the slope. A drainage channel was visible running along the crest of the slope as far as the landslide scarp.
1973	07243/4/5	2000 ft	No changes were apparent other than the increase in the tree canopy over the site.
1982	40735/6	4000 ft	Construction of Sai Sha Road to the southwest of the site was on-going. The cut slope was visible and re-vegetation of the slopes above was apparent.
1984	56808/9	4000 ft	No changes were apparent other than the reduction of the tree canopy over the site.
1989	A19549/50/51	4000 ft	Sai Sha Road and Lok Wo Sha Lane had been constructed otherwise there were no apparent changes to the site.
1991	A27096/7	4000 ft	Li Po Chun United World College was under construction. The scarp of the landslide on the 1969 photographs had been trimmed back.
1994	A39104/5	6000 ft	The construction of Li Po Chun United World College was complete. The area directly upslope of the southern end of the cut slope and the flat-lying area at the toe of the cut slope had become heavily vegetated.
1995	CN10331/2/3	3200 ft	Surface water flow-lines were visible down the access road from the college to the crest of the slope.
1996	CN13355/6	4000 ft	The cut slope had been modified by the addition of a fill slope along the toe. A 25 m-long section of the cut slope remained unmodified at the southern end. A stockpile of fill material was observed at the edge of the access road with a possible washout trail down the edge of the road in the direction of the fill slope.
1997	CN17765/6	4000 ft	A basketball court and two tennis courts had been constructed adjacent to the toe of the fill slope. There was evidence of minor erosion of the fill slope near the northern staircase.

Table 2 – Summary of Information Sources

Source	Information Obtained
Geotechnical Information Unit (GIU).	There were no relevant borehole records.
Mainland East Division and Design Division of GEO.	(a) Correspondence indicating land status from District Lands Office. (b) Correspondence to and from BD in connection with GEO checking of fill slope. (c) Correspondence to BD from GEO recommending Dangerous Hillside Order. (d) A geological cross-section within geotechnical report by Wong & Ouyang (1990).
GEO Publications, Reports, Maps and Memoirs.	(a) Sha Tin : Solid and superficial geology, Hong Kong Geological Survey Map Series HGM20 Sheet 7, 1:20 000 scale. (b) Geology of Sha Tin, Hong Kong Geological Survey Memoir No. 1.
GEO Landslide Incident Report database.	There was no relevant information.
GEO Planning Division.	(a) Phase 2 SIFT Study Map Sheet Report 1:1 000 Map Sheet 7NE-15C&D. (b) Natural Terrain Landslide Inventory. (c) Aerial Photographs 1949, 1963, 1969, 1973, 1982, 1984, 1989, 1991, 1994, 1995, 1996 and 1997.
GEO Slope Safety Division.	SIRST report for Slope No. 7NE-D/C44.
Water Supplies Department (WSD).	Existing Utility Information.
Drainage Services Department (DSD).	Existing Utility Information.
LPM / SIRST / SIFT Databases.	Registration status of Slope No. 7NE-D/C44.
Buildings Department (BD).	(a) Approved General Drainage Layout Plans: Phase I Works dated 3 February 1992. (b) Approved Site Formation Plans: Phase II Works dated 5 November 1995.
Hong Kong Observatory (HKO).	(a) Daily rainfall data from January 1983 to July 1997. (b) Hourly rainfall data from January 1984 to July 1997. (c) Isohyets of rainfall between 00:00 hours and 08:00 hours on 2 July 1997.

Table 3 – Maximum Rolling Rainfall at GEO Raingauge No. N09 for Selected Durations Preceding the 2 July 1997 Incident and The Corresponding Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years)
5 minutes	15	06:20 hours on 2 July 1997	4
15 minutes	41	06:25 hours on 2 July 1997	18
1 hour	100	06:30 hours on 2 July 1997	8
2 hours	168	07:50 hours on 2 July 1997	21
4 hours	239.5	08:00 hours on 2 July 1997	30
12 hours	271.5	08:00 hours on 2 July 1997	8
24 hours	283.5	08:00 hours on 2 July 1997	4
2 days	356.5	08:00 hours on 2 July 1997	5
4 days	384	08:00 hours on 2 July 1997	3
7 days	459.5	08:00 hours on 2 July 1997	4
15 days	617	08:00 hours on 2 July 1997	5
31 days	1005.5	08:00 hours on 2 July 1997	14

Notes:

(1) Return periods were derived from the Gumbel equation and data published in Table 3 of Lam & Leung (1994).

(2) Maximum rolling rainfall was calculated from 5-minute data for durations up to one hour and from hourly data for longer rainfall durations.

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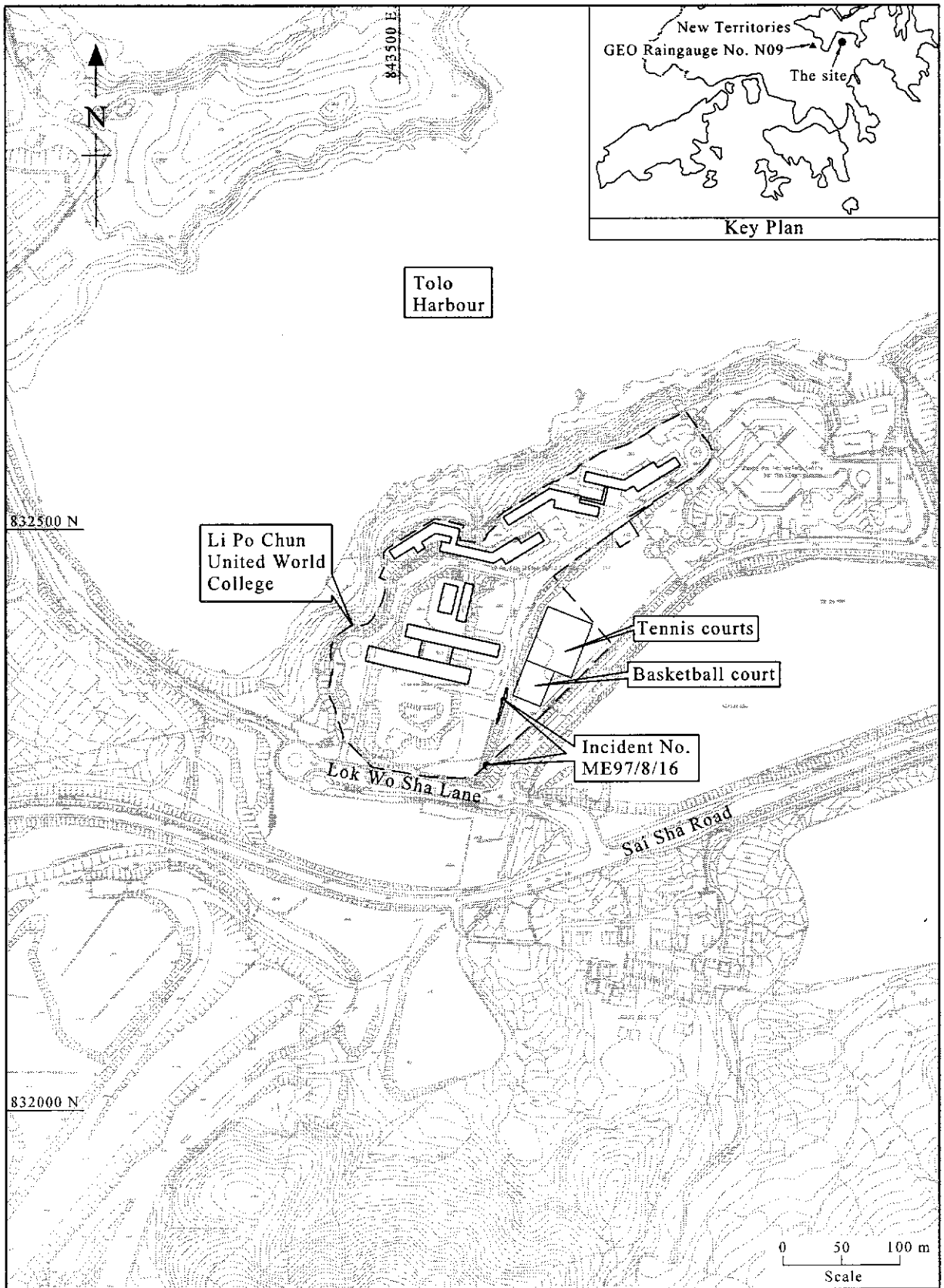


Note : Base map is extracted from Survey Sheet Nos. 7NE-20A, 7NE-15C, 7NE-14D and 7NE-19B dated November 1996 (Original scale 1:1 000).

Figure 1 - Site Location Plan

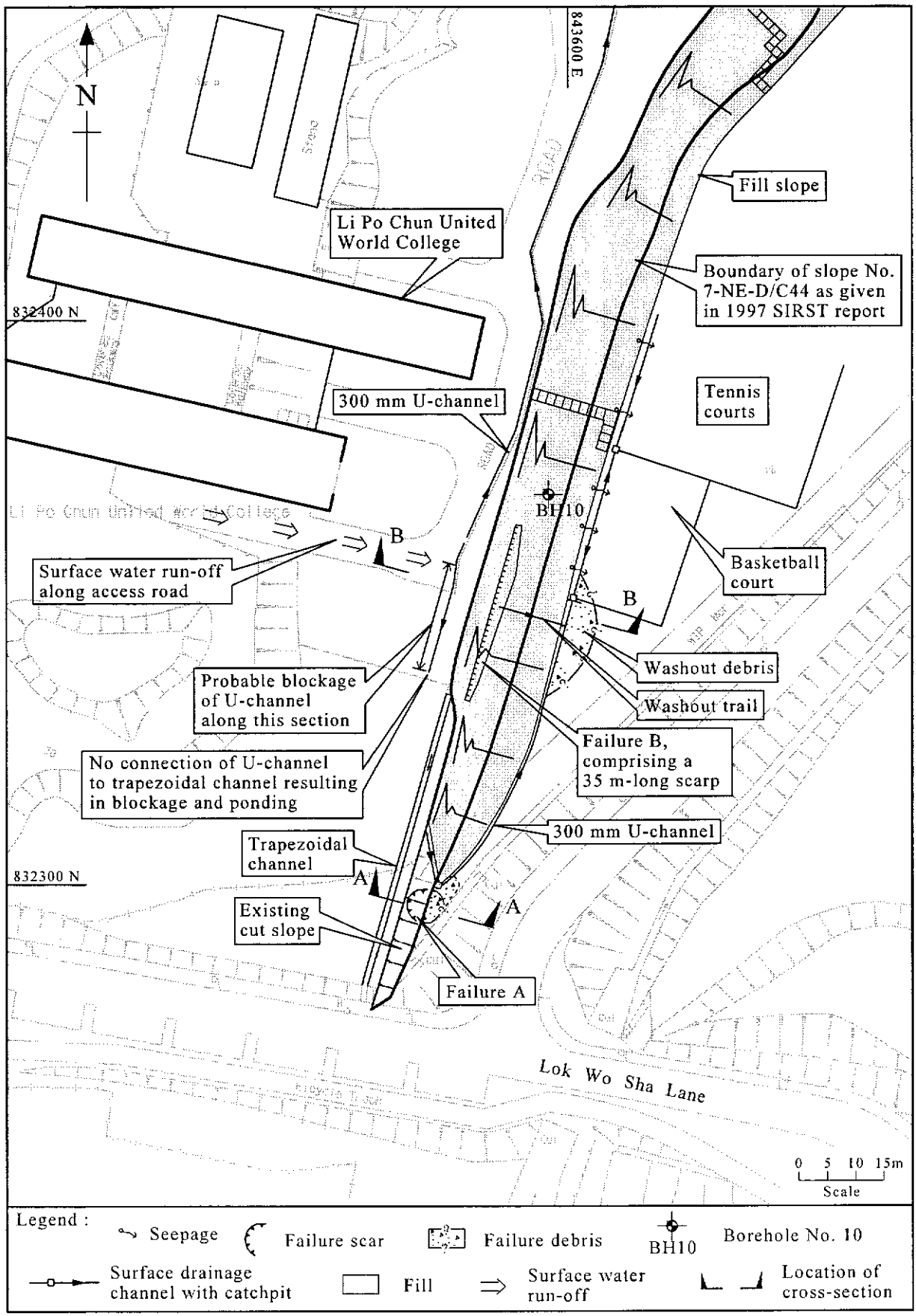


Figure 2 - Plan of the Failure Sites

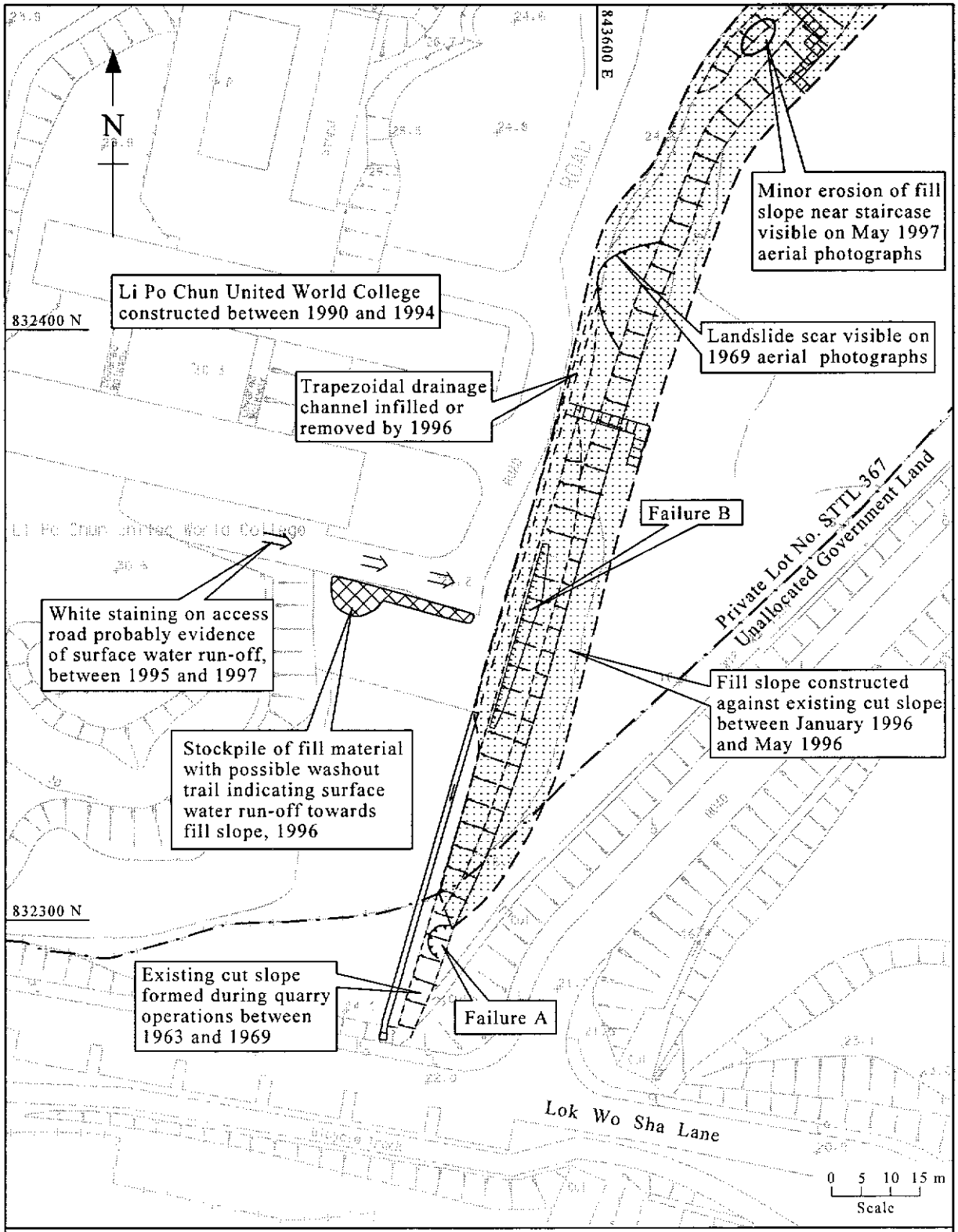
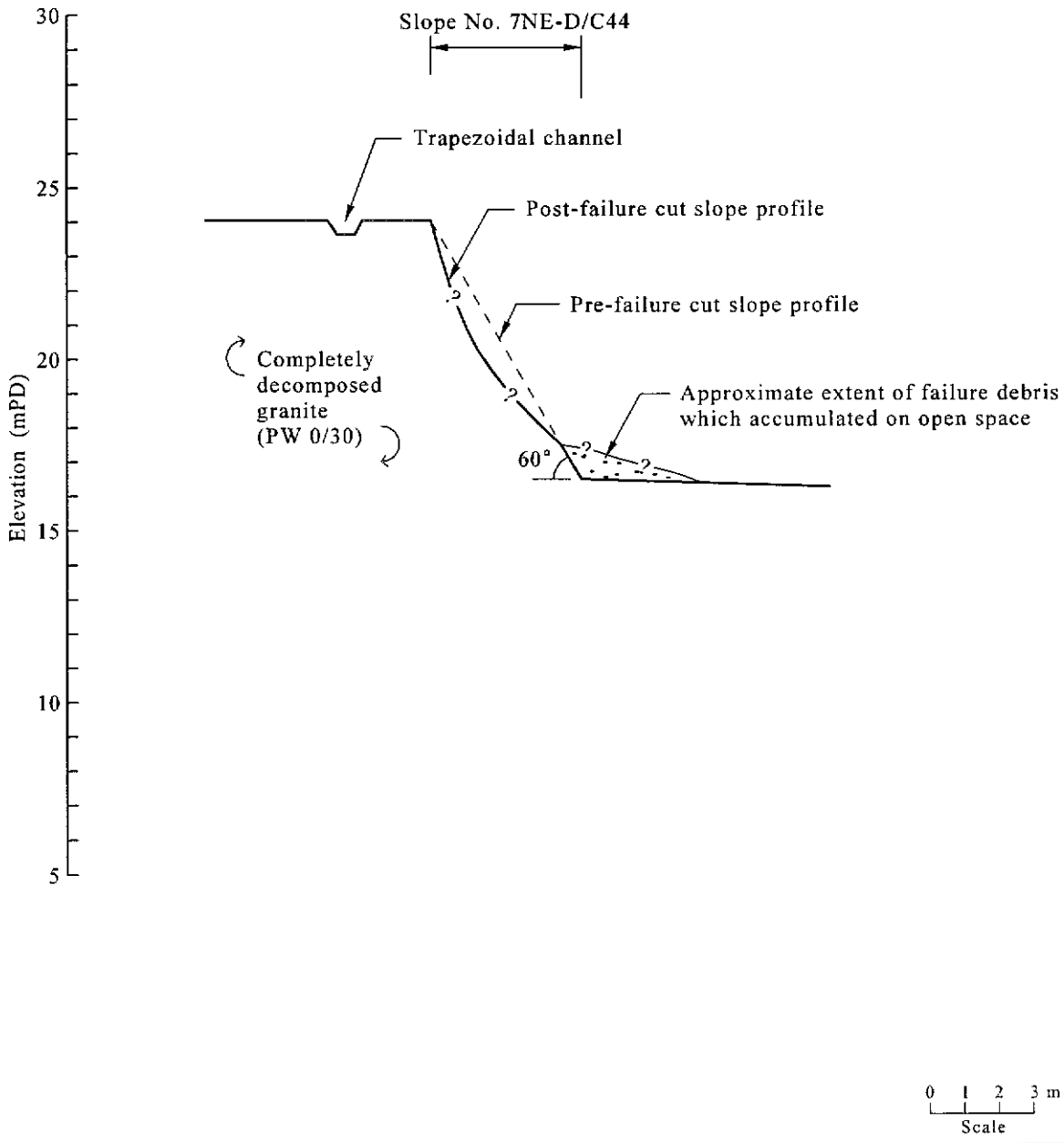


Figure 3 - Site History and Land Status



Note : Refer to Figure 2 for location of cross-section.

Figure 4 - Geological Cross-section A - A

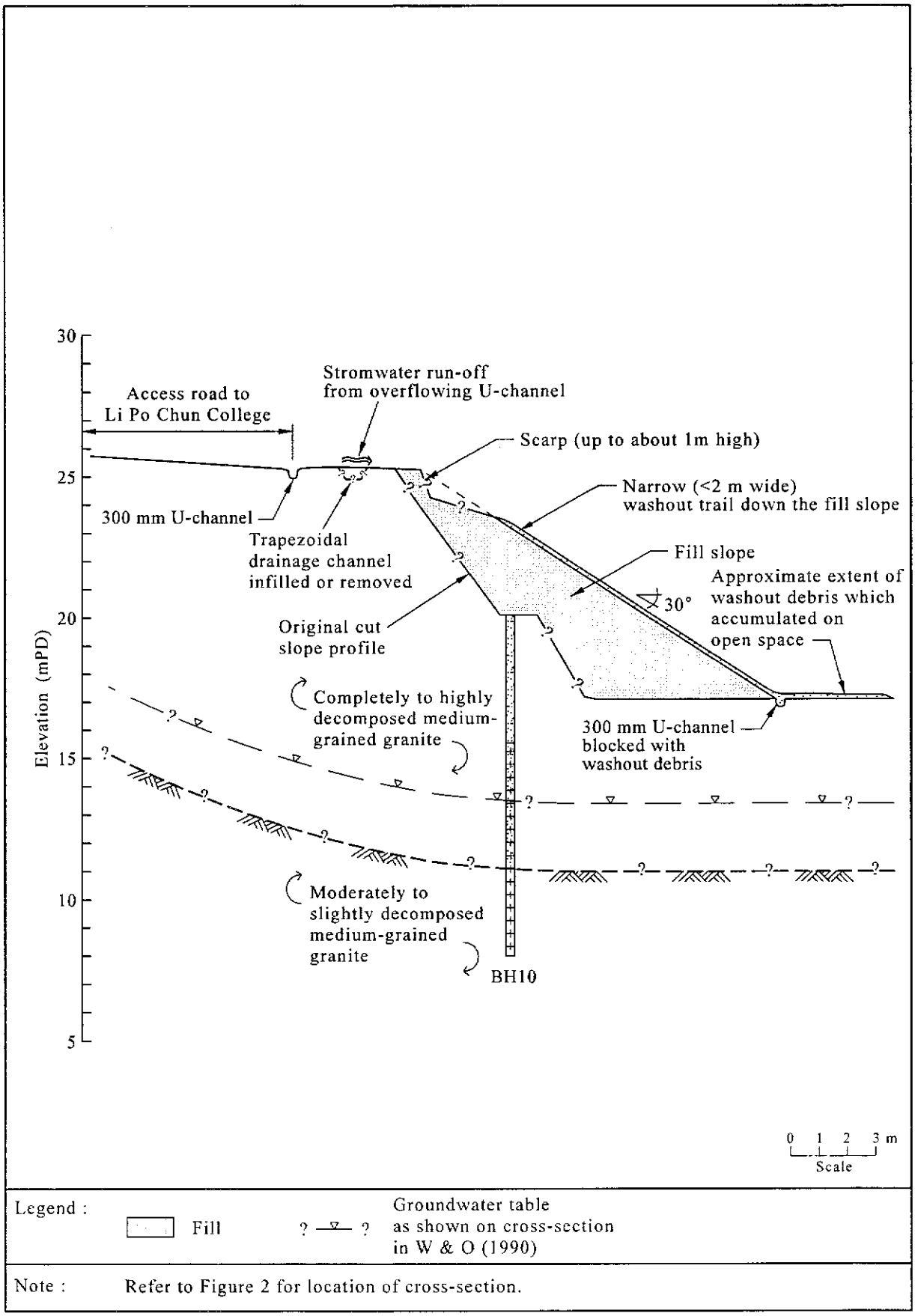
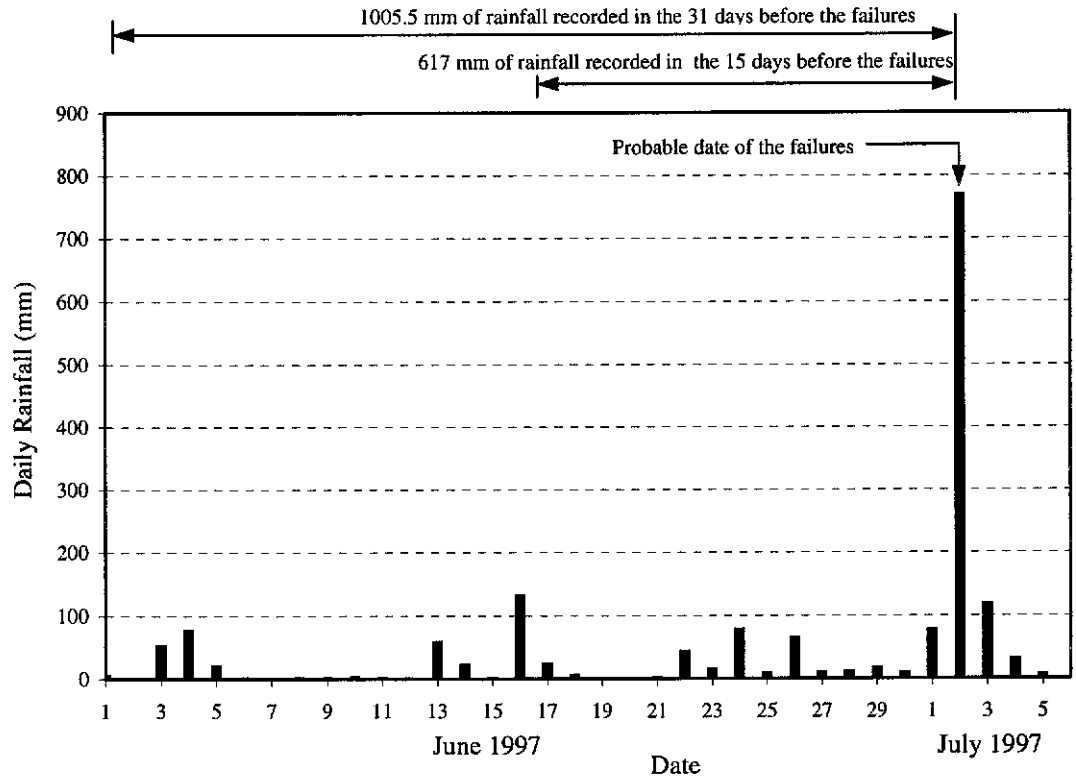
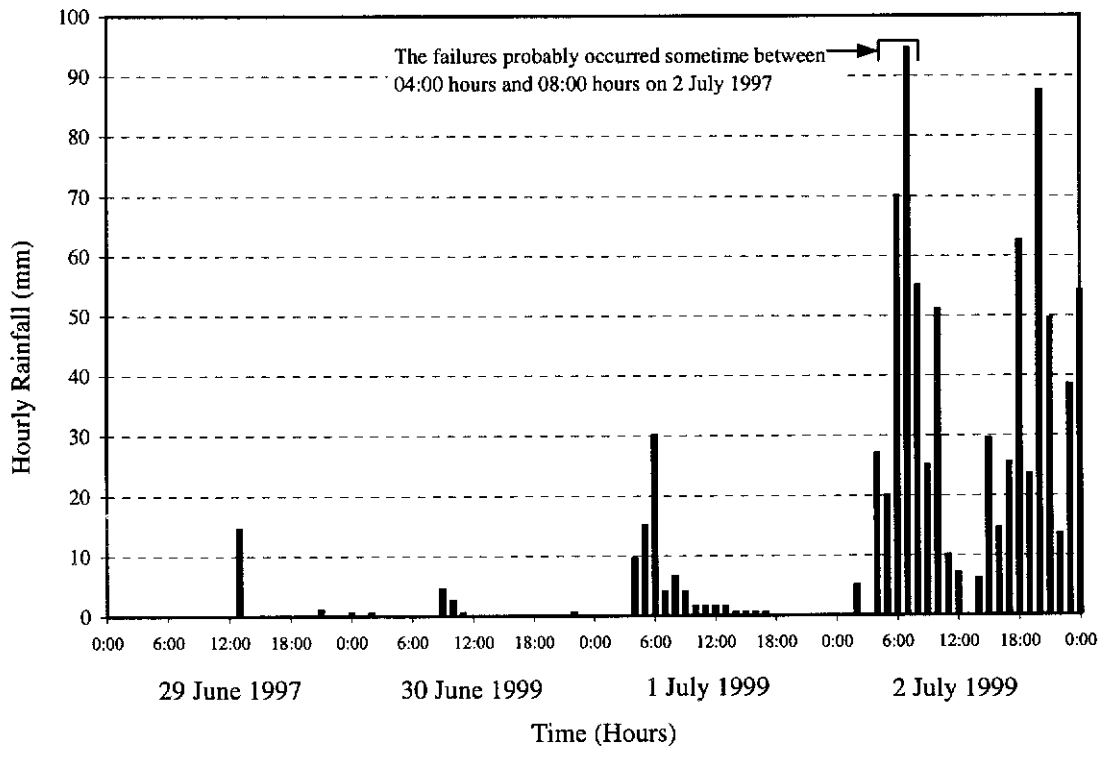


Figure 5 - Geological Cross-section B - B

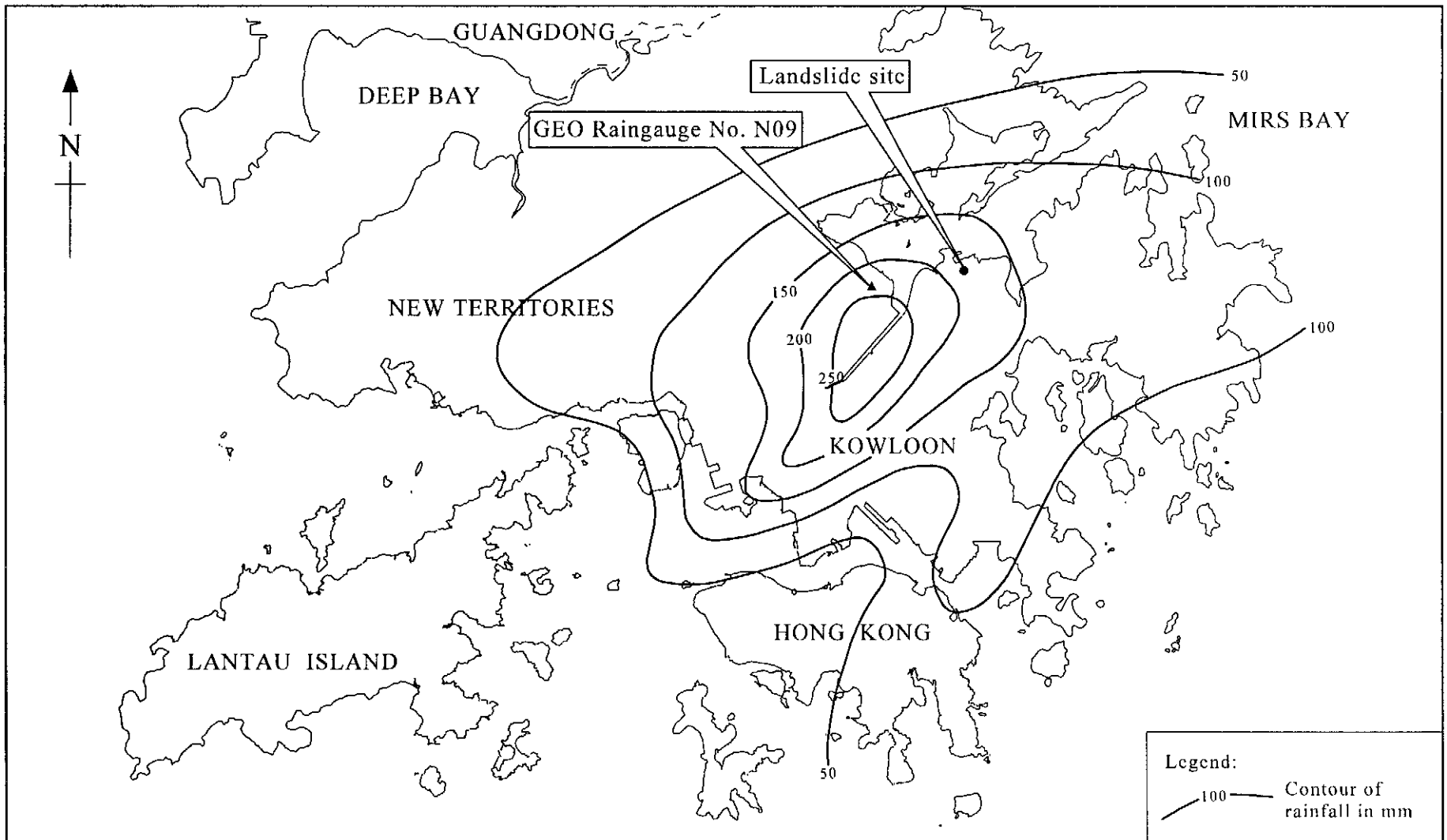


(a) Daily Rainfall Recorded between 1 June and 5 July 1997



(b) Hourly Rainfall Recorded between 29 June and 2 July 1997

Figure 6 - Rainfall Recorded at GEO Raingauge No. N09



Note : Isohyets prepared by the Hong Kong Observatory.

Figure 7 - Isohyets of Rainfall between 00:00 Hours and 08:00 Hours on 2 July 1997

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Plate 1 - View North Showing Failure B comprising 35 m-long Scarp on the Fill Slope (Photograph Taken on 19 August 1997)

Plate 2 - View North Showing Failure A on the Cut Slope with the Fill Slope Shown in the Background (Photograph Taken on 19 August 1997)

Plate 3 - Remedial Works at the Cut Slope
(Photograph Taken on 24 February 1998)

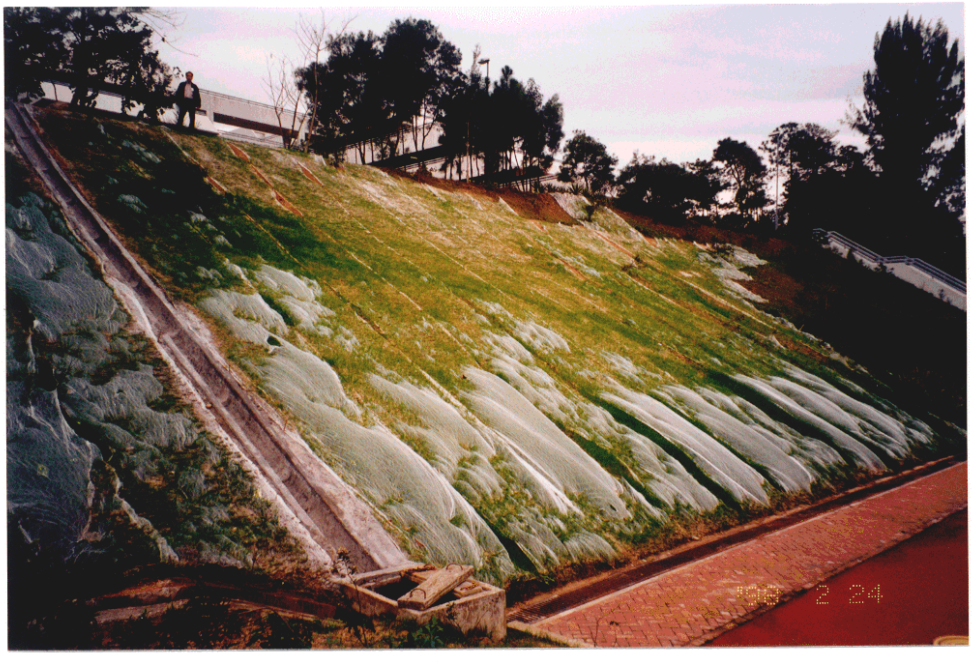

Plate 4 - Remedial Works at the Fill Slope
(Photograph Taken on 24 February 1998)

Plate 5 - U-channel Constructed between the Existing Drainage Channels at the Crest of the Fill Slope During Remedial Works (Photograph Taken on 24 February 1998)