INVESTIGATION OF SOME SELECTED LANDSLIDE INCIDENTS IN 1997 (VOLUME 1)

GEO REPORT No. 79

Halcrow Asia Partnership Ltd.

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

INVESTIGATION OF SOME SELECTED LANDSLIDE INCIDENTS IN 1997 (VOLUME 1)

GEO REPORT No. 79

Halcrow Asia Partnership Ltd.

First published, November 1998

Prepared by :

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

This publication is available from :

Government Publications Centre,
Ground Floor, Low Block,
Queensway Government Offices,
66 Queensway,
Hong Kong.

Overseas orders should be placed with :

Publications Sales Office,
Information Services Department,
28th Floor, Siu On Centre,
188 Lockhart Road, Wan Chai,
Hong Kong.

Price in Hong Kong : HK$192
Price overseas : US$30 (including surface postage)

An additional bank charge of **HK$50** or **US$6.50** is required per cheque made in currencies other than Hong Kong dollars.

Cheques, bank drafts or money orders must be made payable to
The Government of the Hong Kong Special Administrative Region

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. A charge is made to cover the cost of printing.

The Geotechnical Engineering Office also publishes guidance documents as GEO Publications. These publications and the GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the last page of this report.

R.K.S. Chan
Principal Government Geotechnical Engineer
November 1998

EXPLANATORY NOTE

This GEO Report consists of four Landslide Study Reports on the investigation of selected slope failures that occurred in 1997. The investigations were carried out by Halcrow Asia Partnership Ltd (HAP) for the Geotechnical Engineering Office as part of the 1997 Landslip Investigation Consultancy.

The LI Consultancies aim to achieve the following objectives through the review and study of landslides:

(a) establishment of an improved slope assessment methodology,

(b) identification of slopes requiring follow-up action, and

(c) recommendation of improvement to the Government's slope safety system and current geotechnical engineering practice in Hong Kong.

The Landslide Study Reports prepared by HAP are presented in four sections in this Report. Their titles are as follows :

The Landslip Investigation Division of the Geotechnical Engineering Office worked closely with the LI Consultants and provided technical input and assistance to the landslide studies.

SECTION 1 : DETAILED STUDY OF THE LANDSLIDE AT UNIVERSITY KOWLOON-CANTON RAILWAY CORPORATION STATION ON 2 JULY 1997

Halcrow Asia Partnership Ltd

This report was originally produced in March 1998
as GEO Landslide Study Report No. LSR 1/98

FOREWORD

This report presents the findings of a detailed study of a landslide (GEO Incident No. ME97/7/29) which occurred on the 2 July 1997 on a slope south of the Kowloon-Canton Railway Corporation (KCRC) University Station. Debris from the landslide obstructed the north-bound KCRC rail track and caused significant disruption to rail services throughout the morning. No fatalities or injuries were reported.

The key objectives of the detailed study were to document the facts about the landslide, present relevant background information and establish the probable causes of the landslide. The scope of the study was generally 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 M Riley and reviewed by Dr R Moore and Mr H Siddle. The assistance of the GEO in the preparation of the report is gratefully acknowledged.

G. Daughton
Project Director/Halcrow Asia Partnership Ltd.

CONTENTS

1. INTRODUCTION

On the morning of 2 July 1997, a landslide (GEO Incident No. ME97/7/29) occurred on a slope south of the Kowloon-Canton Railway Corporation (KCRC) University Station (Figure 1). Debris from the landslide blocked the north-bound KCRC rail track and caused significant disruption to rail services throughout the morning. No fatalities or injuries were reported.

Following the landslide, Halcrow Asia Partnership Ltd (the 1997 Landslip Investigation Consultants) carried out a detailed study of the failure for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 68/96. This is one of 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 landslide, present relevant background information and establish the probable causes of failure. 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) interviews with KCRC staff involved in the incident,

(d) detailed site observations and measurements at the landslide, and

(e) diagnosis of the probable causes of failure.

2. THE SITE

2.1 Site Description

The location of the landslide is shown in Figure 2. The failure occurred at the crest of registered cut slope No. 7NE-C/C106 and extended upslope into the sloping ground below Tai Po Road. The total height of the slope, from the toe of the cut to Tai Po Road, is about 28 m. The KCRC north-bound rail track is approximately 3 m from the toe of the cut slope section.

At the location of the landslide the dominant slope angle is about 40°. The inclination of the lowest 2 m of the slope is about 60°. There is no discernible difference in slope angle across the apparent boundary between the cut slope and the ground above its crest shown on the topographic map. The true extent of cutting is uncertain.

Prior to failure the lower 6 m section of the cut slope had been shotcreted, but elsewhere the slope was densely vegetated (Figure 2 and Plate 1).

A 2.5 m high concrete retaining structure, approximately 3 m long and inclined at about 55°, is present at the toe of the slope immediately south of the failed section (Figure 2).

No surface drainage measures are present on the slope, but a covered U-channel associated with the railway is located near the toe. Tai Po Road is located at the crest of the slope about 8 m beyond the crest of the landslide. The road falls to the south at about 5° which directs surface water flow to a drainage system located at the western (inside) kerb of the road and away from the failure location. A 100 mm diameter metal pipe, thought to be a water carrying installation, was observed at the ground surface near the crest of the slope. Subsurface, water-carrying services are also present in the eastern pavement of Tai Po Road associated with a fire hydrant located about 10 m north of the landslide site.

The landslide principally occurred on land within the KCRC boundary but its western part also affected unallocated Government land (Figure 2). Sha Tin Town Lot (STTL) No. 437 is located near to the northern part of the landslide but was not directly affected by the incident.

2.2 Site History

KCRC records indicate that many of the slopes along the railway corridor remained "virtually untouched since their construction in 1910" (Ove Arup & Partners, 1987a) until the mid 1980's. At that time, a programme for upgrading the railway, involving double-tracking and realignment of the route was completed, and involved modification to some slopes. KCRC have no records of any modifications made to cut slope No. 7NE-C/C106 during these works.

The cut slope can be seen on the earliest available aerial photographs of the area, taken in 1963. Features which appear to be shallow failures were evident in the central and northern parts of the cut slope in photographs taken in 1964 and 1980 respectively (Figure 3). No records relating to these incidents have been located.

The cut slope has been densely vegetated for much of its history though the lower part of the slope was shotcreted in 1991.

Following the recent landslide, loose debris was removed and the scar was shotcreted by KCRC at the recommendation of the GEO. Weepholes were installed at regular intervals to enable drainage of water from the slope.

GEO recommended to Buildings Department (BD) that a Dangerous Hillside Order (DHO) be served on KCRC with respect to the failed slope. The DHO, however, had not been served at the time of preparation of this report.

Following this and other recent failures, KCRC have instigated a geotechnical review of slopes within their boundaries and adjacent to the railway tracks.

2.3 Previous Studies

Cut slope No. 7NE-C/C106 was registered in the 1977/78 Catalogue of Slopes and a field sheet was prepared by the consultants engaged by Government to prepare the Catalogue following an inspection of the slope in April 1978 (Binnie & Partners, 1978). No visible evidence of previous instability or distress was identified at that time.

In 1984, KCRC began a comprehensive geotechnical investigation of all existing slopes adjacent to the newly upgraded rail tracks. The project was divided into three stages, namely:

(a) Stage 1: Preliminary inspection and cataloguing of cut slopes and embankments between Hung Hom and Lo Wu to identify slopes requiring further study. Inspection data were then considered together with the results of a quantitative stability assessment of all cut slopes carried out using assumed soil parameters. Embankments were considered to present a lower risk to the railway than cut slopes and were therefore excluded from further study. The findings were presented in a Preliminary Report in 1984 (Ove Arup & Partners, 1984).

(b) Stage 2: Geotechnical investigation of 24 slopes identified during Stage 1 as posing a threat to the railway or to structures and private property above the slopes. The assessments were based on a programme of site specific ground investigation and laboratory testing. The findings were presented in a report dated April 1987 (Ove Arup & Partners, 1987b).

(c) Stage 3: Detailed design of remedial works for "fourteen slopes identified as not meeting current standards" (Ove Arup & Partners, 1987a) and the letting and supervision of the construction contracts.

Cut slope No. 7NE-C/C106 was selected for further study as part of the Stage 2 investigation programme which began in March 1986.

The Stage 2 investigation determined that remedial works were required to improve the factor of safety (FOS) of the slope against potential deep failure to the desired standard (FOS = 1.2). The proposals recommended installation of doweled ground beams over a central 45 m length, and minor trimming and surfacing of the lower slopes at either end of the cutting (Ove Arup & Partners, 1987b). KCRC have confirmed that "works, including removal of loose materials, installation of dowel bars and (application of) shotcrete to the slope surface to the height of 10 m from the toe" were completed in 1991, but noted that the recent landslide originated at the "upper part of the slope where no improvement work has been carried out" (KCRC, 1997a). KCRC have no records to indicate that the design of the slope improvement works was checked and approved by the GEO prior to construction. A review of GEO records also found no evidence that the design had been submitted to GEO for checking.

Cut slope No. 7NE-C/C106 was considered for Stage 1 Study by the Geotechnical Control Office (GCO) in 1988, but was not selected because the "slope (had) already been investigated to at least Stage 1 Study level by KCRC's consultant" (GCO, 1988).

KCRC carry out annual inspections of slopes adjacent to the railway tracks (KCRC, 1997b). The cut slope is registered as Slope No. U14.3 (7.10) in the KCRC system and was last inspected before the landslide on 3 May 1997. The inspection report (KCRC, 1997c) concluded that the slope was in generally good condition, and recommended only minor maintenance works including removal of blockages noted in weepholes. It is not clear whether the ground above the crest of the cut slope was included in the inspections.

In mid-1992, the GEO initiated a consultancy agreement entitled 'Systematic Inspection of Features in the Territory' (SIFT) to update information on existing registered slopes based on studies of aerial photographs. Cut slope No. 7NE-C/C106 was identified as a Class C1 feature by SIFT in 1994. According to SIFT's classification system, Class C1 features are "cut features considered to meet GEO criteria for slope registration" and "have been formed or substantially modified before 30.6.1978 or have been illegally formed after 30.6.1978" (King, 1994).

In 1994, the GEO commenced a consultancy agreement entitled 'Systematic Identification and Registration of Slopes in the Territory (SIRST) to systematically update the 1977/78 Catalogue of Slopes and prepare the New Catalogue of Slopes. The SIRST field sheet, prepared for cut slope No. 7NE-C/C106 in July 1995 indicates that Stage 1 Study was not required as the feature had previously been "checked by GEO".

2.4 Subsurface Conditions

Sheet 7 of the Hong Kong Geological Survey 1:20 000 scale map (GCO, 1986) and the 1987 Geotechnical Area Studies Programme Engineering Geology Map for the Central New Territories (GCO, 1987), indicate that the site is underlain by medium-grained granite.

Ground investigation data obtained for the KCRC Stage 2 investigation of the cut slope in 1986 (Bachy Soletanche Group, 1986) included two boreholes and three surface strips at the locations shown in Figure 3.

Borehole BH18, sited upslope of the landslide (Figure 3), encountered slightly decomposed medium- to coarse-grained granite at a depth 9.3 m, overlain essentially by completely decomposed granite (CDG). Surface strip CS3, located nearest to the landslide site, exposed completely decomposed granite over most of its length, though the lower 7.3 m were recorded as highly to moderately decomposed granite.

Borehole BH17, located about 50 m south of the landslide (Figure 3) proved slightly decomposed, coarse-grained granite at a depth of 10.8 m overlain by a variable sequence (6.8 m thick) of moderately to completely decomposed granite. The borehole also recorded a 4 m thickness of "loose greyish and yellowish brown silty fine to coarse sand" which was classified as fill (Bachy Soletanche Group, 1986). Surface strips S1 and S2 also identified "very loose" fill materials which extended 6.1 m and 15.5 m from the top of the exposed area respectively. The fill was recorded on the surface strip logs to have been placed by "dumping" (Bachy Soletanche Group, 1986).

The borehole and surface strip logs show the presence of a loose fill body at the crest of the southern part of the slope away from the location of the recent landslide site. The possible extent of the fill body, based on interpretation of KCRC's ground investigation data is shown in plan in Figure 3 and in section on Figure 4.

Piezometers were installed in BH17 at 7 m depth in June 1986 and at 9 m depth in BH18 in July 1986. These were reported as dry in the 1987 Stage 2 geotechnical assessment report (Ove Arup & Partners, 1987b).

3. THE LANDSLIDE

3.1 Time of Failure

The landslide was first observed by the driver of a south-bound train that was waiting at University Station early on the morning of 2 July 1997. The train was scheduled to arrive at the station at 06:00 hours, and the driver noted a "big noise at about 8 minutes after arrival" (KCRC, 1998). The driver then left the train and saw the landslide debris obstructing the north-bound tracks. The landslide most probably occurred therefore at about 06:08 hours on the morning of 2 July 1997. A landslide warning was issued at 06:25 hours on 2 July 1997.

3.2 Description of the Landslide

Observations made during inspections of the landslide are annotated in Figure 5 and a cross-section through the failed section is given in Figure 6. Photographs of the landslide are shown in Plates 1 to 4.

The landslide occurred 8 m below Tai Po Road, producing a rupture surface about 9.2 m long and up to 7 m wide. The volume of failure was estimated at about 30 m^3. The landslide involved both the cut slope and the ground over its crest. The failure was shallow, reaching a maximum depth of about 1 m.

The failure scar exposed between 0.6 m and 1 m of granitic residual soil overlying completely decomposed fine- to medium-grained granite (Figure 6). A planar surface inclined at 55°, possibly a relict discontinuity, was exposed in the completely decomposed granite at the upper part of the failure scar.

No seepage was observed at the failure scar during inspections of the landslide on 4 July and 22 July 1997.

The debris spread out as it ran down the cut slope forming a debris fan about 12 m wide at the toe of the cut slope. The majority of the debris accumulated in the area between the toe of the slope and the railway, though a number of boulders and approximately 1 m^3 to 2 m^3 of finer material crossed the up-line track 3 m away from the toe of the slope. Some debris was also retained in the rupture area. The travel angle of the landslide debris, measured from the crest of the failure to the distal end of the main body of the landslide debris, was about 38° (Figure 6). This angle is within the typical range for rain-induced soil cut slope failures in Hong Kong (Wong & Ho, 1996), indicating that the debris mobility of this landslide is comparable to that commonly observed.

Obstruction of the railway tracks by the debris disrupted the normal KCRC service between 07:53 hours and 10:39 hours. Maximum north-bound and south-bound service gaps of 92 minutes and 98 minutes were recorded respectively. Disruption to the service was aggravated by another failure (GEO Incident No. ME97/7/30) on the same morning near Fo Tan Station to the south of University Station. The landslide is the subject of a separate detailed study report.

4. RAINFALL

The nearest GEO automatic raingauge No. N09 is located at the Meteorology Laboratory at Chinese University, about 400 m northwest of the site (Figure 1). The daily rainfall recorded by the raingauge between 1 June 1997 and 6 July 1997 together with hourly rainfall between 29 June 1997 and 2 July 1997 are presented in Figure 7a and 7b respectively. Isohyets of rainfall recorded between the onset of the storm on 2 July 1997 and 06:10 hours are shown in Figure 8.

Rain began to fall at about 03:00 hours on 2 July 1997 and intensified significantly between 05:00 hours and 07:00 hours when 164.5 mm of rainfall was recorded. The 12-hour and 24-hour rainfall prior to 06:10 hours were 130 mm and 151.5 mm respectively. The maximum rolling hourly rainfall was 72 mm, recorded between 04:50 hours and 05:50 hours on 2 July 1997. A total of 864 mm of rainfall was recorded by GEO raingauge No. N09 in the 31 days before the failure.

Table 1 presents estimated return periods for the maximum rolling rainfall for selected durations based on historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994). The 31-day rainfall was the most severe with a corresponding return period of about 8 years.

The historical maximum hourly rainfalls recorded in each month at GEO raingauge No. N09 are shown in Figure 9. The figure shows that the maximum hourly rainfall of 94.5 mm for July 1997 was recorded between 06:00 hours and 07:00 hours on 2 July 1997, though 86.5 mm of this fell after the landslide had occurred. Prior to the landslide, the maximum clock-hourly rainfall in July 1997 was 70 mm, recorded between 05:00 hours and 06:00 hours on 2 July 1997 (Hong Kong Observatory, 1997). This is the third highest on record, with rainstorm events in April 1989 and October 1996 recording greater maximum hourly rainfalls.

5. PROBABLE CAUSES OF FAILURE

The close correlation between the rainfall event of 2 July 1997 and estimated time of failure indicates that heavy rainfall probably triggered the landslide.

Three possible sources of water may have contributed to the landslide:

(a) surface stormwater run-off from Tai Po Road,

(b) leakage from subsurface drainage and water carrying services in Tai Po Road, and

(c) direct rainfall on and adjacent to the landslide site.

Stormwater run-off from Tai Po Road to the landslide is considered unlikely since the design of the road drainage is such that surface water on the road falls away from the direction of the failed slope. Furthermore, there was no evidence of any significant surface water flow on the slope between the road and the landslide area.

Throughflow beneath the road, perhaps involving leakage from the subsurface drainage system in Tai Po Road was also discounted as there were no signs of such throughflow such as piping. It is also unlikely that significant quantities of water could travel underground from the drains located in the inside kerb of Tai Po Road to the failure site, a distance of some 30 m, in the period between the on-set of the storm (04:00 hours) and the time at which the failure was first recognised (06:08 hours). There is no evidence that water-carrying services at the crest of the slope were leaking prior to the failure.

Direct rainfall on and adjacent to the landslide is, therefore, the most probable source of water involved in the failure.

The failure was very shallow, and involved loose, apparently undisturbed residual soil, and underlying completely decomposed granite. A planar surface in weathered rock was exposed in much of the base of the rupture surface.

Two distinct possible causes of failure related to direct rainfall on and adjacent to the landslide area are considered:

(a) localised erosion by washout action of surface water, and

(b) infiltration of water into the unprotected slope, leading to increased bulk unit weight and reduced shear strength along the failure surface.

Washout action by surface water flow is considered an unlikely mechanism, in view of the lack of evidence of storm water run-off from Tai Po Road and absence of features that might concentrate and direct flow over the slope.

Infiltration into the unprotected slope, therefore, is the most probable cause of the landslide, but the actual mechanism of failure remains unclear. Probably, a number of factors contributed, notably increased bulk unit weight of the overburden due to saturation, loss of suction, and development of positive water pressures. It is likely that the planar surface exposed in the failure scar was a pre-existing discontinuity and as such may have had a slightly lower shear strength than the surrounding completely decomposed granite. Furthermore, critical water pressures possibly developed along this surface, thereby reducing the available shear strength and enabling failure to occur. It is not clear why the slope did not fail during previous heavy storms in 1989 and 1996. The possibility that local stability of the slope had deteriorated with time cannot be excluded. The comparatively wet month that preceded the landslide may have contributed to wetting of the slope, making it susceptible to failure in response to the short-term rainfall of relatively low severity that occurred.

There are no known links between the previous failure in 1980, on the lower cut slope, and the recent failure of 1997, other than their proximity. It is possible that they might both reflect a local adversely oriented joint network.

6. CONCLUSIONS

It is concluded that the landslide was principally caused by infiltration of water into the unprotected slope following a period of intense rainfall. The presence of a relict adverse discontinuity in the weathered rock may have also contributed to the failure due to possible lower shear strength and development of localised water pressures at the discontinuity.

7. REFERENCES

Bachy Soletanche Group (1986). KCRC – Geotechnical Investigation of Existing Slopes – Stage 2. Ground Investigation Factual Report, vol. 2, Bachy Soletanche Group, Contractors to KCRC, 1986.

Binnie & Partners (1978). Landslide Studies Phase 1 Re-Appraisal of Cut Slopes and Natural Slopes and Retaining Walls. Slope No. 7NE-C/C106. Technical Report, Binnie & Partners (HK) Limited, Consulting Engineers for Government of Hong Kong, 2 p.

Geotechnical Control Office (1986). Shatin: Solid and superficial geology. Hong Kong Geological Survey, Map Series HGM 20, Sheet 7, 1:20 000 scale. Geotechnical Control Office, Hong Kong.

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

Geotechnical Control Office (1988). Feature Reference No. 7NE-C/C106, University Railway Station (South End). Stage 1 Studies Summary Report, Geotechnical Engineering Office, Hong Kong, 1 p.

Hong Kong Observatory (1997). Rainfall Record. Hong Kong Observatory Correspondence to HAP Reference HKOG21/50, dated 12 September 1997, 2 p.

KCRC (1997a). Landslide Incident at KCRC, Slope near University Station. KCRC Correspondence to HAP Reference ERD/1BWN/PJT/01 dated 22 August 1997, 1 p.

KCRC (1997b). Notes of Meeting For Preventive Measures – Landslide. Notes of KCRC Meeting on 23 July 1997, 6 p.

KCRC (1997c). KCRC Slope Inspection Data Sheet Slope No. U14.3, May 1997, 9 p.

KCRC (1998). KCRC Incident Report Form (File No. 970098). KCRC Correspondence to HAP dated 4 February 1998, 3 p.

King, J.P. (1994). Guidelines for Phase 2 SIFT (Version 3.1). Internal Report, Geotechnical Engineering Office, Hong Kong, 66 p., plus 5 addenda.

Lam, C.C. & Leung, Y.K. (1994). Extreme rainfall statistics and design rainstorm profiles at selected locations in Hong Kong. Royal Observatory, Hong Kong, Technical Note no. 86, 89 p.

Ove Arup & Partners (1984). Kowloon-Canton Railway Geotechnical Study - Initial Assessment and Preliminary Report. Technical Report, Ove Arup and Partners Limited, Consulting Engineers for KCRC.

Ove Arup & Partners (1987a). Geotechnical Investigation of Existing Slopes Report on Stage 2 Investigation, Executive Report. Technical Report, Ove Arup and Partners Limited, Consulting Engineers for KCRC.

Ove Arup & Partners (1987b). Geotechnical Investigation of Existing Slopes Report on Stage 2 Investigation, Analysis. Technical Report, Ove Arup and Partners Limited, Consulting Engineers for KCRC.

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

LIST OF TABLES

Table 1 – Maximum Rolling Rainfall at GEO Raingauge No. N09 for Selected Durations Preceding the 2 July 1997 Landslide and The Corresponding Estimated Return Periods

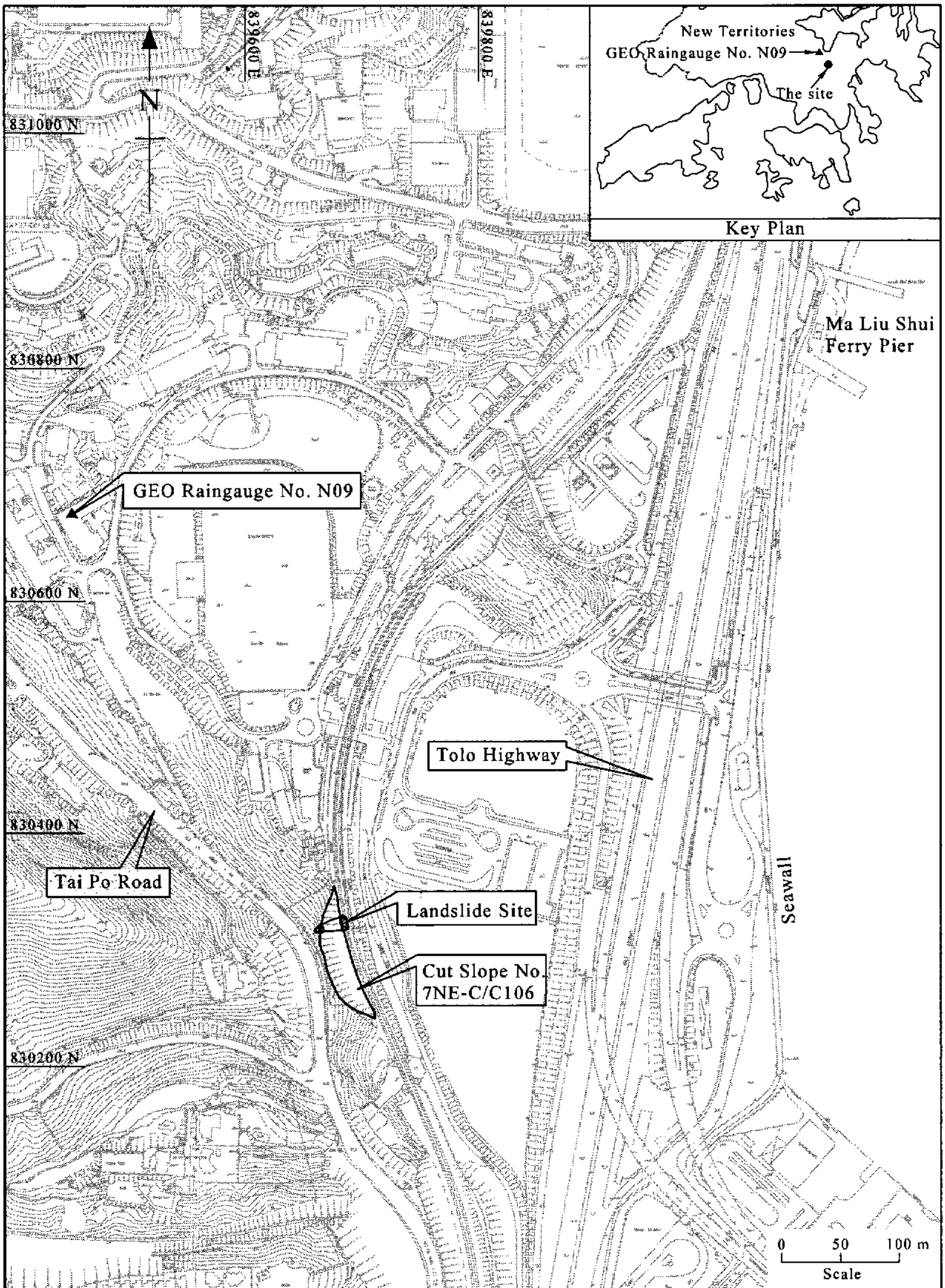
Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years)
5 minutes	12	05:40 hours on 2 July 1997	2
15 minutes	31.5	05:45 hours on 2 July 1997	3
1 hour	72	05:50 hours on 2 July 1997	2
2 hours	90	06:00 hours on 2 July 1997	2
4 hours	117	06:00 hours on 2 July 1997	2
12 hours	122	06:00 hours on 2 July 1997	1
24 hours	144.5	06:00 hours on 2 July 1997	1
2 days	207	06:00 hours on 2 July 1997	2
4 days	234.5	06:00 hours on 2 July 1997	1
7 days	310.5	06:00 hours on 2 July 1997	2
15 days	476	06:00 hours on 2 July 1997	2
31 days	925	06:00 hours on 2 July 1997	8

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.

LIST OF FIGURES



Note : Base map is extracted from Survey Sheet Nos. 7NE-22A, 7NE-22B, 7NE-22C & 7NE-22D dated October 1992 (Original scale 1:1 000).

Figure 1 - Site Location Plan

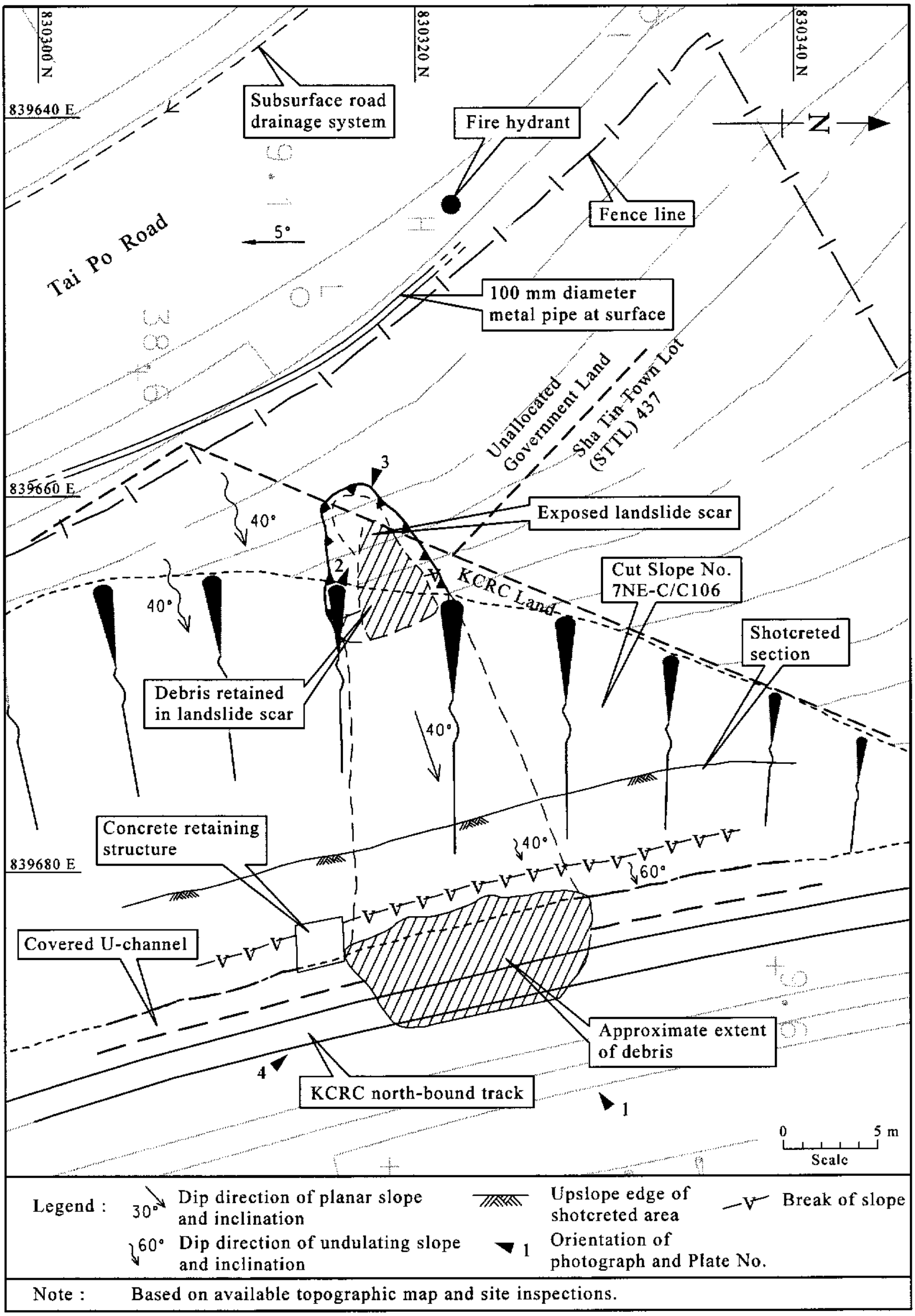
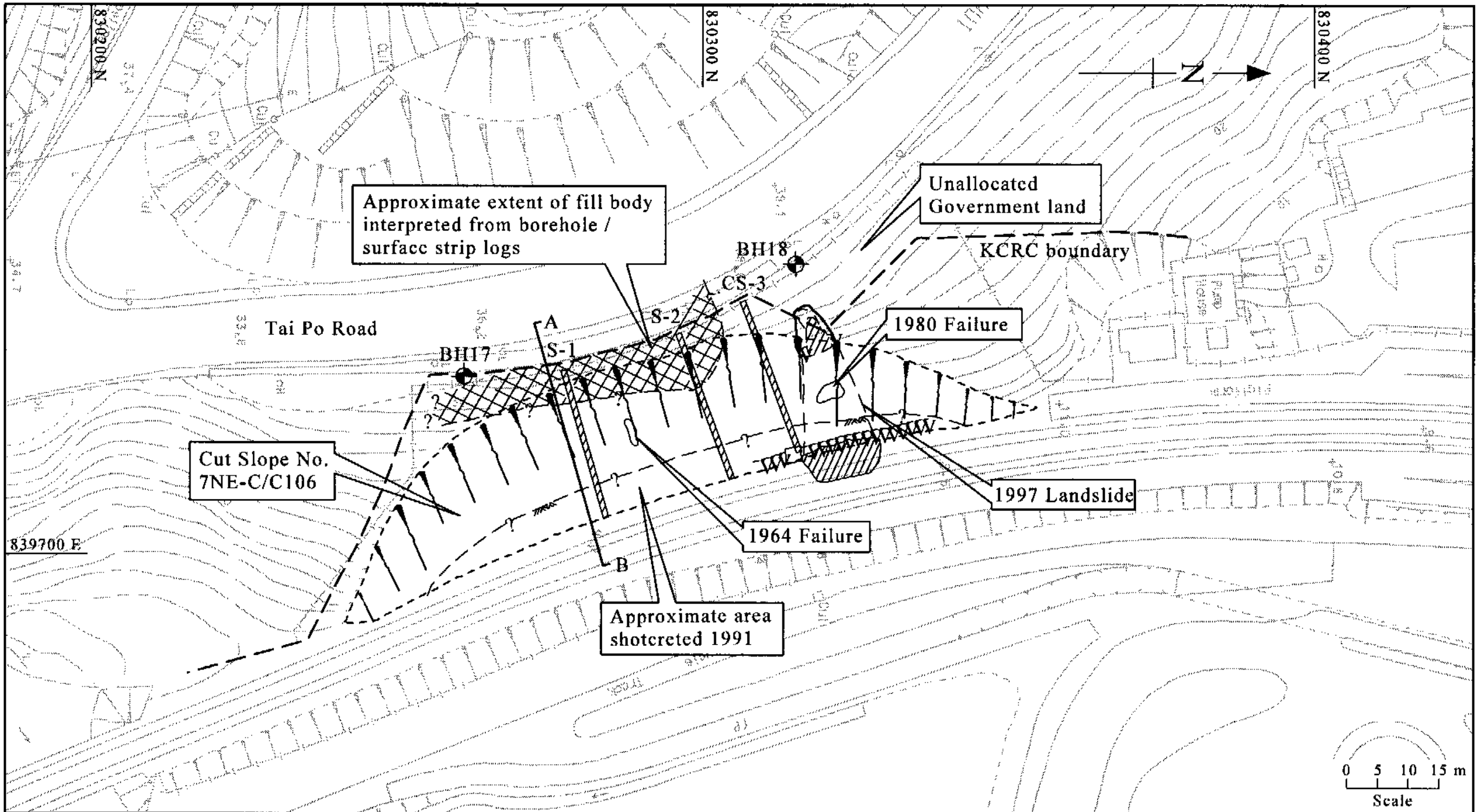


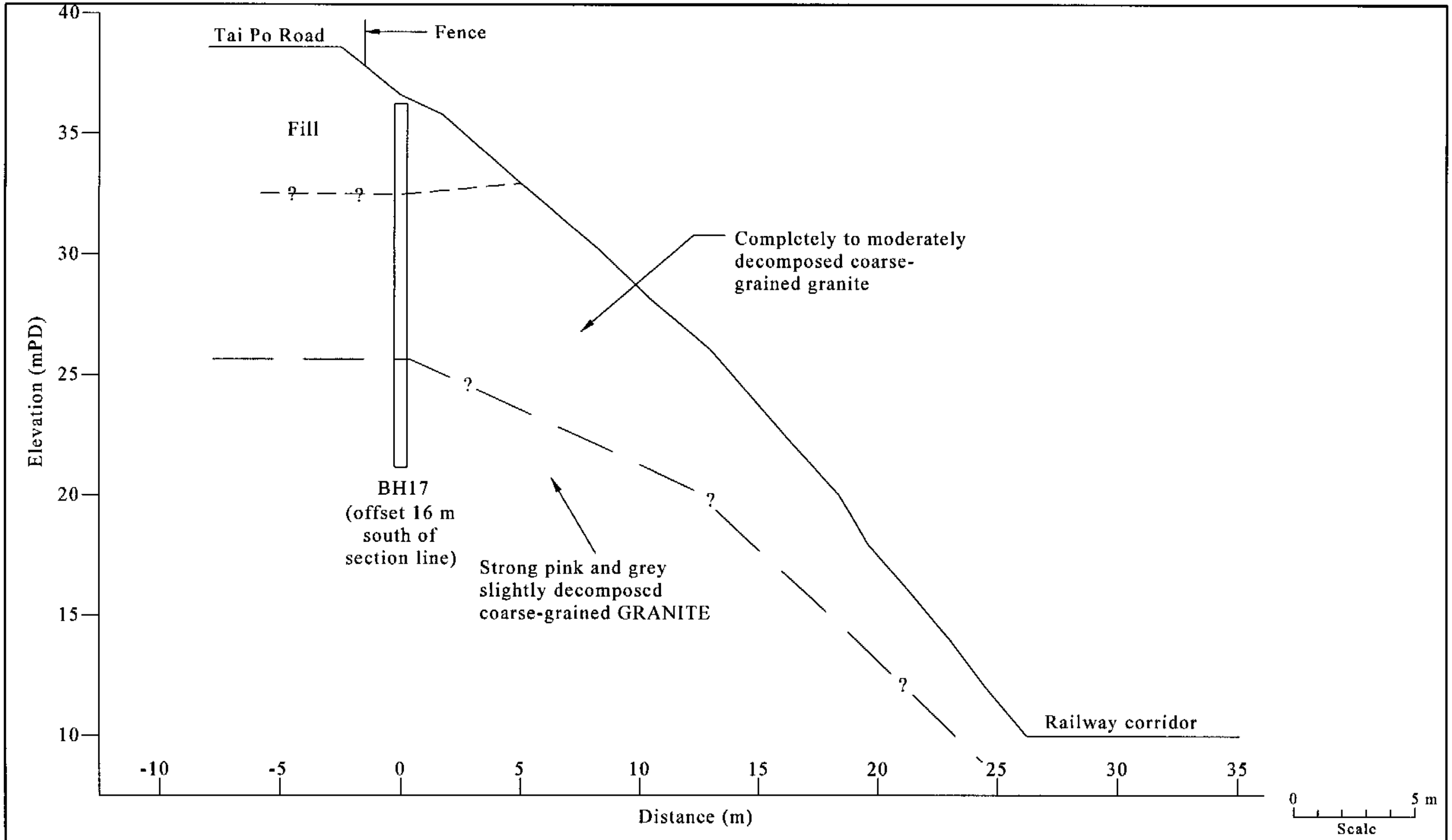
Figure 2 - Plan of the Landslide Site



Legend :	BH17	Borehole Location	S-1	Surface Strip		Location of cross-section A-B in Figure 4

Notes :
(1) Ground investigations carried out for KCRC's investigation of Slope No. 7NE-C/C106 (Ove Arup and Partners Ltd., 1987).
(2) Site history established from review of aerial photographs and available documentary records.

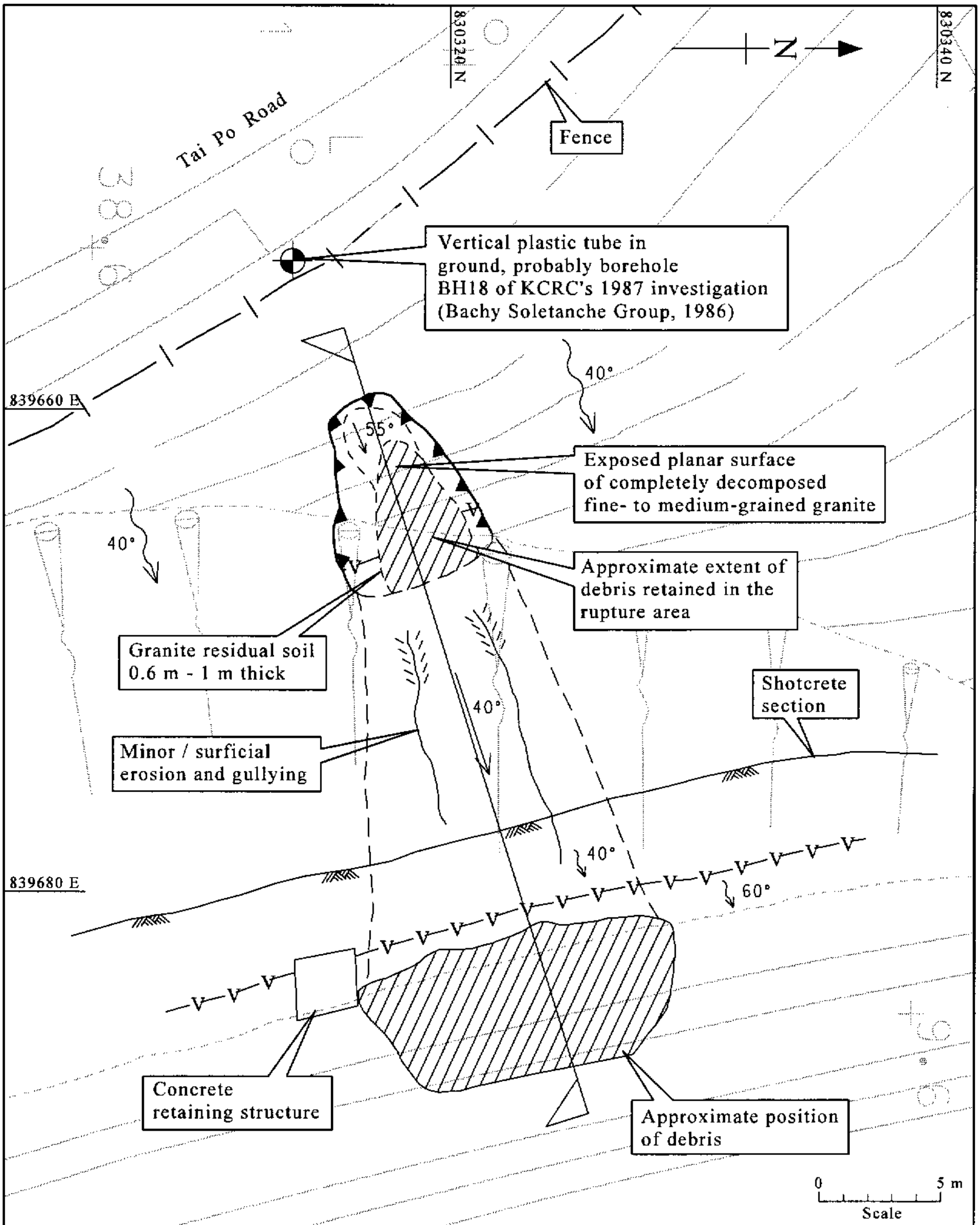
Figure 3 - Land Status and Site History



Notes : (1) Refer to Figure 3 for location of section.

(2) Cross-section interpreted from Borehole BH17 and surface strip S-1 from Bachy Soletanche Group (1986).

Figure 4 - Cross-section A-B through the Southern Part of Cut Slope No. 7NE-C/C106 Showing the Presence of the Fill Body

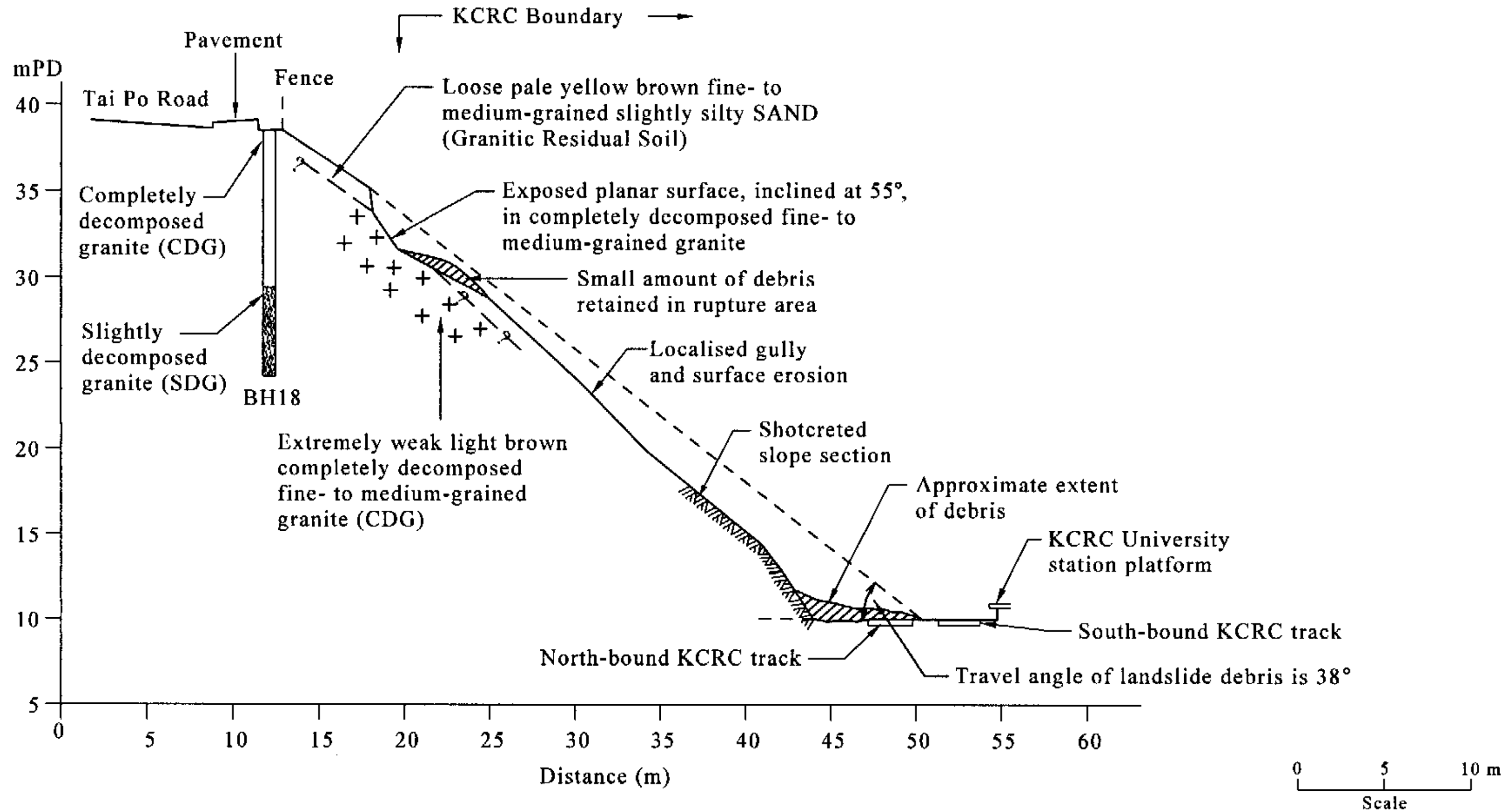


Legend: 30° Direction of planar slope and inclination; 60° Direction of undulating slope and inclination; Break of slope; Location of cross-section shown in Figure 6

Notes: (1) Based on information recovered from site inspections.

(2) Refer to Figure 6 for more detailed soil descriptions.

Figure 5 - Site Plan and Landslide Details



Notes:

(1) BH18 summarised from Bachy Soletanche Group, 1986.

(2) In the borehole log of BH18, CDG typically recorded as medium-dense, variously coloured silty fine- to coarse-grained sand SDG described as strong brownish pink and grey, spotted black slightly decomposed medium- to coarse-grained granite.

(3) Refer to Figure 5 for location of cross-section.

(4) Post-failure ground profile determined by site measurement.

Figure 6 - Cross-section through the Landslide

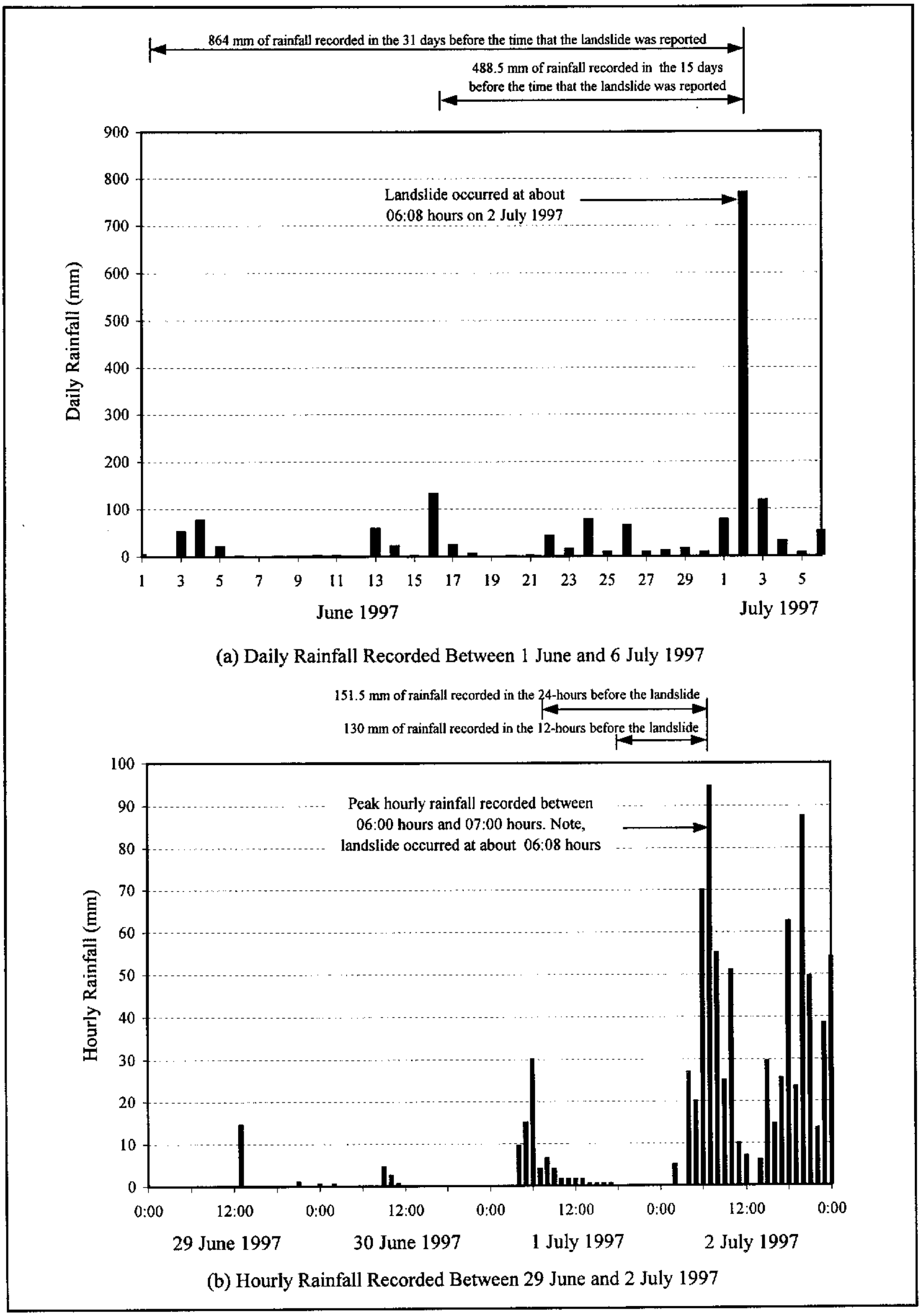
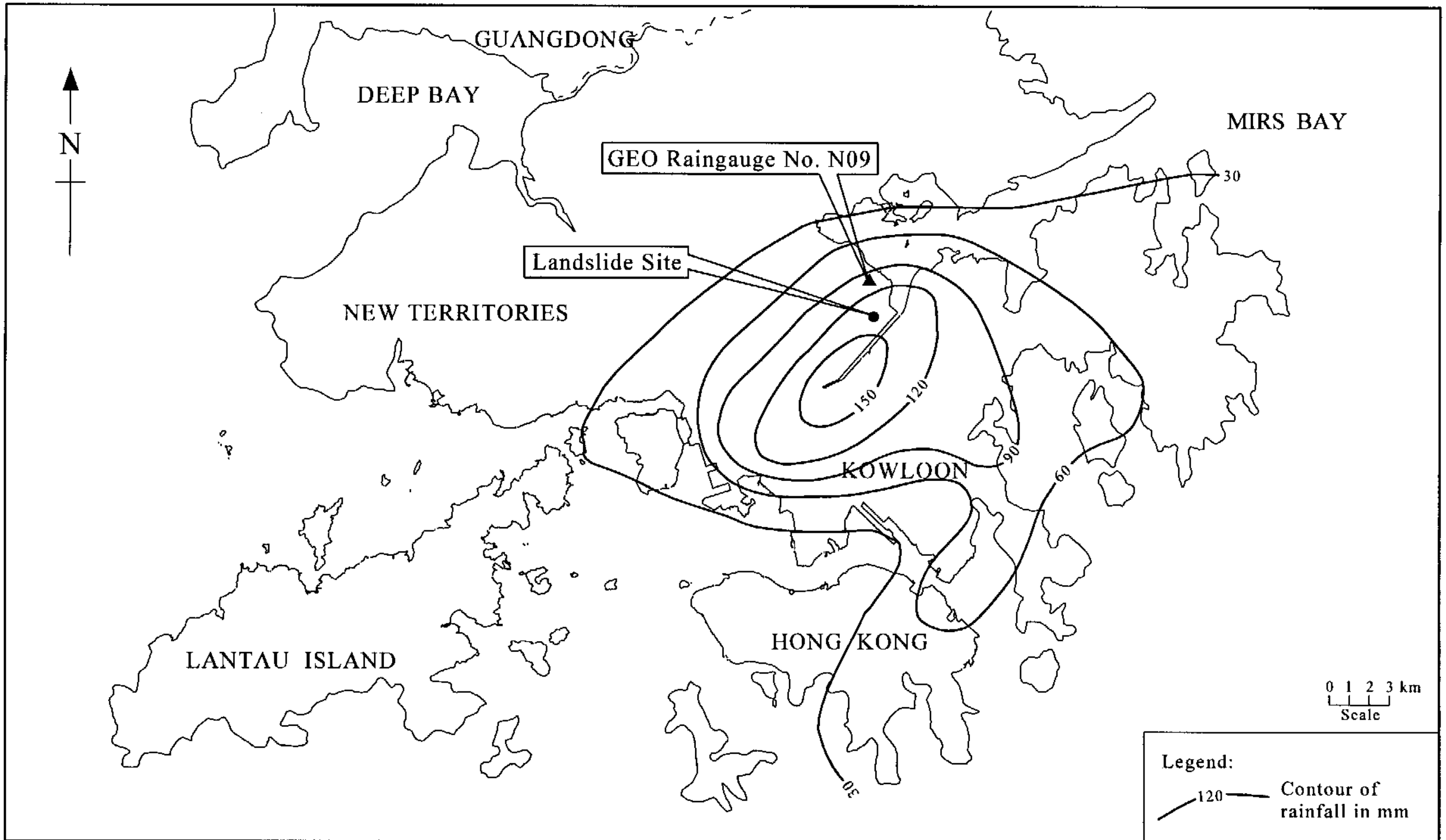


Figure 7 - Rainfall Records at GEO Raingauge No. N09



Note : Isohyets prepared by the Hong Kong Observatory.

Figure 8 - Isohyets of Rainfall between 03:20 Hours and 06:10 Hours on 2 July 1997

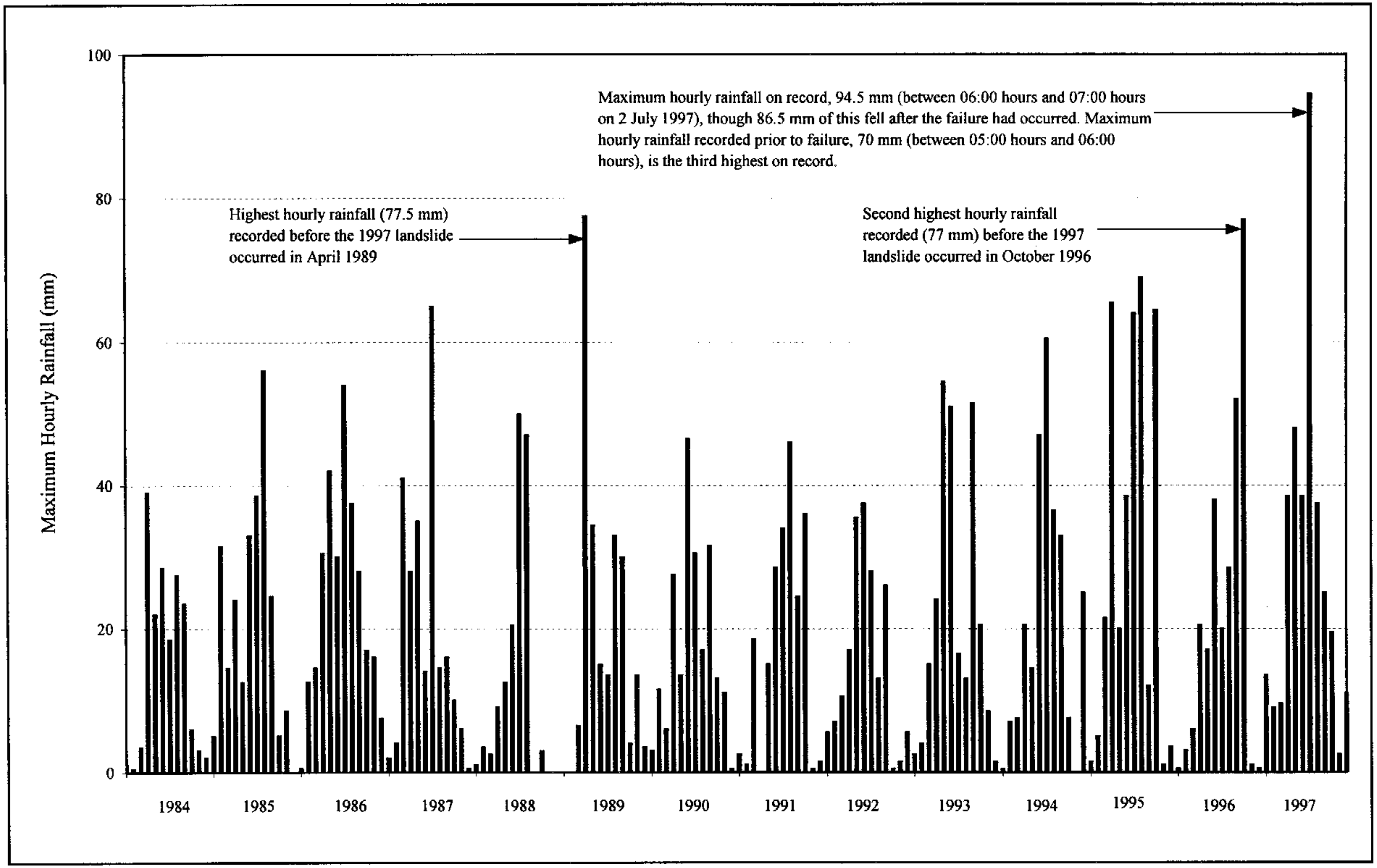


Figure 9 - Maximum Hourly Rainfall (mm) Recorded in Each Month at GEO Raingauge No. N09 from 1984 to 1997

LIST OF PLATES

Plate 1 - General View of the Landslide Site
(Photograph Taken on 4 July 1997)

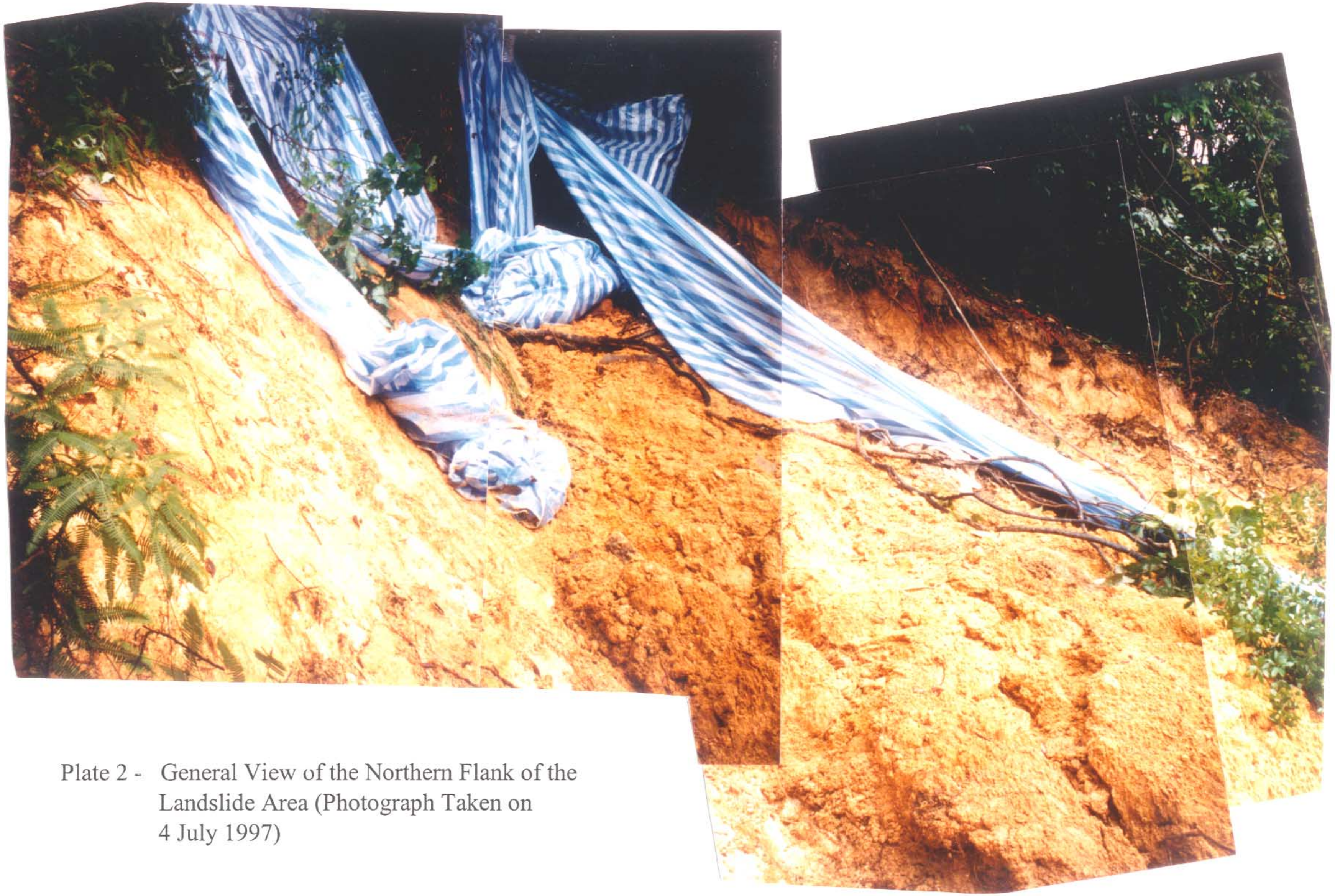


Plate 2 - General View of the Northern Flank of the Landslide Area (Photograph Taken on 4 July 1997)

Plate 3 - General View of the Southern Flank of the Landslide Area (Photograph Taken on 4 July 1997)

Plate 4 - Copy of Photograph Taken by KCRC Staff Soon After Failure on 2 July 1997 (Photograph Taken on 2 July 1997)