SECTION 3: DETAILED STUDY OF THE LANDSLIDES AT KA TIN COURT, SHATIN ON 2 JULY 1997

Halcrow Asia Partnership Ltd

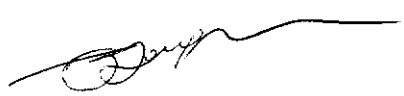
This report was originally produced in December 1998 as GEO Landslide Study Report No. LSR 24/98

FOREWORD

This report presents the findings of a detailed study of a landslide and a washout (GEO Incident Report No. MW97/7/24) that occurred above Ka Tin Court, Shatin on 2 July 1997. The landslide occurred on a partly-modified natural valley-side slope, that has a fill platform at the crest and a cut slope at the toe. The landslide debris partially blocked a minor river course in the valley. The washout occurred further down the river course, adjacent to the entrance of a drainage cascade that had become blocked with landslide debris transported by the river. The blockage caused debris and silty water to overspill onto an adjacent cut slope and the resulting washout into Ka Tin Court. The washout affected walkways adjacent to Ka Wing House, Ka Tin Court. No injuries or fatalities were reported.

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 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 Dr Mark Swales 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

On the morning of 2 July 1997, a landslide (GEO Incident Report No. MW97/7/24) affected a partly-modified natural valley-side slope and a cut slope (No. 7SW-D/C551) overlooking a minor river valley above Ka Tin Court (Figures 1 and 2; Plate 1). The landslide partly obstructed the minor river and resulted in blockage of the entrance to a drainage cascade downstream of the landslide. Blockage of the drainage cascade caused the minor river to overtop its banks, resulting in a washout (Plate 2) on an adjacent cut slope (No. 7SW-D/C525) bordering the residential development known as Ka Tin Court. The washout affected walkways adjacent to Ka Wing House, Ka Tin Court. 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 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 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.

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 witnesses and persons affected by the failures,

(d) detailed site observations and measurements, and

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

2. THE SITE

2.1 Site Description

The landslide and washout affected an unregistered partly-modified natural valley-side slope and a registered man-made cut slope adjacent to a minor river course above the Ka Tin Court housing development in Shatin (Figure 2). The river valley passes below a level fill platform constructed for the Union Hospital building, and between Slope No. 7SW-D/C551 on the east side and Slope No. 7SW-D/C525 on the west side of the river. At the boundary of Ka Tin Court, the river is controlled by a drainage cascade above a culvert (Figure 2).

The crown of the landslide was located, at about 60 mPD, on partly-modified natural terrain within a topographic depression on the valley-side slope (Figure 2). The landslide debris stripped material from downslope parts of the valley-side slope and the 8 m-high cut slope (No. 7SW-D/C551) at the toe. The valley-side slope and cut slope were inclined at angles between about 45° and 50° (Plate 3). The cut slope was covered in dense vegetation. No drainage provision was found on the cut slope, valley-side slope or fill platform above.

The washout occurred on the eastern end of an unsealed cut slope (No. 7SW-D/C525) which is situated on the west-side of the drainage cascade (Figure 2). The part of the cut slope affected by the washout was about 6 m high and inclined at about 30° to the horizontal.

A U-channel with a concrete apron was present around the perimeter of Ka Tin Court and a system of U-channels drain cut slope Nos. 7SW-D/C525 and 7SW-D/C401 (Figures 2 and 4).

According to the District Lands Office (1997), the landslide occurred on unallocated Government land. According to the SIMAR (Systematic Identification of Maintenance Responsibility of Slopes in the Territory) consultancy, the co-owners of Lot S.T.T.L. 290 are responsible for the maintenance of Slope No. 7SW-D/C525, which was affected by the washout.

2.2 Site History

The history of the site was determined from a review of aerial photographs and available documentary information. Key developments in the history of the site are given in Table 1 and Figure 3 and the key observations are summarised below,

Aerial photographs taken in 1963 show the site of the 1997 incidents to be located on the eastern side slope of a deeply incised valley, trending approximately northwest- to southeast.

The fill platform now occupied by Union Hospital was constructed between 1963 and 1976, and extended towards the site of the 1997 landslide between 1978 and 1980. A superficial body of fill was deposited on the valley-side slope below the platform, at the location of the 1997 landslide, at sometime between 1978 and 1980. The appearance of the fill on the aerial photographs suggests that it was end-tipped and may therefore be expected to be in a relatively loose state.

The cut slope (No. 7SW-D/C551) at the toe of the valley-side slope was formed as an agricultural terraced area between 1976 and 1978 and a few village huts were located at the toe of the slope at that time. The huts had been cleared and the terracing was abandoned by 1980.

Slope Nos. 7SW-D/C525 and 7SW-D/C401 were formed by cutting of the lower part of the hillside at sometime between 1980 and 1984.

Construction of Ka Tin Court began in 1985 and was complete by 1990. The fill

platform upslope of the 1997 landslide site was cleared of vegetation in 1990 prior to construction of the buildings of Union Hospital which were completed by 1993. No significant changes were apparent at the site since then.

There are no records of previous landslides in the near vicinity of the 1997 incident.

2.3 Previous Studies

As part of the site formation design submission for the construction of Union Hospital, the consultants appointed by the developers carried out an "assessment of the conditions of the slopes within and surrounding the site" with the intention of carrying out "slope upgrading works if found necessary" (C.M. Wong & Associates, 1992). The area considered by the assessment, however, did not include the valley-side slope involved in the 1997 landslide.

In 1992, GEO initiated the consultancy agreement entitled "Systematic Inspection of Features in the Territory" (SIFT) which, inter alia, aims to update information on existing registered slopes in the 1977/78 Catalogues of Slopes based on studies of aerial photographs and limited site inspections. The landslide occurred on partly-modified natural terrain which according to SIFT was not registerable.

The cut slope at the toe of the valley-side slope affected by the landslide was not registered in the 1977/78 Catalogue of Slopes (Binnie and Partners, 1978a & 1978b). The SIFT report prepared in 1995 for the cut slope indicated that it had been assigned Class "C1", i.e. a cut slope formed or substantially modified before June 1978. The fill platform occupied by Union Hospital was also identified during the SIFT consultancy (Figure 3) but the fill body was considered not to meet GEO's criteria for slope registration.

The cut slope was subsequently registered as No. 7SW-D/C551 in the New Catalogue of Slopes by consultants engaged in the "Systematic Identification and Registration of Slopes in the Territory" consultancy for the GEO.

2.4 Subsurface Conditions

The Hong Kong Geological Survey map sheet No. 7 (GCO, 1986) and memoir for the area (Addison, 1986) indicate that the river channel follows the line of a northwest-trending fault and that the narrow valley floor and most of Ka Tin Court are underlain by debris flow deposits. The area around the main landslide and the platform on which the Union Hospital is located is underlain by coarse-grained granite which is cut by a northeast-trending intrusion of quartz monzonite.

In 1982 a ground investigation was carried out in the area (Lam Construction, 1982). Borehole ST 31/23, drilled from 39 mPD in the river bed below the landslide (Figure 2) identified predominantly boulders of moderately decomposed granite to about 34 mPD, below which alluvial sands and silts were logged to a depth of 28 mPD. The alluvial sands and silts overlay a sequence of moderately and slightly decomposed granite (Figure 4).

In 1996, a ground investigation was carried out by Geotechnics & Concrete Engineering Ltd (GCE) to provide information for a geotechnical assessment of Slope No. 7SW-D/C401 by the HD (GCE, 1997). Borehole KT/B1 was formed from about 55 mPD (Figures 2 and 5) and proved completely decomposed granite to about 39 mPD, which overlay a sequence of highly and moderately decomposed granite that extended to the base of the borehole at about 28 mPD. Borehole KT/B2 was formed from about 47 mPD (Figures 2 and 5) and proved completely decomposed granite to 42 mPD, overlying moderately to slightly decomposed granite that extended to the base of the borehole at about 37 mPD.

A piezometer was installed in borehole KT/B1 within the highly to moderately decomposed granite at about 33.5 mPD and a standpipe was installed in borehole KT/B2 in moderately to slightly decomposed granite near the base of the borehole (Figure 5). Water levels were recorded in the piezometer and standpipe at about 41 mPD and 38.5 mPD respectively during November 1996.

Borehole logs from the ground investigation on the fill platform were unavailable, but the consultant's report states that "the subsoil profile consists of a relatively thin layer of fill up to 3.5 m thick overlying the decomposed granite" (C.M. Wong & Associates, 1989). The report also states that "rockhead in the form of moderately to slightly decomposed granite varies in level from about +60 mPD to about +30 mPD towards both north and west". The report indicates the groundwater level was located at about 33 mPD.

3. THE LANDSLIDE

3.1 Time of the Failures

Residents of Ka Tin Court reported to the Housing Department that the time of the failure was 09:30 hours on 2 July 1997. The reported time of failure probably corresponded to the occurrence of the washout on cut slope No. 7SW-D/C525, with the landslide occurring upstream sometime before this. A Landslip Warning was issued by GEO at 06:25 hours on 2 July 1997 until 08:40 hours on 5 July 1997.

3.2 Description of the Landslide and Washout

A plan and cross-section of the landslide and washout are shown in Figures 4 and 5 respectively.

The landslide principally involved the failure of the partly-modified natural valley-side slope below the fill platform. The main scarp of the landslide was up to 10 m wide, 15 m in length and 2 m deep. The estimated volume of displaced material was 150 m^3, excluding the material stripped from the valley-side slope (Section 2.1). The Incident Report prepared by the GEO following an inspection of the landslide on 5 July 1997 indicated that the failure occurred on "natural terrain" and involved "partially weathered rock". There was no record of groundwater seepage in the main scarp. HAP carried out a preliminary inspection of the landslide on 6 August 1997. During the inspection observations confirmed the presence of completely decomposed granite. No seepage of groundwater in the main scarp was observed at

the time. Application of shotcrete subsequent to this inspection as part of the urgent repair works to the landslide scar prevented more detailed description of the materials involved in the failure.

Field reconnaissance of the area surrounding the landslide scar carried out by HAP during the investigation, however, identified highly to completely decomposed, coarse-grained granite with some sub-angular to rounded boulders up to 1.5 m in diameter on the north side of the landslide (Plate 5). On the south side of the landslide, the geology comprised completely decomposed granite with some rounded, similarly sized boulders. The landslide scar was also observed to have occurred within a topographic depression on the valley-side slope, that would have directed surface water towards the landslide site.

The morphology and observations made in and around the landslide scar suggest that the landslide probably involved sliding failure of the completely decomposed granite as well as the fill that had been placed on that part of the slope between 1978 and 1980 (Figure 3).

HAP also observed that the fill platform above the crest of the landslide was overgrown and contained a hollow, about 17 m wide, 7 m long and up to 0.5 m deep (Figure 4). A bund of fill, about 0.3 m high, was also present beyond the crest of the valley-side slope, which was probably formed during the site formation work for the hospital platform (Figure 4). The hollow and bund together would have acted as a sink for water collection.

Debris from the landslide stripped material from the area lower down the valley-side slope and cut slope No. 7SW-D/C551 (Figure 4) and was deposited in the river bed at the toe. The river bed was found to be strewn with stream deposits including rounded boulders, typically between about 0.5 m and 1 m in diameter, that would have been present before the 2 July 1997 incident. The travel angle of the landslide debris was estimated to be about 30°, which is typical for rain-induced landslides in Hong Kong (Wong & Ho, 1996).

A steel grill gate across the entrance to the cascade was observed to be partly obstructed by landslide debris that included a significant proportion of vegetation. This material appeared to have been transported by water flow within the river course, that would have been relatively high in response to heavy rainfall in the area on 2 July 1997 (see Section 4).

Localised erosion, stripping of vegetation and deposition of fines immediately upstream of the steel grill gate indicated that the river overtopped the concrete wing wall on the west side of the drainage cascade (Figure 4). There is also evidence that large areas of the west bank of the river have been affected by overtopping in the past (Figure 4).

A 1 m-deep channel was observed to have been eroded on the unsealed cut slope (No. 7SW-D/C525) adjacent to the drainage cascade. This was caused by water that had overtopped the river course and flowed over the concrete wing wall of the drainage cascade and onto the cut slope, resulting in the washout into Ka Tin Court (Plate 6).

4. RAINFALL

Rainfall data was obtained from the nearest GEO automatic raingauge No. N01 which is located about 650 m northwest of the site.

The cumulative 31-day rainfall before the landslide was 1108 mm and the 12-hour rainfall was 255.5 mm (Figure 6). Isohyets of rainfall between 02:55 hours and 09:30 hours on 2 July 1997 are shown in Figure 7.

Figure 8 presents the 5-minute rainfall data prior to the reported time of the incident. It is apparent that the reported time of the failures at 09:30 hours occurred around 3.5 hours after the most intense period of the rainstorm. This may be attributed to the lag-time response of increased discharge within the river valley and the likely occurrence of the landslide and subsequent blockage of the entrance to the drainage cascade sometime before the washout.

The estimated return periods for the maximum rolling rainfall up to 09:00 hours on 2 July 1997, for selected durations based on historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994) are given in Table 2. The most severe durations were between 1 and 4 hours, with estimated return periods of between about 20 and 45 years. The 31-day duration rainfall was also relatively severe, with an estimated return period of about 27 years.

5. PROBABLE CAUSES OF FAILURE

The close correlation between the rainstorm and the likely time of the landslide on 2 July 1997 indicates that the failure was probably triggered by rainfall.

The incident involved the failure of a substandard valley-side slope in completely decomposed granite with a superficial layer of fill which was probably loose.

The fill platform above the crest of the landslide was unsealed with no surface drainage provisions in that locality thus allowing direct infiltration over a large area. The hollow present on the fill platform (Sub-section 3.2) above the crest of the landslide may have resulted in ponding and concentrated infiltration during heavy rainfall. The setting of the landslide site in a natural depression on the valley-side slope would have directed surface water flow to the landslide site and the loose fill present on the slope may have locally promoted infiltration. Infiltration of water would have locally saturated the soil mass in the partly-modified natural terrain and reduced its shear strength, leading to failure.

The superficial fill body may have contributed further to the landslide by loading and oversteepening the marginally-stable valley-side slope.

Debris from the landslide partly blocked the river, and was eroded and transported downstream by stormflow within the river course causing blockage of the entrance to the drainage cascade. Blockage of the cascade led to overtopping of the west river bank, with water and debris causing washout of the unsealed slope adjacent to Ka Tin Court.

6. CONCLUSIONS

The landslide occurred on a slope which had not been subjected to detailed stability assessment and was probably triggered by severe rainfall.

The main scarp of the landslide approximately coincided with a topographic depression on the natural terrain. This, together with the presence of a hollow on the fill platform above the landslide and a thin veneer of fill on the valley-side slope, may have concentrated surface infiltration into the unprotected ground. Water ingress into the slope led to the failure.

7. REFERENCES

Addison, R. (1986). Geology of Sha Tin. Geotechnical Control Office, Hong Kong, 85 p. (Hong Kong Geological Survey Memoir No. 1).

Binnie & Partners (1978a). Preliminary Studies for Special Investigation into Fill Slopes. Binnie and Partners (Hong Kong) Limited.

Binnie & Partners (1978b). Landslide Studies Phase I: Re-Appraisal of Cut Slopes and Natural Slopes and Retaining Walls. Binnie and Partners (Hong Kong) Limited.

C.M. Wong & Associates (1989). Geotechnical Assessment Report for Proposed Extended Care Hospital at S.T.T.L. 168 Shatin. C.M. Wong & Associates, November 1989, 6 p. plus 1 figure.

C.M. Wong & Associates (1992). Geotechnical Report for Overall Assessment on the Conditions of the Slope within and surrounding the Site. C.M. Wong & Associates, May 1992, 5 p. plus 2 appendices.

District Lands Office (1997). Landslide in Government land near Ka Tin Court. Correspondence to CHE/NT, reference (2) in LND/ST 730/28 dated 3 July 1997.

Geotechnics & Concrete Engineering (Hong Kong) Ltd (1997). Contract No. HKHA 3 of 1995, Works Order M58, Detailed Studies for Slope No. 7SW-D/KT1 & KT4. Ground Investigation Report, Geotechnics & Concrete Engineering (Hong Kong) Limited, Consulting Engineers to Housing Department, Hong Kong.

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

Housing Department (1997). Correspondence to the Director of Civil Engineering, reference (na) in HD(H)H/KAT 11/24/42/1 dated 2 July 1997.

Lam Construction (1982). Site Investigation Report – P.W.D. Contract 613 of 1979. Maunsell Consultants (Hong Kong).

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.

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.

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Table 1 – Summary of Aerial Photograph Interpretation

Year	Photograph Reference No.	Observation
1963	Y08740-1	The site of the landslides is situated on the eastern side slope of a roughly northwest-southeast trending a deeply-incised valley, densely vegetated with trees and shrubs. No developments evident in the area other than a few village huts/platforms at the base of the valley.
1976	13166-67	The fill platform for the Union Hospital has been constructed requiring cutting and filling of existing terrain. No spoil fill evident on the natural slope involved in the 1997 landslide.
1978	23486-87	The lower part of the slope affected by the 1997 landslide has been modified by the construction of agricultural terraces. The terraced area does not extend upslope as far as the main scarp of the 1997 landslide.
1980	30795-96	The platform for Union Hospital has been extended towards the site of the 1997 landslide by placement of fill. A 'teardrop' shaped lobe of spoil fill has been deposited on the natural slope at the location of the 1997 landslide. The fill body appear to be between 1 m and 1.5 m thick and extended over most of the height of the slope. The agricultural terraces at the base of the valley are now derelict.
1984	56838-9	Village houses and associated terraces at the base of the valley have been cleared and the area infilled to form a level platform for construction of Ka Tin Court. Slope Nos. 7SW-D/C551 and 7SW-D/C401 have been formed by cutting into the natural hillside either side of the lower part of the valley. Surface drainage channels and the drainage cascade are evident, associated with the cut slope.
1985	A2403-4	Construction of foundations for Ka Tin Court has commenced. Recently formed cut slopes re-vegetating.
1990	A23459-60	Buildings of Ka Tin Court have been completed.
1992	A30168-69	The fill platform upslope of the 1997 landslide site has been cleared of vegetation in preparation for construction of Union Hospital.
1993	A34688-89	Buildings associated with Union Hospital have now been completed.

Table 2 – Maximum Rolling Rainfall at GEO Raingauge No. N01 for Selected Durations Preceding the 2 July 1997 Failures and The Corresponding Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years)
5 minutes	12.5	06:10 hours on 2 July 1997	2
15 minutes	36.5	06:20 hours on 2 July 1997	8
1 hour	125	06:30 hours on 2 July 1997	34
2 hour	188.5	06:40 hours on 2 July 1997	45
4 hours	224	07:00 hours on 2 July 1997	21
12 hours	255.5	09:00 hours on 2 July 1997	6
24 hours	270	09:00 hours on 2 July 1997	3
2 days	315	09:00 hours on 2 July 1997	3
4 days	321	09:00 hours on 2 July 1997	2
7 days	329	09:00 hours on 2 July 1997	2
15 days	463	09:00 hours on 2 July 1997	2
31 days	1108	09:00 hours on 2 July 1997	27

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 duration up to two hours and from hourly data for longer rainfall durations.

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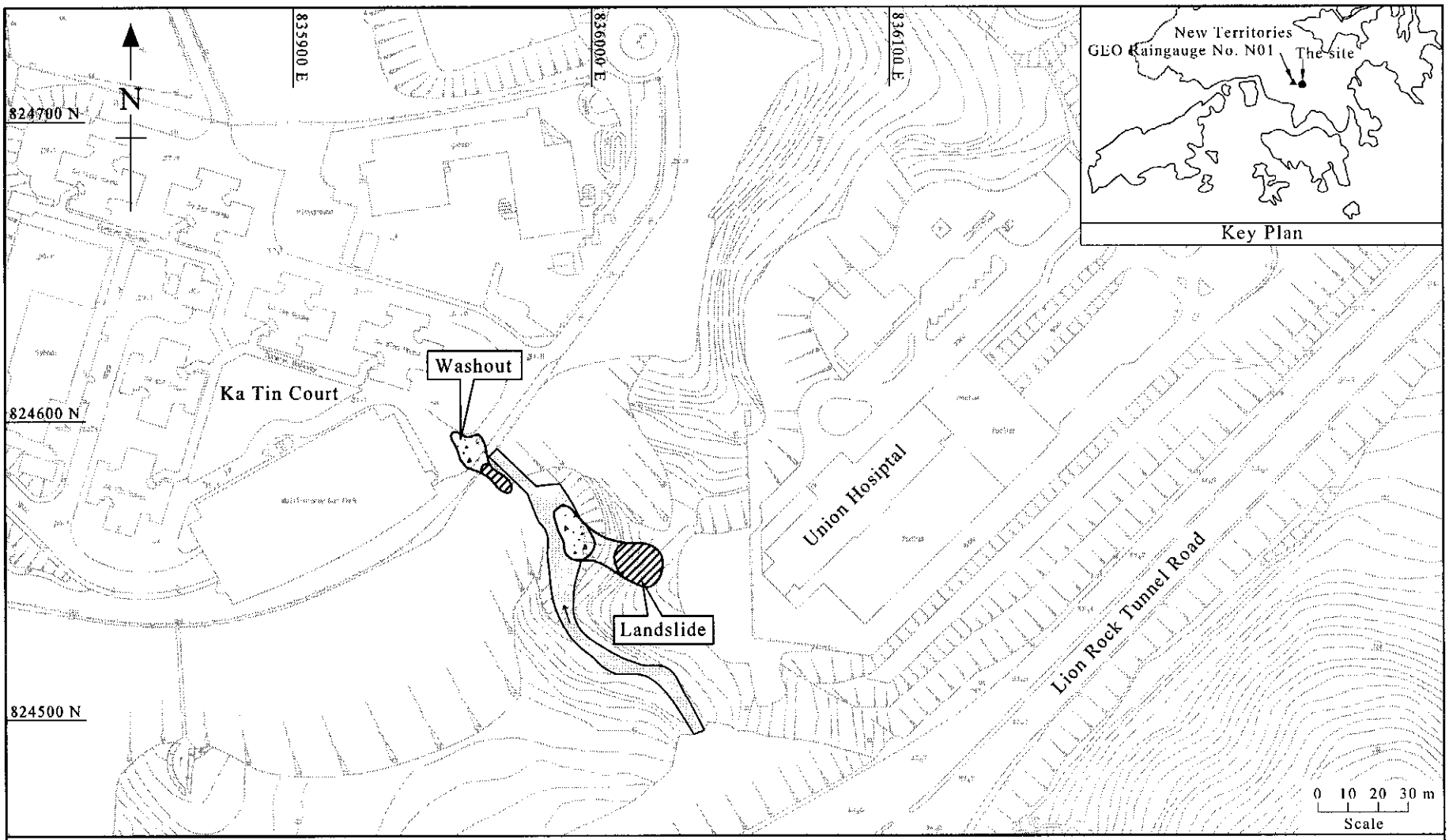


Figure 1 - Site Location Plan

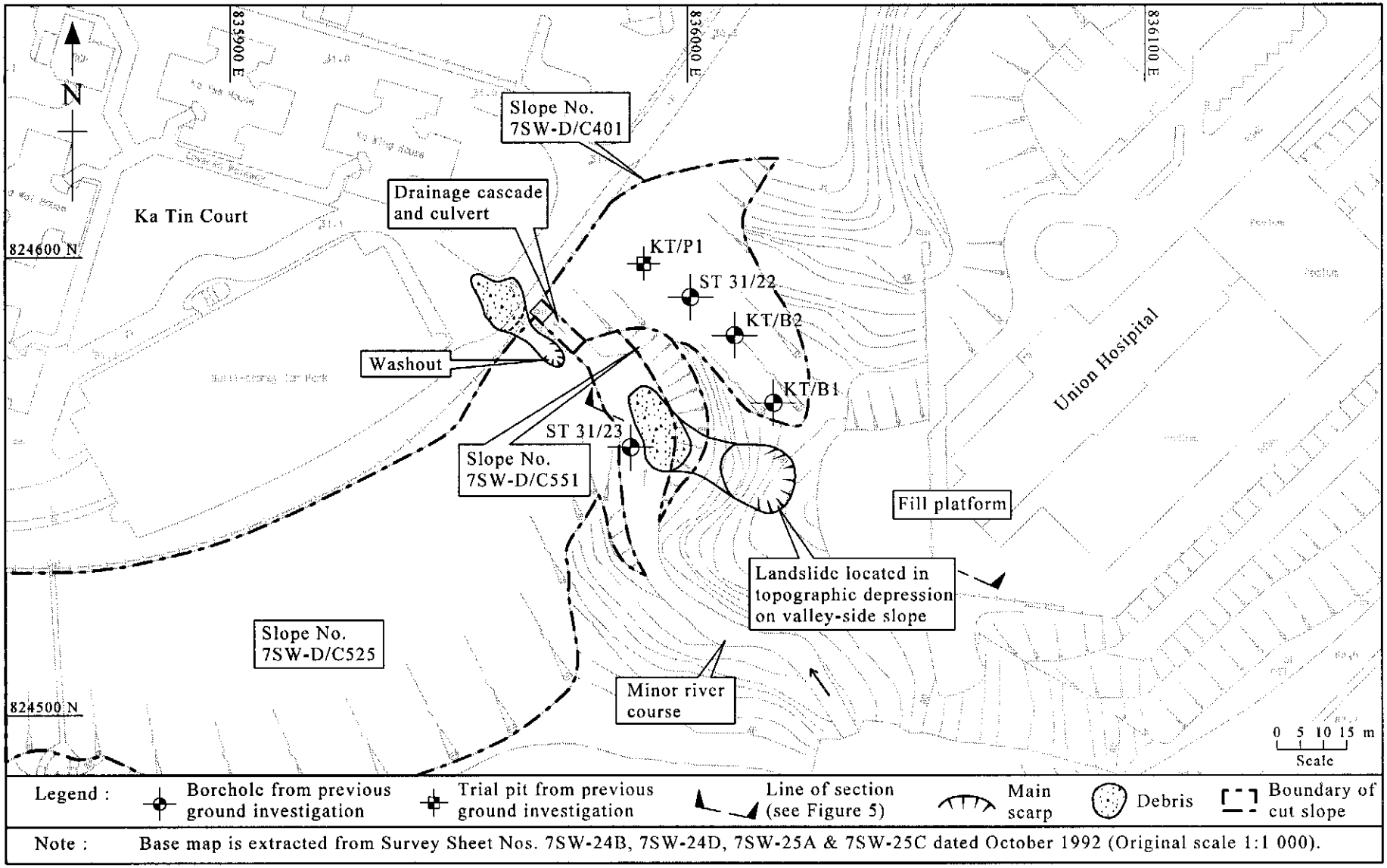


Figure 2 - Plan of the Failures and Previous Ground Investigations

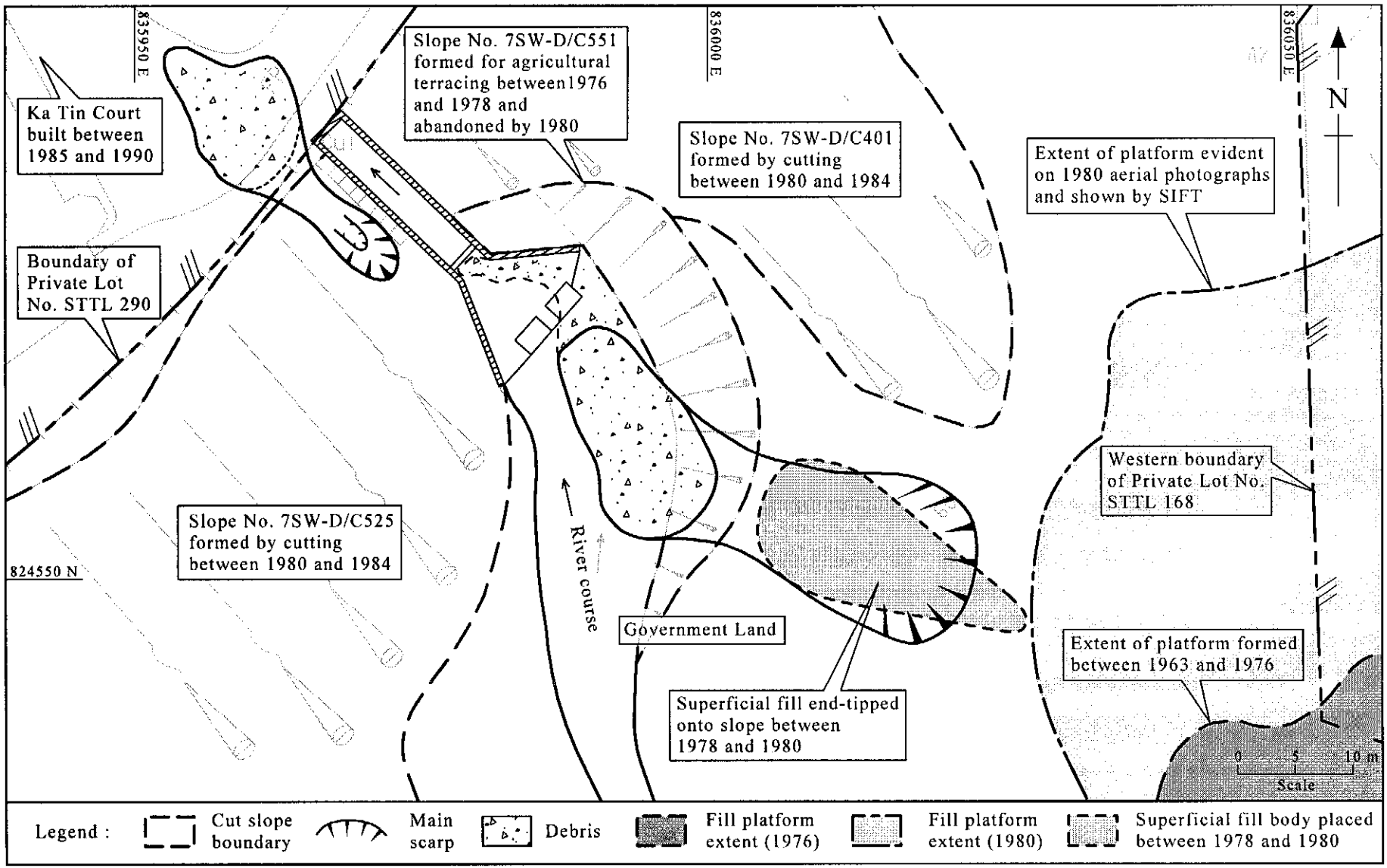


Figure 3 - Land Status and Site History

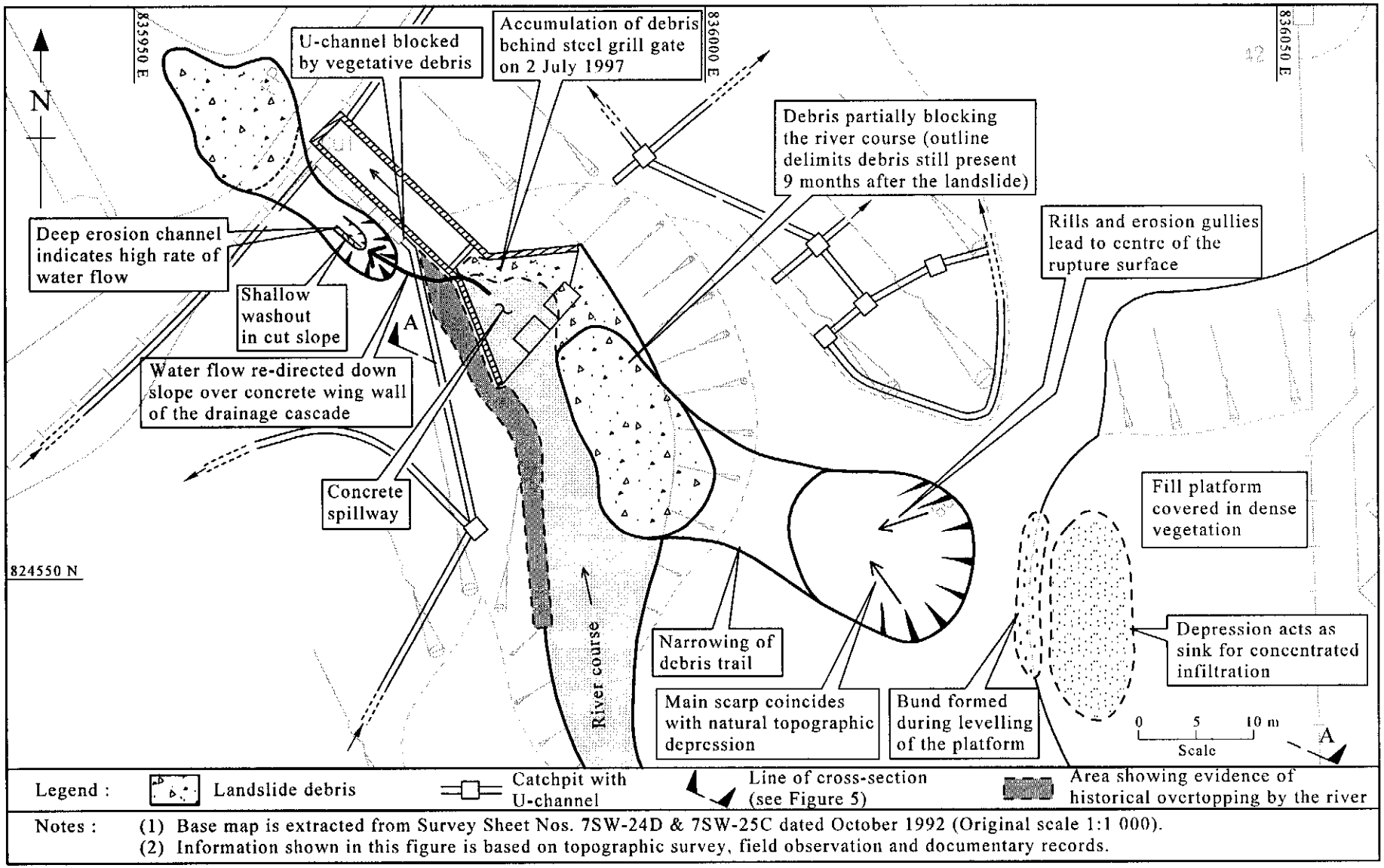


Figure 4 - Detailed Plan of the Landslide and Washout

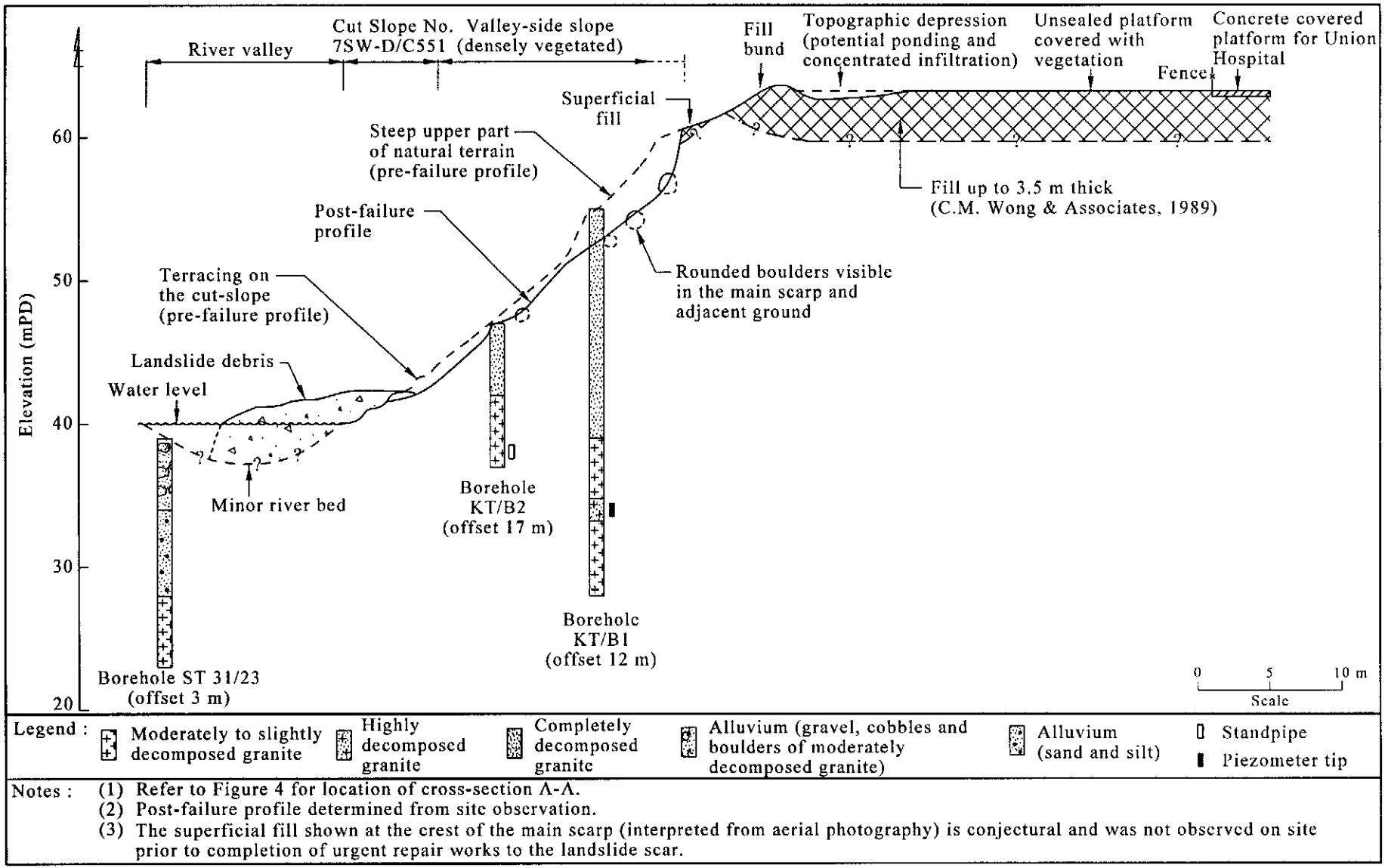
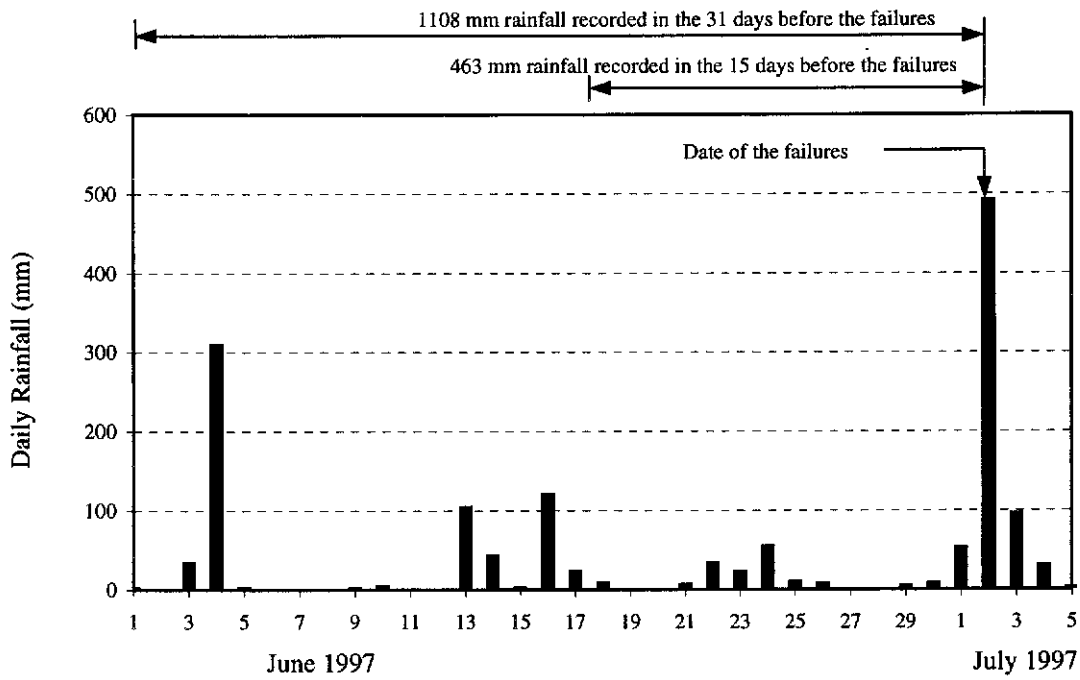
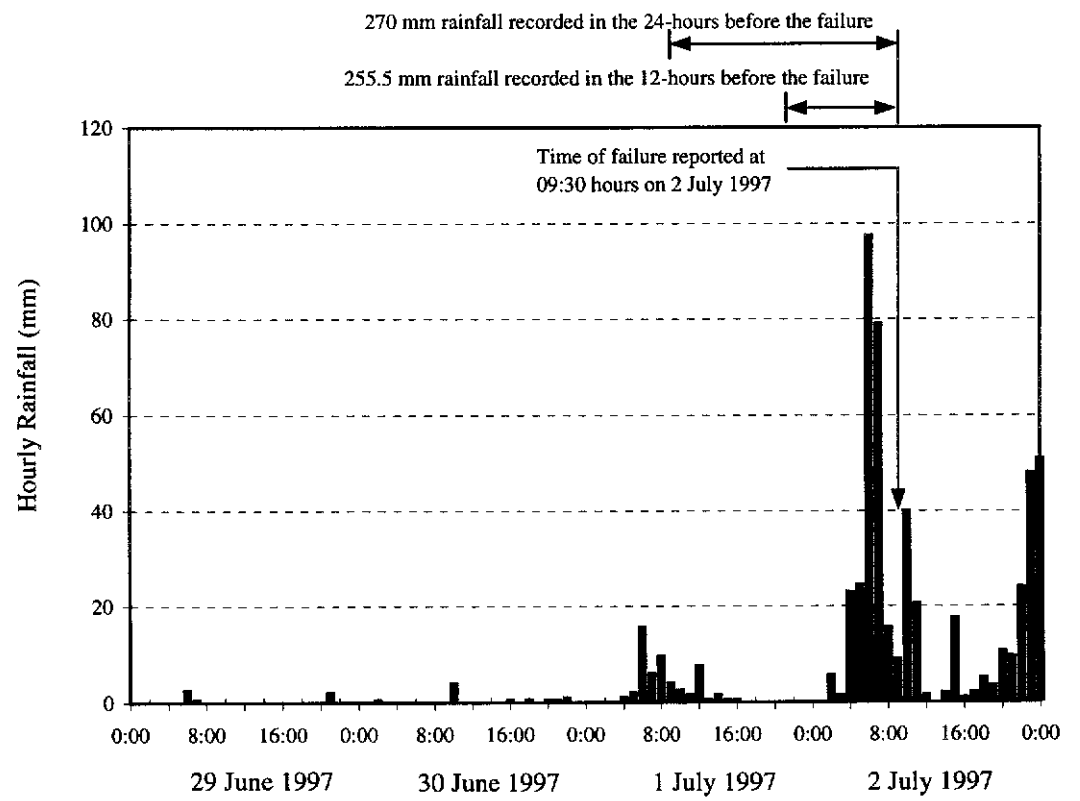


Figure 5 - Cross-section A - A through the Landslide

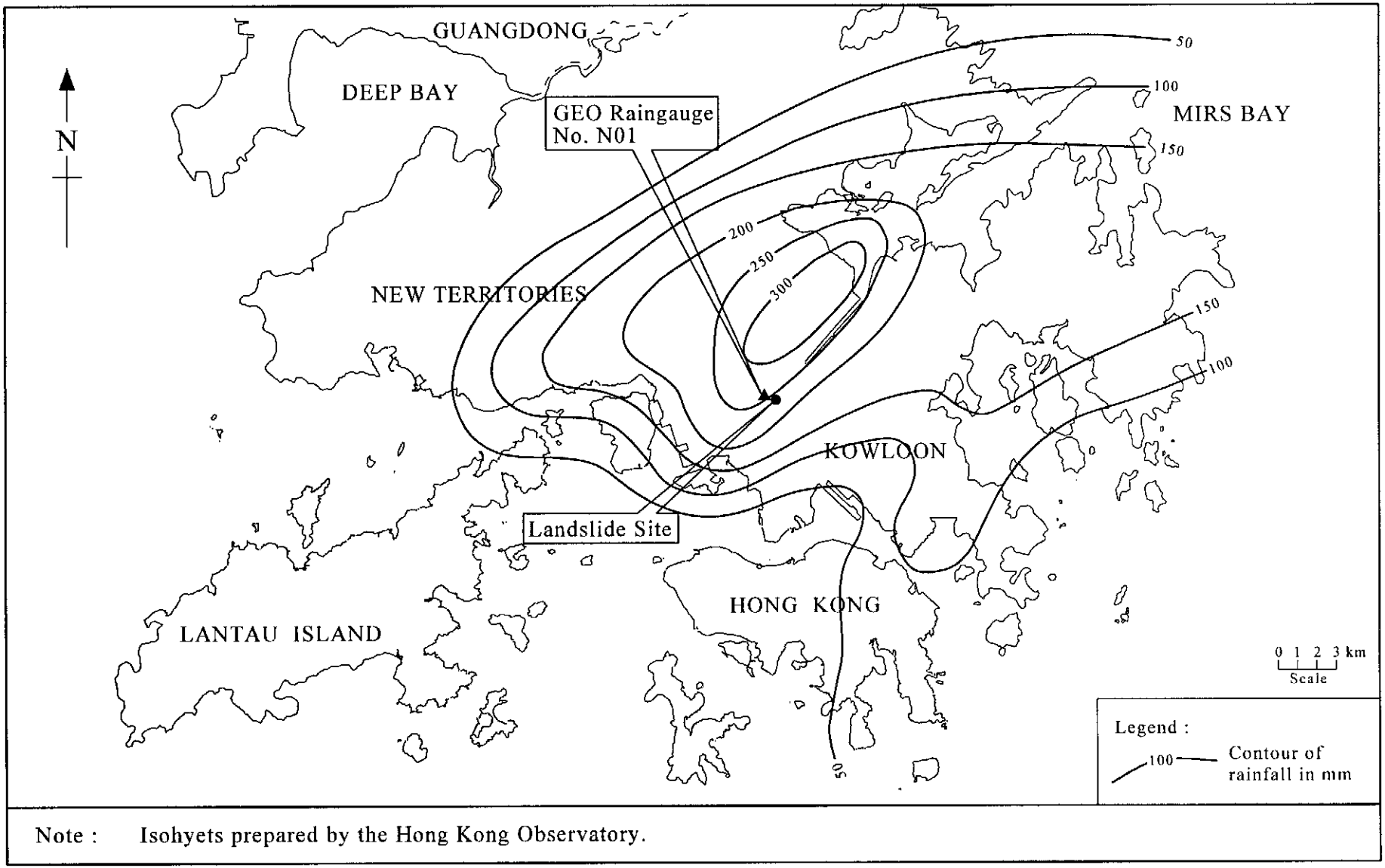


(a) Daily Rainfall Recorded between 1 June and 5 July 1997



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

Figure 6 - Rainfall Records at GEO Raingauge No. N01



Note : Isohyets prepared by the Hong Kong Observatory.

Figure 7 - Isohyets of Rainfall between 02:55 Hours and 09:30 Hours on 2 July 1997

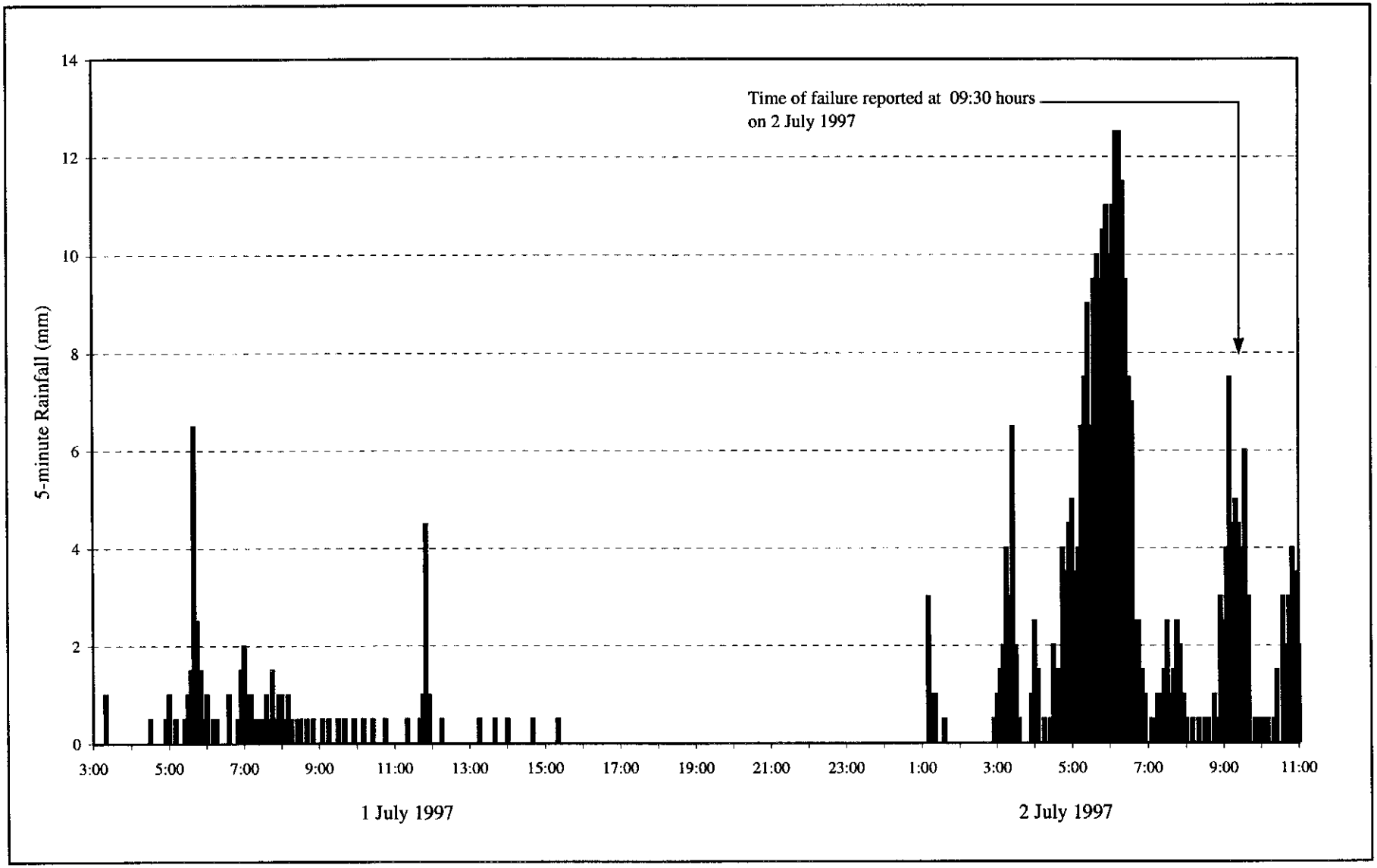


Figure 8 - Rainfall Recorded at GEO Raingauge No. N01 at 5-minute Intervals on 1 July and 2 July 1997

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Plate 4 - View of the Entrance to the Drainage Cascade, Showing the Steel Grill Gate (Photograph Taken on 16 June 1998)

Plate 5 - Boulders Set in a Matrix of Highly to Completely Decomposed Granite (Photograph Taken on 16 June 1998)

Plate 6 - Erosion Channel and Washout Scarp
(Photograph Taken on 3 July 1997)