

**SECTION 3:  
DETAILED STUDY OF THE  
LANDSLIDE AT  
GLORIOUS PRAISE CHRISTIAN  
CENTRE, KWAI CHUNG  
ON 8 MAY 1997**

**Halcrow Asia Partnership Ltd**

**This report was originally produced in July 1998  
as GEO Landslide Study Report No. LSR 5/98**

## FOREWORD

This report presents the findings of a detailed study of a landslide (GEO Incident No. MW97/5/18) which occurred on 8 May 1997 on a partly modified natural hillside between Kwai Chung Public School (KCPS) and Glorious Praise Christian Centre (GPCC), Kwok Shui Road, Kwai Chung. Debris from the landslide accumulated at the toe of the slope adjacent to GPCC. The landslide also undermined part of a fill platform of KCPS at the crest of the slope. 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 to 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. It is one of a series of reports produced during the consultancy by Halcrow Asia Partnership Limited (HAP). The report was written by Mr R Simonds and reviewed by Dr R Moore and Mr H Siddle. The assistance of the GEO in the preparation of the report is gratefully acknowledged.



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## 1. INTRODUCTION

On the morning of 8 May 1997, a landslide (GEO Incident No. MW97/5/18) occurred on a 9 m high partly modified natural hillside between Kwai Chung Public School (KCPS) and Glorious Praise Christian Centre (GPCC), Kwok Shui Road, Kwai Chung (Figure 1, Plate 1). Debris from the landslide accumulated at the toe of the slope adjacent to GPCC. The landslide also undermined part of a platform of the KCPS at the crest of the slope. No fatalities or injuries were reported.

Following the landslide, Halcrow Asia Partnership Limited (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. It is one of a series of reports produced during the consultancy by Halcrow Asia Partnership Limited (HAP).

The key objectives of the detailed study were to document the facts about the landslide, present relevant background information and to establish the probable causes of the landslide. 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 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) discussions with the headmaster of KCPS and occupants of GPCC,
- (d) detailed observations and measurements at the landslide site, and
- (e) diagnosis of the probable causes of the landslide.

## 2. THE SITE

### 2.1 Site Description

The location of the landslide is shown in Figures 1 and 2. There is a 1 m to 2 m thick fill platform at the crest of the slope and a 0.5 m high masonry wall at the toe of the slope between KCPS and GPCC. The fill platform and the masonry wall are not of sufficient height to satisfy the criteria for registration (GEO, 1996).

Kwai Chung Public School is situated on the fill platform which has been formed on two levels. The main school buildings and playground are situated on an upper platform,

which is approximately 2 m above a lower platform, on which the girls and boys toilet blocks were constructed (Figure 2). The majority of the upper platform has a concrete hardstanding. The northern edge of the upper platform surface and the whole of the lower platform surface have a thin (<10 mm thick) highly cracked chunam cover, which is locally absent (as shown in Figure 2).

The main part of the slope between KCPS and GPCC has not been previously modified by any noticeable man-made cutting or filling. The slope angle varies between 30° to 35° to the horizontal. The slope had a dense cover of vegetation and trees prior to the landslide and there are no surface water drainage channels on the slope. At the toe of the slope, adjacent to GPCC, there is an open ditch 1 m to 2 m wide and about 1 m in depth.

According to the District Lands Office (DLO) “the location of the landslip failure falls within Government Land” (DLO, 1997). Correspondence received by HAP from the Property Services Branch of the Architectural Services Department (Arch SD) indicated that “the Branch is responsible for maintenance of slope” (Arch SD, 1998).

## 2.2 Site History

The site history was traced from a sequential series of aerial photographs of the site spanning the period 1949 to 1996 and a review of other available documentary information (Tables 1 and 2).

In 1949, the site was on the northern flank of an isolated undeveloped, hillside which was covered with trees and vegetation. The slope was moderately steep and gently undulating with several slight depressions. The 1949 aerial photograph indicates that Castle Peak Road was present to the south of the site.

Kwai Chung Public School was constructed in 1952 on a fill platform by levelling the top of the hill. The aerial photograph taken in 1963, indicates that the slope on which the 1997 landslide occurred was densely vegetated. The valley floor to the north of the site was flat and used for agricultural purposes. Kwok Shui Road to the north of the site was constructed at sometime between 1963 and 1967.

Aerial photographs taken in 1972 show that fill materials had been placed downslope of Kwok Shui Road and the aerial photographs taken a year later, in 1973, indicate that a small amount of filling may have taken place in the valley floor at the site on which GPCC was subsequently built. In 1973, the slope below KCPS was densely vegetated and there were no apparent changes upto 1997. By 1978, GPCC had been constructed on a fill platform in the shallow valley. The western extension of GPCC had been constructed by 1981 and there were no apparent changes to the other buildings. The slope above GPCC remained densely vegetated and there was no apparent evidence of slope instability during this period.

### 2.3 Previous Studies

There have been no previous studies of the slope and there are no relevant documentary records in the GEO for the slope between KCPS and GPCC.

### 2.4 Subsurface Conditions

The geological memoir (Addison, 1986) and Sheet 7 of the Hong Kong Geological Survey 1:20 000 Map Series (GCO, 1986), indicate that the site is underlain by fine-grained granite. There were no records of boreholes drilled within close proximity to the landslide at the Geotechnical Information Unit (GIU) of GEO. A geological cross-section through the landslide is shown in Figure 4.

### 2.5 Drainage and Utilities

Surface water draining from the upper platform area of KCPS is intercepted by a system of interconnecting 300 mm and 250 mm U-channels which discharge onto the slope below the school at two locations, 'X' and 'Y' (Figure 2). Surface water draining from the lower platform area of KCPS is intercepted by a system of interconnecting 150 mm U-channels which discharge onto the slope below the school at location 'Z' (Figure 2).

During inspections made by HAP, on 9 and 15 May and 27 August 1997, the following observations were made:

- (a) Surface water discharge points 'X', 'Y' and 'Z' on the upper and lower platforms were partially blocked with silt and fallen leaves.
- (b) There was rill and gully erosion (up to 0.3 m deep) on the slope below the surface water discharge points 'X' and 'Y'.
- (c) The U-channel drainage systems on the upper and lower platforms were cracked and partially blocked with fallen leaves.
- (d) The 150 mm U-channel behind the girls toilet block above the crest of the landslide was partially blocked with silt.
- (e) Along the northern edge of the upper and lower platforms at the crest of the slope between GPCC and KCPS, the surface protection consisted of a thin (<10 mm thick) highly cracked chunam cover.
- (f) A shallow localised depression of the ground surface was observed in the area between the crest of the landslide and the girls toilet block.

- (g) Two water supply pipes (installed above ground) were located along the crest of the slope connecting to the girls toilet block. No leakage was apparent from the two pipes.

The Headmaster of KCPS reported that “overflowing of the toilets has always been a serious problem in our school and it can hardly be got rid of though we had asked for the assistance of the plumbers” (KCPS, 1997). Overflow from the toilets in the girls and boys toilet blocks resulted in overtopping of the U-channel drainage system and discharge of foul water directly downslope below the toilet blocks at the site of the 1997 landslide.

The pasteur of GPCC reported (pers com) that “during the summer wet months the platform area on which the centre was built periodically flooded.” It was observed that there was a plastic pipe laid in the open channel at the toe of the slope, the pasteur indicated (pers com) that “this pipe was ineffective and regularly became blocked.”

### 3. THE LANDSLIDE

#### 3.1 Time of Failure

No eye-witnesses of the landslide incident could be identified. The landslide was first reported by the Headmaster of KCPS to the GEO at 10:00 hours on 8 May 1997. A landslip warning was issued at 11:05 hours on 8 May 1997.

#### 3.2 Description of the Landslide

The failure was a rapid translational slide within fill and residual soil forming the upper part of the slope, located beneath the lower platform of KCPS. The failure was up to 4.9 m wide, 5.8 m long and 0.8 m deep and the estimated volume of the landslide was 20 m<sup>3</sup>. The base of the rupture surface was at the interface between residual soil and completely decomposed granite. The landslide debris accumulated in an open ditch at the toe of the slope and the lobe of debris extended to within 5 m of GPCC (Plates 3 & 4). There was secondary washout of the debris by heavy rainfall after the landslide, which resulted in the erosion and deposition of fine silt and sand to a small ephemeral pond, about 30 m to the west of the landslide (Plate 5).

The landslide debris comprised fill and residual soil which was very wet at the time of inspection by HAP on 9 May 1997. The crest of the lower platform below the toilet blocks was slightly undermined by the near-vertical main scarp of the landslide (Plates 6 & 7). There was evidence of piping in the main scarp at a depth of 1 m below the level of the lower platform, however, no seepages were observed from pipelides in the main scarp at the time of inspection.

The material exposed in the main scarp of the landslide was described as follows:

- (a) From the crest of the landslide to a depth of 1 m, loose, light orangish brown fine silty sand (Fill).
- (b) 1 m to 2.5 m below the crest of the landslide, loose, light to medium dense light orangish brown fine- to coarse- grained sand (Residual Soil).
- (c) 2.5 m to 3.5 m below the crest of the landslide, medium dense completely decomposed fine-grained granite (CDG).

Following the landslide the Architectural Services Department (Arch SD) carried out urgent slope repair works. The works consisted of the clearance of vegetation from the slope, placement of no fines concrete in the landslide scarp, the provision of shotcrete surface protection and the replacement of surface water drainage channels.

#### 4. RAINFALL

The nearest GEO automatic raingauge No. N03 is located at Tsuen Wan Treatment Works, Shing Mun Road, about 400 m to the northwest of the landslide (Figure 1). The daily rainfall recorded in April and May 1997 is shown in Figure 5a. There was 441.5 mm and 357.5 mm of rainfall in the 31 days and 15 days before the landslide respectively. The hourly rainfall from 5 May to 8 May 1997 is shown in Figure 5b. There was 167 mm and 160.5 mm of rainfall in the 24 hours and 12 hours before the landslide respectively. Isohyets of rainfall prior to the landslide on 8 May 1997 are shown in Figure 6. The figure shows that the distribution of peak intensity rainfall was centered about 7 km east northeast of the site.

The estimated return periods for maximum rolling rainfall of selected durations based on historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994) are presented in Table 3. The maximum rolling 2-hour rainfall between 08:00 hours and 10:00 hours on 8 May 1997 was the most severe, with a corresponding return period of about 8 years.

The rainfall recorded at GEO raingauge No. N03 at 5-minute intervals is shown in Figure 7. The figure shows that the maximum 5-minute rainfall was 14.4 mm between 09:50 hours and 09:55 hours. In addition, the figure shows that there was 45 minutes of heavy rainfall after the reported time of the landslide at 10:00 hours on 8 May 1997.

#### 5. PROBABLE CAUSES OF FAILURE

Based on field observations and information collected from this detailed study, it is considered that the landslide was most likely to have been caused by three principal factors:

- (a) Localised infiltration of rainfall and surface water through poorly maintained surface protection into the lower platform in the area above the landslide.



- (b) Direct infiltration of rainfall into the unsurfaced slope which had no surface water drainage provision.
- (c) Concentrated stormwater run-off from the platform onto the slope below the partially blocked U-channel drainage system and adjacent to the partially blocked discharge point 'Z' at the crest of the slope.

The above factors contributed to the wetting of the ground, the development of perched water tables and elevated porewater pressures at the interfaces between fill and residual soil and residual soil and completely decomposed granite. It is noted that the lower part of the rupture surface was located along the interface between residual soil and completely decomposed granite.

Further probable contributory factors to the landslide are considered to have been the long-term effects of the infiltration of foul water, which periodically overflowed from the girls and boys toilets onto the lower platform. This will have led to the development of preferential water pathways or erosion 'pipe-holes' within the fill and residual soil. One such pipe hole was observed at the interface between the loose fill and residual soil in the main scarp. It is also considered probable that settlement of the loose fill below the lower platform may have occurred due to the progressive washout of fine material.

## 6. CONCLUSIONS

It is concluded that the landslide on 8 May 1997 was triggered by intense short duration rainfall. The landslide was probably caused by stormwater infiltration in the area of a shallow surface depression at the rear of the girls toilet block near the crest of the slope. Stormwater would also have run-off from the edge of the platform onto the unsurfaced slope below, due to the partial blockage of the U-channel drainage system and discharge point 'Z'. The concentrated discharge of a large volume of surface water onto the slope, which had no surface water drainage provision, would have resulted in rapid infiltration, the saturation of the fill and residual soil and a reduction in soil suction leading to slope failure.

## 7. REFERENCES

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- Geotechnical Control Office (1986). Sha Tin : Solid and superficial geology. Hong Kong Geological Survey, Map Series HGM20, Sheet 7, 1:20 000 scale. Geotechnical Control Office, Hong Kong.
- Geotechnical Engineering Office (1996). Registration and updating of records of slopes and retaining walls. GEO Circular no. 8/96, Geotechnical Engineering Office, Hong Kong, 15 p.
- Hong Kong Observatory (1997). Rainfall Record. Correspondence to HAP reference HKOG21/50 dated 22 September 1997.
- Kwai Chung Public School (1997). Correspondence to HAP from Headmaster dated 24 November 1997.
- 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, Hong Kong, 89 p.

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Table 1 – Summary of Site Development from Aerial Photograph Interpretation  
(Sheet 1 of 2)

Year	Photographic Reference No.	Altitude	Observations
1949	Y02108/09	-	The site on which the Kwai Chung Public School (KCPS) was subsequently constructed was originally a densely vegetated isolated hill. The hillsides were moderately steep and gently undulating, with several slight depressions on the steeper northern and northwestern sides. Castle Peak Road (CPR) was present near the toe of the southern side of the hill.
1963	Y08960/61	3900 ft	KCPS had been constructed and was in its present configuration on an upper and lower platform. The hillside was steep and well vegetated with bushes and appeared to be essentially undisturbed. The valley floor to the north of KCPS was flat and covered with agricultural fields. CPR had been widened to the south of the site.
1967	Y13475/76	6250 ft	Filling was taking place on the downslope, southern side of Kwok Shui Road (KSR).
1968	14477	-	Filling was still in progress to the south of KSR. The Telephone Exchange to the northwest of the site had been completed.
1969	Y15387/88 Y15441/42	-	Filling was in progress at the site of the Kwok Shui Road Transit Centre (KSRTC). The slope on which the landslide occurred was well vegetated, however the ground surface could just be seen through the tree canopy.
1972	0238/39		KSRTC was under construction, with three long buildings completed. Filling was in progress along the southern edge of the fill platform forming the southern edge of the KSRTC.
1973	4531/32	1700 ft	A small amount of filling was in progress in the valley floor at the site where Glorious Praise Christian Centre (GPCC) was subsequently constructed. The site was used to park vehicles. KSRTC was completed and the slope below KCPS was heavily vegetated.

Table 1 – Summary of Site Development from Aerial Photograph Interpretation  
(Sheet 2 of 2)

Year	Photographic Reference No.	Altitude	Observations
1976	14624/25	1900 ft	No changes were apparent.
1977	20054/55	4000 ft	No changes were apparent.
1978	24031/32	4000 ft	The Glorious Praise Christian Centre (GPCC) had been constructed near the toe of the slope.
1981	36312/13	4000 ft	The western extension to the GPCC was present.
1982	43080/81	3000 ft	No changes were apparent.
1984	56512/13	4000 ft	No changes were apparent.
1987	A10505/06 A10516/17	4000 ft	No changes were apparent.
1988	70320/22	4000 ft	No changes were apparent.
1989	A18369/70	4000 ft	No changes were apparent.
1990	A23537/38	4000 ft	No changes were apparent.
1991	A27588/89	4000 ft	No changes were apparent.
1992	A31183/84	4000 ft	No changes were apparent.
1993	A35985/87	4000 ft	No changes were apparent.
1994	A39941/42	4000 ft	No changes were apparent.
1995	A11075	3500 ft	No changes were apparent.
1995	CN11105/07	3500 ft	No changes were apparent.
1996	CN15766/67	4000 ft	The slope between KCPS and GPCC was densely vegetated and the area of the slope on which the 8 May 1997 landslide occurred could not be seen through the tree canopy.

Table 2 – Summary of Information Sources

Source	Information Obtained
Geotechnical Information Unit (GIU) at Civil Engineering Department (CED) Library.	(a) Tai Wo Hau Road to Castle Peak Road Site Investigation Report, Highways NTDD Report No. 07630. (b) Intersection of Castle Peak Road and Kwai Chung Road Site Investigation Report, Lam Geotechnics Ltd. Report No. 07760.
Slope Files and District Files from Mainland West Division Files from Design Division of GEO.	There were no relevant files.
GEO Publications, Reports, Maps and Memoirs.	(a) Sha Tin : Solid and superficial geology, Hong Kong Geological Survey, Map Series HGM 20, Sheet 7, 1:20 000 scale. (b) Geology of Sha Tin, Hong Kong Geological Survey Memoir No. 1.
Water Supplies Department (WSD).	Existing Utility Information.
Lands Department and District Lands Office (DLO).	(a) Land Status (b) Maintenance Responsibility.
Drainage Services Department (DSD).	Existing Utility Information.
LPM / SIRST / SIFT Databases.	Status of the slope between Kwai Chung Public School and Glorious Praise Christian Centre.
GEO Landslide Inspection Report (LIR) database.	Details of past landslides reported to GEO.
GEO Planning Division.	Aerial Photographs 1949, 1963, 1967, 1968, 1969, 1972, 1973, 1976, 1977, 1978, 1981, 1982, 1984, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995 and 1996.
Hong Kong Observatory (HKO).	(a) Hourly rainfall data between January 1984 and May 1997. (b) Isohyets of rainfall between 00:00 hours and 10:00 hours on 8 May 1997.

Table 3 – Maximum Rolling Rainfall at GEO Raingauge No. N03 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	14.4	09:55 hours on 8 May 1997	3
15 minutes	34.5	10:00 hours on 8 May 1997	5
1 hour	90	10:00 hours on 8 May 1997	5
2 hours	126.5	10:00 hours on 8 May 1997	8
4 hours	156	10:00 hours on 8 May 1997	4
12 hours	160.5	10:00 hours on 8 May 1997	2
24 hours	167	10:00 hours on 8 May 1997	1
2 days	182	10:00 hours on 8 May 1997	1
4 days	217.5	10:00 hours on 8 May 1997	1
7 days	242.5	10:00 hours on 8 May 1997	1
15 days	245.5	10:00 hours on 8 May 1997	1
30 days	329.5	10:00 hours on 8 May 1997	1
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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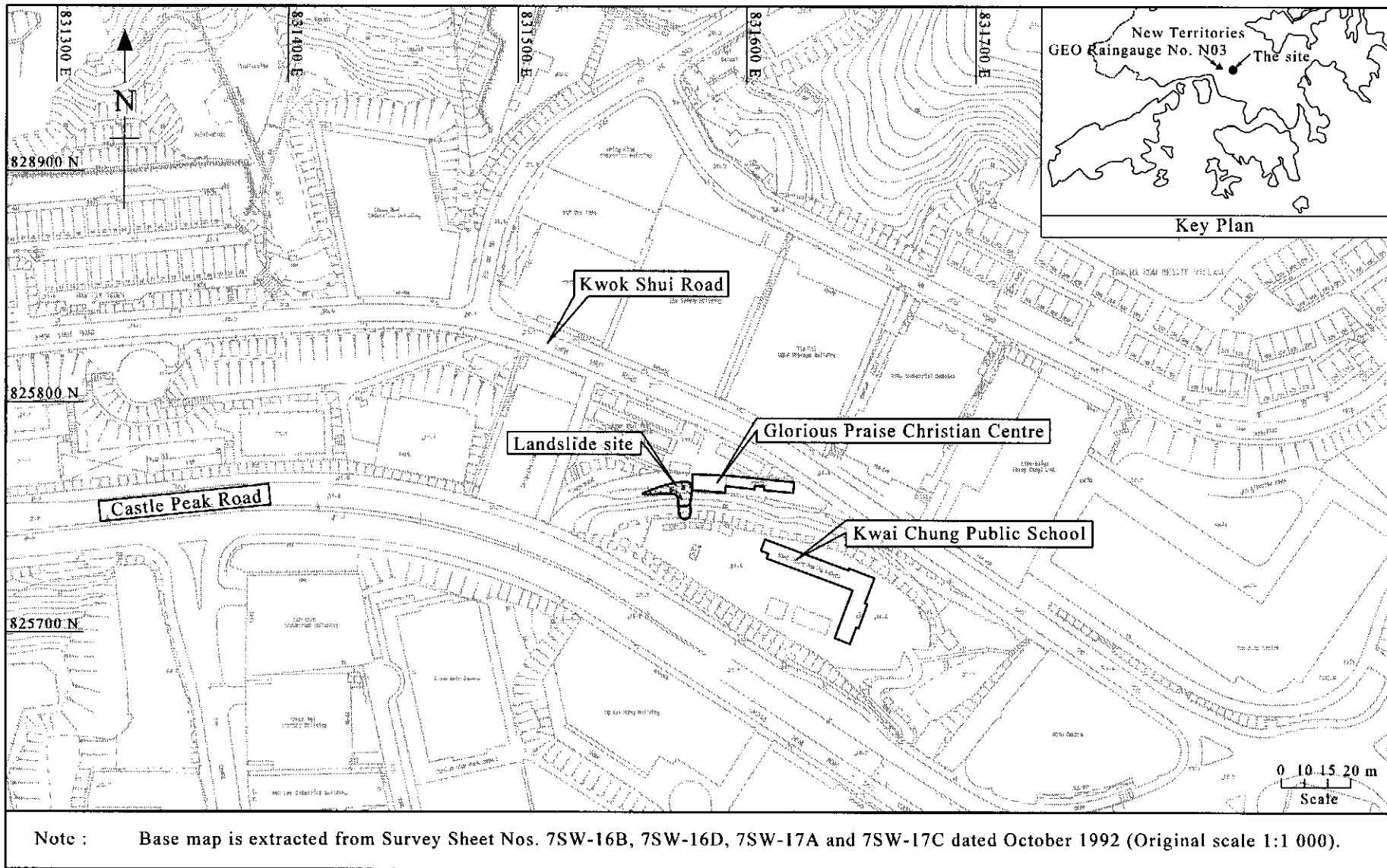


Figure 1 - Site Location Plan



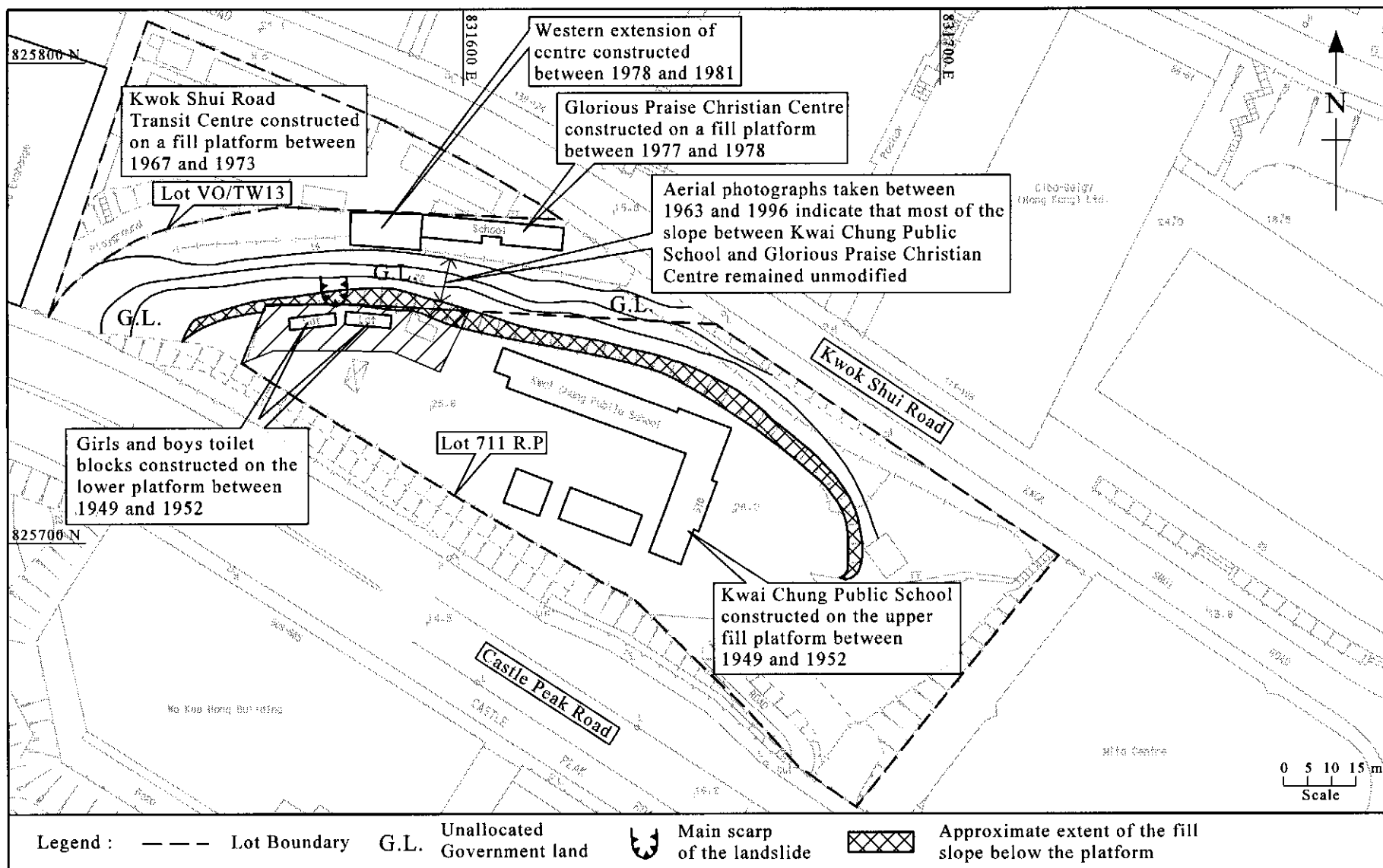


Figure 3 - Land Status and Site History

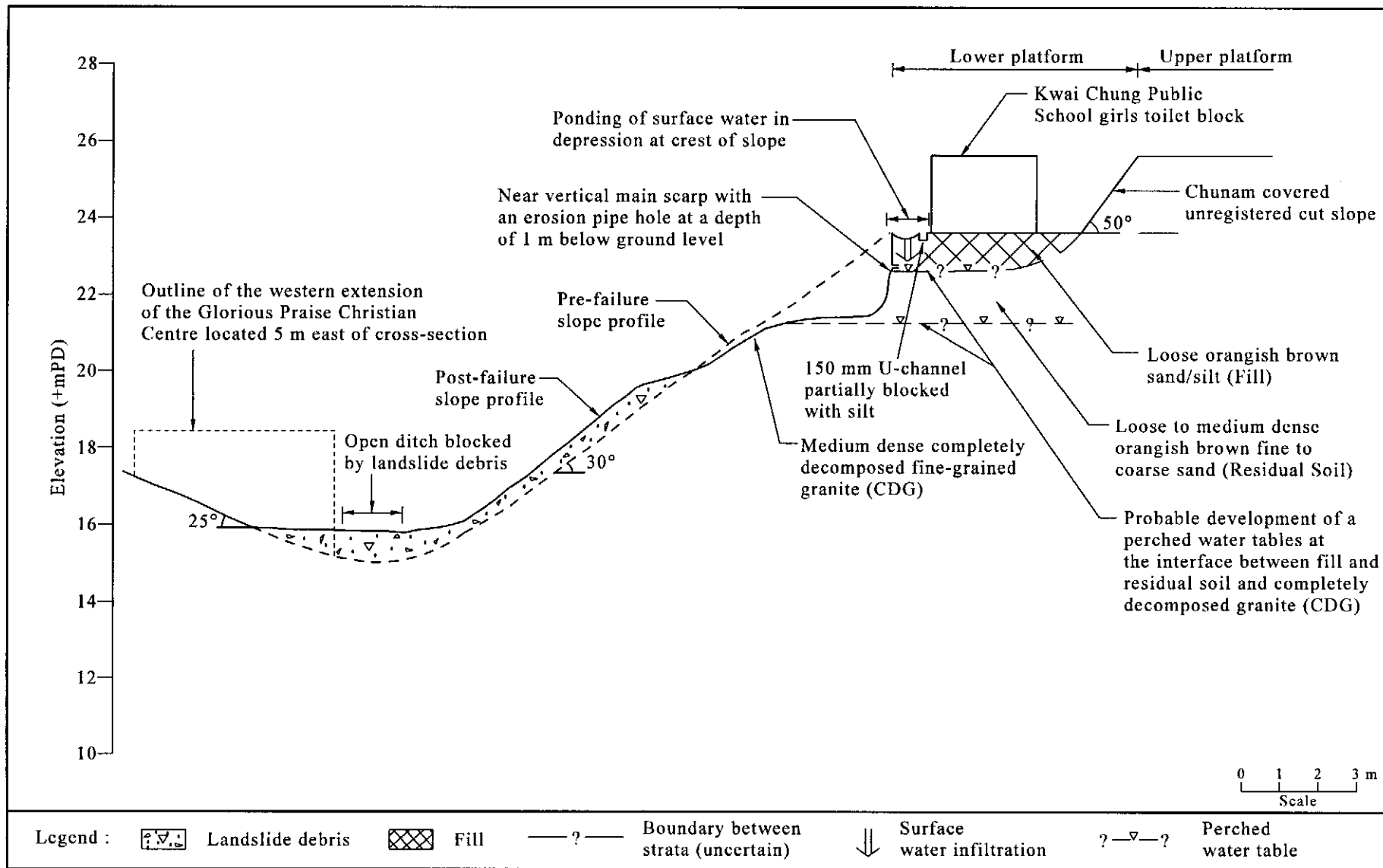
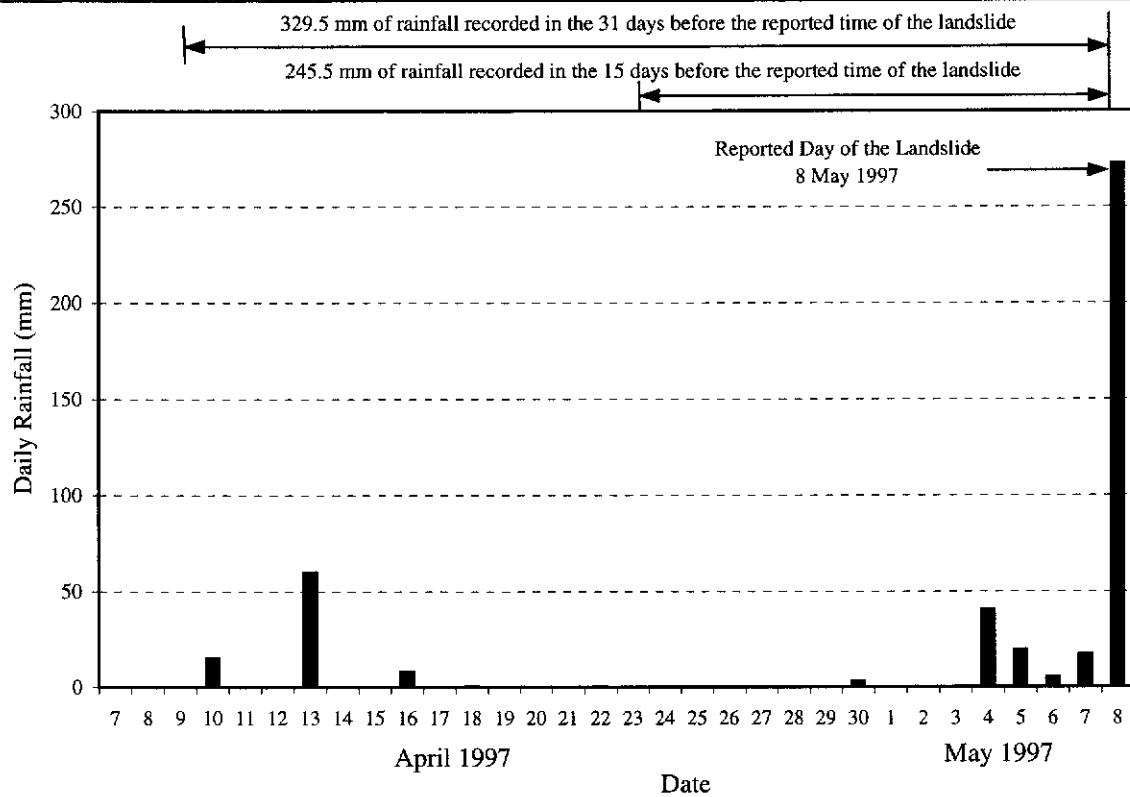
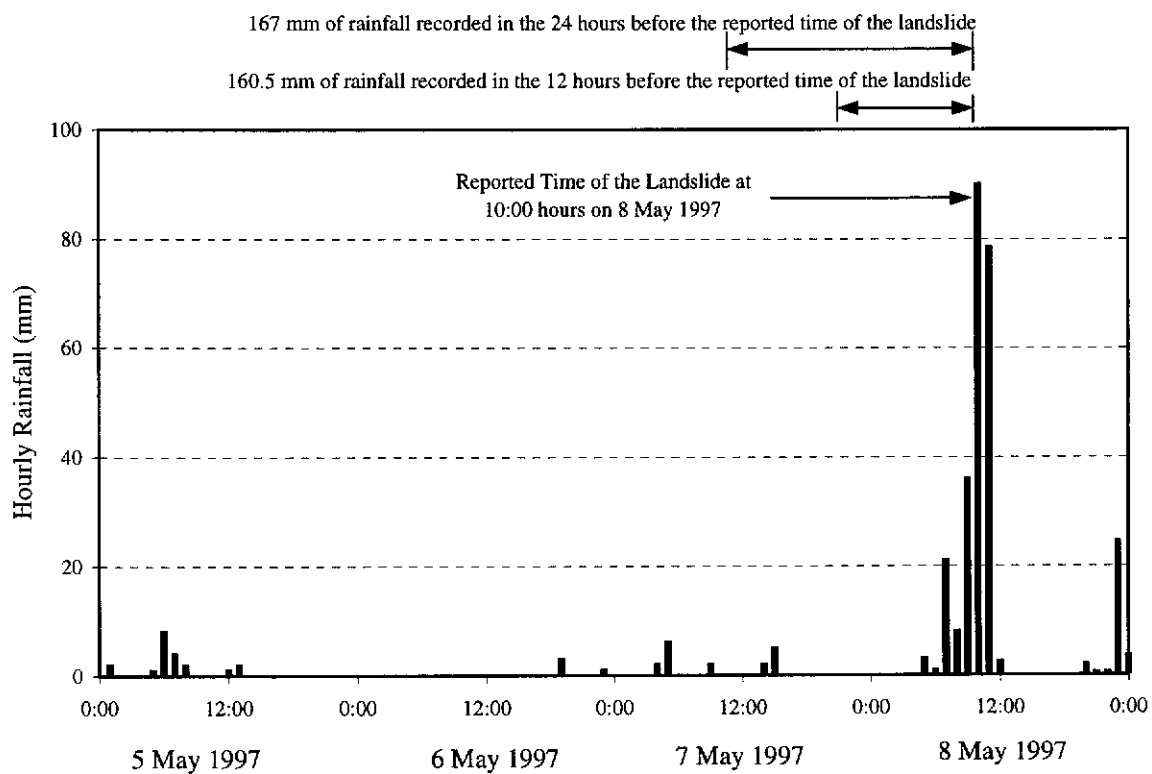


Figure 4 - Geological Cross-section

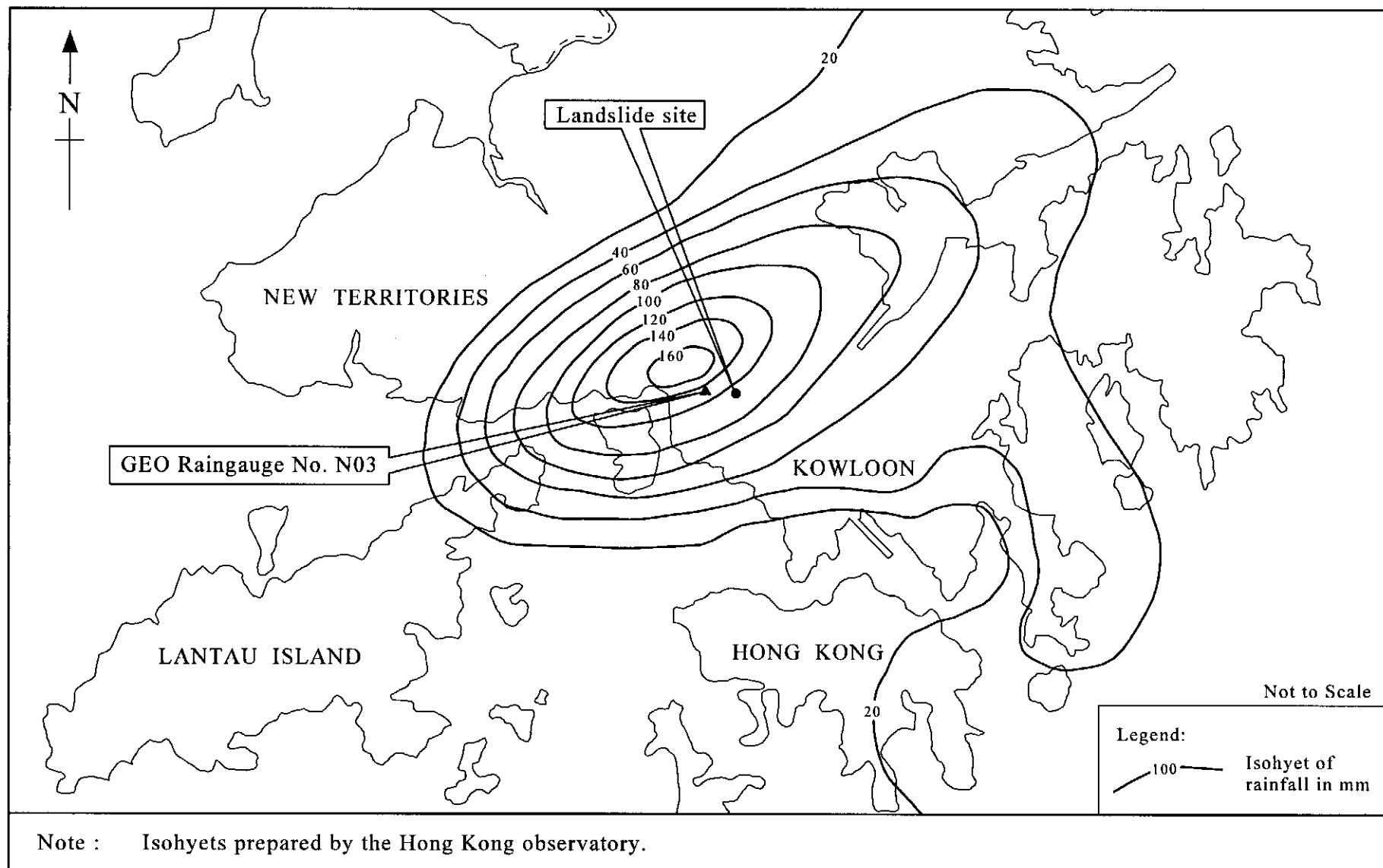


(a) Daily Rainfall Recorded between 7 April and 8 May 1997



(b) Hourly Rainfall Recorded between 5 May and 8 May 1997

Figure 5 - Rainfall Recorded at GEO Raingauge No. N03



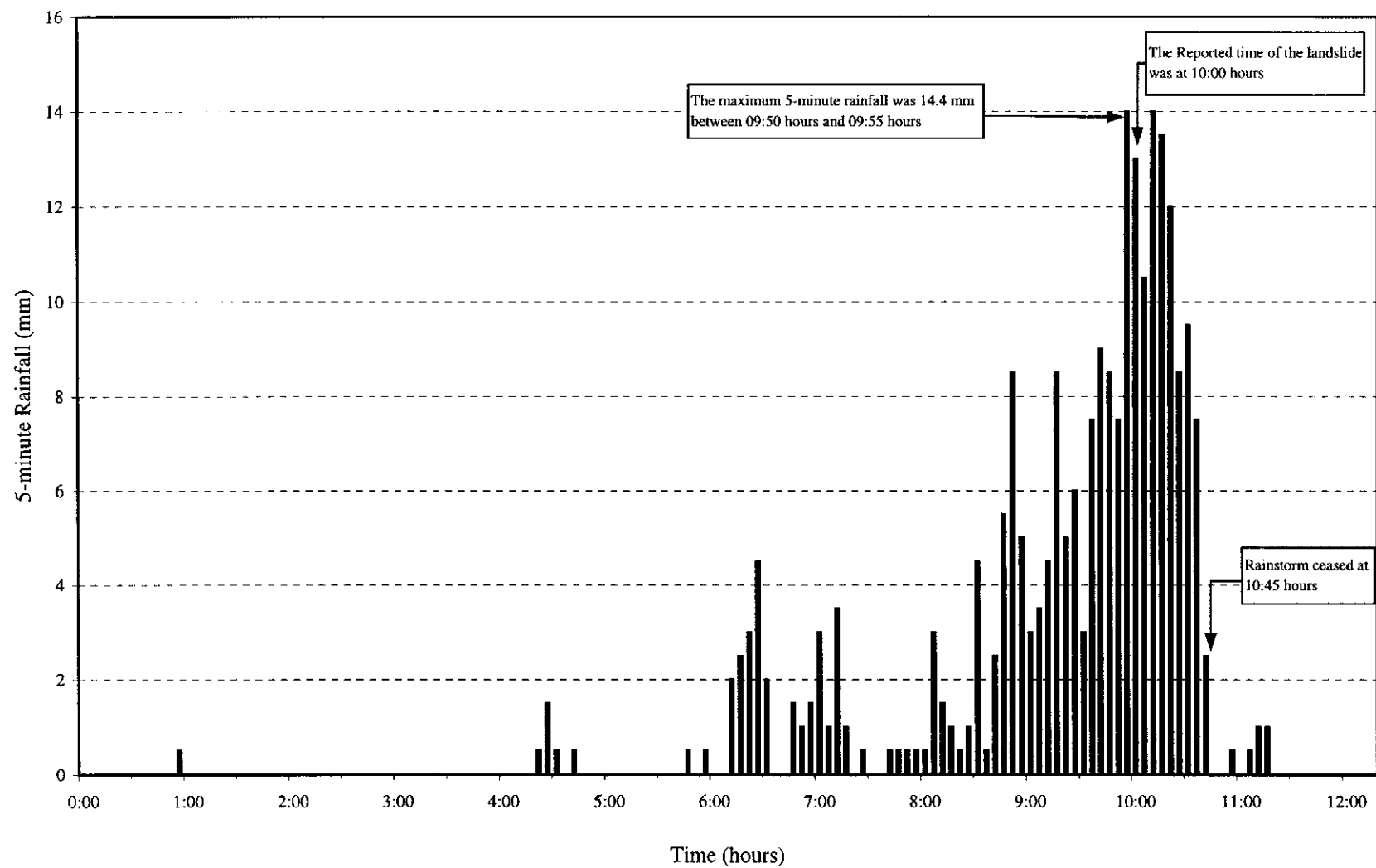


Figure 7 - Rainfall Recorded at GEO Raingauge No. N03 at 5-minute Intervals on 8 May 1997

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Plate 1 - View of the Landslide Showing the Debris on the Slope (Photograph Taken on 9 May 1997)  
(Note the Main Scarp is Obscured at the Crest of the Slope)



Plate 2 - View Along the Lower Platform Behind the Toilet Blocks of Kwai Chung Public School (Photograph Taken on 15 May 1997)  
(Note the Slight Depression of the Ground Surface in the Area behind the Girls Toilet Block Above the Main Scarp of the Landslide)





Plate 3 - View Downslope to Glorious Praise Christian Centre Showing the Open Ditch at the Toe of the Slope  
(Photograph Taken on 27 August 1997)





Plate 4 - View to the East Showing the Rear of Glorious Praise Christian Centre and the Open Ditch at the Toe of the Slope (Photograph Taken on 27 August 1997)



Plate 5 - View to the West Showing the Secondary Washout of Debris (Photograph Taken on 27 August 1997)





Plate 6 - Close-Up View Showing the Near-Vertical Main Scarp (Photograph Taken on 15 May 1997)



Plate 7 - View Showing the Undermining of the Lower Platform at the Crest of the Slope behind the Girls Toilet Block of Kwai Chung Public School (Photograph Taken on 15 May 1997)  
(Note the Two Water Supply Pipes in the Right-Hand Corner of the Photograph)