INVESTIGATION OF SOME SELECTED LANDSLIDES IN 1999 (VOLUME 2)

GEO REPORT No. 121

Fugro Maunsell Scott Wilson Joint Venture

GEOTECHNICAL ENGINEERING OFFICE

CIVIL ENGINEERING DEPARTMENT

THE GOVERNMENT OF THE HONG KONG

SPECIAL ADMINISTRATIVE REGION

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PREFACE

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. 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
Head, Geotechnical Engineering Office
December 2001

EXPLANATORY NOTE

This GEO Report consists of two Landslide Study Reports on the investigation of selected slope failures that occurred in 1999. The investigations were carried out by Fugro Maunsell Scott Wilson Joint Venture (FMSW) for the Geotechnical Engineering Office as part of the 1999 Landslide Investigation Consultancy.

The LI Consultancies aim to achieve the following objective 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 FMSW are presented in two 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 ABOVE KAP LUNG, SHEK KONG, DURING THE SEVERE RAINSTORMS BETWEEN 22 AND 24 AUGUST 1999

Fugro Maunsell Scott Wilson Joint Venture

This report was originally produced in August 2000 as GEO Landslide Study Report No. LSR 3/2000

FOREWORD

This report presents the findings of a detailed study of a landslide that occurred in quasi-natural terrain, below an electricity pylon above Kap Lung, Shek Kong, following the rainstorm of 22 to 24 August 1999. Debris from the landslide entered a natural drainage line and was transported approximately 650 m downslope. There were no casualties as a result of the landslide.

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 failure. The scope of the study comprised site inspections, limited site investigation, desk study and analysis. Recommendations for follow-up actions are reported separately.

The report was prepared as part of the 1999 Landslide Investigation Consultancy (LIC), for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 101/98. This is one of a series of reports produced during the consultancy by Fugro Maunsell Scott Wilson Joint Venture (FMSW).

Y.C. Koo
Project Director/Fugro Maunsell Scott Wilson
Joint Venture

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1. INTRODUCTION

On 25 August 1999, a landslide was identified by the China Light and Power Company Limited (CLP) on the hillside above Kap Lung near Shek Kong in the New Territories (Figure 1 and Plate 1). The landslide was observed during CLP's aerial reconnaissance following the severe rainstorms between 22 and 24 August 1999. The incident was reported to the Mainland West Division of the Geotechnical Engineering Office (GEO) on 30 August 1999.

The landslide occurred largely within CLP's compound area, which contains an electricity pylon, Tower No. 4BPB73, carrying the overhead transmission lines between Black Point Power Station and Sha Tin Substation. There were no casualties arising from the landslide.

Following the landslide, Fugro Maunsell Scott Wilson Joint Venture (FMSW), the 1999 Landslide Investigation Consultants, commenced a detailed study of the failure for the GEO, Civil Engineering Department (CED) under Agreement No. CE 101/98. The study was carried out by a team comprising members from Fugro (Hong Kong) Ltd. only. This is one of a series of reports produced during the consultancy by FMSW.

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 comprised site inspections, limited site investigation, 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) desk study, including a review of relevant documentary records relating to the history of the site,

(b) aerial photograph interpretation (API),

(c) topographic survey, mapping and detailed observations and measurements at the landslide site,

(d) limited ground investigation works,

(e) analysis of rainfall data, and

(f) diagnosis of the probable causes of the landslide.

2. THE SITE

2.1 Site Description

The landslide occurred on a northeast-facing hillside at an elevation of 360 mPD, about 200 m to the north of the main ridgeline of Tai Mo Shan (Figure 1). Kap Lung, comprising a row of village houses surrounded by derelict farmland, is situated at the base of the hillside, about 600 m to the northeast and about 220 m below the landslide site at an elevation of 145 mPD. Some of the village houses have been abandoned and are currently used for storage only. The August 1999 landslide did not affect the village houses and did not result in any structural damage to the electricity pylon.

The morphology of the area surrounding the landslide site is characterised by alternating prominent spurs and valleys. The landslide site lies below a prominent spur line that trends in a north-northeast direction off the main ridgeline (Figure 1). The landslide is located on the eastern flank of the spur adjacent to a natural drainage line, which flows in a northeasterly direction through Kap Lung. In accordance with the geological map of the area (GCO, 1988), Kap Lung lies on a lobe of debris flow deposits.

The electricity pylon is a standard CLP pylon with 4 legs, referenced Legs A to D. Legs A and C are located along the spur, whereas Legs B and D straddle the spur and are located on opposite flanks (Figures 1 & 2). The landslide occurred at the southeastern corner of the electricity pylon, with Leg D located in the upper portion of the landslide scar (Figure 2).

The upper portion of the landslide occurred within the CLP compound area, for which topographic survey data before and after the landslide was available. This data has been used in conjunction with post-failure field observations and measurements to establish the plan and section of the landslide (Figures 2 and 3).

Topographic survey data from within the CLP compound shows that the slope angle to the northwest of the spur line varies from about 35° below the spur to about 25° further downhill. To the northeast of the spur, the slope angle is typically about 30°. Site mapping by FMSW identified a sharp convex break of slope below and to the southeast of Leg D, where the slope angle steepens to about 50°. The break of slope occurs about 20 m downhill of Leg D, slightly outside the boundary of the CLP compound (Figures 2 & 3).

The CLP compound is surrounded by trees with a dense canopy formed about 10 m above ground level (Plates 1 & 2). Within the CLP compound, the vegetation cover is not as dense, with sporadic trees of a maximum height of about 4 m.

2.2 Water-carrying Services

No water-carrying services are present in the vicinity of the landslide site.

2.3 Maintenance Responsibility

The upper portion of the landslide lies within the CLP compound (Figures 1 & 2). Based on the Lands Department's advice, the lower portion of the landslide lies within unallocated Government land.

2.4 Site History

2.4.1 General

The history of the site has been determined from a preliminary API, together with a review of the documentary records associated with the electricity pylon. Details of the API are presented in Table 1. Key observations are presented in the following sections.

2.4.2 Site Development History

According to CLP, the electricity pylon was commissioned in August 1996, along with the overhead transmission lines between Black Point Power Station and Sha Tin Substation. Documentary records contained in the Mainland West Division of the GEO indicate that the electricity pylon is supported on 1.8 m to 2.0 m diameter hand-dug caissons socketed into Grade II/III rock at depths of between 14.3 m and 27.9 m below ground level. The foundations were constructed between 11 September 1995 and 1 December 1995. No development in the vicinity of the landslide site was identified in the aerial photographs prior to pylon construction works. No signs of significant erosion or hillfires were observed in the area adjoining the landslide site from the API.

Vegetation clearance within the CLP compound over an area of about 1400 m^2 is clearly shown on the aerial photograph taken on 19 December 1995 (Plate 2). Little new vegetation growth was evident in the aerial photograph taken on 8 February 1999 (Plate 3). Post-failure site inspections have identified that the vegetation within the CLP compound remains sparse.

2.4.3 Previous Landslides

The review of low-level aerial photographs dating back to 1924 did not reveal any past instability at the 1999 landslide site.

The Natural Terrain Landslide Inventory (NTLI) compiled by the GEO has recorded numerous landslide events along the ridge of Tai Mo Shan. Five of them occurred above and within 100 m of the landslide site, within the same subcatchment and are referenced Landslides Nos. 35, 36, 37, 190 and 191 in the NTLI (Figure 5). Landslides Nos. 35, 36 and 37 were identified as having occurred in 1964. Landslides Nos. 190 and 191 were identified as having occurred in 1982, and were recurrent failures at the locations of Landslides Nos. 37 and 36 respectively. For Landslide No. 190, the maximum width exceeded 20 m and debris was shown to have travelled downhill along the same drainage line affected by the 1999 landslide for almost 600 m on plan coming to rest outside Kap Lung.

2.4.4 Past Assessments

The stability of the hillside around the electricity pylon was assessed by Maunsell Geotechnical Services Limited (MGS) in 1995, as part of the foundation design for the electricity pylon. Details of the stability analysis were presented in MGS's report dated 6 January 1995. The submission was approved by the Buildings Department (BD) on 20 May 1995, following checking of the design by the GEO.

The stability of the steepest ground profile across each of the legs of the pylon, derived from topographic survey from within the CLP compound (Section 2.1) were assessed by MGS assuming a groundwater table 2 m above rockhead (defined as Grade III material or better). Stability analysis established that the factor of safety (FOS) of the hillside varied from about 1.1 across Legs A and B to about 1.3 across Legs C and D. The stability of the hillside under lateral loads transmitted by the foundations was also assessed. The report concluded that the FOS across Legs C and D was adequate. The FOS across Legs A and B was found to be inadequate and slope stabilisation works comprising the installation of soil nails were recommended and subsequently carried out.

It is noteworthy that the depth to rockhead in each of the analysed sections was at least 11 m. Therefore, under the assumed design groundwater conditions the slopes were effectively analysed under dry conditions for the slip surfaces considered. Furthermore, for each stability cross-section the ground profile beyond the CLP compound was determined by linear extrapolation. Consequently, the sharp convex break of slope and steeper ground profile across Leg D, as identified by post-failure mapping by FMSW (Section 2.1), were not accounted for (Figure 3 and Plate 4).

3. THE LANDSLIDE

3.1 Description of the Landslide

The date and time of the landslide is not known, as there were no eye-witness accounts of the failure. The first sighting of the landslide was by CLP on 25 August 1999, during an aerial reconnaissance by helicopter. According to CLP, the aerial reconnaissance is a routine operation after major rainstorms. The previous aerial reconnaissance of the area, undertaken by CLP during June 1999, did not identify any signs of instability at the landslide site. It is considered likely that the landslide occurred during the severe rainstorms between 22 and 24 August 1999.

Field observations and mapping of the landslide site were carried out by FMSW principally between August and October 1999. Details from the field mapping are presented in Figure 2 and general views of the landslide are shown in Plates 4 to 7.

The landslide was first inspected by FMSW on 26 August 1999, at which time much of the upper portion of the rupture surface was covered by displaced vegetation and a thin superficial layer of landslide debris. The debris remaining within the source area of the landslide had a maximum thickness of about 0.5 m and an overall volume of between 150 m^3 and 200 m^3. Two prominent incised channels with a maximum depth of about 300 mm were noted towards the northern flank of the landslide (Figure 2 and Plate 4). These channels were considered to have been formed by erosion/washout due to concentrated surface water flow following the detachment of material.

The crown of the landslide was located about 18 m to the southwest of Leg D at an elevation of about 359 mPD. The surface of rupture was about 55 m long and 20 m wide, with an average depth of 2 m (Figures 2 & 3 and Plate 5). The failure occurred in colluvium. A sharp change in direction of the rupture surface occurred at approximately the mid-point of the scar, creating two distinct upper and lower portions (Figure 2).

From field observations it is apparent that the ground profile before the landslide comprised a sharp convex break of slope approximately at the boundary of the CLP compound (Figure 3). The slope break is visible in the southern flank of the landslide (Plate 6) and it is estimated that the ground above and below the slope break was inclined at about 30° and 50° respectively before the landslide.

Based on the geometry of the landslide scar, it is estimated that about 2000 m^3 of debris detached from the hillside. The majority of detached material entered the natural drainage line below the landslide and became channelised forming a debris flow.

Parallel and adjacent to the northern flank of the landslide, a smaller landslide scar, 6 m wide by 20 m long by 2 m deep, with a detached volume of about 50 m^3 was observed (Figure 2 and Plate 7). This failure also occurred in colluvium and the failed material merged with debris from the main source area.

Following the landslide, CLP's contractor carried out emergency slope repair works within the boundary of the compound area comprising:

(a) removal of loose debris and trimming of the over-steepened edges from the landslide scarp,

(b) application of 75 mm thick shotcrete for protection against ingress of surface water and erosion, and

(c) installation of weepholes at 2 m centres and peripheral surface channels.

The emergency repair works were completed on 4 November 1999. A site inspection by FMSW on 22 March 2000 identified recent tension cracking, 20 mm to 30 mm wide, by 300 mm deep (maximum), by about 4 m long, directly below the treated area (Plate 8). This cracking appears to be associated with the thin superficial layer of 1999 landslide debris that had not yet been removed from the scar. Also, the drainage channel along the toe of the treated area had no upstand to it, such that water flowing from the steep shotcreted surface above may tend to over-shoot the channel and discharge onto the bare portion of the failed slope below.

To safeguard against further landslides, slope remedial works comprising the installation of soil nails were proposed by CLP's term geotechnical consultant and approved by the BD on 28 January 2000. These works had not commenced as at 10 July 2000.

3.2 Mapping of the Drainage Line below the Landslide

The drainage line below the source area of the landslide was traced downhill in order to record its characteristics and to establish the nature of deposition of landslide debris (Figure 4 and Table 2). The upper section of the drainage line was inspected shortly after the 1999 landslide, but the middle and lower sections were not inspected until some time after the failure. Photographs, showing typical profiles are presented in Appendix A.

Detached material entered the drainage line at an elevation of about 310 mPD (hereafter referenced as Chainage 0 m). From Chainage 0 m to 530 m (140 mPD), transportation of the failed material was dominant, with only minor evidence of erosion along the flanks of the stream course. Localised deposition was observed along the upper section of the transportation zone between Chainage 0 m and 130 m (Figure 4 and Plates A1 to A3, Appendix A). The total volume of deposition in this area was about 120 m^3. Deposition was also identified at Chainage 215 m (226 mPD), where a mass of plant and tree debris with an approximate volume of 50 m^3 had partially blocked the drainage line (Plate A4, Appendix A). From Chainage 530 m (140 mPD) to the estimated toe of the debris flow at Chainage 635 m (129 mPD), deposition was dominant, with some minor erosion (Figure 4 and Plate A5, Appendix A). Further deposition of about 60 m^3 was evident between about Chainage 670 m and 720 m. It is not certain whether this represented 1999 landslide debris or debris from previous debris flows.

The upper section of the drainage line, between Chainage 0 m and 530 m, typically comprised an incised gully with sub-vertical sides exposing tuffaceous bedrock and colluvium (Plates A3 and A6, Appendix A). The profile of the drainage line was characterised by a series of sharp drops, controlled by northwest-southeast trending joints, between which the gradient of the drainage line was fairly linear (Plate A7, Appendix A). Across the sharp drops, the inclination of the drainage line varied between 25° and 30°, and the sections between were typically inclined at about 15°, giving an average inclination of 19º. The ground along the flanks of the drainage line was fairly steep and covered with trees and dense vegetation. The vegetation in this area remained largely intact, indicating that the debris flow was contained within the drainage line, but at certain locations, particularly in the upper section, vegetation was flattened and aligned in a downslope direction (Plates A2 and A3, Appendix A). These areas of flattened vegetation occurred where the drainage line widened or where there was a sharp change in direction. Flow lines observed along the flanks of the drainage line suggest a high flow regime, with a maximum depth of up to 3 m in areas.

The lower section of the drainage line between Chainage 530 m and 970 m like the upper section, still had typically steep incised flanks in places, exposing mainly relic debris flow deposits, with only localised outcrops of tuffaceous bedrock (Plate A8, Appendix A). The topography of this section of the drainage line was flatter, and characterised by extensive relic debris flow deposits, which formed areas of gently sloping ground that were typically covered by grasses, trees and relic agricultural terracing (Plate A9, Appendix A). The inclination of this section of the drainage line was typically between 3° and 11°, with an average inclination of 7º. It is estimated that between 300 m^3 and 400 m^3 of the 1999 landslide debris material deposited along this section of the drainage line spread out between Chainage 530 m to 635 m (140 mPD to 129 mPD). This appears to have been the main area of deposition (Plates A5 and A8, Appendix A). The approximate travel angle of the debris flow, assuming the toe of the debris to be at Chainage 635 m, has been calculated as 16º (Wong & Ho, 1996).

Up to 600 m^3 of 1999 landslide debris was observed along the drainage line by FMSW, which combined with the material remaining within the source area of the landslide accounts for about 800 m^3 of material. This represents approximately 50% of the total estimated volume of the failure. The difference is considered to be mainly due to the fact that a major portion of the detached mass comprised fine gravel to silt and clay sized particles, which would have been transported a greater distance and/or washed out following initial deposition. Based on the minor nature of erosion observed along the flanks of the drainage line, it is considered that the degree of entrainment of material into the debris flow is minimal and did not significantly increase the total volume of the debris flow.

Field mapping of the drainage line identified that there were no large accumulations of debris within the drainage line that could be reactivated during heavy rainfall.

4. SUBSURFACE CONDITIONS

4.1 General

The subsurface conditions at the site were established using the following information:

(a) published geological data,

(b) pre-landslide documentary records available from CLP and the GEO,

(c) post-landslide trial pit data from CLP, and

(d) field mapping by FMSW after the landslide.

4.2 Geology

According to Sheet 6 of the Hong Kong Geological Survey 1:20,000 Map Series (GCO, 1988), the geology at the landslide site comprises crystalline and vitric tuff (Shing Mun Formation of the Upper Jurassic Repulse Bay Group). An extract from the geological map is shown in Figure 6. No major faults are shown as crossing the landslide site.

Observations made during the field mapping by FMSW are generally in line with the above, but debris flow deposits (colluvium) up to a maximum thickness of about 4 m were also identified by FMSW.

4.3 Previous Ground Investigations

During the period from November to December 1993, ground investigation works comprising seven drillholes (BS73/A to D and BS73/S1 to S3) were carried out by Freyssinet

Hong Kong Limited for CLP's foundation design of the electricity pylon and slope stability assessment. Drillholes BS73/A to D were undertaken adjacent to Legs A to D of the pylon respectively, while drillholes BS73/S1 to S2 were undertaken downslope of Leg B and drillhole BS73/S3 was undertaken downslope of Leg D. The locations of the drillholes are shown in Figure 2 and logs of the relevant boreholes for the establishment of the geological profile at the landslide site are included in Appendix B.

Drillholes closest to the spur line (BS73/A to D) showed that typically between 9 m and 14 m of completely decomposed tuff (CDT) overlie rockhead (although drillhole BS73/C identified 24 m of CDT without encountering rockhead). No colluvium was identified in any of the drillholes and residual soil (about 2 m thick) was encountered in drillhole BS73/A only. Drillholes BS73/S1 to S3, undertaken further down the hillside between about 40 m and 80 m below the spur line, indicated that the depth of CDT overlying rockhead decreased, with BS73/S2 identifying rockhead at 1.7 m below ground level.

Drillholes BS73/A and BS73/D were undertaken in the vicinity of the upper and middle portions of the 1999 landslide main scarp respectively. These identified 10.7 m to 11.1 m of CDT overlying moderately to slightly decomposed tuff.

When comparing the survey information recorded for drillhole BS73/S3 with the ground profile at the recorded location of the drillhole, there is a significant discrepancy with a level difference of at least 10 m. Accordingly, the information presented in drillhole BS73/S3 has not been used in establishing the geological profile at the landslide site.

Following the landslide, four trial pits (TP1 to 4 adjacent to Legs A to D respectively) were undertaken by CLP to obtain more information about the site. The materials encountered at TP4 (adjacent to Leg D at the central portion of the landslide site) comprised landslide debris to a maximum depth of 1.8 m overlying residual soil to the maximum excavated depth of 3.4 m. However, trial pit TP4 was located upslope of the caisson forming Leg D, where landslide debris had accumulated during sliding (Figure 3 and Plate 5). Accordingly, the depth of landslide debris recorded by the trial pit is not representative of the general conditions across the main scarp, where the maximum depth of debris is considered to be less than 0.5 m.

Trial pits TP1 to TP3 typically encountered between 1 m and 2 m of colluvium overlying variable thicknesses of residual soil and CDT.

4.4 Field Mapping

Field mapping was carried out during a series of site inspections between August and October 1999 by FMSW. The geological features observed at the landslide site are shown in Figure 2. Based on the available ground investigation information (Section 4.3) and the results of the field mapping, a cross-section showing the inferred ground conditions through the landslide site is presented in Figure 3.

Mapping of the flanks of the landslide identified that the landslide predominantly involved colluvium, which increased in a downhill direction from about 0.5 m at the crown to a maximum of about 4 m at the convex break of slope. The colluvium comprised a loose, greyish yellow, silty, slightly clayey to clayey sand with some to many sub-angular to sub-rounded gravel, cobble and boulders of highly to moderately decomposed tuff.

Along the upper portion of the main scarp, the colluvium was underlain by residual soil and CDT. The thicknesses and lateral extent of these materials were very variable. The residual soil comprised a firm to stiff, brown, fine sandy, clayey silt up to a maximum thickness of about 2 m. A number of soil/erosion pipes were observed along the upper portion of the main scarp (Plate 9).

Localised outcrops of highly to moderately decomposed tuff (H-MDT) were exposed across the rupture surface (Figure 2 and Plate 10), and in the vicinity of the convex break of slope, several outcrops of H-MDT occurred in a cluster. Towards the toe of the landslide, outcrops of moderately to slightly and slightly decomposed tuff (M-SDT and SDT respectively) were observed (Plate 11). The outcrops of H-MDT observed in the main scarp could be isolated corestones, but towards the convex break of slope, where they occur in a cluster, they could be an indication of a shallower rockhead profile (Figure 3).

On plan, the landslide is characterised by an abrupt change in direction at about the mid-point, with the upper portion orientated in a northeasterly direction, and the lower portion orientated in an easterly direction. This suggests more than one phase of movement, with instability retrogressing up the hillside.

An existing gully, which appears to form an ephemeral drainage line, lies to the south of the landslide (Figure 2). The gully is not considered to have influenced the landslide directly, but the presence indicates the possibility of some form of geological weakness and the fact that surface water converges to this area during rainfall.

4.5 Groundwater Conditions

The ground investigation in 1993 included the installation of a standpipe in drillhole BS73/S3, with the tip of the piezometer near rockhead 10.2 m below ground. No groundwater was observed over the period of monitoring from 7 to 14 December 1993. Monthly supervision reports on the caisson excavation works to depths of between 14 m and 28 m carried out between September and December 1995 show that no groundwater was encountered.

Based on the upslope topography, the catchment draining to the landslide site is small. The recharge from this small catchment is unlikely to sustain a substantial rise in the base groundwater table above the slip surface.

5. RAINFALL ANALYSIS

The GEO raingauge nearest to the landslide site is raingauge No. N14, located at the Wireless Station on Tai Mo Shan Peak, about 2.5 km to the east. This raingauge records and transmits rainfall at 5-minute intervals via a telephone line to GEO.

There were no eyewitnesses to the landslide and so the time and date of the failure is not known with confidence, but it is considered to have occurred sometime between 22 and 24 August 1999.

The daily rainfall recorded by the raingauge for the end of July 1999 and the month of August 1999 is presented in Figure 7. The daily rainfall records show that the storm was concentrated around 23 August 1999. The corresponding hourly rainfall for the period from 10:00 a.m. on 21 August 1999 to 4:00 p.m. on 23 August 1999 is also shown in Figure 7. Peaks in rainfall were recorded between 5:00 a.m. and 8:00 a.m. on 23 August 1999 in the range of about 50 mm/hr to 80 mm/hr. The peak rainfall intensity corresponds to a return period of about 85 years based on rainfall analysis. However, as noted above, the timing of the failure is uncertain and it is possible the failure occurred at an earlier stage of the rainstorm, which would have a smaller return period.

6. DISCUSSION

The close correlation between the landslide and the severe rainstorm between 22 and 24 August 1999 indicates that the landslide was probably triggered by rainfall.

It is considered that the landslide was most likely caused by the development of transient elevated groundwater pressure in the colluvium following prolonged and heavy rainfall. The loose state, coarse nature and relatively shallow depth of the surface colluvium, as observed on site, is favourable to direct infiltration and the formation of a perched water table at the colluvium/decomposed rock interface. It is possible that the sparse vegetation cover within the CLP compound (arising from vegetation clearance as part of the pylon construction works in 1995, see Section 3.2), may have led to increased infiltration locally, which combined with the hydrogeological setting of the site enabled a perched water table to develop.

The landslide is considered to have principally involved sliding failure of a thin layer of colluvium overlying residual soil and CDT. The morphology of the main scarp, involving a sharp change in direction at about the mid-point of the scarp, suggests possible retrogressive failure of the hillside.

The sharp convex break of slope identified below about the mid-point of the main scarp suggests the possibility of previous instability at this location and that the existing hillside was probably only marginally stable. The NTLI also shows extensive past instability in the vicinity of the landslide site.

Based on the field mapping, it is considered that the failure probably involved more than one phase of movement. Landsliding probably started in the oversteep section of hillside below the sharp convex break of slope, with successive failures retrogressing uphill. The long run out distance and relatively shallow travel angle of the debris identifies that large volumes of water were involved in the failure(s). Rainfall analysis indicates that the heavy rainfall on 23 August 1999 had a return period of about 85 years for the most critical rainfall duration of 24 hours. The incised channels observed within the main scarp also indicate the presence of concentrated surface water flow across the landslide scarp.

The stability analysis performed by MGS in 1995 was based on the assumption of a water table 2 m above rockhead. This resulted in the water table at least 9 m below ground level and the analysis did not consider any perched water table within the surface colluvium mantle, which controlled the 1999 failure. Also, the steeper portion of the hillside below Leg D was not considered in the past stability analysis.

7. CONCLUSIONS

It is concluded that the 1999 landslide was probably caused by the development of transient elevated groundwater pressure following the prolonged and heavy rainfall that preceded the failure.

The hydrogeological setting of the site, comprising loose surface colluvium overlying decomposed rock, is favourable to the development of a perched water table in the colluvium.

The affected hillside was previously assessed by detailed stability analysis based on a site-specific ground investigation and found to be adequately stable. It would appear that the past stability analysis did not reflect the key factors that contributed to the 1999 failure, viz. the presence of loose colluvium at shallow depths and a sharp convex break of slope with a steeper section of hillside of about 50º, which was possibly the location of a past failure.

8. REFERENCES

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LIST OF TABLES

Table 1 - Record of Details of Aerial Photograph Interpretation (Sheet 1 of 2)

Year	Photograph Reference No.	Altitude (feet)	Observations
1924	Y00135-Y00136	20,000	• Photograph of poor quality. • The hillside is undeveloped and vegetation is generally sparse.
06/11/45	Y00641-Y00642	20,000	• At Kap Lung, cultivation with outline similar to that at present is noted. • The hillside remains sparsely vegetated with just a few scattered trees. • Otherwise as before.
08/05/49	Y01963-Y01964	8,600	• Photographs of poor quality. • Cultivation noted on the side slopes in the vicinity of the 1999 landslide site. • Otherwise as before.
02/02/63	Y09313-Y09314	3,900	• Widespread tree plantation is evident across the hillside, and the spur line below which the 1999 landslide occurred is densely vegetated. • A number of landslide scars and areas of erosion are evident to the south of the 1999 landslide. The locations of these landslide scars coincide with NTLI landslide record nos. 35, 36 and 37 identified in 1964.
20/02/73	3190-3191	5,000	• The hillside is densely vegetated with trees, which obscures surface detail. • The landslide scars and areas of erosion observed in the 1963 photographs to the south of the 1999 landslide are still evident.
23/11/76	16488-16489	12,500	• The landslide scars that were noted in the 1963 aerial photograph are no longer visible due to dense vegetation cover. • Otherwise as before.
11/09/80	31557-31558	6,000	• No new landslide scars are noted in the immediate vicinity of the 1999 landslide site. • Otherwise as before.
10/10/82	44621-44622	10,000	• Extensive shallow instability is evident along the spur line to the south of the 1999 landslide site.
22/12/83	51519-51541	10,000	• As noted before.
01/10/85	67269-67270	10,000	• As noted before.

Table 1 - Record of Details of Aerial Photograph Interpretation (Sheet 2 of 2)

Year	Photograph Reference No.	Altitude (feet)	Observations
17/09/86	A05836-A05837	5,000	• Landslide scars noted in 1982 are beginning to re-vegetate. • Otherwise as before.
03/12/90	A24322-A24323	10,000	• Landslide scars noted in 1982 are now completely re-vegetated.
09/11/93	A36596-8	4,000	• As noted before.
19/12/95	CN13062-CN13063	3,500	• Construction of the caisson foundations for Electricity pylon 4BPB73 is complete. The caisson heads marking the 4 legs of Electricity pylon 4BPB73 can been seen on these aerial photographs. • Vegetation clearance has been carried out around the electricity pylon site. • No new landslide scars are noted in the immediate vicinity of the 1999 landslide site.
11/11/98	CN21521-CN21522	8,000	• Electricity pylon 4BPB73 has been erected and the overhead transmission lines have been connected. • No new landslide scars are noted in the immediate vicinity of the 1999 landslide site.
08/02/99	CN22578-CN22580	4,000	• At Electricity pylon 4BPB73, where vegetation clearance was noted in the 1995 aerial photograph, little new vegetation growth is evident. • No new landslide scars are noted in the immediate vicinity of the 1999 landslide site.

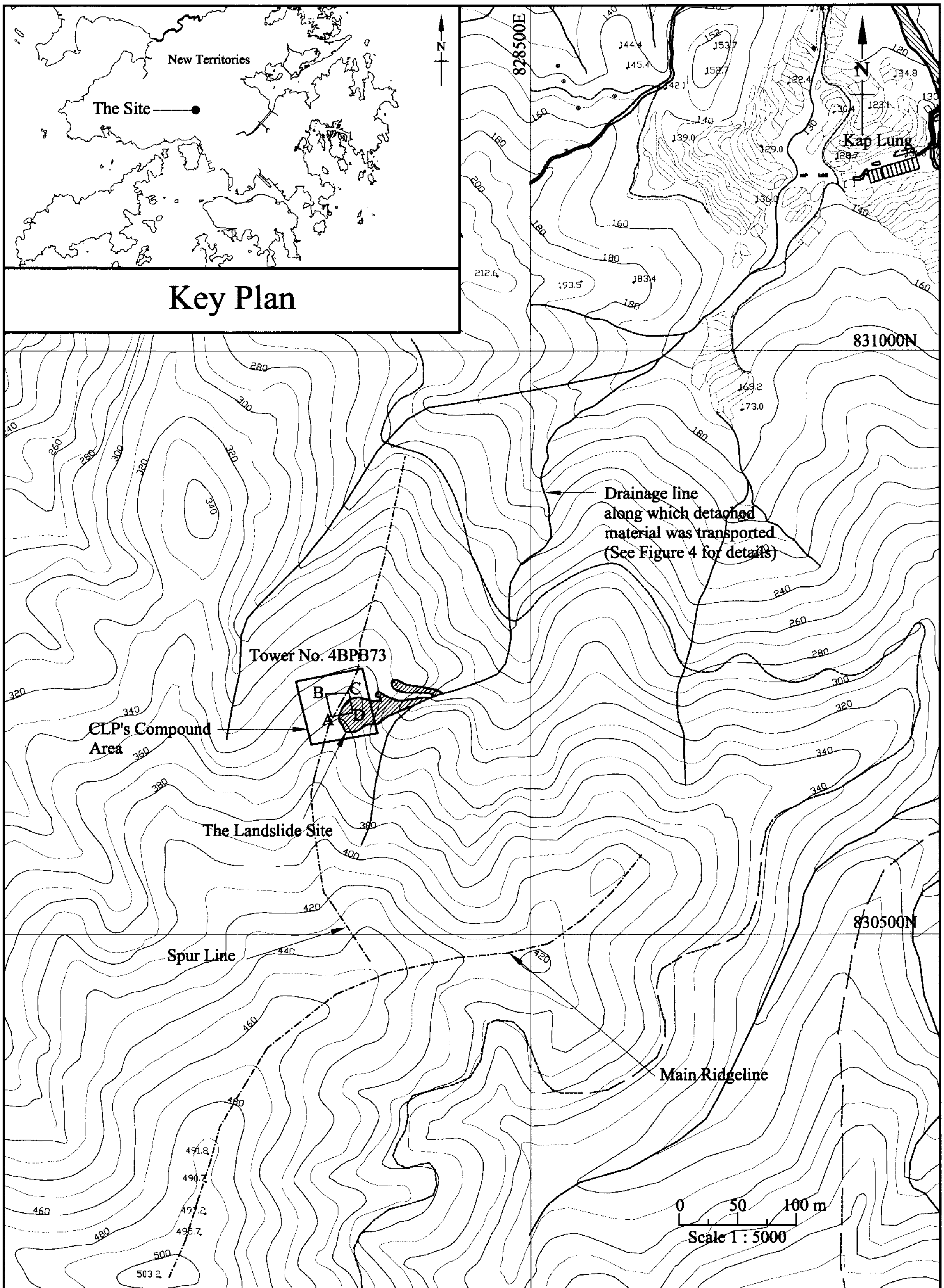
Table 2 - Channel Measurements along the Drainage Line below the Landslide (Sheet 1 of 2)

Chainage (m)	Slope Angle (Degrees)	Channel Width (m)	Dominant Flow Regime	Approximate Volume of 1999 Landslide Debris Deposition (m^3)	Remarks/Observations
0	At CH 0 the landslide debris material entered the natural drainage line				
0 to 55	20 to 25	8	Deposition and Transport	115	Steep sided incised stream course, with some deposition along the flanks and in the floor of the drainage line (See Plates A1 and A2).
55 to 81	20 to 25	5	Transport	0	
81 to 130	14	4 to 6	Transport with some minor deposition	5	Footpath located at CH 130. Drainage line widens for a short distance below the footpath (See Plate A3).
130 to 168	30	8	Transport	0	Wide area (15 m) of flattened vegetation/removed topsoil below footpath.
168 to 198	25 to 30	8	Transport	0	
198 to 215	13	10	Deposition	50	Large area of deposition behind vegetation dam (See Plate A4).
215 to 261	21	2 to 3	Transport	0	Incised stream course with numerous waterfalls.
261 to 295	14	4 to 5	Transport	10 to 20	
295 to 375	17	5 to 6	Transport	0	Large waterfall at CH 295, 8 m high.
375 to 445	12	5 to 6	Transport	0	Steeply incised, debris free drainage line with colluvial material in flanks.
445 to 530	10 to 15	7 to 8	Transport with some Deposition	10	Possible 1999 Landslide debris material.
530 to 554	8 to 10	8	Mainly Transport with some Deposition	20	

Table 2 - Channel Measurements along the Drainage Line below the Landslide (Sheet 2 of 2)

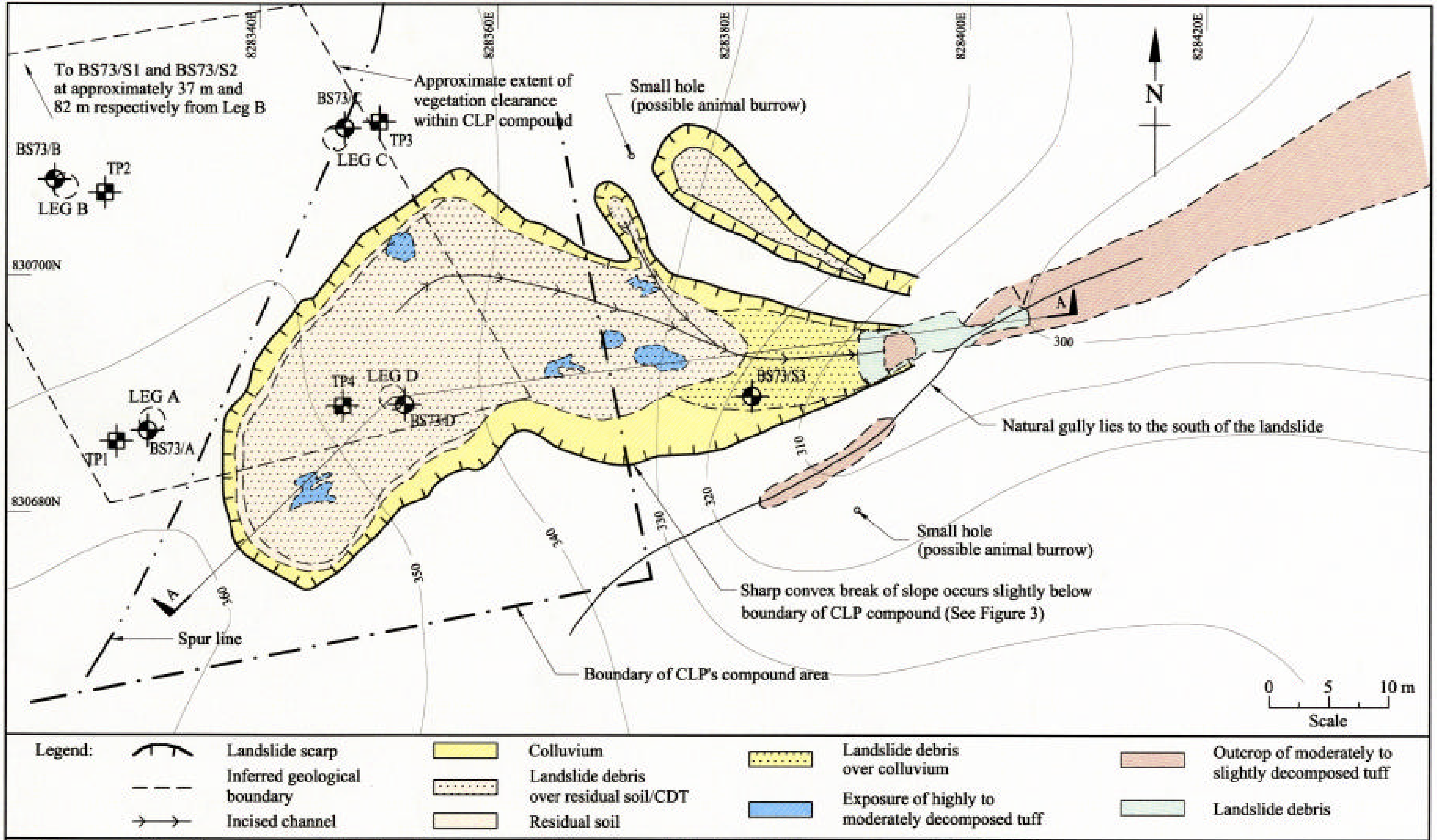
Chainage (m)	Slope Angle (Degrees)	Channel Width (m)	Dominant Flow Regime	Approximate Volume of 1999 Landslide Debris Deposition (m^3)	Remarks/Observations
554 to 592	11	8	Depositional	40	Large area of deposition (See Plates A5 and A8). CH 635 possible toe of 1999 debris flow.
592 to 635	4	8 to 12	Depositional	250	
635 to 705	4	2 to 3	Transport and Deposition	50	Area of deposition, possible 1999 landslide debris washed out from toe.
705 to 718	4	2 to 3	Deposition	15	
718 to 815	3	6	Deposition and Transport	0	Bedrock (Tuff) visible in the drainage line overlain by colluvium.
815 to 871	7	5 to 6	Deposition and Transport	0	Stream meanders across flat relic agricultural terraces, with 2 to 3 m of incision. Aligned vegetation along the flanks of the drainage line indicating evidence of high stream flows. Relic debris flow deposits (colluvium) visible in flanks of channel, thickness approximately 2 to 3 m. (See Plate A9)
871 to 888	7	5 to 6	Deposition and Transport	0	
888 to 912	11	6	Deposition and Transport	0	
912 to 943	11	5	Depositional	0	Landslide drainage line CH 912 start of Kap Lung Village (agricultural terracing).
943 to 970	25 to 30	2 to 3	Transport	0	CH 970. Location where the landslide drainage line enters the main river above the catchwater.
970 to 1085	3	10	Deposition and Transport	0	CH 1085 Located on the upstream side of the catchwater.

LIST OF FIGURES



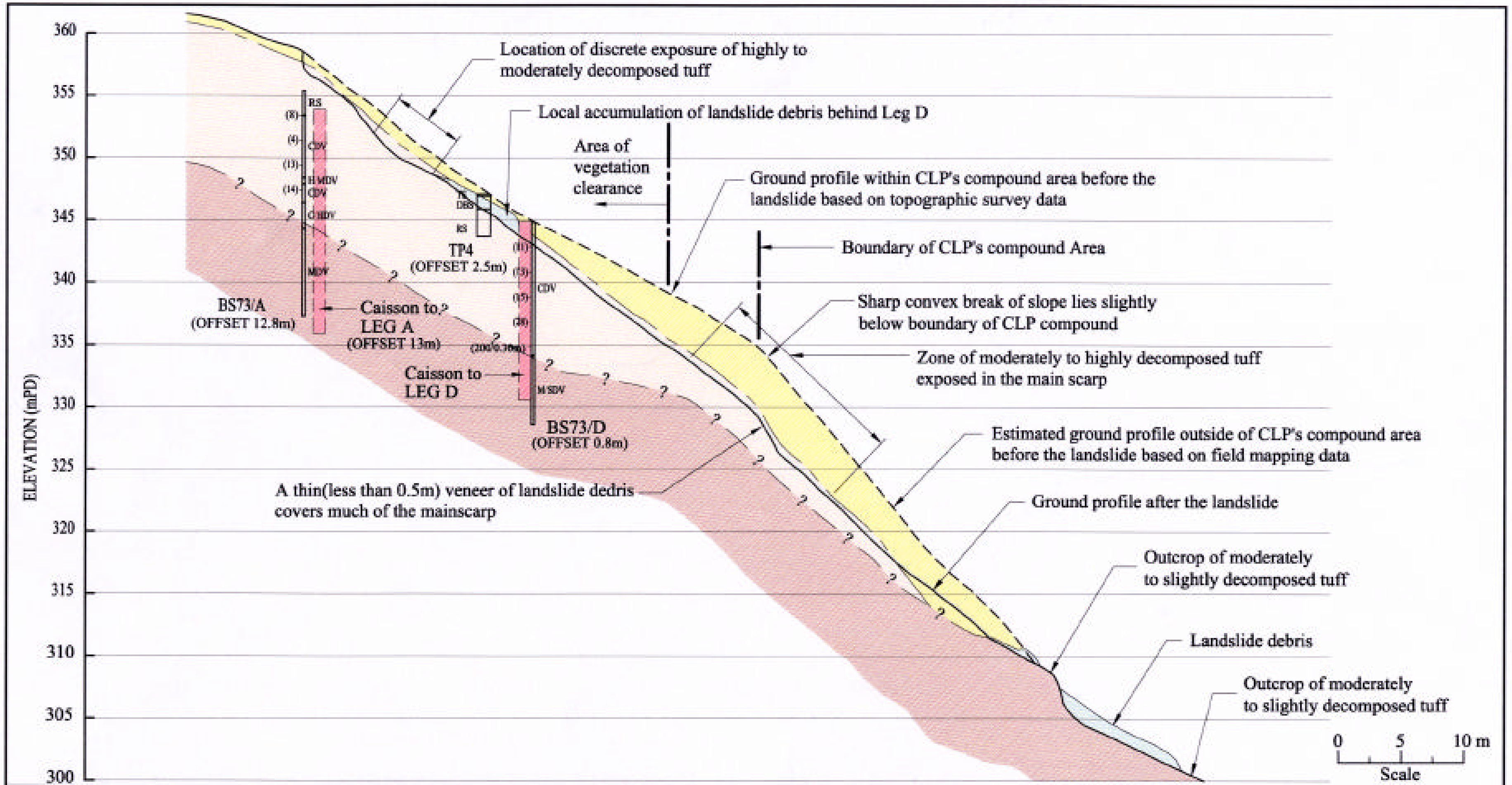
Notes: (1) Base Map is extracted from Survey Sheet No. 6NE-D, scale 1 : 5000.
(2) Overhead transmission lines and adjacent towers are not shown for clarity.

Figure 1 - Site Location Plan



Notes:
(1) Information shown in this figure is based on geological mapping carried out by FMSW between August and October 1999.
(2) Contours lines have been estimated based on topographic survey works within CLP's compound area and the published 1:1000 scale topographic map.

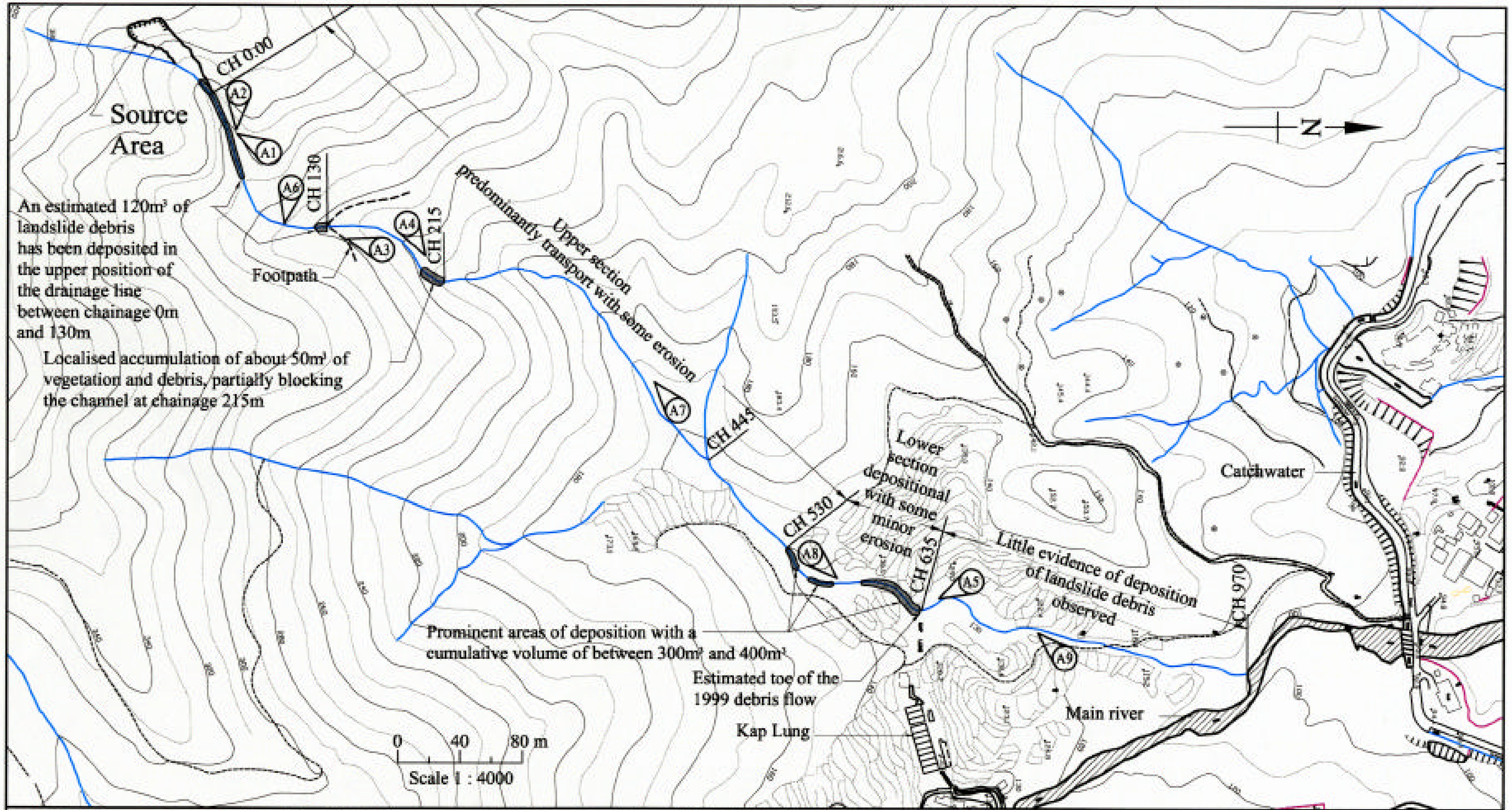
Figure 2 - Plan of the Landslide



Legend: Colluvium; Residual Soil/Completely Decomposed Tuff; Moderately to Slightly Decomposed Tuff; Landslide Debris; — ? — Inferred Geological Boundary; (8) SPT N-value

Notes:
(1) See Figure 2 for location of section.
(2) Information shown in this figure is based on geological mapping in conjunction with available ground investigation data.
(3) The ground profile within CLP's compound area is based on topographic survey data available for both before and after the landslide.
(4) The ground profile outside of CLP's compound is based on field observations by FMSW.
(5) Borehole BS 73/S3 has not been shown due to uncertainties of the position and elevation of the borehole.

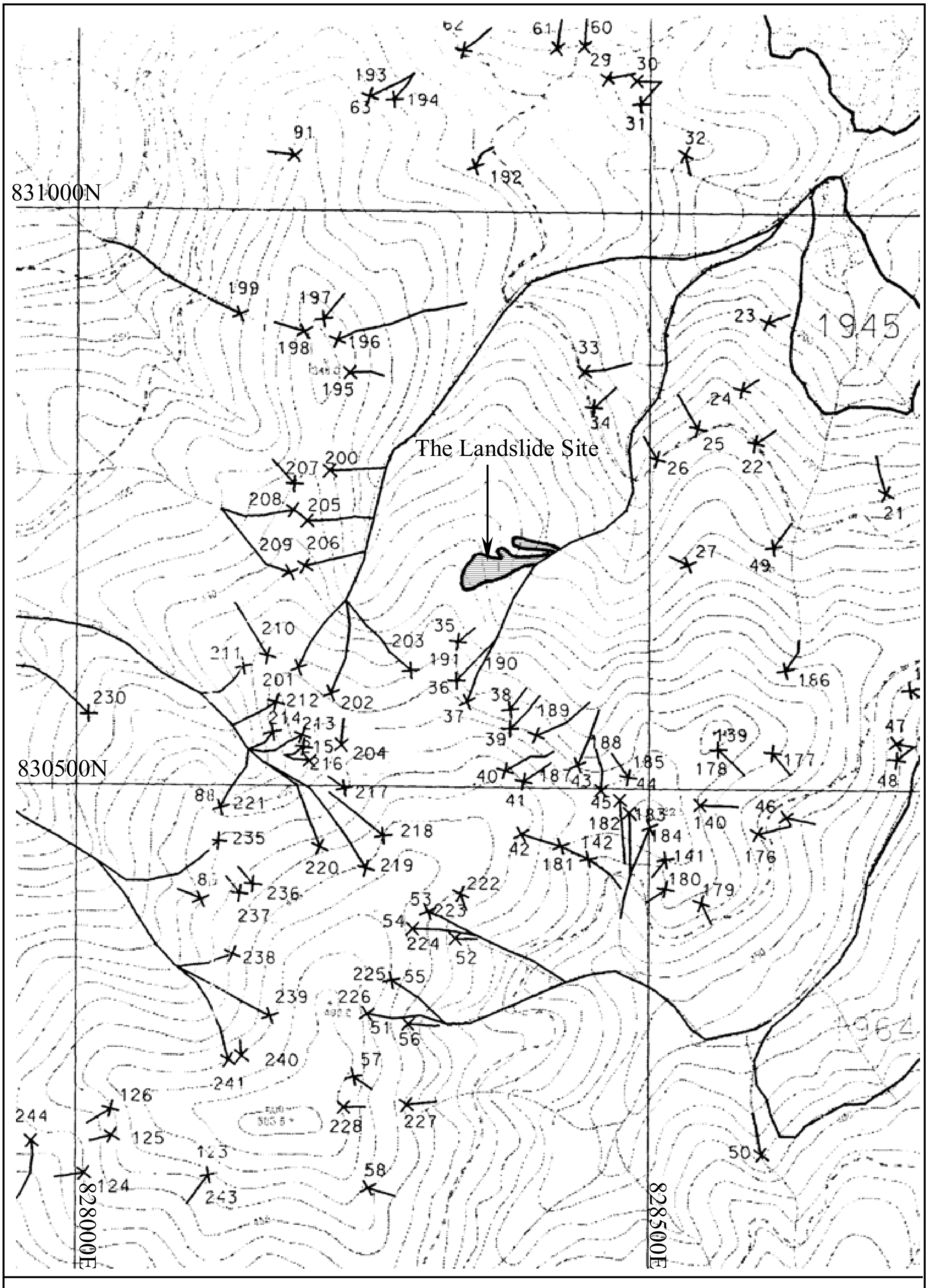
Figure 3 - Section A-A Showing the Inferred Geological Profile through the Landslide Site



Legend:		Area of possible 1999 landslide debris material.	CH 635,	Possible toe of 1999 debris flow.	Source Area
		Drainage lines.	CH 0.00,	Start of debris flow	Location and direction of photographic Plate A1 (See Appendix A, for the photographs taken along the drainage line)

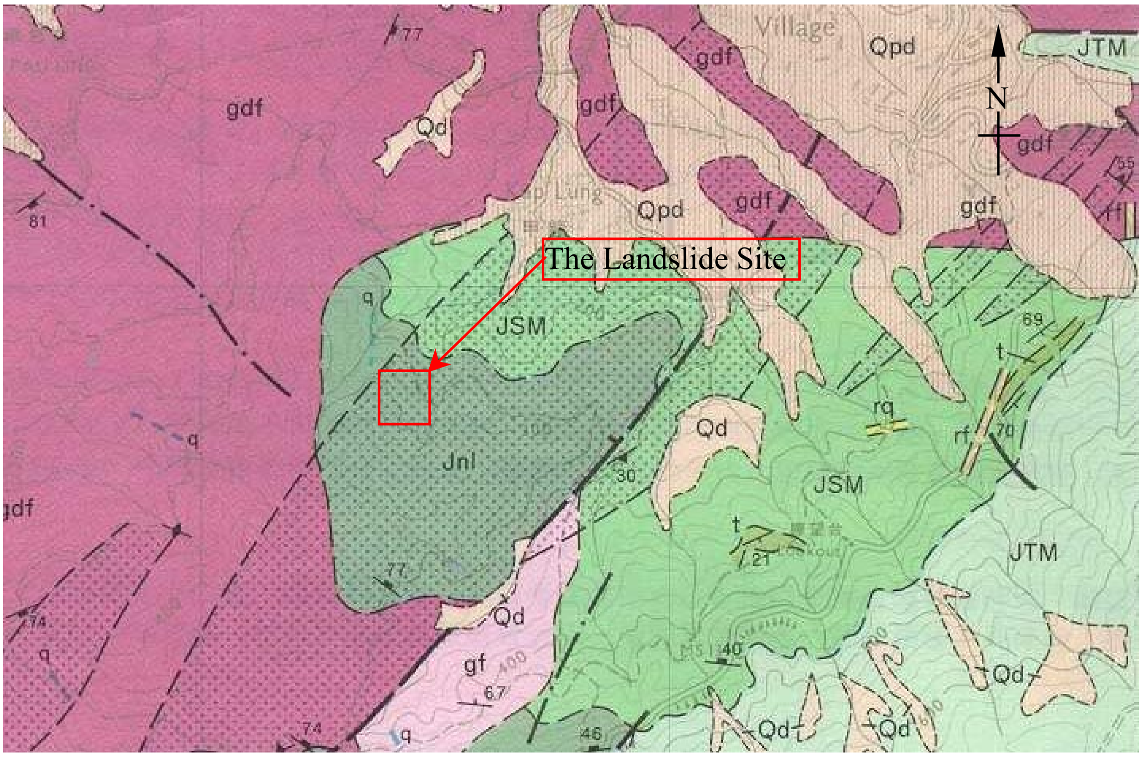
Notes:
(1) Runout length of debris flow 635m.
(2) Travel angle of debris flow 16°.
(3) CH 0.00 to CH 530, upper section of drainage line.
(4) CH 530 to 970, lower section of drainage line.

Figure 4 - Plan Showing Details of the Drainage Line below the Landslide



Note: Base map is extracted from NTLI sheet 6NE-D, Scale 1:5000.

Figure 5 – Extract from NTLI Sheet for Area Surrounding the Ridge of Tai Mo Shan



0m 500 m

LEGEND:

SUPERFICIAL DEPOSITS

Qd Debris flow deposits

Qpd Debris flow deposits (Pleistocene)

SOLID GEOLOGY

JTM Coarse ash crystal tuff

JSM Crystal and lithic tuff, tuff-breccia and tuffite

Jnl **Crystal and vitric tuff**

t Undiffrerntiated tuff and tuffite

gf Fine-grained granite; < 2 mm

gdf Fine-grained granodiorite, <2mm

rf Feldsparphyric rhyolite

rq Quartzphyric rhyolite

Metamorphosed

GEOLOGICAL LINES

Geological boundary, superficial deposits

Geological boundary, solid rock

Fault (crossmark indicates downthrow side)

Mineral vein

Photogeological lineament

(* Broken lines on map denote uncertainty)

STRUCTURAL SYMBOLS

20 Inclined bedding

20 Inclined flow fabric

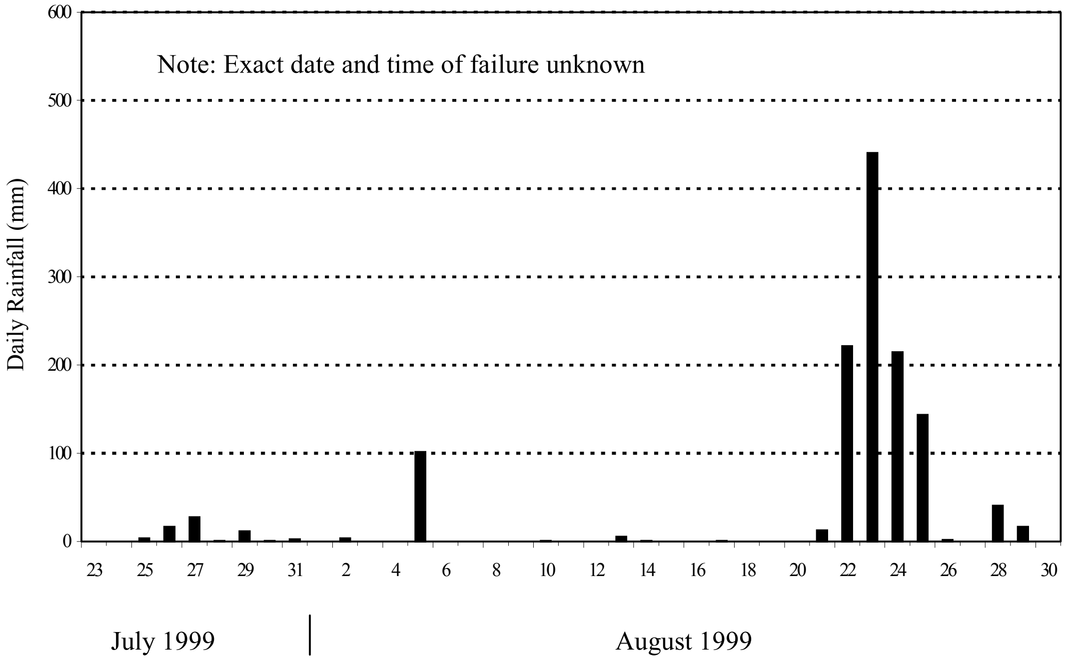
20 Inclined intrusive contact

20 Inclined jointing

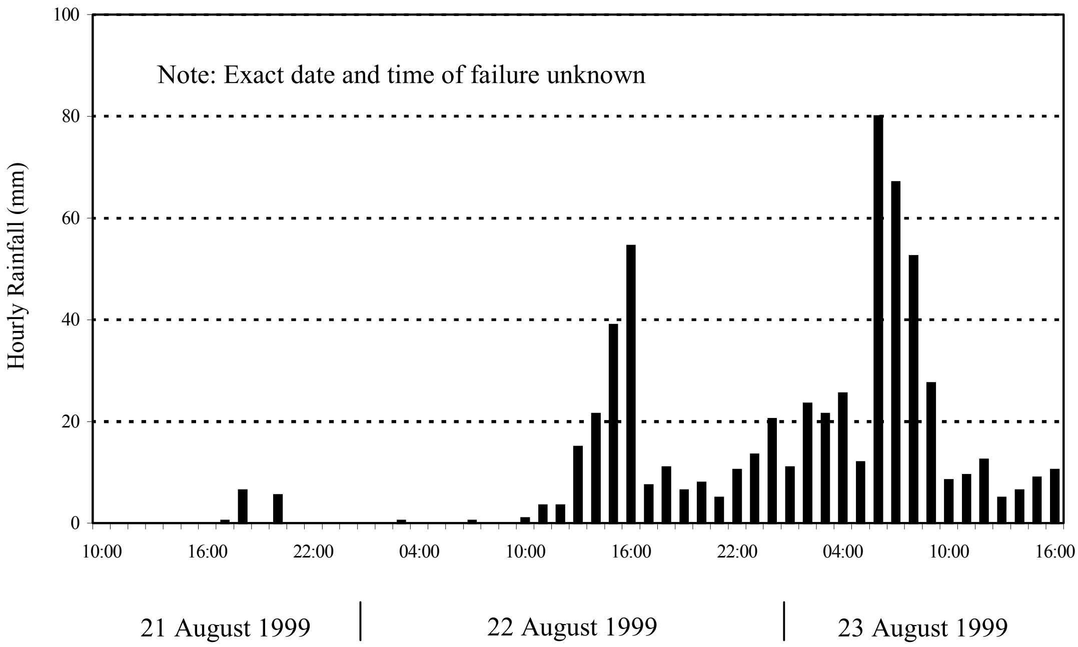
20 Inclined metamorphic foliation

Notes: (1) Geology relevant to study area shown bold.
(2) Extracted from Sheet 6 of the Hong Kong Geological Survey 1 : 20,000 Scale Map Series HGM20 (GCO, 1988).

Figure 6 – Regional Geological Map

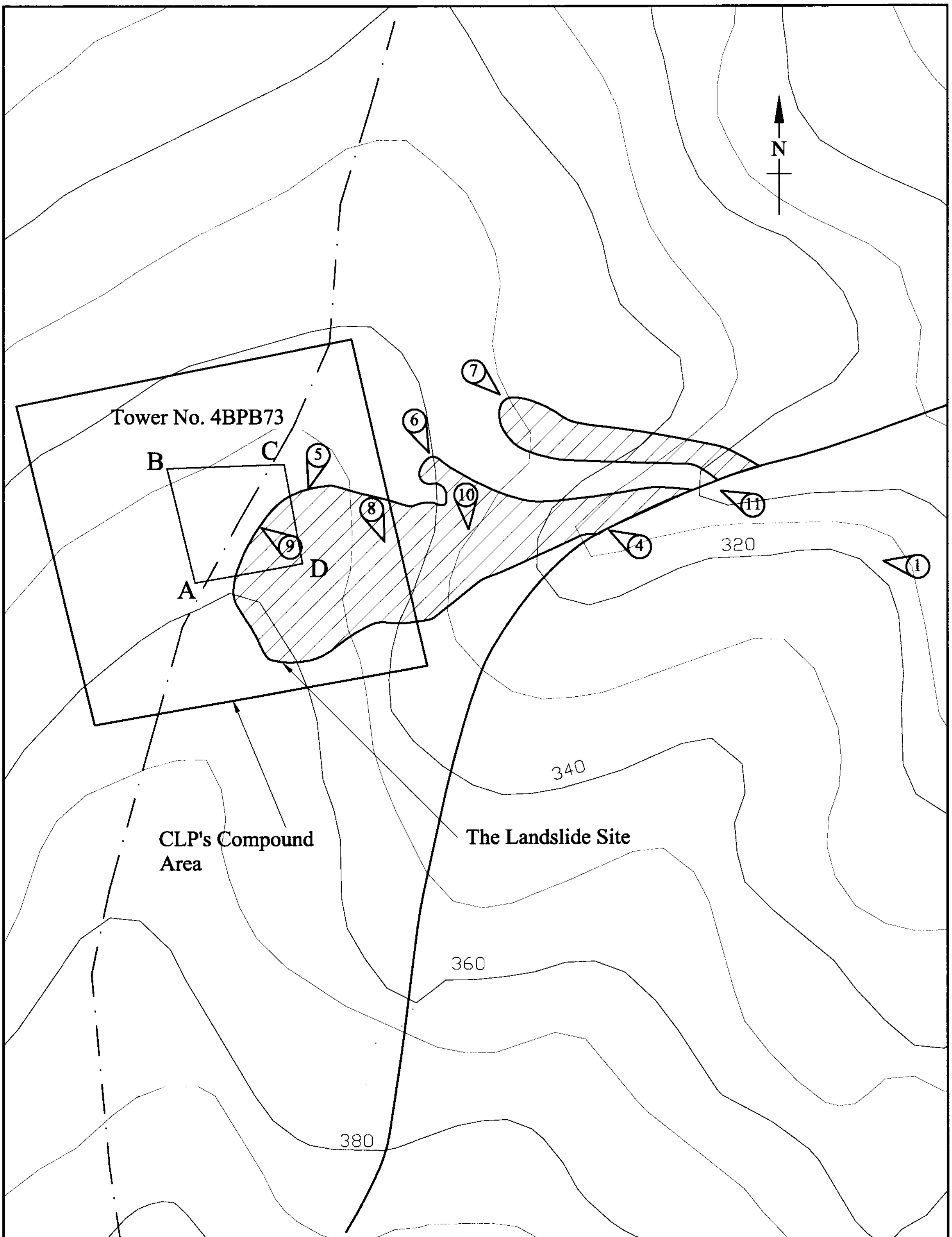


(a) Daily Rainfall Recorded between 23 July and 30 August 1999



(b) Hourly Rainfall Recorded between 10:00 hours on 21 August and 16:00 hours on 23 August 1999

Figure 7 - Rainfall Recorded at GEO Raingauge No. N14



Legend: (1) Direction of photographic Plate 1 — 1999 Landslide Scar

Note: Photographic Plate Nos. 2 and 3 are extracts from aerial photographs.

Figure 8 - Plan of the Landslide Site Showing the Location and Direction of Photographic Plates

LIST OF PLATES

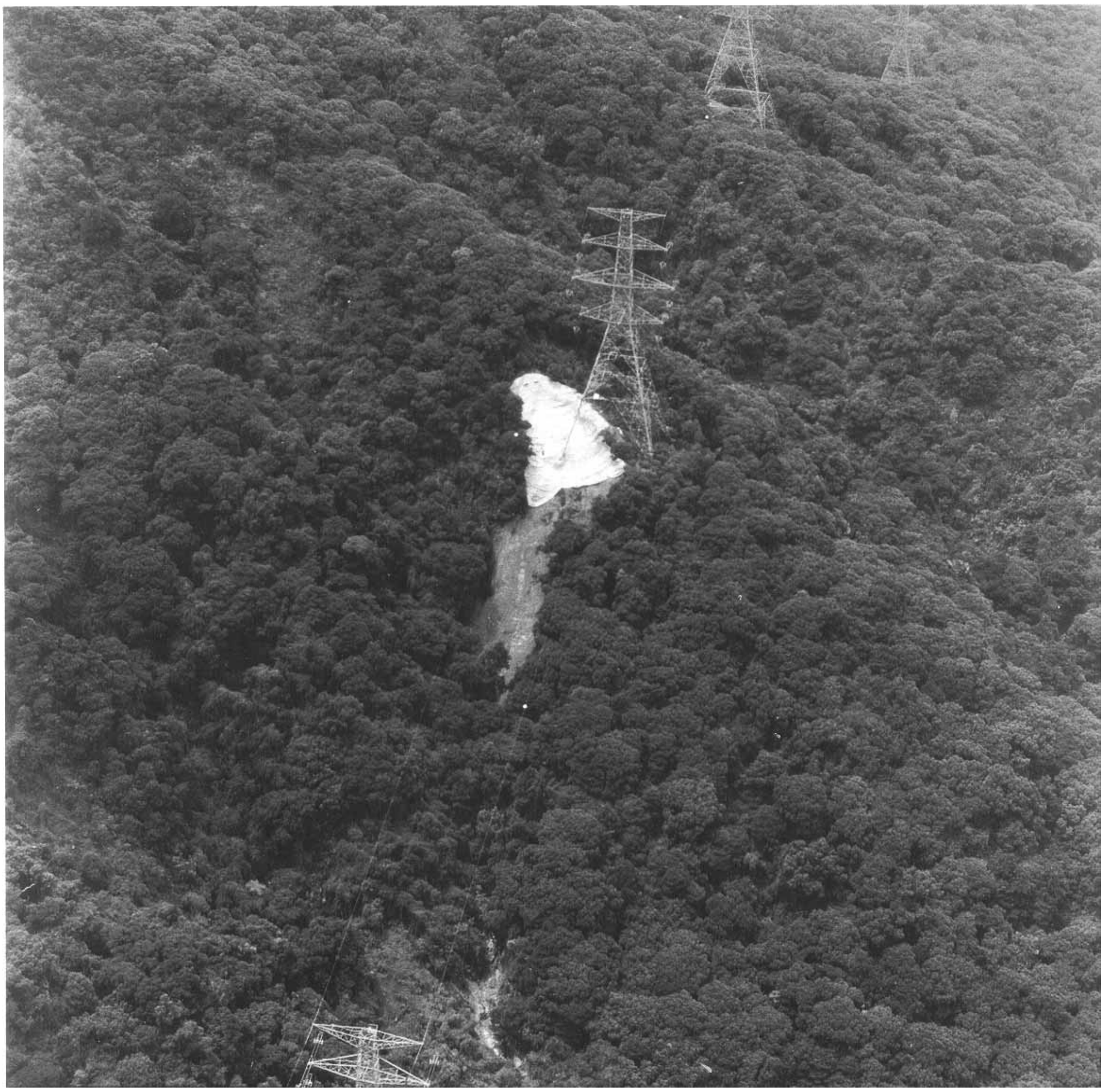


Plate 1 – Oblique Helicopter Photograph of the Landslide Looking West (Ref. No. PS 1007-8) (Photograph Taken on 1 September 1999)

Note: See Figure 8 for Location of Photographs.

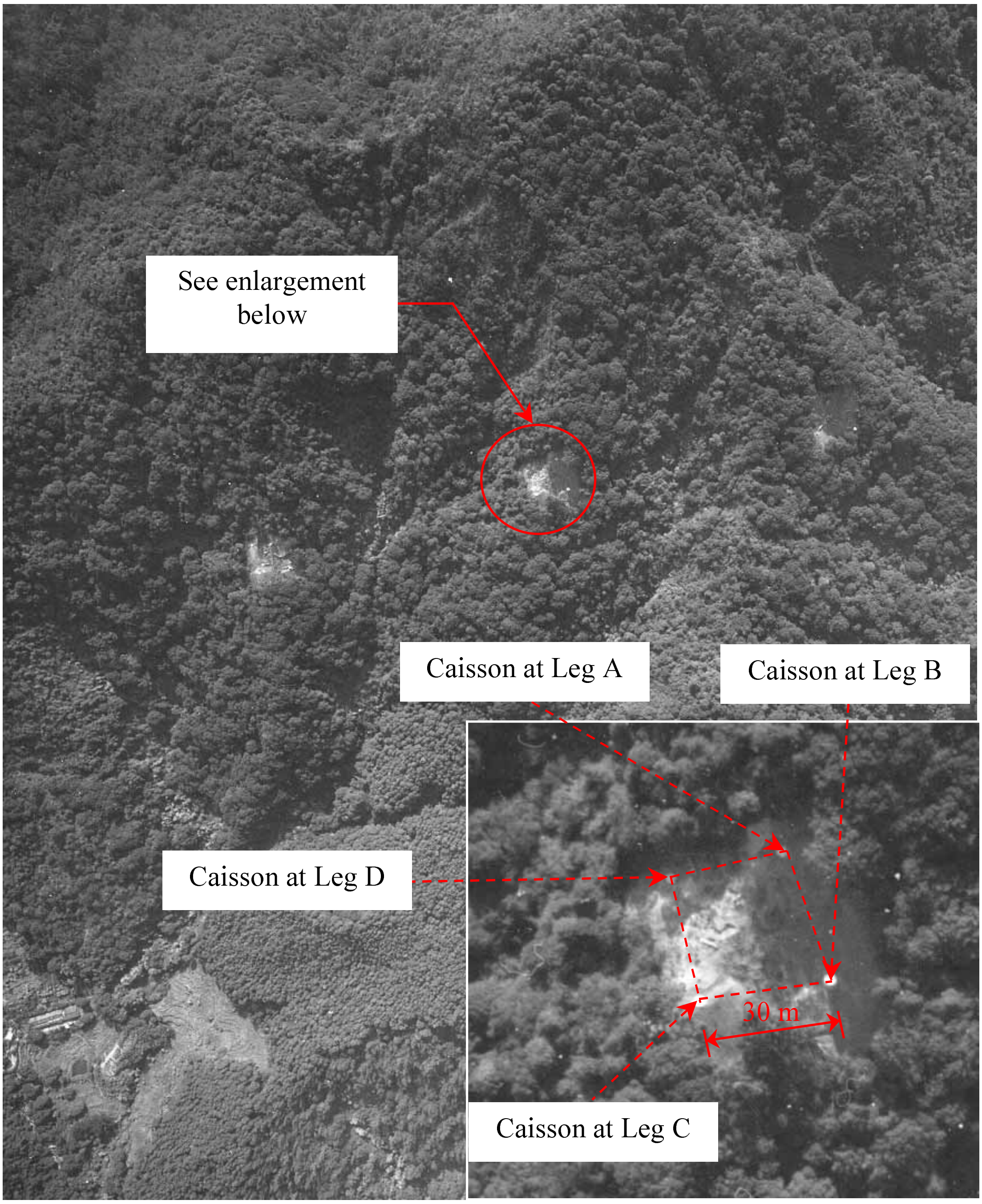


Plate 2 – Aerial Photograph of the Work Area of the Electricity Pylon (Photograph Taken on 19 December 1995)

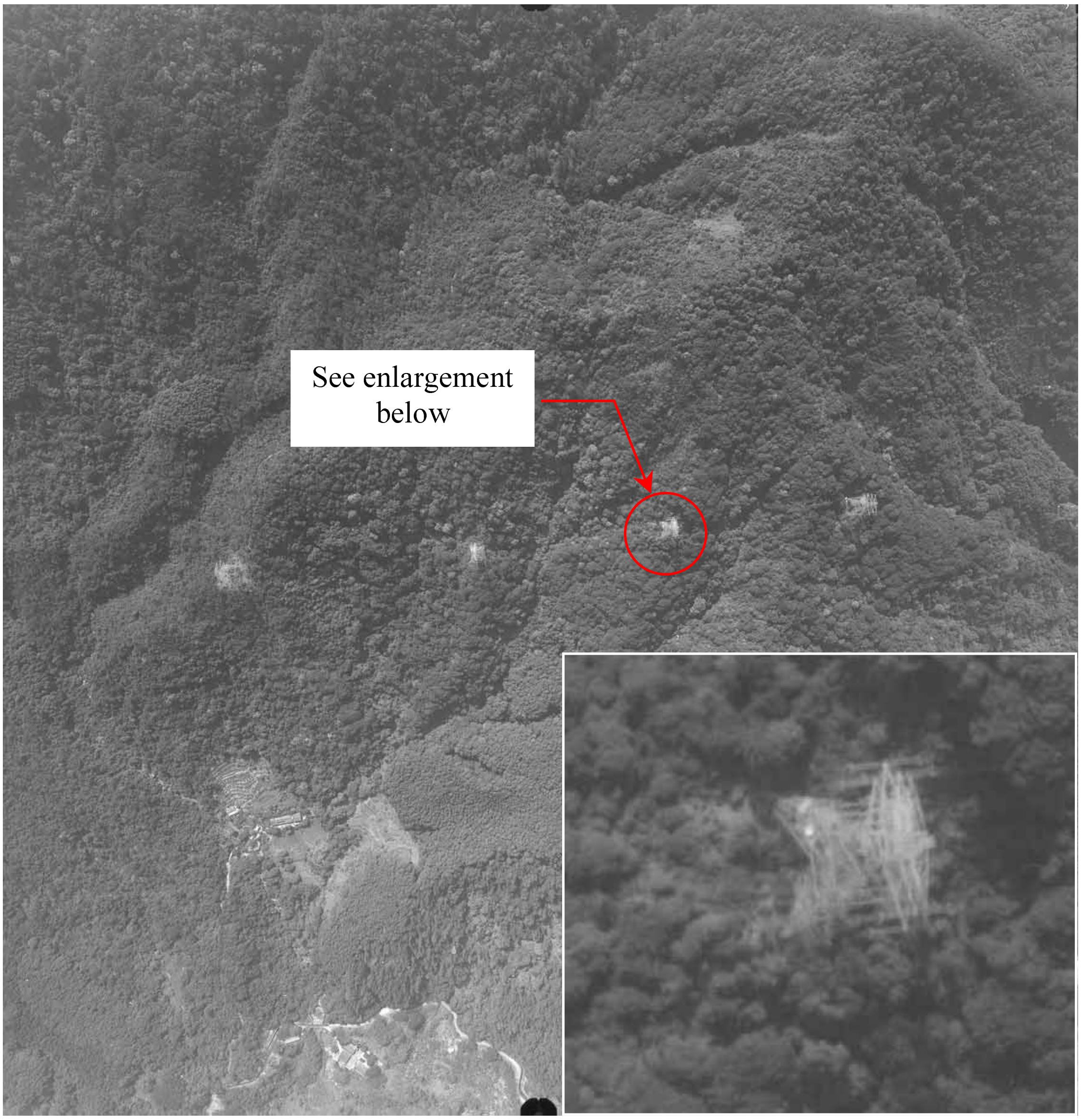


Plate 3 – Aerial Photograph of the Electricity Pylon
(Photograph Taken on 8 February 1999)

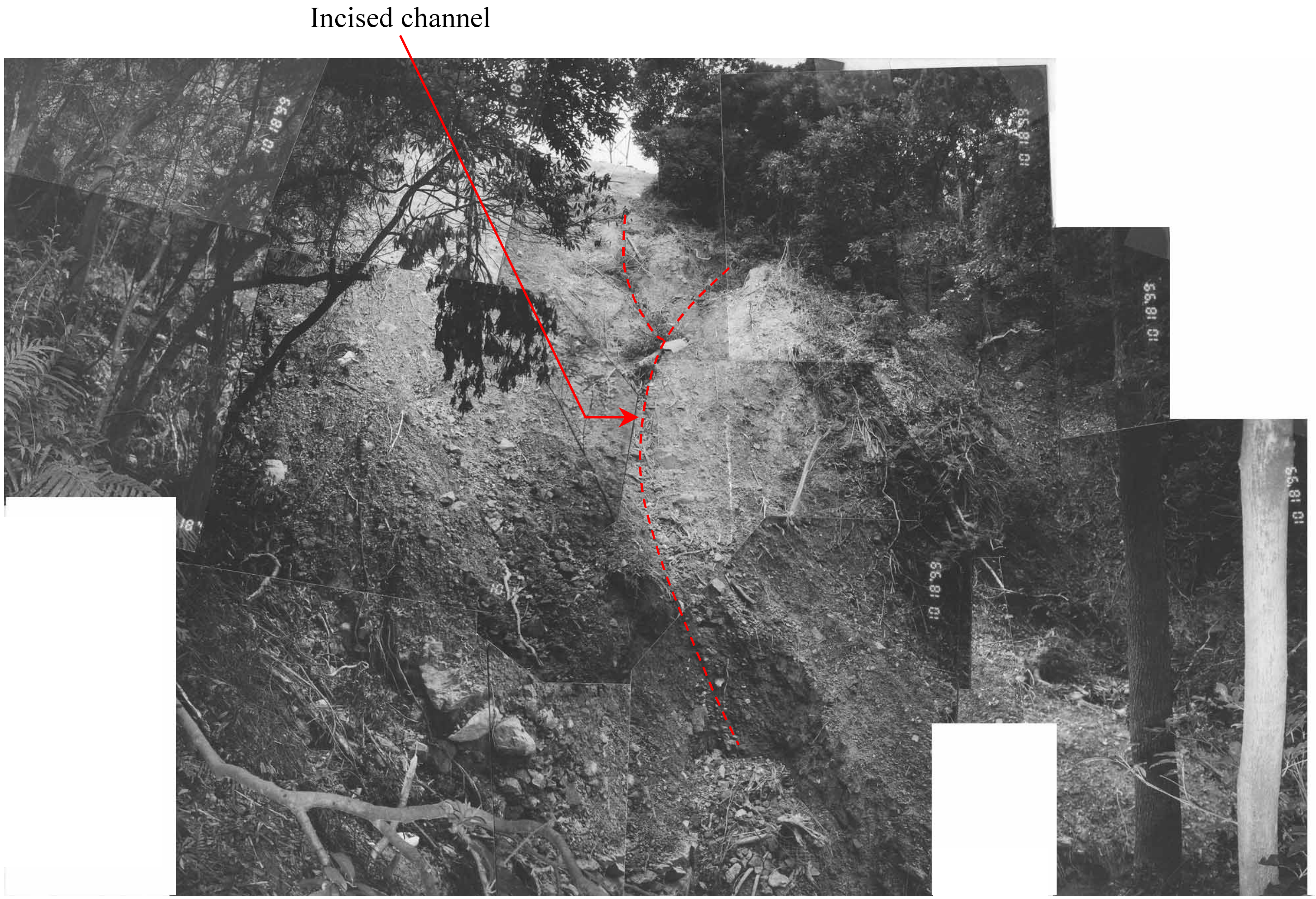


Plate 4 – General View of the Landslide Looking West (Photograph Taken on 18 October 1999)

Note: See Figure 8 for Location of Photographs.

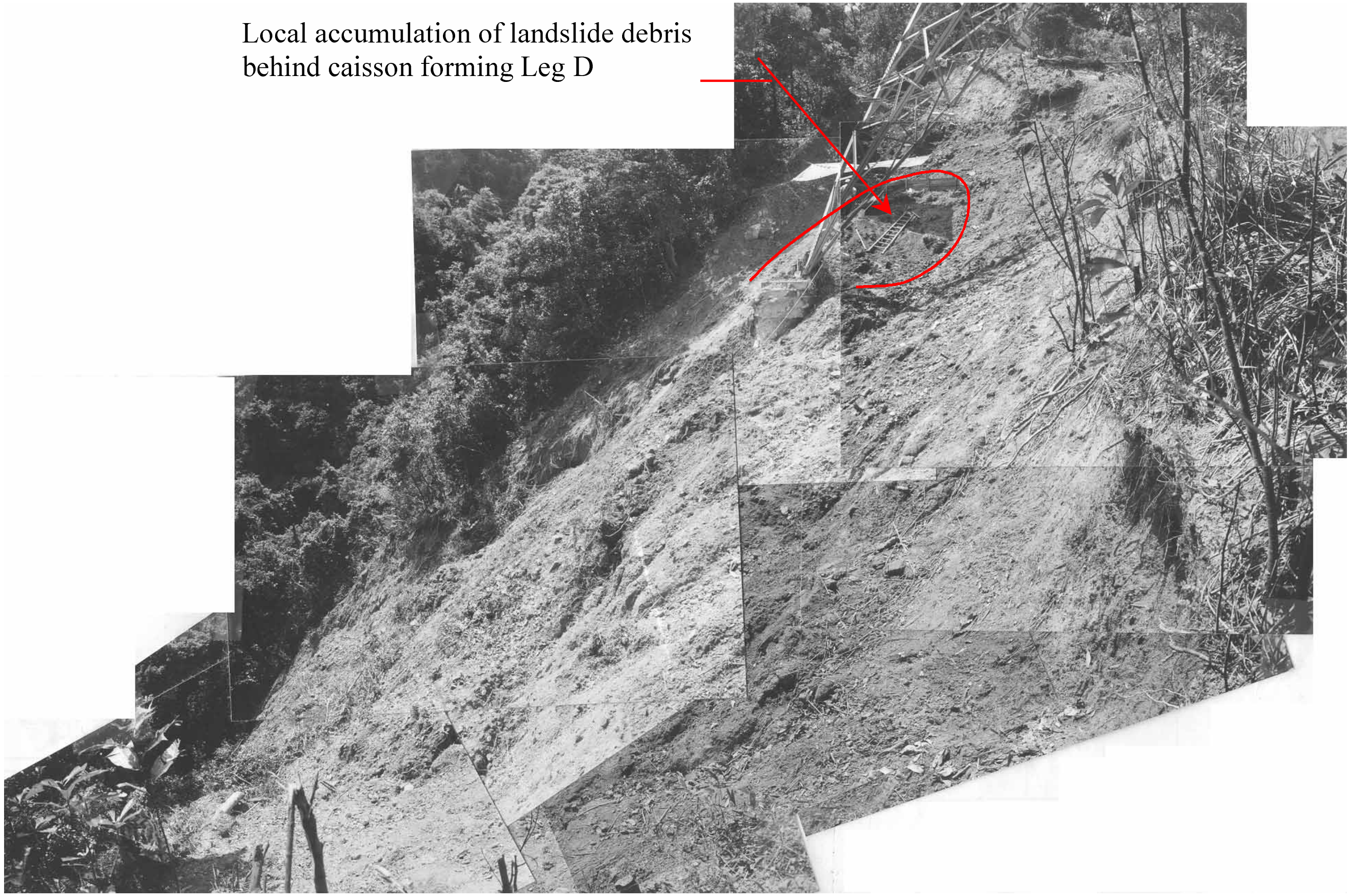


Plate 5 – General View of the Upper Portion of the Landslide Looking South
(Photograph Taken on 23 September 1999)

Note: See Figure 8 for Location of Photographs.

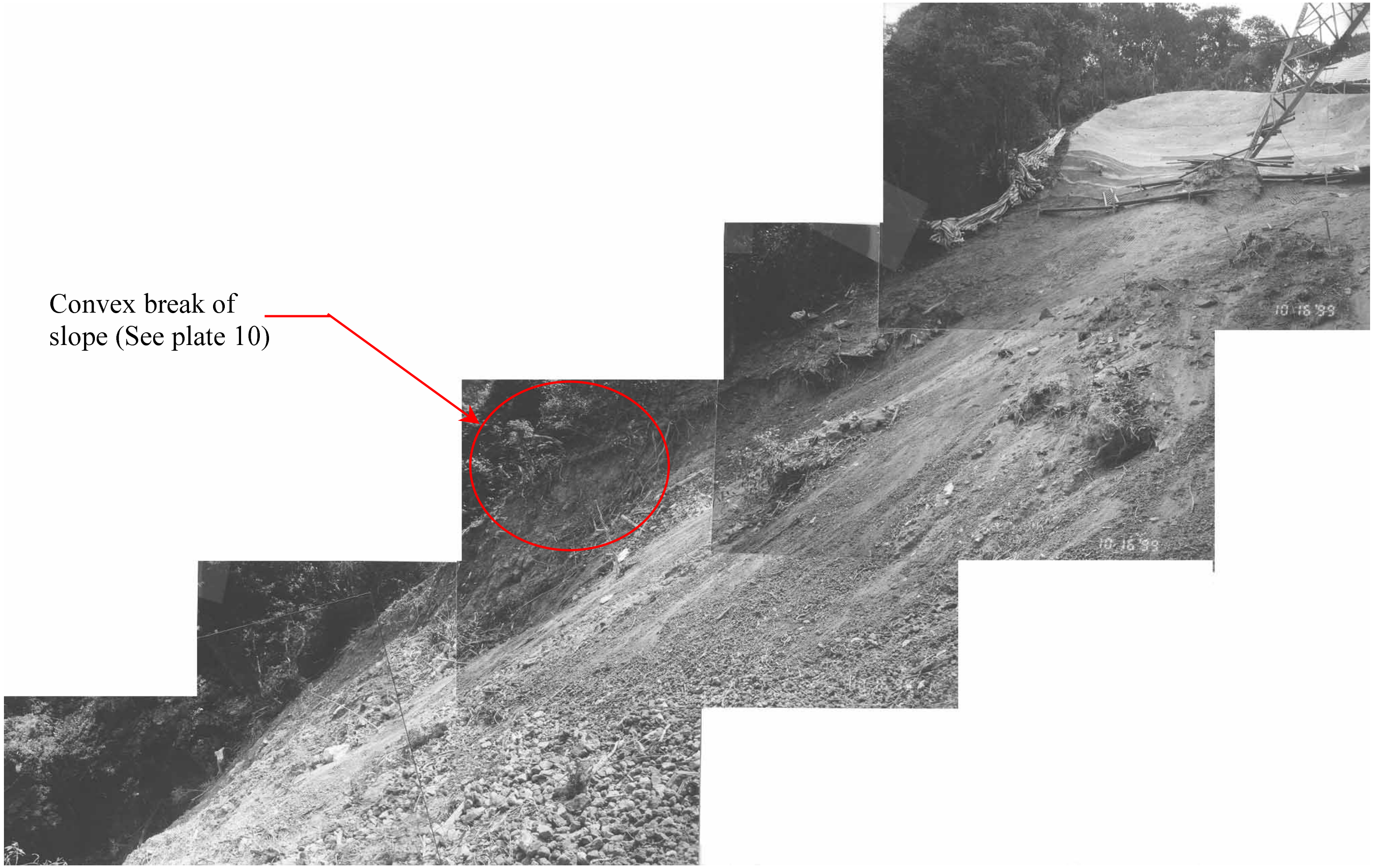


Plate 6 – General View of the Lower Portion of the Landslide Looking South
(Photograph Taken on 16 October 1999)

Note: See Figure 8 for Location of Photographs.

Plate 7 – View of the Smaller Landslide Scar Immediately North of the Main Landslide Scarp
(Photograph Taken on 19 October 1999)

Note: See Figure 8 for Location of Photographs.

Surface water runoff from the shotcreted portion of the slope may tend to over-shoot the toe channel

Recent tension cracks, 20 mm to 30 mm wide by 300 mm deep by 4 m to 5 m long, were observed in the untreated portion of the landslide scarp

Plate 8 – View of Emergency Repair Works Following the Landslide
(Photographs Taken on 22 March 2000)

Note: See Figure 8 for Location of Photographs.

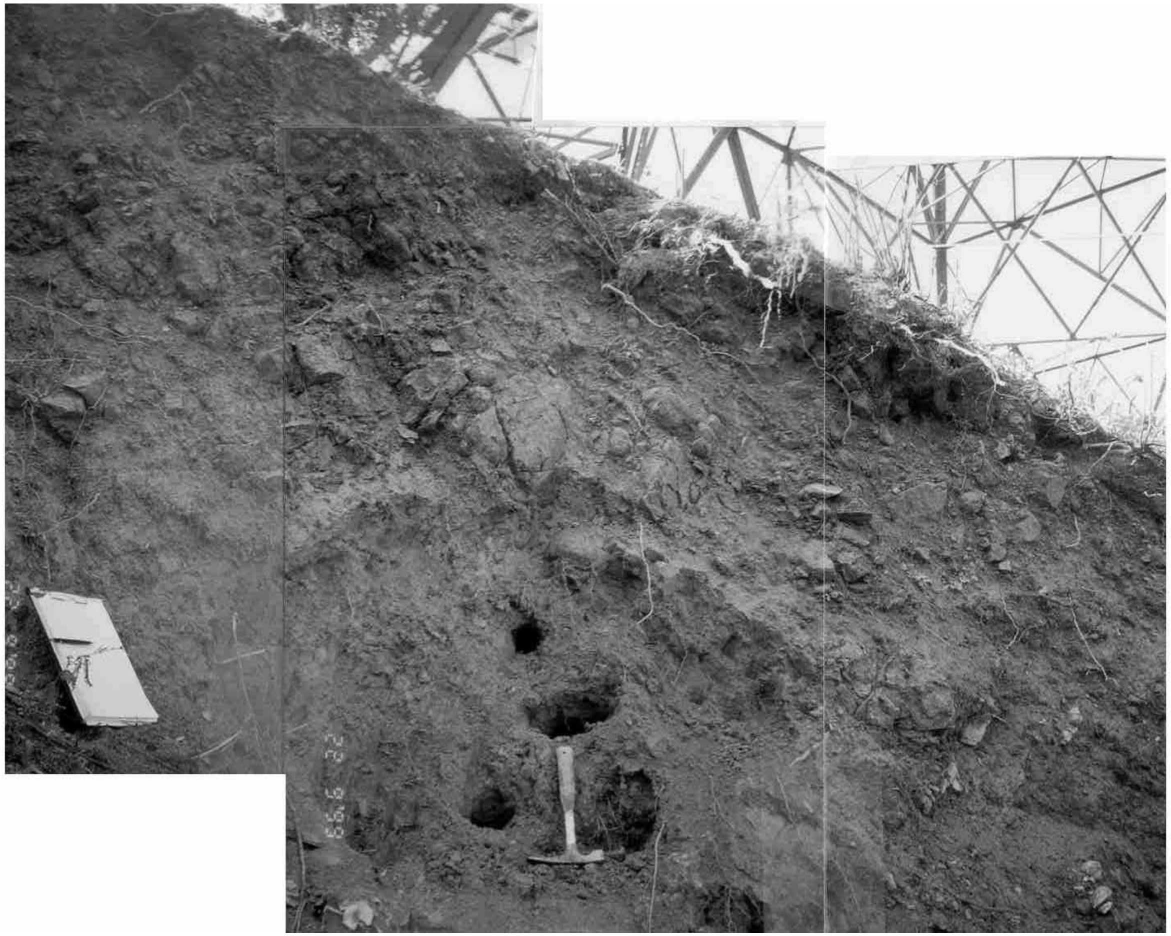


Plate 9 – View of Soil/Erosion Pipes Observed in the Upper Portion of the Landslide Main Scarp
(Photograph Taken on 22 September 1999)

Note: See Figure 8 for Location of Photographs.

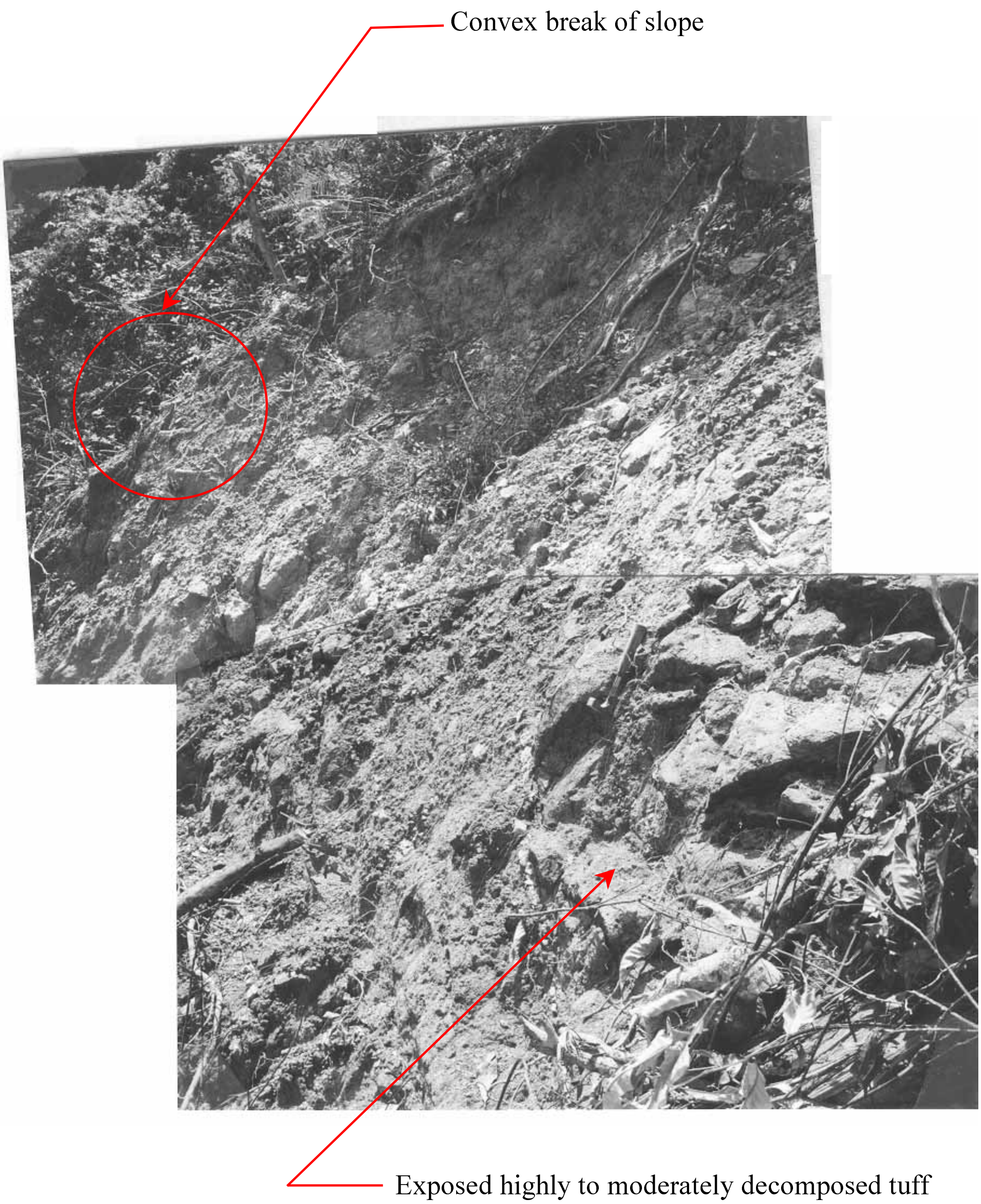


Plate 10 – Highly to Moderately Decomposed Tuff Exposed on the Landslide Scar (Photograph Taken on 23 September 1999)

Note: See Figure 8 for Location of Photographs.

Rock outcrop along natural gully

Plate 11 – View of Rock Outcrop in the Drainage Line at the Toe of the Landslide (Photograph Taken on 24 September 1999)

Note: See Figure 8 for Location of Photographs.

APPENDIX A

RECORD PHOTOGRAPHS TAKEN ALONG THE DRAINAGE LINE BELOW THE 1999 LANDSLIDE

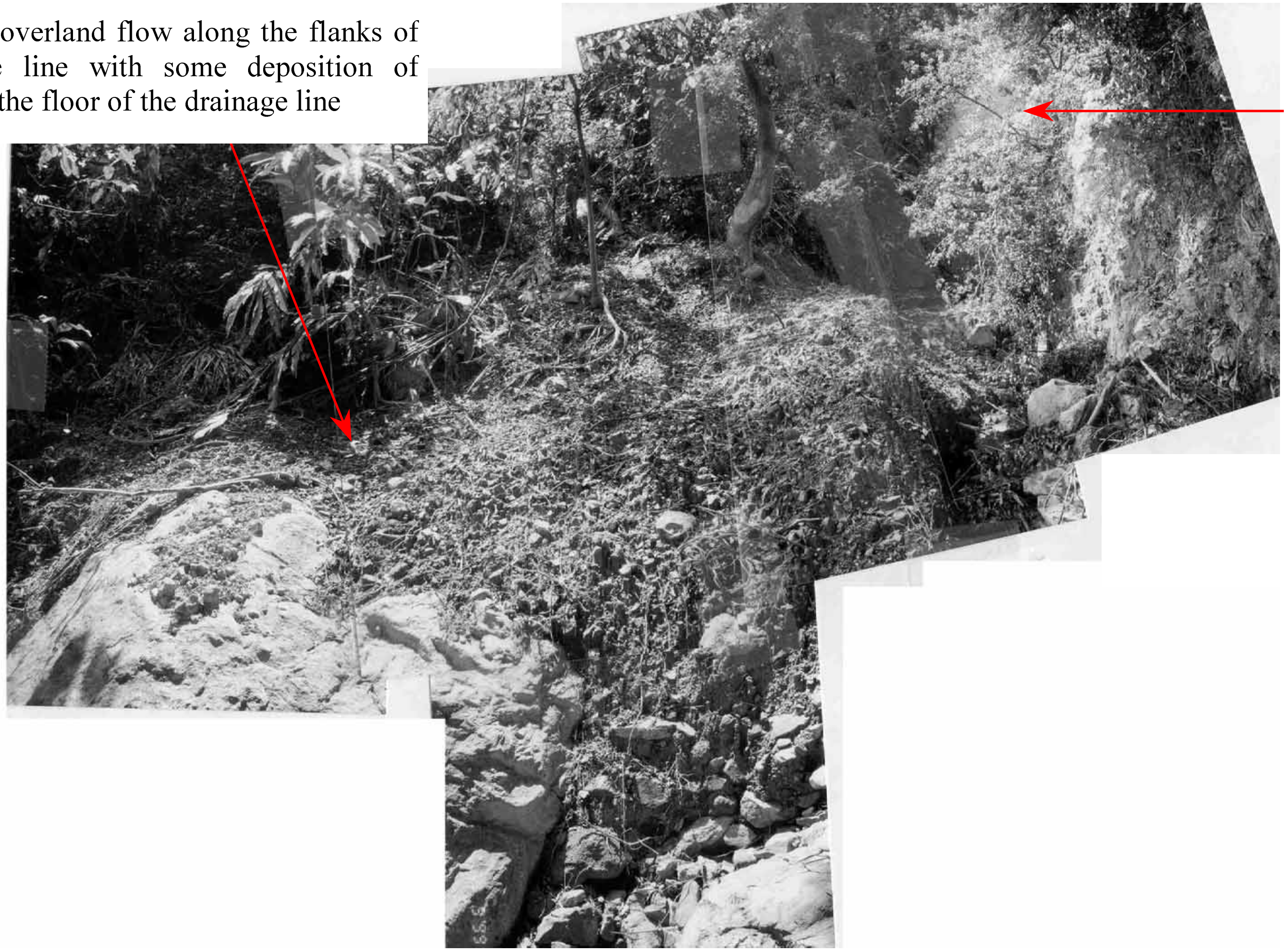


Plate A1 – View Looking Upslope of the Upper Portion of the Drainage Line below the Toe of the Landslide

Note: See Figure 4 for Location of Photographs.

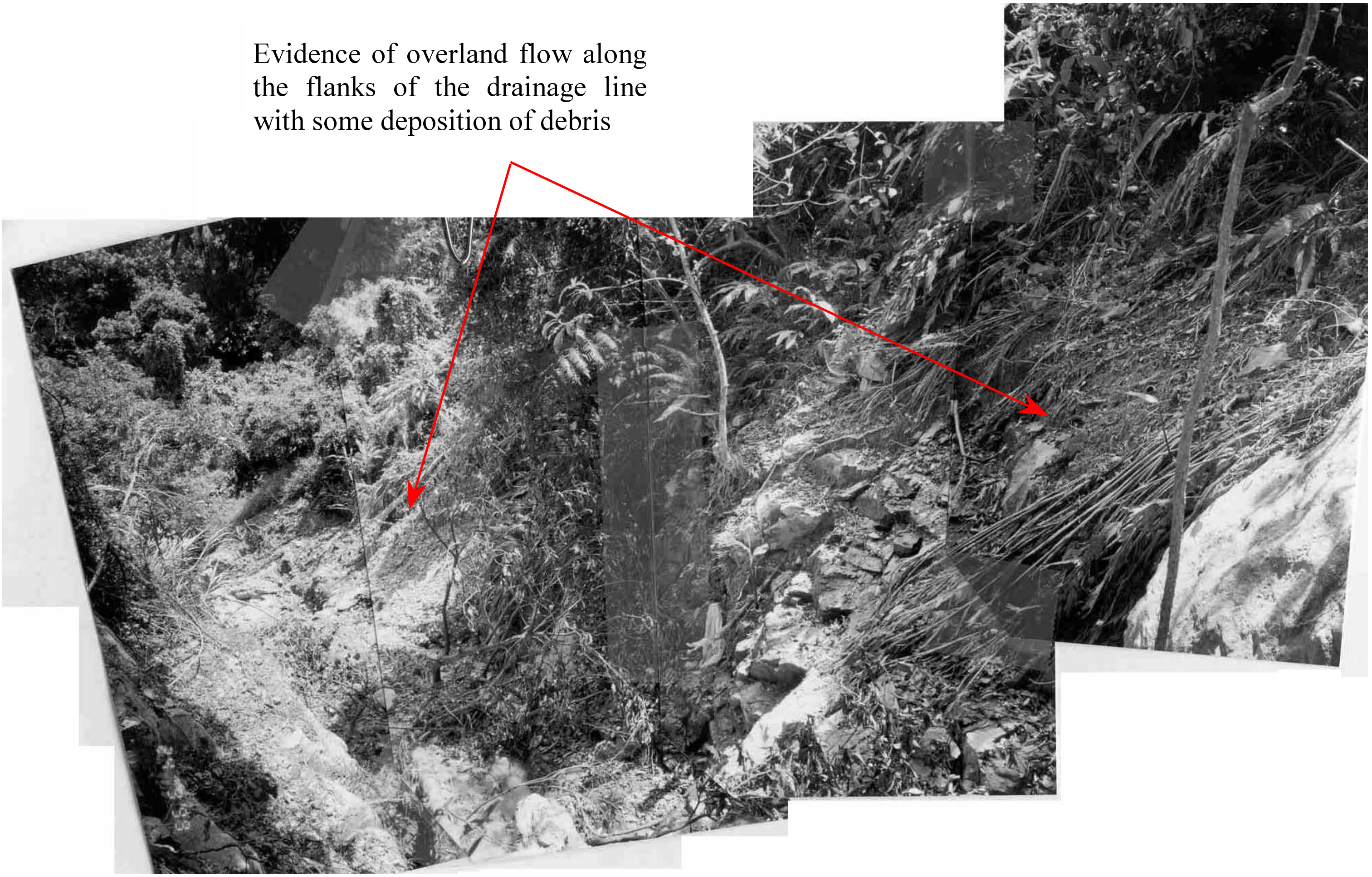


Plate A2 – View Looking Downslope of the Upper Portion of the Drainage Line below the Toe of the Landslide

Note: See Figure 4 for Location of Photographs.

Plate A3 – View Looking Upslope of the Drainage Line at Chainage 130 m

Note: See Figure 4 for Location of Photographs.

Plate A4 – View Looking Downslope of Localised Accumulation of Debris at Chainage 210 m

Note: See Figure 4 for Location of Photographs.

Area of bouldery deposition along the centre line of the drainage line considered to be 1999 landslide debris

Plate A5 – View Looking Upslope of Area of Possible Deposition of 1999 Landslide Debris at Chainage 700 m

Note: See Figure 4 for Location of Photographs.

Plate A6 – View of Loose/Voided Colluvium Exposed in the Flank of the Drainage Line at about Chainage 120 m

Note: See Figure 4 for Location of Photographs.

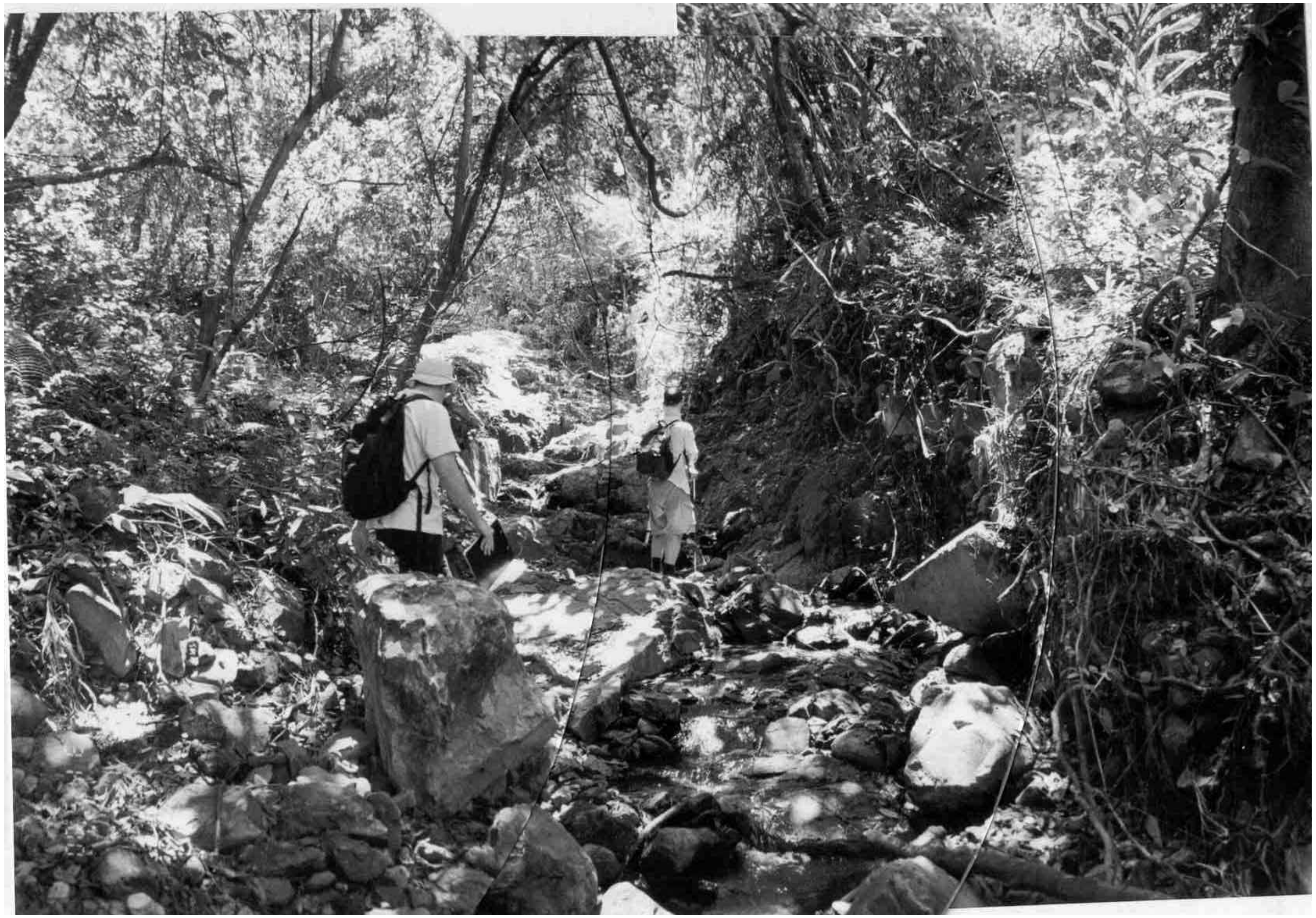


Plate A7 – View Looking Upslope Showing the Typical Profile of the Upper Section of the Drainage Line

Note: See Figure 4 for Location of Photographs.

Plate A8 – View Looking Downslope Showing the Profile of the Lower Portion of the Drainage Line

Note: See Figure 4 for Location of Photographs.

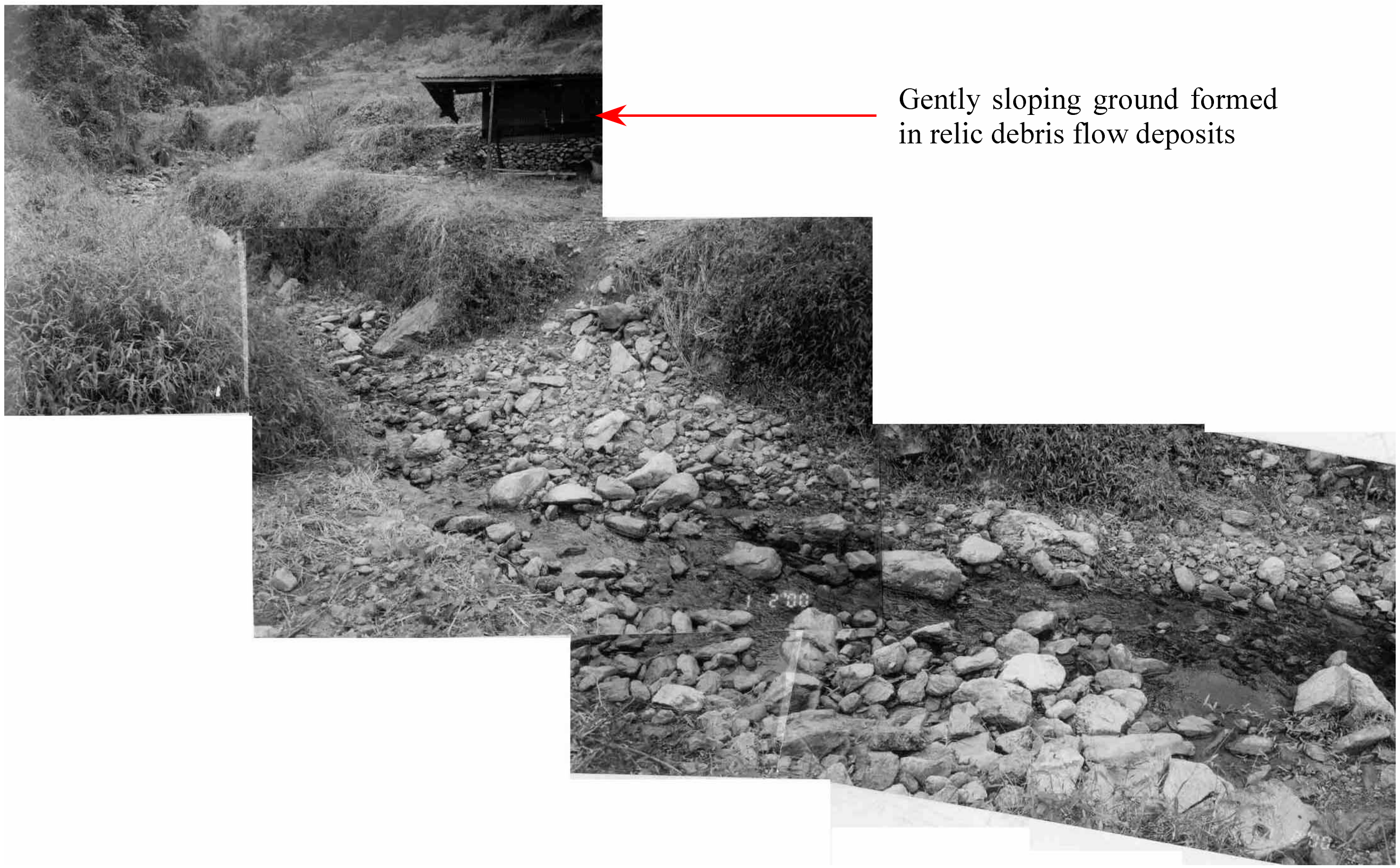


Plate A9 – View Showing the Topography and Nature of the Lower Portion of the Drainage Line

Note: See Figure 4 for Location of Photographs.

APPENDIX B

DETAILED LOGS OF RELEVANT DRILLHOLES AND TRIAL PITS

Freyssinet HONG KONG

DRILLHOLE LOG

FREY. Contract No. S 966
HOLE NO. BS 73/A
SHEET 1 of 2
DATE from 01/12/93 to 02/12/93

PROJECT	SITE INVESTIGATION 400KV OVERHEAD TRANSMISSION LINE ASSOCIATED WITH BLACK POINT POWER STATION		
METHOD Rotary	CO-ORDINATES		ROCK COREBIT TNW
Rig & No. TOHO C05	E 828330.17 N 830685.84		HOLE DIA. HW 76 mm IN BED ROCK
FLUSHING MEDIUM Water	ORIENTATION VERTICAL		GROUND-LEVEL +355.41 m P.D.

Drilling Progress	Casing depth/size	Water level/time/date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description
1/12	H			85					1	+353.41	1.00 2.00		VI		Soft to firm, brown sandy SILT with some gravel (RESIDUAL SOIL)
								(1,1 1,2,2,3) N=8	2	+352.41	3.00		V		Extremely weak, brown spotted black completely decomposed ASH TUFF (Loose silty SAND with some gravel).
				82					3	+351.41	4.00		V		Extremely weak, brown spotted black completely decomposed ASH TUFF (Loose silty SAND with gravel/rock fragments)
				90				(1,1 1,1,1,1) N=4	4 5	+349.41	5.00 6.00		V		Extremely weak, brown spotted black & grey completely decomposed ASH TUFF (Loose silty SAND with quartz gravel)
								(1,1 1,1,1,4) N=13	6	+348.41	7.00		V		Extremely weak, brown mottled dark brown & yellowish brown completely decomposed ASH TUFF (Medium dense silty SAND)
				14	8	0	NI		TNW	+347.91	7.50		IV/III		Moderately strong to weak, grey spotted pink and white moderately to highly decomposed ASH TUFF.
								(1,2 1,1,1,5) N=14	7	+346.41	8.00 9.00		V		Extremely weak, reddish brown streaked greyish yellow, dark brown spotted grey completely decomposed ASH TUFF (Medium dense silty SAND)
1/12	H			100					8	+345.41	10.00		V/IV		Extremely weak to very weak, reddish brown & grey completely to highly decomposed ASH TUFF

• Small disturbed sample	▲ Water sample	LOGGED RS
Large disturbed sample	Water level	DATE 09/12/93
SPT liner sample	Standard penetration test	CHECKED
U76 undisturbed sample	Permeability test	DATE
U100 undisturbed sample	Piezometer tip	
Mazier sample	In-situ vane shear test	
P/S Piston sample		

REMARKS

(to be cont'd)

[redacted]

Freyssinet

HONG KONG

DRILLHOLE LOG

FREY. Contract No. 5 956
HOLE NO. BS 73/A
SHEET 2 of 2
DATE from 01/12/93 to 02/12/93

PROJECT	SITE INVESTIGATION 400KV OVERHEAD TRANSMISSION LINE ASSOCIATED WITH BLACK POINT POWER STATION		
METHOD Rotary	CO-ORDINATES		ROCK COREBIT TNW
Rig & No. TOHO C05	E 828330.17 N 830885.84		HOLE DIA. HW 76 mm IN BED ROCK
FLUSHING MEDIUM Water	ORIENTATION VERTICAL		GROUND-LEVEL +355.41 m P.D.

Drilling Progress	Casing depth/size	Water level/time/date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R. Q. D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description (cont'd)
1/12	H 11.10 H									+344.31	11.10		V/IV		(Dense to very dense silty sandy GRAVEL/ ROCK FRAGMENTS)
1/12				99	6	0	NI		TNW		12.30		III		Moderately strong, grey streaked dark brown spotted white moderately decomposed ASH TUFF with highly fractured to closely spaced rough planar, brown iron staining joints.
2/12		NIL at 8:00		82	5	0	NI				13.70				
				82	10	0	NI				15.00				
				98	19	13	NI			+339.86	15.55				
				58	50	50	NI				16.00 16.96		III		Moderately strong, grey streaked dark brown spotted white moderately decomposed ASH TUFF with closely-spaced to medium-spaced rough planar, brown iron staining joints. Dipping at 10-30, 30, 40 and 60 degrees. Sub-vertical joints encountered at depth 16.74-17.18m.
2/12		—		100	70	70	5.8			+337.29	18.12				
															End of investigation hole at 18.12m

Small disturbed sample Large disturbed sample SPT liner sample U76 undisturbed sample U100 undisturbed sample Mazier sample P/S Piston sample	Water sample Water level Standard penetration test Permeability test Piezometer tip In-situ vane shear test	LOGGED RS DATE 09/12/93 CHECKED DATE

REMARKS

Freyssinet
HONG KONG

DRILLHOLE LOG

FREY. Contract No. S 966
HOLE NO. BS 73/D
SHEET 1 of 2
DATE from 03/12/93 to 04/12/93

PROJECT: SITE INVESTIGATION
400KV OVERHEAD TRANSMISSION LINE ASSOCIATED WITH BLACK POINT POWER STATION

METHOD Rotory	CO-ORDINATES	ROCK COREBIT THW
Rig & No. TOHO C05	E 828852.96 N 830689.29	HOLE DIA. HW 76 mm IN BED ROCK
FLUSHING MEDIUM Water	ORIENTATION VERTICAL	GROUND-LEVEL +344.84m P.D.

Drilling Progress	Casing depth/size	Water level/time/date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description
3/12	H										0.00–1.00				
				100				(1,1 1,3,3,4) N=11	1, 2		1.00–3.00		V		Extremely weak, brown spotted dark brown yellow, grey & pink completely decomposed ASH TUFF (Firm, slightly sandy SILT)
				100					3	340.84	4.00				
								(2,2 2,3,3,5) N=13	4	339.84	5.00		V		Extremely weak, yellowish grey mottled yellowish brown spotted dark brown, yellow, pink & grey completely decomposed ASH TUFF (Firm, slightly sandy SILT)
				100					5	338.84	6.00		V		Extremely weak, yellowish grey to brownish grey streaked dark brown spotted pink & yellow completely decomposed ASH TUFF (Firm, sandy SILT with GRAVEL rock fragments)
								(1,2 3,4,4,4) N=15	6	337.84	7.00		V		Extremely weak, brownish pink streaked brown & dark brown spotted pink & yellow completely decomposed ASH TUFF (Firm sandy SILT)
		—		100					7	336.84	8.00		V		Extremely weak, yellowish brown streaked dark brown spotted pink, dark brownish grey completely decomposed ASH TUFF (Firm sandy SILT)
								(3,5 5,6,8,9) N=28	8	335.84	9.00		V		Extremely weak, yellowish grey mottled grey streaked dark brown spotted pink & yellow completely decomposed ASH TUFF (Firm sandy SILT)
3/12	H			100					9	334.84	10.00		V		Extremely weak, brown to reddish brown mottled white & dark brown spotted pink & yellow completely decomposed ASH TUFF (Firm sandy SILT)

•	Small disturbed sample	▲	Water sample
↕	Large disturbed sample	▼	Water level
	SPT liner sample	↓	Standard penetration test
	U76 undisturbed sample		Permeability test
■	U100 undisturbed sample		Piezometer tip
⌑	Mazier sample	✓	In-situ vane shear test
P/S	Piston sample		

LOGGED RS
DATE 09/12/93
CHECKED
DATE

REMARKS

Freyssinet HONG KONG

DRILLHOLE LOG

FREY. Contract No. S 966
HOLE NO. BS 73/D
SHEET 2 of 2
DATE from 03/12/93 to 04/12/93

PROJECT	SITE INVESTIGATION 400KV OVERHEAD TRANSMISSION LINE ASSOCIATED WITH BLACK POINT POWER STATION
METHOD	Rotary
CO-ORDINATES	E 828252.96 N 830629.29
ROCK COREBIT	THW
Rig & No.	TOHO C05
HOLE DIA.	HW 76 mm IN BED ROCK
FLUSHING MEDIUM	Water
ORIENTATION	VERTICAL
GROUND-LEVEL	+344.84m P.D.

Drilling Progress	Casing depth/size	Water level/time/date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced level	Depth (m)	Legend	Grade	Zone	Description
3/12	H 10.70 H							200bls 0.30m	10	+334.14	10.70		V		Extremely weak, grey streaked white spotted yellow & pink completely decomposed ASH TUFF. (Stiff sandy SILT)
				50	26	0	14.3		THW		11.70		III/II		Moderately strong to very strong, grey streaked dark brown spotted white, moderately to slightly decomposed ASH TUFF with closely spaced to medium spaced, rough planar, brown iron staining joints. Dipping at 10-20, 30, 40 & 50 degrees. Sub-vertical joints encountered at depth 16.74m-17.18m.
				100	25	13	13.9				12.53				
3/12				100	87	49	12.2				13.53				
4/12		Nil at S:00		100	20	50	6.6				14.43				
				85	70	65	9.2				15.30				
16.23				95	99	70	8.6			+[illegible]	16.23				

End of investigation hole at 16.23m

Small disturbed sample	Water sample	LOGGED	RS
Large disturbed sample	Water level	DATE	09/12/93
SPT liner sample	Standard penetration test	CHECKED	
U76 undisturbed sample	Permeability test	DATE	
U100 undisturbed sample	Piezometer tip		
Mazier sample	In-situ vane shear test		
P/S Piston sample			

REMARKS

Freyssinet Hong Kong Ltd.
4/Fl., Wah Do House, 322 Junction Road, Kowloon Tong, Hong Kong.
Tel: 794 0322 Fax: 338 3264

Freyssinet
HONG KONG

DRILLHOLE LOG

FREY. Contract No. S 966
HOLE NO. BS 73/53
SHEET 1 of 2
DATE from 06/12/93 to 07/12/93

PROJECT: SITE INVESTIGATION
400KV OVERHEAD TRANSMISSION LINE ASSOCIATED WITH BLACK POINT POWER STATION

METHOD: Rotary	CO-ORDINATES	ROCK COREBIT: TNW
Rig & No.: TOHO C05	E 828381.62 N 830589.82	HOLE DIA.: HW 76 mm IN BED ROCK
FLUSHING MEDIUM: Water	ORIENTATION: VERTICAL	GROUND-LEVEL: 330.67 m P.D.

Drilling Progress	Casing depth/size	Water level/time/date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description
06/12	H			100				(0,0 / 1,1,1,1) N=4	1, 2	328.22	2.45		VI		Soft, yellowish brown clayey, slightly sandy SILT. (Residual Soil)
				100					3	326.67	4.00		V		Extremely weak, grey streaked dark brown spotted white & pink completely decomposed, ASH TUFF. (Very dense silty SAND)
								(5,10 / 13,20,25,31) N=50	4	325.67	5.00		V		Extremely weak, grey streaked dark brown spotted yellow completely decomposed, ASH TUFF. (Very dense silty SAND)
				100					5	324.67	6.00		V		Extremely weak, yellow spotted brown & grey completely decomposed, ASH TUFF. (Very dense silty SAND)
								(3,15 / 25,25,(6,50)) N=170	6	323.67	7.00		V		Extremely weak, greyish yellow streaked dark brown spotted dark brown to pink completely decomposed, ASH TUFF. (Very dense silty SAND)
06/12	H	–		25, 100				200 Nz / 0.22 m	7, 8, 9	320.67	10.00		V		Extremely weak, grey streaked dark brown spotted pink & white completely decomposed, ASH TUFF. (Very dense silty SAND)

• Small disturbed sample	▲ Water sample
Large disturbed sample	⊻ Water level
SPT liner sample	Standard penetration test
U76 undisturbed sample	Permeability test
U100 undisturbed sample	Piezometer tip
Water sample	In-situ vane shear test
P/S Piston sample	

LOGGED: RS
DATE: 07/12/93
CHECKED:
DATE:

REMARKS

Freyssinet
HONG KONG

DRILLHOLE LOG

FREY. Contract No. S 966
HOLE NO. BS 73/S3
SHEET 2 of 2
DATE from 06/12/93 to 07/12/93

PROJECT SITE INVESTIGATION
400KV OVERHEAD TRANSMISSION LINE ASSOCIATED WITH BLACK POINT POWER STATION

METHOD Rotary	CO-ORDINATES	ROCK COREBIT TNW
Rig & No. TOHO C05	E 828381.52 N 830689.82	HOLE DIA. HW 76 mm IN BED ROCK
FLUSHING MEDIUM Water	ORIENTATION VERTICAL	GROUND-LEVEL 330.67 m P.D.

Drilling Progress	Casing depth/size	Water level/time/date	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture index	Tests	Samples	Reduced Level	Depth (m)	Legend	Grade	Zone	Description
								200 N/0.10 m	10	320.42	10.25		V		Same as sheet 1 of 2
				100	17	14	7.9		TNW		11.13		III/II		Moderately strong to strong, grey spotted pink and dark brown and grey, moderately to slightly decomposed ASH TUFF with closely-spaced to medium-spaced, rough planar, brown iron staining joints. Dipping at 10, 30 and 35 degrees. Sub-vertical joints encountered at depth 12.55m-12.85m, 13.20m-13.40m and 15.30-14.80m)
				100	65	63	7.2				12.10				
07/12		Nil at 8:00		96	34	31	16.3				13.08				
				99	55	10	1.0				14.08				
				100	55	18	13.4				14.75				
				98	50	20	11.7				15.65				
07/12				98	54	60	8.9			313.82	16.85				
															End of investigation hole at 16.85m

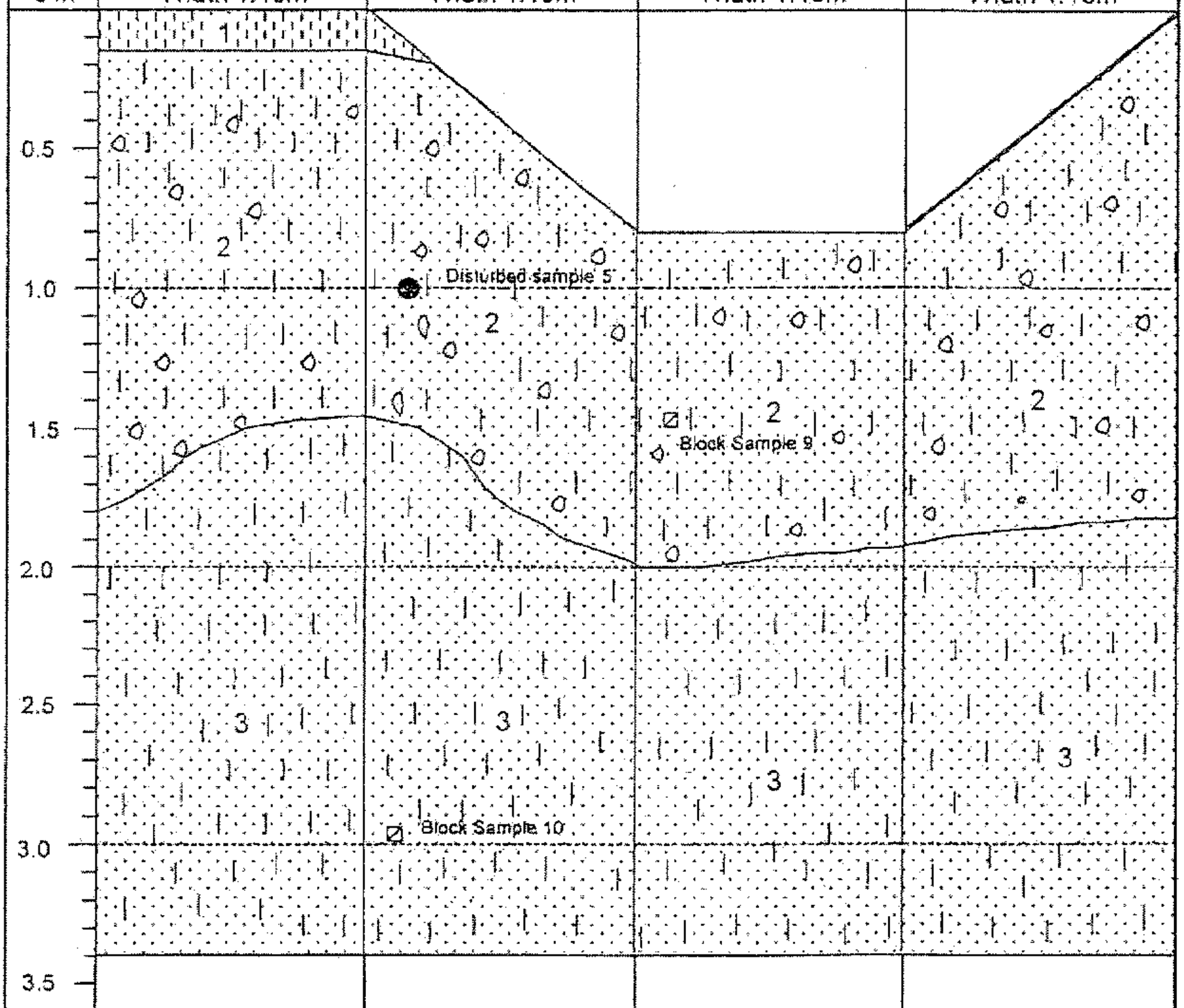
Small disturbed sample	Water sample
Large disturbed sample	Water level
SPT liner sample	Standard penetration test
U76 undisturbed sample	Permeability test
U100 undisturbed sample	Piezometer tip
Mazier sample	In-situ vane shear test
P/S Piston sample	

LOGGED RS
DATE 07/12/93
CHECKED
DATE

REMARKS
A standpipe was installed to 10.30m below ground level

JASON *ENGINEERING COMPANY*		SITE: Emergency Repair to Landslide at Transmission Tower No. 4BPB73 Kap Lung	
Co-ordinates N	830689	DATE EXCAVATION	23-9-1999
E	828347	DATE BACKFILL	2-10-1999
Ground Level	+ 346.52 mPD	Excavation Method	Handdug

Depth	FACE A	FACE B	FACE C	FACE D
0 m	Width 1.10m	Width 1.10m	Width 1.10m	Width 1.10m



Description

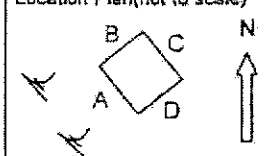
1 Loose, brownish grey, silty fine to coarse SAND with much angular fine to medium,occasional coarse gravel of rock fragments and much rootlets. (TOP SOIL)

2 Loose, yellowish brown, much silty clayey fine SAND with much angular to sub-angular fine to coarse gravel, occasional cobble of rock fragment. (DEBRIS)

3 Medium dense, yellowish brown & reddish brown, clayey much silty fine SAND, with occasional angular fine to medium gravel. (RESIDUAL SOIL)

4 Block Sample

Location Plan(not to scale)



Trial Pit No. TP-4

Logged: V. C. Sou

Date: 30-9-1999