INVESTIGATION OF SOME SELECTED LANDSLIDES IN 1998 (VOLUME 3)

GEO REPORT No. 110

Fugro 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
August 2001

EXPLANATORY NOTE

This GEO Report consists of three Landslide Study Reports on the investigation of selected slope failures that occurred in 1998. The investigations were carried out by Fugro Scott Wilson Joint Venture (FSW) for the Geotechnical Engineering Office as part of the 1998 Landslide Investigation Consultancy.

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

(a) establishment of an improved slope assessment methodology,

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

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

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

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

SECTION 1 : DETAILED STUDY OF THE LANDSLIDE AT SUNNY VILLA, 218 CASTLE PEAK ROAD ON 9 JUNE 1998

Fugro Scott Wilson Joint Venture

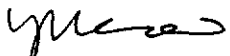
This report was originally produced in July 1999
as GEO Landslide Study Report No. LSR 3/99

FOREWORD

This report presents the findings of a detailed study of a landslide (GEO Incident No. MW 98/6/9) which occurred on a cut slope above the access road to Sunny Villa at 218 Castle Peak Road, in the evening of 9 June 1998. During the landslide, about 200 m^3 of soil and debris were released and deposited onto the access road at the slope toe. No fatalities and injuries were reported.

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

The report was prepared as part of the 1998 Landslide Investigation Consultancy (LIC), for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED) under Agreement No. CE 74/97. It is one of a series of reports produced during the consultancy by Fugro Scott Wilson Joint Venture (FSW). The report was written by Mr A Ng and reviewed by Mr Y C Koo. The assistance of the GEO in the preparation of the report is gratefully acknowledged.



Y C Koo
Project Director/Fugro Scott Wilson Joint Venture

CONTENTS

1. INTRODUCTION

At about 5:50 p.m. on 9 June 1998, a landslide (GEO Incident No. MW 98/6/8) occurred on a soil/rock cut slope (No. 6SE-D/C304) above the access road to the Sunny Villa apartment blocks at 218 Castle Peak Road, New Territories (Figure 1 and Plates 1, 2 & 3). The landslide released about 200 m^3 of debris which completely blocked the access road. No fatalities and injuries were reported in the landslide.

Following the landslide, Fugro Scott Wilson Joint Venture (FSW) was commissioned by the Geotechnical Engineering Office (GEO) to carry out a detailed study of the failure under the 1998 Landslide Investigation Consultancy (LIC).

The principal objectives of the study were to document the facts about the landslide, present relevant background information and establish the probable causes of the failure. This report presents the findings of the study which comprised the following key tasks:

(a) desk study, including a review of relevant documentary records relating to the history of the site, examination of aerial photographs and analysis of rainfall data,

(b) interviews with witnesses of the landslide and other concerned persons,

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

(d) theoretical stability analyses of the slope that failed, and

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

2. THE SITE

2.1 Site Description

Sunny Villa is situated some 400 m to the east of Approach Bay at Yau Kam Tau, Tsuen Wan (Figure 1). The access road from Castle Peak Road to Sunny Villa is about 300 m long and was formed partly by cutting and partly by filling. The area that failed is within the cut slope located on the uphill side of the access road. This cut slope was registered as No. 6SE-D/C304 in the New Catalogue of Slopes, which was compiled between 1994 and 1998.

The maximum height of slope No. 6SE-D/C304 is about 45 m and 30 m at its western and eastern portions respectively. The slope face was generally formed in three batters and each batter is separated by a 1.5 m-wide berm. The slope has been formed to various inclinations, typically 80° at the lowest batter where the material is rock, and 30° to 45° at upper levels where the material is generally soil. Surface drainage channels have been provided along the crest and on the surface of the cut slope. The natural terrain above the cut slope rises up at about 30° and reaches Tuen Mun Road, which is located some 50 m upslope.

In general, the soil portion of the cut slope is heavily vegetated and the rock portion is generally bare. The landslide that occurred on 9 June 1998 is on the upper batters of the eastern slope portion. The location of the landslide is shown on Figure 2.

No water-carrying services are present in the vicinity of slope No. 6SE-D/C304 and the natural hillside above.

2.2 Maintenance Responsibility

According to the findings of the project entitled "Systematic Identification of Maintenance Responsibility of Registered Slopes in the Territory" (SIMAR) undertaken by the consultant engaged by the Lands Department, the owners of land lots TWTL 327 and Lot 269 in DD 354 are jointly responsible for the maintenance of slope No. 6SE-D/C304. However, according to District Lands Officer/Tsuen Wan, only the owner of Lot 269 in DD 354 is responsible for the maintenance of this slope.

2.3 Site History and Past Landslides

The development history of the site has been established from a review of aerial photographs and documentary records. Detailed observations from the aerial photograph interpretation (API) are given in Appendix A. A summary of the key findings of the API is given below.

Aerial photographs taken in 1924 show that the area was generally covered with thin vegetation. In the 1964 aerial photographs, a topographical depression has been identified on the natural terrain above the present cut slope (Figure 2), which may be a possible sign of previous instability.

Site formation works for Sunny Villa started in 1981. In 1982 the access road connecting the site to Castle Peak Road was under construction. By the end of 1982, the concerned slope was formed and a system of drainage channels was constructed on the slope surface.

There are no records of past failures in the natural terrain in the proximity of the present landslide site in the GEO's Natural Terrain Landslide Inventory. The GEO's landslide database indicates that prior to the present landslide there was only one landslide incident at cut slope No. 6SE-D/C304 reported to the GEO (GEO Incident No. MW 89/8/1) which occurred on 1 August 1989 (Figure 2).

The 1989 landslide was reported to have involved a boulder fall of about 0.25 m^3 in volume. Following the incident, the GEO recommended the Buildings and Lands Department (BLD, reorganised as Buildings Department (BD) in 1993) to issue a Type 2 Advisory Letter concerning the necessary maintenance works to the slope. The Advisory Letter was issued on 27 December 1989 requiring the Incorporated Owners of Sunny Villa to "clear all debris and scale off the loose blocks on slopes and/or construct protective wire mesh anchored to the berms and rock face to prevent rock fall". Subsequently, the owners carried out some scaling works for the slope.

2.4 Previous Studies and Assessments

Geotechnical assessments for cut slope No. 6SE-D/C304 were carried out in the late 1970's and early 1980's in support of the development proposal for Sunny Villa. Site formation proposal, together with the geotechnical report, submitted by Tom K Engineering & Construction Co. Ltd., were approved by the BLD on 14 March 1980.

An amendment of the site formation, including the formation works for the cut slope, prepared by Earth Sciences (Asia) Civil & Geotechnical Consulting Engineers (ESA) was approved by the BLD on 13 July 1980. The soil portion of the slope, which stood at about 20° to 40° to the horizontal, was recommended to be cut back to 45°. During the construction stage, a geotechnical report prepared by ESA on amendments to the cut slope was accepted by the GEO and approved by the BLD on 23 November 1982. The geotechnical report recommended the central upper portion of the proposed cut slope (i.e. between 48.8 mPD and 57.9 mPD), which covered the lower portion of the present landslide site, to be amended from 45° to gradients of between 30° and 40°. According to the geotechnical report, this amendment was necessary because a zone of closely fractured highly decomposed volcanic rock in the concerned slope area was found to be "controlled by two parallel faults".

No as-built records of the constructed cut slope have been found in the available documents. A photograph taken by ESA at the location of the present failure in late 1982 is shown in Plate 4.

The constructed cut slope was identified in August 1996 under a project initiated by the GEO entitled "Systematic Inspection of Features in the Territory" (SIFT). The project aims to search systematically for sizeable man-made slopes not previously registered in the 1977/78 Catalogue of Slopes and to update information on existing registered slopes.

In July 1994, the GEO commenced a consultancy agreement, entitled "Systematic Identification and Registration of Slopes in the Territory" (SIRST), to systematically update the 1977/78 Catalogue of Slopes and to prepare the New Slope Catalogue. The GEO's consultants for the SIRST project inspected slope No. 6SE-D/C304 in January 1997. The SIRST report recorded that no signs of seepage or distress were noted.

3. THE LANDSLIDE

3.1 Time of the Landslide

The caretaker, who was on duty at the Castle Peak Road entrance of the access road to Sunny Villa, stated that the landslide occurred at about 5:50 p.m. on 9 June 1998 with no prior warning being observed.

3.2 Description of the Landslide

FSW inspected the site on 10 June 1998, and subsequently in July, August and October 1998. The mapping results are shown on Figure 3. General views of the landslide site are shown in Plates 1 to 3.

The landslide released about 200 m^3 of debris from the upper part of the eastern portion of slope No. 6SE-D/C304, which completely blocked the access road to Sunny Villa. The majority of the landslide debris comprised very loose, very wet silty sand with gravel, cobbles and occasional boulders of highly to moderately decomposed coarse ash tuff. Remnants of concrete drainage channels were also found in the debris and intact raft of vegetation were located below the main scarp. The landslide debris was mainly from the cut slope with a small portion from the natural hillside above the slope crest. As the landslide debris was constrained by the bank at the far side of the access road, the travel angle of the landslide debris cannot be determined reliably.

The main scarp of the landslide was about 28 m wide and 4.5 m high as measured at the middle section of the scarp. The height of the main scarp reduced to about 0.5 m towards its flanks. The inclination of the scarp varied between about 75° near the crown and about 50° along the surface of rupture. The surface of rupture was about 2 m deep and 15 m long, with the lower three quarters covered by detached materials. In the main scarp, highly to completely decomposed tuff (about 3 m thick) was overlain by a layer of colluvium (about 1 m thick) (Figure 4). Moderately to slightly decomposed tuff overlying slightly decomposed to fresh tuff was exposed in the slope immediately below the toe of the surface of rupture. No signs of distress were observed in the area adjacent to the landslide site.

Steeply-dipping, close to medium spaced relict joints of persistence of about 1 m to 2 m, which were generally infilled with kaolin (about 2 mm to 5 mm thick) and occasionally stained with manganese and iron oxides, were observed along the middle and eastern portions of the main scarp of the landslide within completely decomposed volcanics (Plate 5).

The landslide scar was located immediately below a 300 mm crest U-channel, which was almost completely blocked with vegetation (Figure 3). Most of the surface U-channels on the slope were also covered with vegetation and blocked (Plate 6), indicating inadequate maintenance. A dislocated berm U-channel was observed on both flanks of the scar, the remains of which were noted in the debris along the access road.

During the inspection carried out by FSW in the morning of 10 June 1998, a lot of water was noted emanating from four locations of the failure scar (Figure 3). However, no surface runoff was observed, suggesting that sub-surface water may be the source of the observed seepage. No signs of erosion by surface water were noted, indicating that the landslide was unlikely to have involved a washout failure caused by the action of external surface water flow.

3.3 Urgent Repair Works

After the landslide, the GEO recommended urgent repair works which included the cutting back of the sub-vertical back scarp to an inclination of 45^o and the provision of a 75 mm-thick sprayed concrete cover. The urgent repair works were carried out in October 1998.

4. SUBSURFACE CONDITIONS

4.1 General

The subsurface conditions at the site were determined using information obtained from both desk and field studies. The desk study included a review of the available documentation supplemented by the API, whilst the field studies involved post-failure geological mapping.

4.2 Geology and Previous Ground Investigations

According to the Hong Kong Geological Survey Memoir 3 (GCO, 1989) and Sheet 6 of the Hong Kong Geological Survey's 1:20,000 scale Geological Map (GCO, 1988), the geology of the site comprises coarse ash crystal tuff of the Yim Tin Tsai Formation of the Tsuen Wan Volcanic Group.

The ground investigation for the development of Sunny Villa comprised 49 boreholes and 27 trial pits which were carried out between 1976 and 1980. BH13 and BH14 were located in close proximity to the landslide site (Figure 2). The borehole logs indicate a soil mantle of about 4 m thick.

The landslide site consisted of a layer of colluvium comprising gravelly sandy clayey silt of about 1 m thick overlying completely to highly decomposed tuff comprising medium dense sandy clayey silt and silty sand with corestones of about 3 m thick, which in turn overlies moderately to slightly decomposed tuff. Two sets of relict joints were measured in the main scarp dipping at 18º and 85º towards 210° and 230° respectively. The joints were generally infilled with kaolin between about 2 mm and 5 mm thick (Plate 5). Joints of similar orientation were also measured on the rock cut slope below the landslide scar and the results are presented on Figure 5. However, no joints were observed in the western portion of the main scarp.

Based on the post-failure site inspections and the information from the previous ground investigation, a representative geological section of the landslide site has been prepared as shown in Figure 4. The vegetated slope with a relatively shallow soil mantle of colluvium and saprolite would be favourable to the development of perched water table above the Grade III or less decomposed rock.

In the geotechnical report on the approved site formation design, the cross-section nearest to the landslide site is about 4 m to its east (i.e. cross-section Y-Y on Figure 2). At this cross-section, the thickness of soil at the upper portion of the cut slope was assumed to be about 8 m, becoming thinner down slope with bedrock (i.e. Grade III or less decomposed rock) exposed in the lower half of the slope (Appendix B). Based on the results of triaxial compression tests on undisturbed soil samples, the same set of shear strength parameters, i.e. $c' = 10$ kPa and $\phi' = 35^{o}$, was adopted for colluvium, alluvium and completely decomposed tuff in the slope stability analyses.

The closest groundwater monitoring station on the site of the 1998 landslide are the standpipe piezometers installed in borehole BH16, which was located at about 30 m to the

east of the landslide site (Figure 2). The piezometers were installed at 5 m and 6 m below rockhead and slope surface respectively. However, no monitoring records are available in either GEO or BD files. The design groundwater table assumed for the 1-in-10 year return period rainfall at cross section Y-Y (i.e. 4 m away from the landslide site) appears to have been based on the standing water levels inside boreholes BH13, BH14 and BH15, which were sunk between 2 December and 17 December 1976, before they were backfilled. This design groundwater table was at a level slightly below rockhead and no perched water table above rockhead was considered in the stability analysis (Appendix B).

5. ANALYSIS OF RAINFALL RECORDS

The nearest GEO automatic raingauge No. N10 is located at Emmanuel Primary School, about 3 km to the west of the landslide site (Figure 1). The daily rainfall between 1 May 1998 and 25 June 1998 is shown in Figure 6. A total of 611 mm of rainfall was recorded in the 31 days before the landslide.

Hourly rainfall between 7 June 1998 and 9 June 1998 is also presented in Figure 6. Rainfall was almost continuous from mid-night of 8 June 1998 to the time of the landslide. In this period, the average hourly rainfall was about 15 mm and the maximum hourly rainfall recorded was 40 mm between 4 a.m. and 5 a.m. on the day of the landslide. Table 1 presents the estimated return periods of maximum rolling rainfall recorded before the landslide for selected durations, based on historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994). The estimated return period for the 24-hour rainfall before the landslide was greatest, being about 5 years.

Figure 7 shows the maximum rolling rainfall recorded at GEO raingauge No. N10 during selected previous major rainstorms between 1 January 1984 and 9 June 1998. The rainfall preceding the 9 June 1998 landslide was not as severe as some of the previous rainstorms.

6. THEORETICAL ENGINEERING ANALYSES

Theoretical stability analyses using the method of slices following the rigorous solution of Morgenstern & Price (1965) were carried out to assist in the diagnosis of the probable causes of the landslide. The purpose of these analyses was to investigate the likely range of operational shear strength parameters along the failure surface for different groundwater conditions at the time of failure.

A representative cross-section of the landslide site along which stability analyses have been carried out is presented in Figure 8. The pre-failure slope profile was established from the approved site formation plans, whereas the geometry of the landslide surface was based on post-failure field mapping and site measurements made by FSW. The relationship between probable groundwater levels and shear strength parameters corresponding to a factor of safety of unity for the observed failure surface is given in Figure 8.

The shear strength parameters adopted in the approved site formation design (i.e. $c' = 10$ kPa and $\phi' = 35^{o}$) are also shown in Figure 8. It can be seen that if these shear

strength parameters were appropriate for the observed failure, the groundwater level would have to be at about 2 m above rockhead. On the other hand, if there was no build-up of positive water pressure at the time of failure except for saturation of the failed material, as assumed in the site formation design, the operational shear strength parameters of the near-surface materials involved in the failure would be in the range of about c' = 1 kPa and $\phi' = 33^o$ to c' = 3 kPa and $\phi' = 30^o$.

7. DIAGNOSIS OF PROBABLE CAUSES OF THE LANDSLIDE

7.1 Probable Causes of the Landslide

Given the temporal coincidence between the time of the landslide and the rainstorm on 9 June 1998 together with observation of significant seepage from the landslide site in the morning following the failure, the landslide was most likely triggered by rainfall.

The rainfall on 9 June 1998 was a source of water ingress into the vegetated slope via direct infiltration. Subsurface seepage from the vegetated natural hillside above the cut slope into the landslide site through preferential flow paths could also have been a source of water. Overtopping of surface water from the blocked crest drainage channel during heavy rainfall had probably promoted further water ingress into the area that failed. There is no evidence of significant surface runoff from Tuen Mun Road upslope of the cutting providing a source of water.

Water ingress into the slope had probably led to wetting up of the near-surface material, development of transient elevated water pressure within the relatively thin colluvium and saprolite (about 3 m thick) above the less weathered rock, and reduction in shear strength of the soil mass. The failure mechanism probably involved the development of a perched water table, which is consistent with the hydrogeological setting of the site (i.e. a thin mantle of soil above rockhead) and corroborated by the observation of significant seepage from the landslide site shortly after failure and the supporting slope stability analyses.

The presence of kaolin infill in the relict joints resulted in a relatively low mass shear strength which probably contributed to the failure but field mapping suggests that the landslide did not involve unduly weak material (e.g. persistent clay seam). It is therefore probable that development of positive water pressure was involved in the failure, either through perching on strata boundaries (such as the interface of saprolite/Grade III or less weathered rock), less permeable layers or zones within the saprolite, or seepage pressure arising from downslope subsurface flow.

7.2 Factors Relevant to the Landslide

The failure of 9 June 1998 occurred on a slope that had previously been designed based on site-specific ground investigation and laboratory testing, and checked to current geotechnical standards. Factors that are considered to be relevant to the landslide are discussed below.

The failure occurred during a rainstorm that was not particularly severe. The fact that the slope had previously been exposed to more severe rainstorms in 1986, 1994 and 1996 without failures suggests that inadequate slope maintenance (e.g. blocked crest drainage channels), possibly exacerbated by progressive deterioration of the slope condition, might have been a significant contributory factor to the failure.

Examination of the landslide scar revealed the presence of adversely orientated kaolin-infilled relict joints in the weathered tuff of the slope. These form planes of weakness in the soil mass and affect the mass strength of the soil. Hence, the operational shear strength of the weathered tuff is likely to be weaker than that assumed in the site formation design (viz. $c' = 10$ kPa and $\phi' = 35°$). It would appear that the kaolin-infilled relict joints that controlled the failure scar were not specifically considered in the site formation design.

In addition to the presence of adversely orientated relict joints, the actual groundwater condition at the time of the failure was likely to have exceeded that assumed in the site formation design (i.e. groundwater taken to be below rockhead).

8. CONCLUSIONS

It is concluded that the landslide that occurred on 9 June 1998 at the slope above the access road to the Sunny Villa was most likely triggered by rainfall. The probable causes of the failure involved wetting up of the near-surface material and development of transient elevated water pressure as a result of ingress of water during rainfall, leading to reduction in shear strength. Overtopping of surface water from the blocked crest channel immediately above the landslide site probably promoted water ingress into the soil mass on its down-slope side. The presence of adversely orientated relict joints with kaolin infill within the completely decomposed volcanics gave rise to a relatively low mass strength.

The 200 m^3 landslide occurred on a slope that had previously been designed and checked to current geotechnical standards based on site-specific ground investigation and laboratory testing. The failure occurred during a rainstorm which was less severe than that experienced in the past. The presence of adversely orientated relict joints with weak infill, overtopping of surface water from the blocked crest channel, development of transient elevated water pressure and inadequate slope maintenance were probably contributory factors to the failure.

9. REFERENCES

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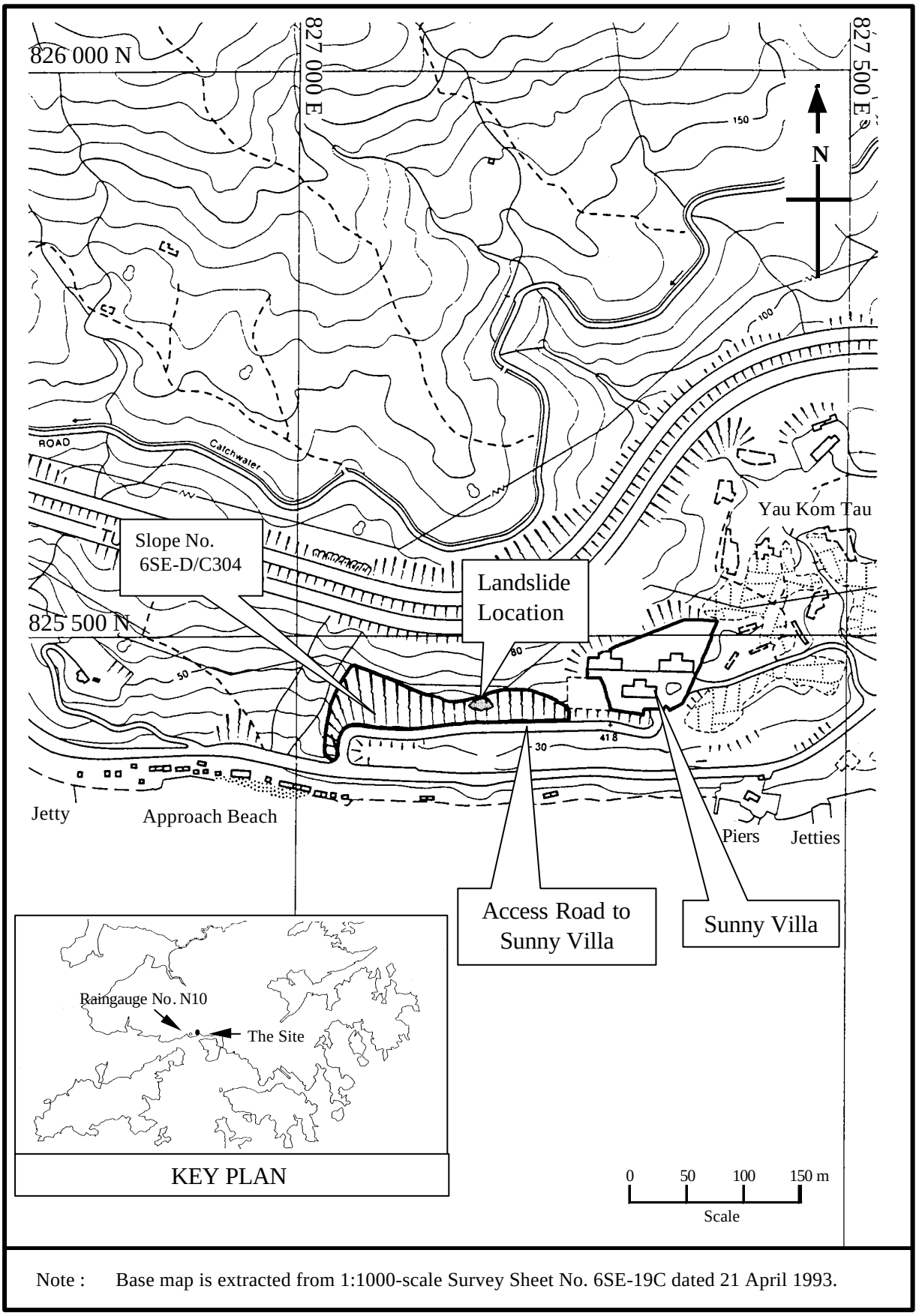
LIST OF TABLES

Table 1 - Maximum Rolling Rainfall at GEO Raingauge No. N10 and Estimated Return Periods for Selected Durations Preceding the Landslide

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (years)
5 minutes	8.5	10:40 on 9 June 1998	< 2
15 minutes	21.0	10:40 on 9 June 1998	< 2
1 hour	47.0	11:25 on 9 June 1998	< 2
2 hours	70.5	4:25 on 9 June 1998	< 2
4 hours	122.0	6:10 on 9 June 1998	2
12 hours	206.5	14:25 on 9 June 1998	4
24 hours	300.5	17:35 on 9 June 1998	5
48 hours	306.5	17:45 on 9 June 1998	4
4 days	340.5	17:10 on 9 June 1998	3
7 days	392.0	17:45 on 9 June 1998	3
15 days	413.5	17:45 on 9 June 1998	< 2
31 days	610.5	17:45 on 9 June 1998	< 2

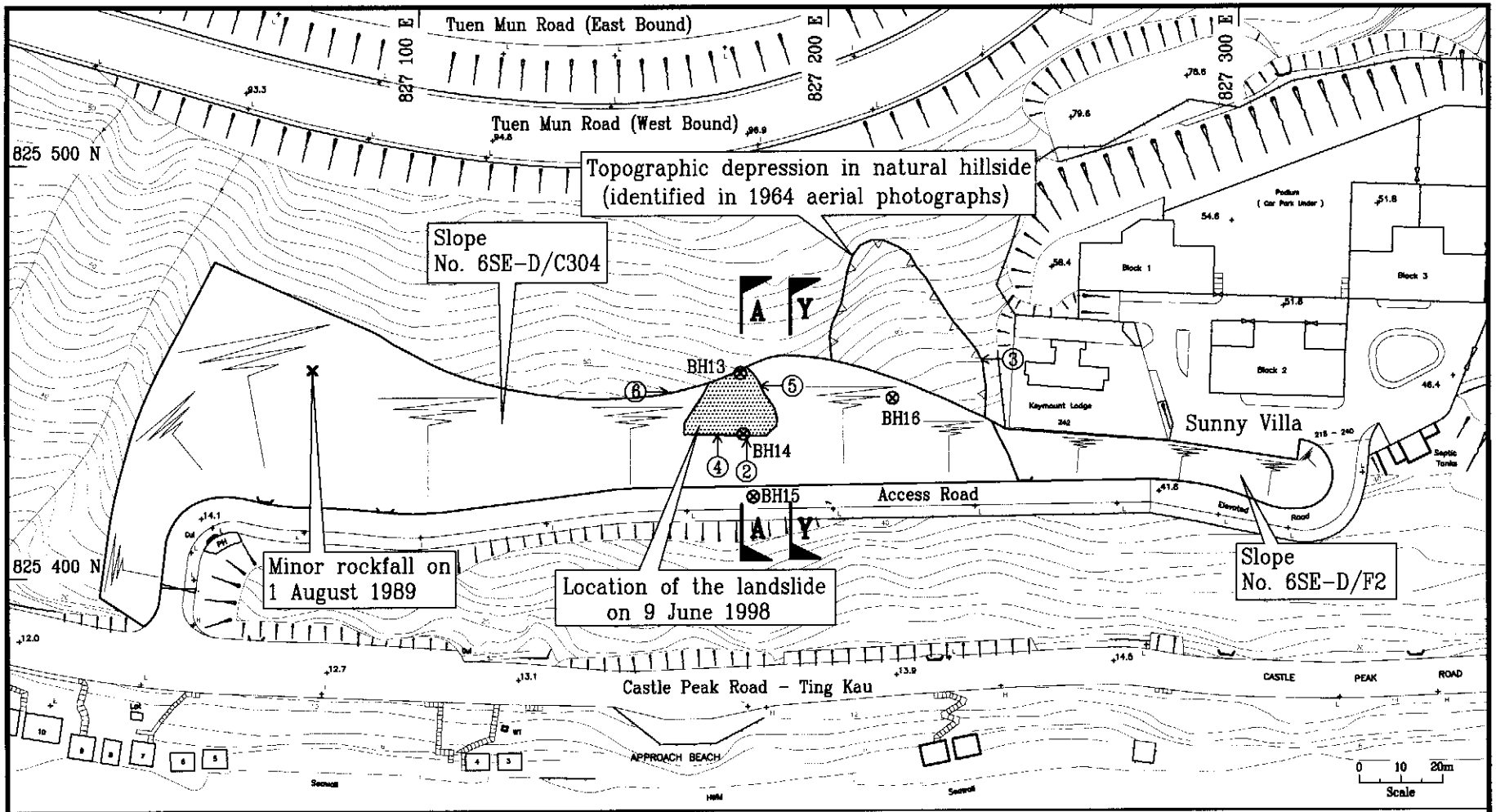
Notes :
(1) Return periods were derived from the Gumbel's equation and data published in Table 3 of Lam & Leung (1994).
(2) Maximum rolling rainfall was calculated from 5-minute rainfall data.
(3) The use of 5-minute rainfall data for durations between 2 hours and 31 days results in better data resolution, but may slightly over-estimate the return periods using Lam & Leung (1994)'s data, which is based on hourly rainfall for these durations.

LIST OF FIGURES



Note : Base map is extracted from 1:1000-scale Survey Sheet No. 6SE-19C dated 21 April 1993.

Figure 1 – Site Location Plan

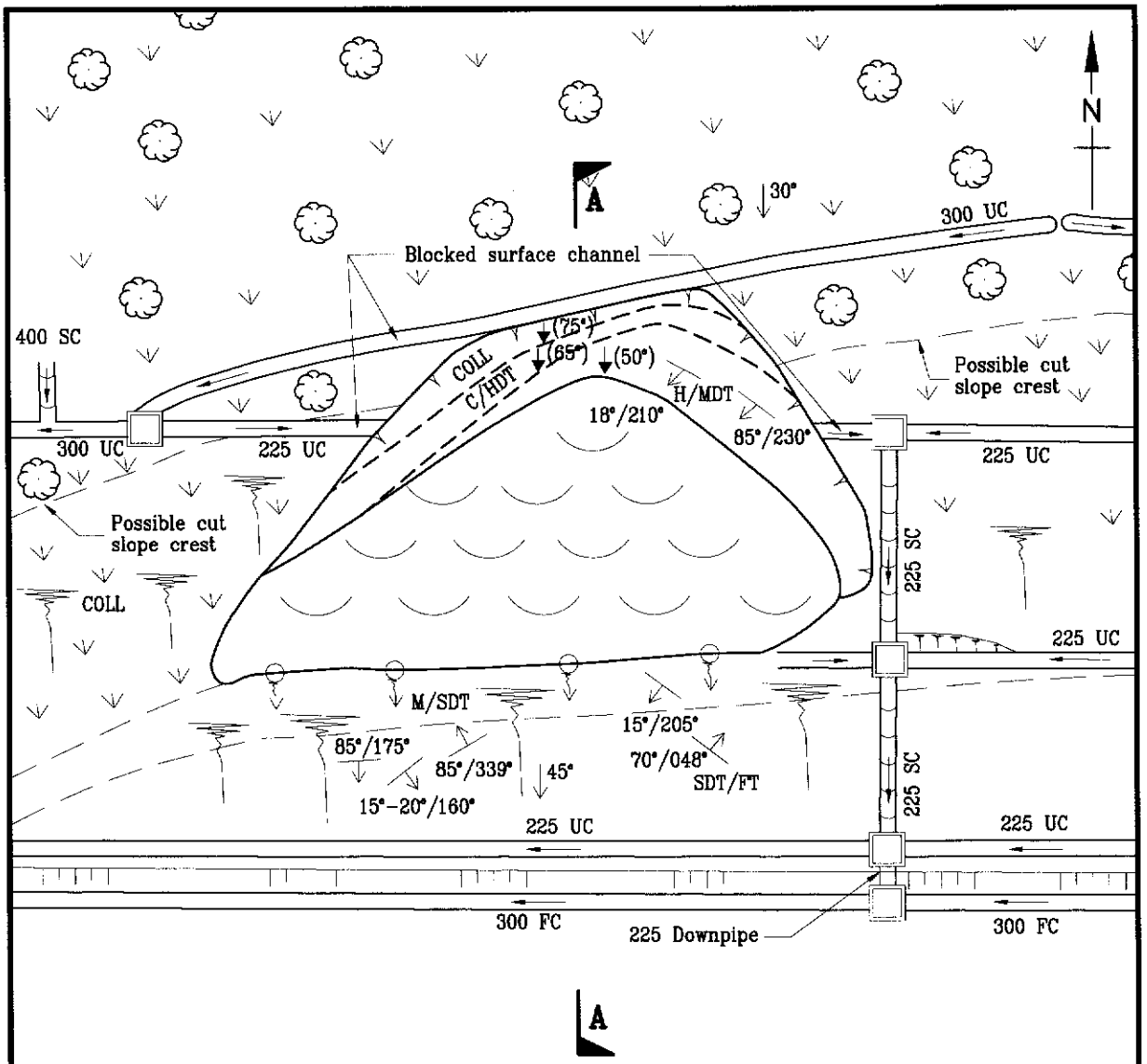


Legend : ←(4) Vantage point of Plate 4 Y-Y The cross section nearest to the landslide in the approved site formation design

BH13 Boreholes for site formation works of Sunny Villa in the vicinity of the landslide site.

Note : See Figure 4 for Section A-A

Figure 2 - Plan of the Landslide



Legend:

Superficial Deposits

COLL	Colluvium

Rock Type and Weathering

C/HDT	Completely to Highly Decomposed TUFF
H/MDT	Highly to Moderately Decomposed TUFF
M/SDT	Moderately to Slightly Decomposed TUFF
SDT/FT	Slightly Decomposed to Fresh TUFF

Geomorphology

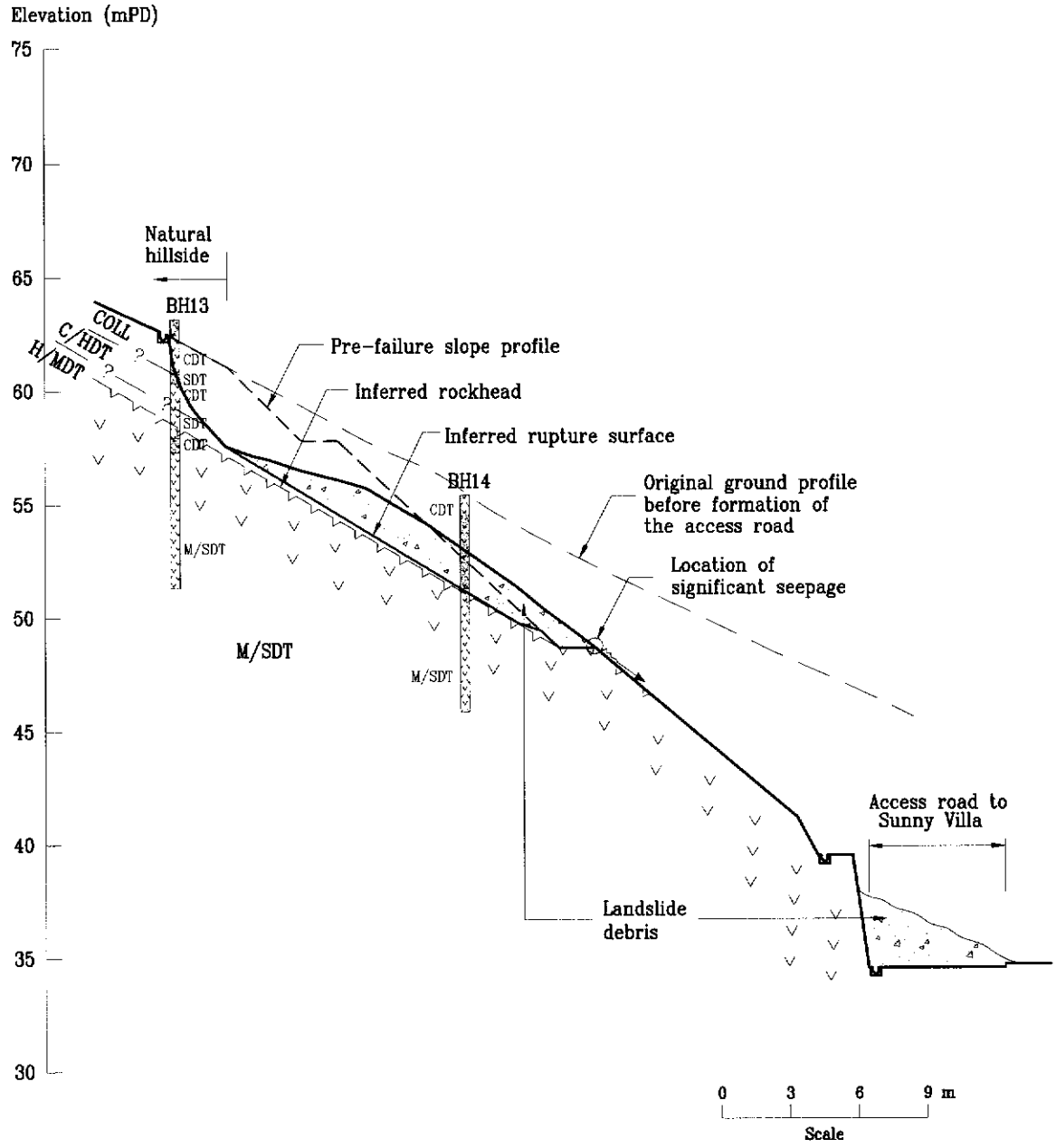
- Failure Scarp
- Debris
- 85°/230° — Dip angle and dip direction of joints
- Geological Boundary
- Cut Slope
- Seepage Point

Vegetation

- Heavily-vegetated natural terrain
- Densely-vegetated cut slope
- (65°) — Scarp face angle

Note: Survey based on tape measurements and site observations.

Figure 3 - Geological Map of the Landslide Site

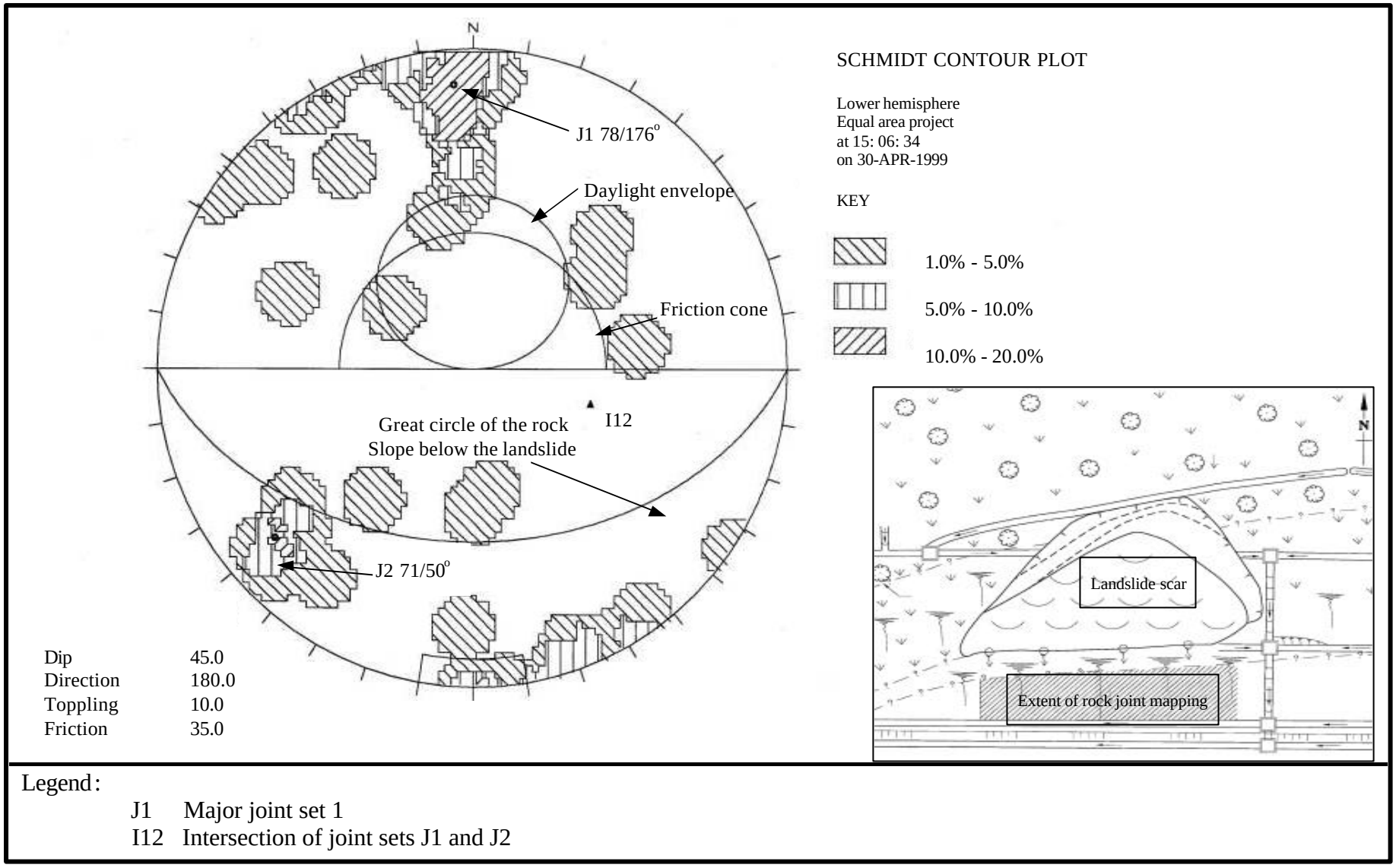


Legend:

COLL	Colluvium	CDT	Completely Decomposed TUFF
C/HDT	Completely to Highly Decomposed TUFF	SDT	Slightly Decomposed TUFF
M/SDT	Moderately to Slightly Decomposed TUFF		

Notes: (1) See Figure 3 for location of cross-section.
(2) Information shown is based on site observation and documentary records.

Figure 4 - Cross Section A-A through the Landslide



Legend:

J1 Major joint set 1

I12 Intersection of joint sets J1 and J2

Figure 5 – Stereoplot of the Discontinuity Survey for the Exposed Rock Slope below the Landslide Scar

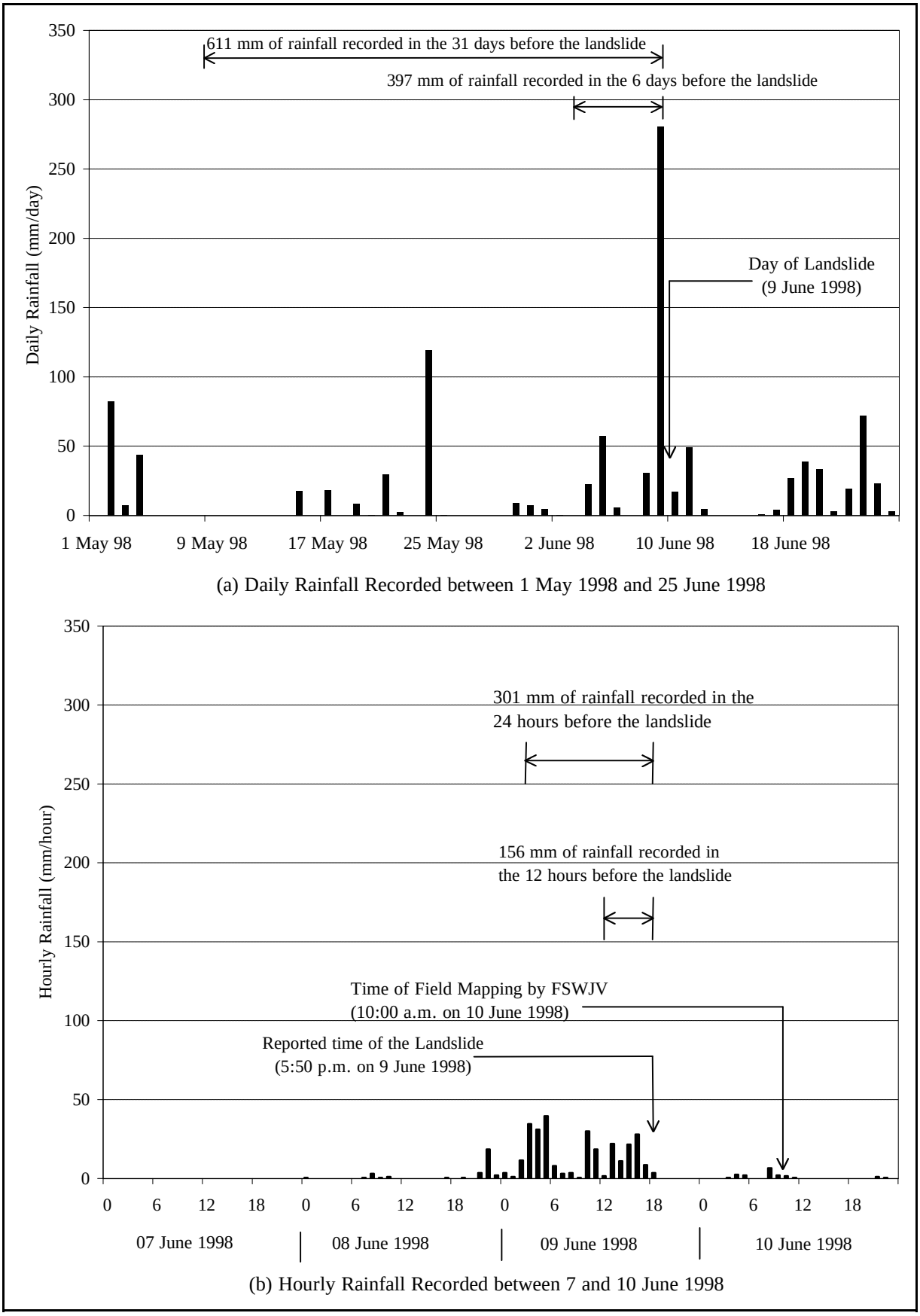


Figure 6 - Rainfall Records of GEO Raingauge No. N10

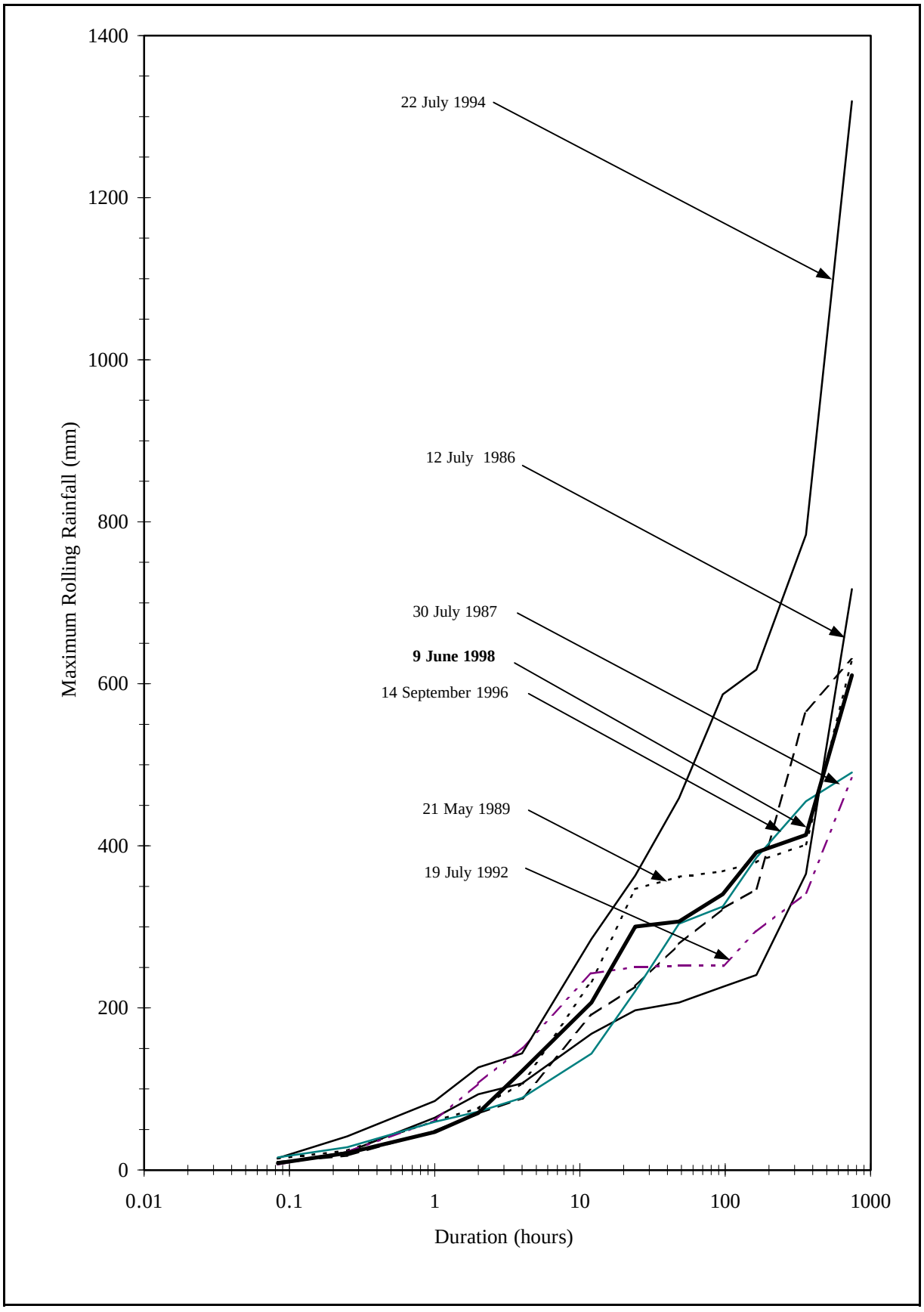
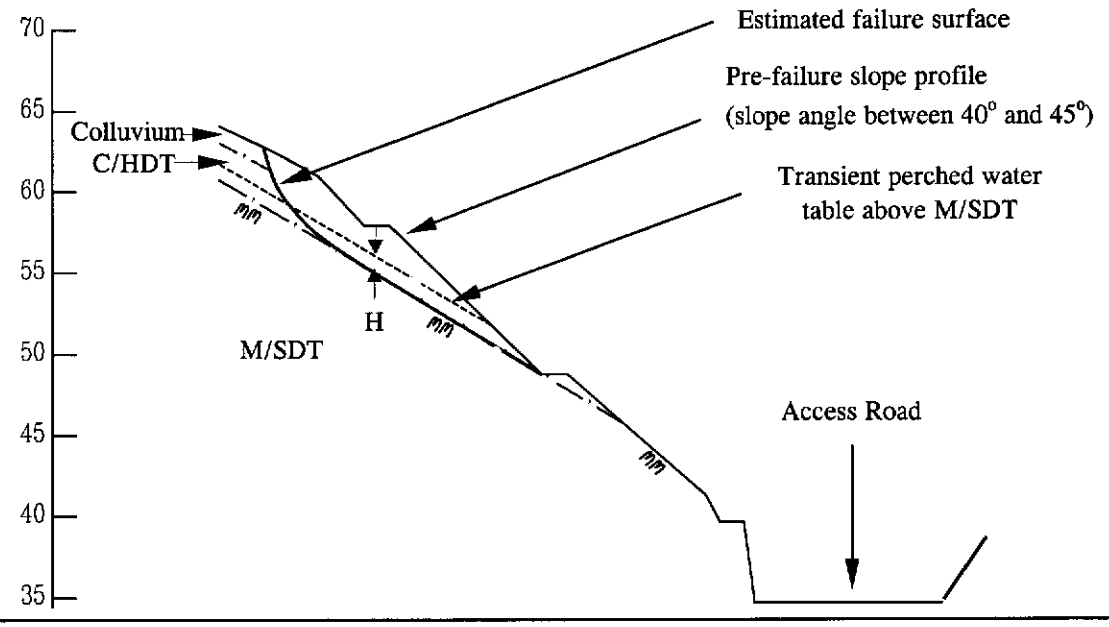
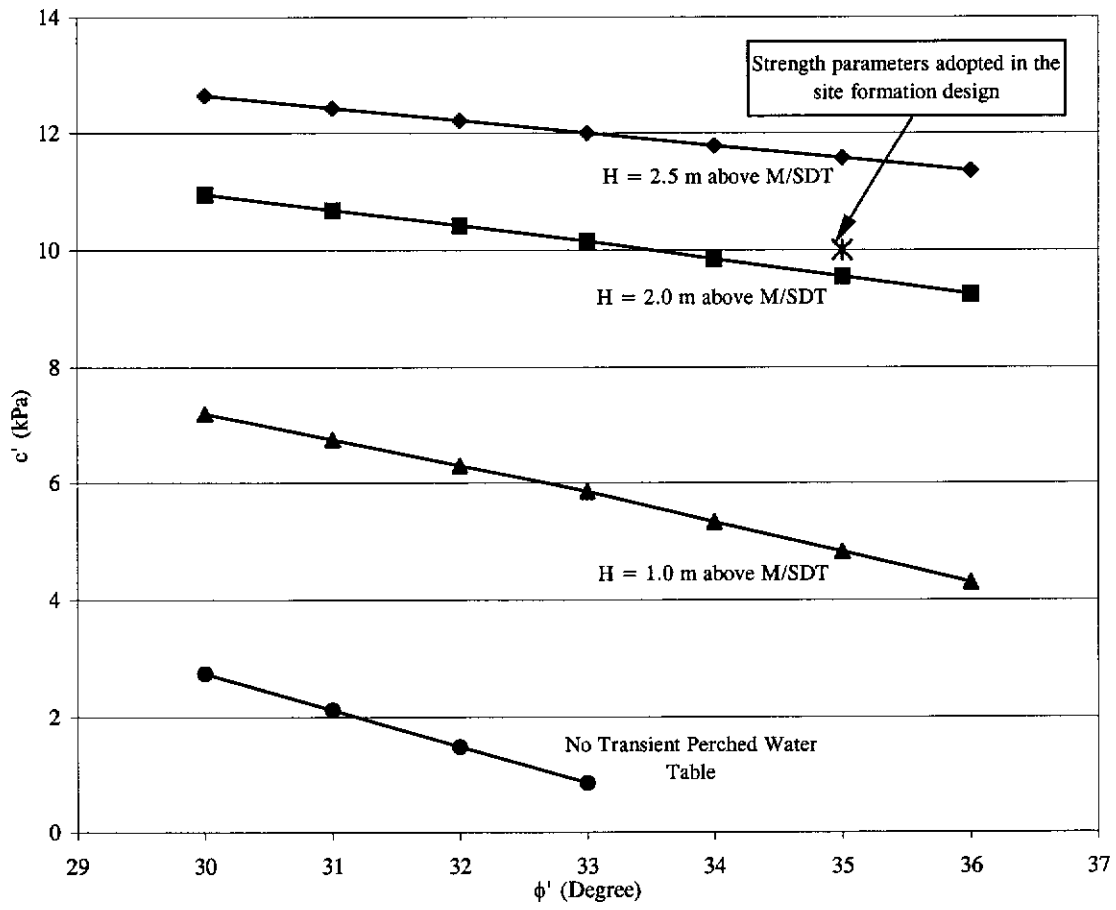


Figure 7 - Maximum Rolling Rainfalls at Raingauge No. N10 for Major Rainstorms



(a) Cross-section of the landslide site



(b) Relationships between water levels and shear strength parameters along the failure surface corresponding to FOS = 1

Figure 8 - Results of Theoretical Stability Analysis

LIST OF PLATES

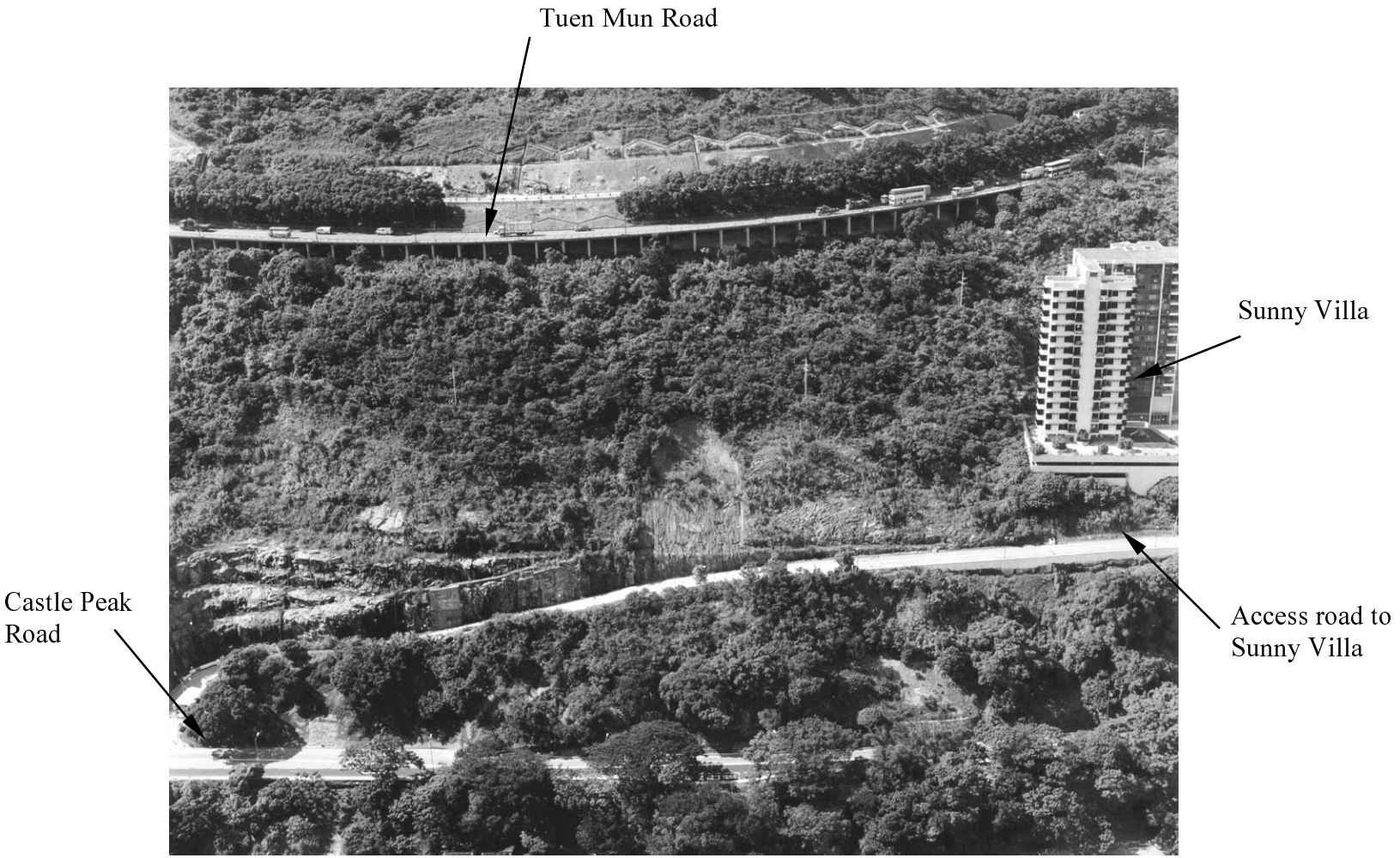


Plate 1 - General View of the Site
(Photograph taken on 29 June 1998)

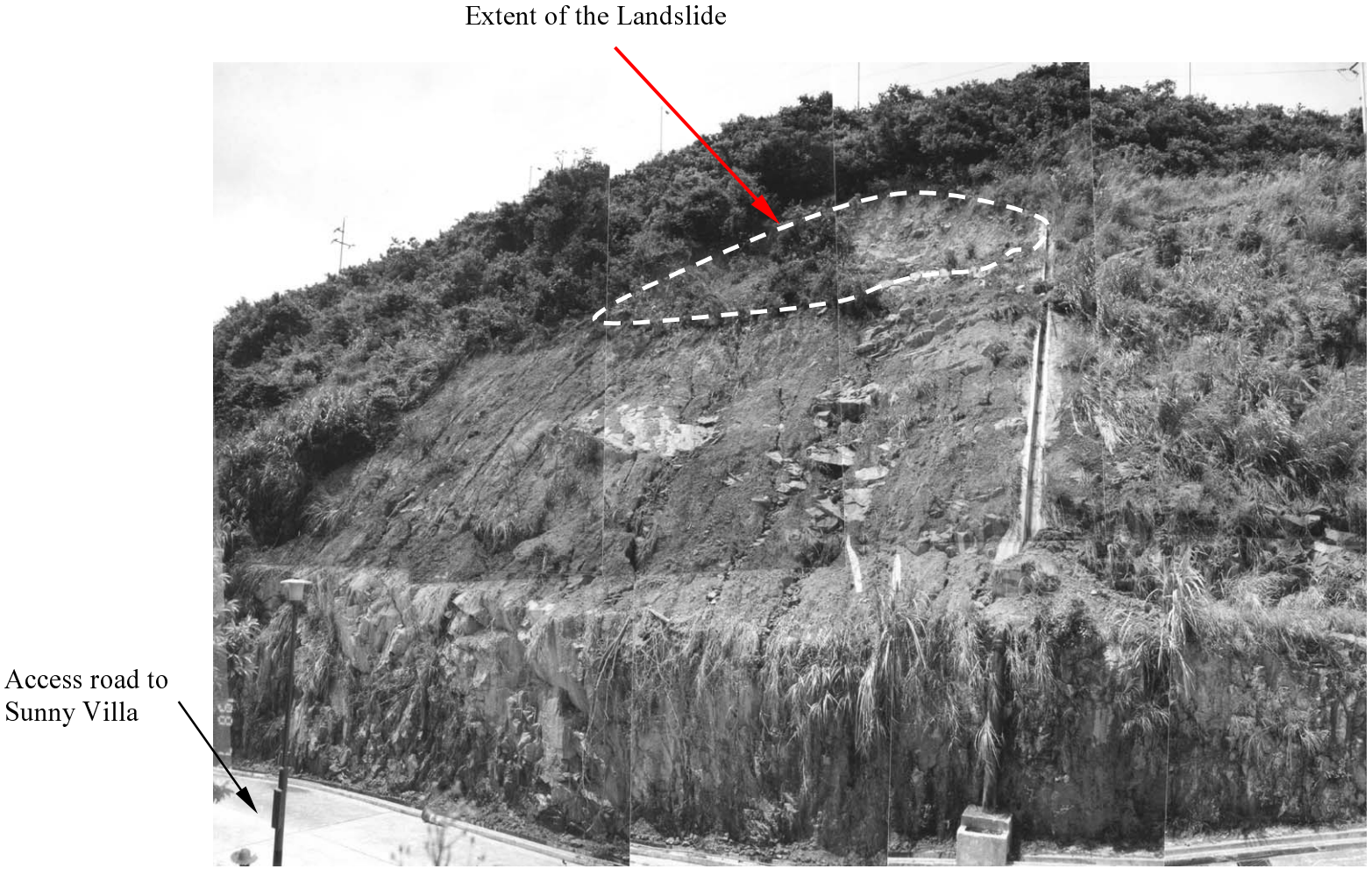


Plate 2 - General View of the Landslide Scar
(Photograph taken on 29 July 1998. See Figure 2 for Location of Photograph)

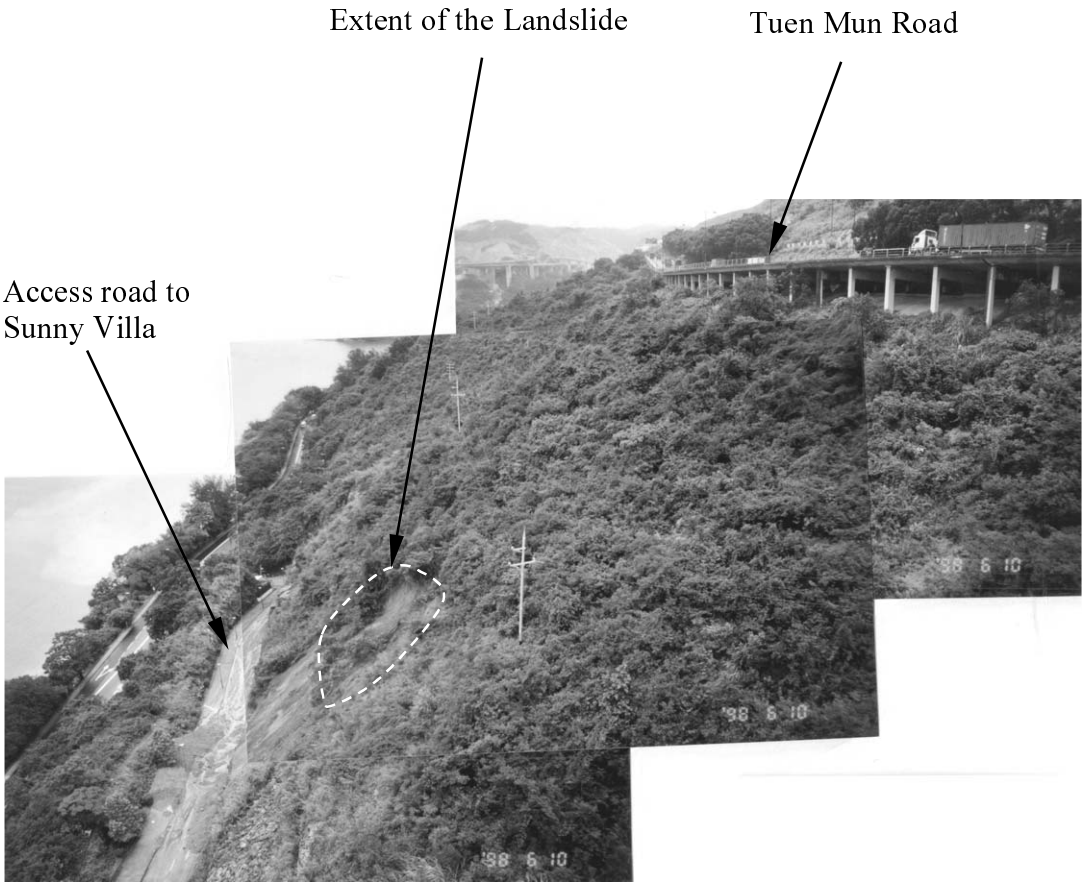


Plate 3 - Side View of the Landslide Scar
(Photograph taken on 10 June 1998.
See Figure 2 for Location of Photograph)

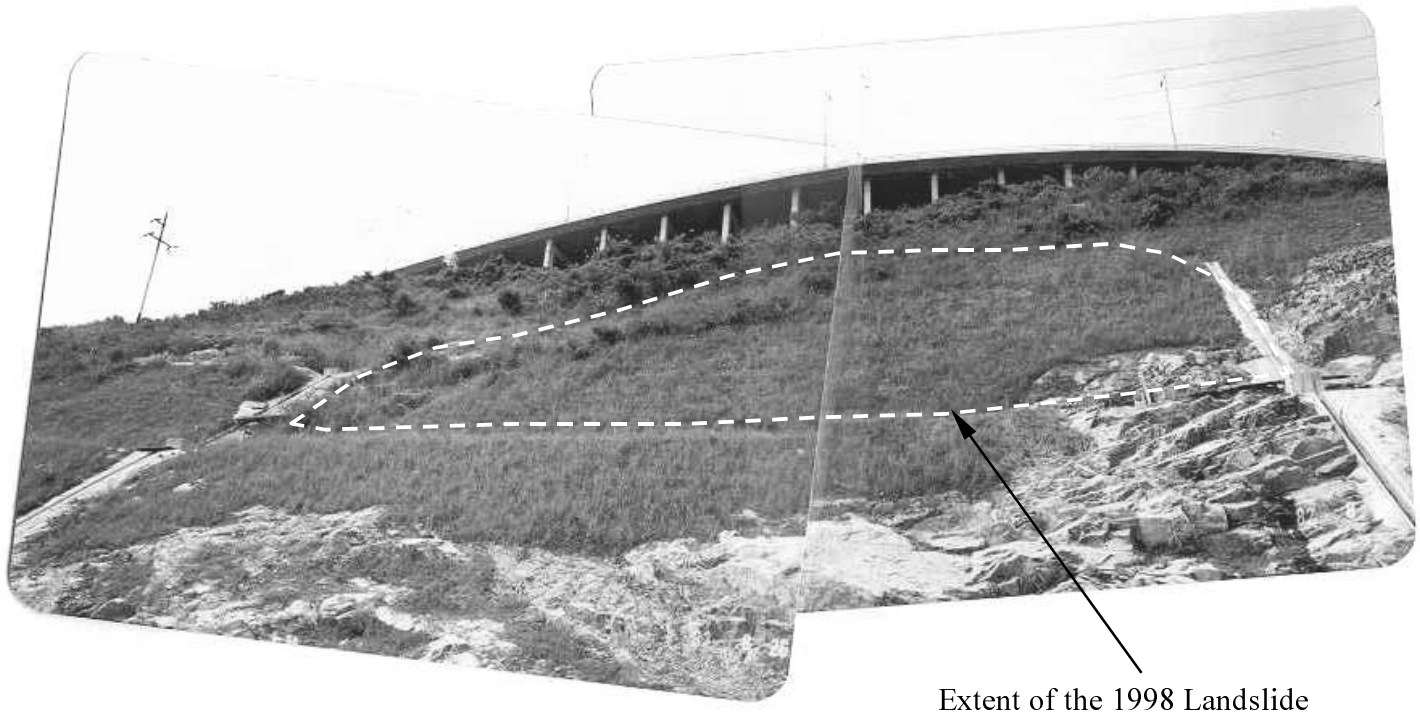


Plate 4 - Front View of the Cut Slope at the Location of the 1998 Landslide
(Photograph reproduced from ESA's Geotechnical Report dated October 1982.
See Figure 2 for Location of Photograph)

Plate 5 - Kaolin-coated Relict Joints at the Landslide Scar
(Photograph taken on 23 July 1998.
See Figure 2 for Location of Photograph)

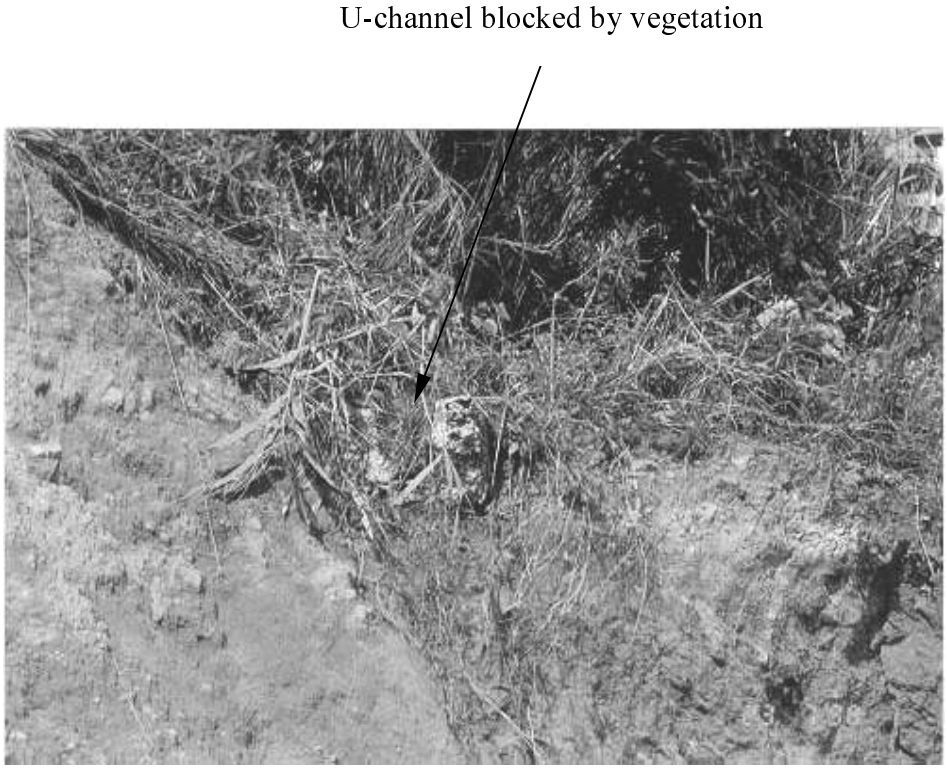


Plate 6 – U-channel Blocked by Vegetation (Photograph taken on 23 July 1998. See Figure 2 for Location of Photograph)

APPENDIX A

REPORT OF AERIAL PHOTOGRAPH INTERPRETATION

CONTENTS

A1. INTRODUCTION

On 9 June 1998 a landslide occurred on cut slope No. 6SE-D/C304 above an access road connecting the Sunny Villa apartment blocks with Castle Peak Road. The access road and cut slope lie between Tuen Mun Road and Castle Peak Road. The landslide resulted in the temporary closure of the access road.

This report presents factual and interpretative observations from a review of aerial photographs covering the area. A brief description of the local geology is also included.

A2. GEOLOGY

The solid and superficial geology of the site is mapped as coarse ash crystal tuff of the Yim Tin Tsai Formation, part of the Repulse Bay Volcanic Group (GCO, 1988). A photogeological lineament and a fault are shown in the area, the lineament approximately 400 m to the northwest of the landslide site trending northwest-southeast, and the fault indicated approximately 350 m to the east trending north northeast-south southwest. Jointing is mapped as sub-vertical striking northwest-southeast.

Four photogeological lineaments, generally trending northwest-southeast, were identified during the review of aerial photographs to the south and west of the 1998 landslide site. These may represent faults and/or a dominant and persistent joint set within the Yim Tin Tsai tuffs.

A3. GEOMORPHOLOGY

The geomorphology, interpreted from the photographs taken in 1964, is shown on Figure A1. An outline of the extent of cut slope No. 6SE-D/C304, Tuen Mun Road, the access road to Sunny Villa Apartments and the approximate location of the 1998 landslide site are superimposed on the geomorphology. The 1998 landslide site is located on a slope that was cut through natural terrain inclined to the south below the main north northwest-south southeast orientated spur. Prior to the formation of the cut slope (and Tuen Mun Road) the natural slope between Catchwater Road and Castle Peak Road was characterised by a series of shallow, rounded depressions and narrow, generally discontinuous and ephemeral drainage lines between rock outcrops, indicating possible previous instability and surface erosion.

Three areas which are likely to contain colluvium were identified on the natural slope which was cut during the formation of the access road. However, these are shown either side of the 1998 landslide site on Figure A1, and the cut appears to be through intact, though variably weathered in-situ material rather than significant colluvium. The discontinuous nature of the drainage features and the presence of shallow depressions suggests that the slope is likely to be covered with patchy colluvium varying in extent and thickness between outcropping rock.

A4. DETAILED OBSERVATIONS

YEAR	OBSERVATIONS
1924	The slope appears to be covered with thin vegetation. A detailed inspection is not possible due to poor definition and lack of a stereopair. Castle Peak Road has been constructed along the coastline.
1963	Catchwater Road, constructed between 1924 and 1963, contours the slopes above Castle Peak Road and Yau Kom Tau. There is an area of construction close to the present location of Sunny Villa Apartments. Two buildings have been constructed and cut slopes formed to the north of these. An access road has been constructed to the east. The slope to the west of the construction is lightly vegetated with low shrubs and/or grasses.
1964	The slope behind the two buildings noted in 1963 has been extended. Construction in this area appears to be on-going. The natural slope between Catchwater Road and Castle Peak Road is generally characterised by a series of shallow, rounded and concave depressions, and discontinuous, narrow ephemeral stream courses (see Figure A1). The presence of such features indicates that the slope has been affected by previous instability and that it may be covered with patchy colluvial deposits. Four areas, not including the area to the west of the present cut slope, are identified which may contain more significant colluvial deposits. These are indicated on either side, and to the northwest of the 1998 landslide site. The possible colluvial deposit to the east of the 1998 landslide site appears to be located at the base of a rounded, concave depression which may represent a relict landslide scar. To the west of the 1998 landslide site the possible colluvial deposit is located within a subtle, slightly concave depression with no discernible backscarp. Many rock outcrops can be seen on the slope, some of which are located above the 1998 landslide site. Photogeological lineaments, illustrated on Figure A1, may reflect a dominant and persistent structural geological feature seen in some outcropping rock. These may be joint and/or fault related. Four lineaments are indicated to the southwest of the 1998 landslide site generally striking northwest-southeast. The scar of a large area of shallow instability and erosion is indicated on Figure A1 (to the west of the present access road). The scar appears to originate at the re-entrant section of Catchwater Road. The depression immediately below Catchwater Road may represent a relict backscarp to a larger slope failure. The area is shown as a debris flow deposit on the 1:20,000-scale geological map (GCO, 1988). The depression is bounded to the south by a rock outcrop, below which the scar appears to have a different vegetation cover. Several large boulders can be seen scattered across the scar and colluvial deposits may be present in the areas indicated as hummocky ground. This area

YEAR	OBSERVATIONS
	of instability does not affect the access road or cut slopes involved in the 1998 landslide event.
1967	Three buildings erected in the present location of the Sunny Villa apartments.
1976	There is on-going construction of the upper (eastbound) section of Tuen Mun Road involving cutting and some filling. Tuen Mun Road traverses the slope between Catchwater Road and Castle Peak Road. The works do not appear to affect the access road or cut slopes involved in the 1998 landslide event. A building has been constructed in the area currently occupied by Keymount Lodge of Sunny Villa Apartments.
1977	The upper (eastbound) section of Tuen Mun Road appears to be mostly completed. A narrow track has been excavated along the slope to the west of the building noted above (in the area currently occupied by Keymount Lodge of Sunny Villa Apartments). The track appears to terminate abruptly to the west of the 1998 landslide site. A footpath traverses the slope above this track. There appears to be active gully erosion in the drainage line which coincides with the position of the western depression (above the cut slope later formed in 1982), suggesting a higher degree of ephemeral surface water flow in this area.
1978	The lower (westbound) section of Tuen Mun Road is under construction involving cutting and filling. The works do not appear to affect the access road or cut slopes involved in the 1998 landslide event.
1981	A cut slope and access road to the west of the area currently occupied by Sunny Villa Apartments, are under construction. A new cut slope has been formed behind the platform of the present Sunny Villa Apartments. All the previous buildings in this area have been dismantled, with the exception of that currently occupied by Keymount Lodge of Sunny Villa Apartments. Tuen Mun Road is still under construction. Support beams for the lower (westbound) section of Tuen Mun Road have been erected.
1982	The access road is still under construction to connect Sunny Villa to Castle Peak Road. The formation of the access road involves an east-facing cut slope at the junction with Castle Peak Road, and a south-facing cut slope parallel to Castle Peak Road. The lowest portion of the cut slope occurs below the subtle depression indicated on Figure A1, and comprises 3 batters divided by drainage berms. On either side of this, the slope comprises 4 to 5 batters. The lower batter comprises a subvertical face along the entire feature. The cut slope does

YEAR	OBSERVATIONS

not appear to have any surface protection and was formed essentially through insitu material. The cut slope surface has a darker appearance generally close to the original ground level, and in particular below the subtle depression towards the centre of the cut slope. The uniform discolouration is likely to be due to vegetation growth on the more weathered portions of the slope.

A crest drain has been installed a few metres above the top of the cut slope within the natural terrain. A further 5 to 6 stepped U-channels were installed to take the water from the berm and crest drains.

Sunny Villa Apartments have been erected to the east of the 1998 landslide site (see Figure A2).

The lower (westbound) section of Tuen Mun Road has been constructed.

1984 The top part of the cut slope is now vegetated to a degree that suggests a greater extent of weathering of the underlying soil/rock than that below. The boundary between weathered and less-weathered soil/rock appears to be inclined towards the subtle depression. Vegetation on the natural terrain is noticeably less dense in the subtle depression between the two higher cut slopes. Many of the surface drains appear to be overgrown with vegetation.

1985 The extent of surface discolouration is generally greater below the subtle depression to the west of the 1998 landslide site. The upper batter slopes, including the 1998 landslide site, are also characterised by a greater degree of surface discolouration compared to the lower batters. There is also a marked discolouration to the drainage berms and to the surface on either side of a stepped U-channel on the northwestern portion of the slope.

Parts of the northwestern portion of the cut slope appear to be affected by some surface erosion as indicated by surface discolouration along some narrow lines dipping downslope. It is not clear whether this is caused by seepage on the upper portion of the slope, by surface water runoff, or by preferential vegetation growth along geological discontinuities.

There is a possible rockfall scar on the upper portion of the middle batter towards the northwestern end of the cut slope (in a similar location as the rockfall incident on 01.08.89 shown in Figure A2).

The crest drain is partly obscured by vegetation in the area associated with the 1998 landslide event. Shrubs and low trees appear to occupy the portion of natural terrain between the cut slope and the crest channel

Part of the track identified in 1977 can be seen in the subtle depression to the northwest of the 1998 landslide site. The ground surface within the subtle depression has a hummocky appearance. This is further evidence that the

YEAR	OBSERVATIONS
	subtle depression may contain colluvial deposits.
1988	The density of vegetation has increased on the cut slope face above the access road, but the extent of vegetation growth has not changed significantly.
1989	Both the density and extent of vegetation growth have increased on the cut slope face. Vegetation now covers most of the cut slope below the subtle depression and the upper three batters in the northwest portion of the slope. There is also a clear preferential vegetation growth pattern along northwest-southeast striking geological photolineaments (same orientation as noted on 1964 photographs).
1990	As above. The platform for Keymount Lodge of Sunny Villa Apartments is under construction.
1991	Vegetation more dense on cut slope. Keymount Lodge has been constructed.
1992	The crest channel is now mostly obscured by vegetation. As previously noted, the vegetation appears to be more dense below the subtle depression.
1994	Vegetation slightly denser and more widespread on the cut slope face.
1995	As above
1996	Vegetation appears to be densest within and to the west of the 1998 landslide site.
1998	Crest channel mostly obscured despite lower, seasonal vegetation cover.

A5. PHOTOGRAPHS

The following table lists the photographs used in the interpretation.

DATE	NUMBER	FLYING HEIGHT (Feet)
1924	Y122	?
31.01.63	Y8916 Y8917	3900
16.12.64	Y11081 Y11082 Y11083	2700
1967	Y13469	3900
1969	Y15369 Y15370	1370
1972	1727 1728 1729	?
1976	13212 13213 13214	4000
12.12.77	20060 20061	4000
07.12.78	24037 24038	4000

DATE	NUMBER	FLYING HEIGHT (Feet)
27.11.81	36289 36290	4000
28.07.82	43114 43115	3000
02.10.85	67626 67627	4000
22.09.86	A5730 A5731	4000
04.10.87	A10523 A10524	4000
10.10.88	70306 70307	4000
09.09.89	A18350 A18351	4000
21.03.90	A20979 A20980	4000
1991	A27580 A27581	?
13.05.92	A31215 A31216	4000
09.07.93	A35345 A35346	4000
02.11.93	A35992 A35993	4000
06.05.94	A38171 A38172	5000
08.11.94	A39949 A39950	4000
26.09.95	CN11112 CN11113	3500
14.11.96	CN15759 CN15760	4000
16.12.96	CN14259 CN14260	4000
05.03.98	CN19516 CN19517	4000

A6. CONCLUSIONS

Between 1981 and 1982 an access road connecting Castle Peak Road to Sunny Villa Apartments was formed mainly by cutting through natural terrain between Tuen Mun Road and Castle Peak Road.

Cut slope No. 6SE-D/C304 comprised 3 to 5 batter slopes divided by drainage berms. The formation of the south-facing slope closely followed the natural terrain morphology producing two high cut slopes essentially through insitu, though variably weathered material, separated by a lower cut below a subtle depression associated with possible colluvial deposits. The cut slopes were designed with a crest drain installed a few metres above the top of the cut slope within the natural terrain. A further 5 to 6 stepped U-channels were installed to take the water from the berm and crest drains.

The growth of vegetation on the cut slope surface following the formation of the cut slope suggests a weathered soil/rock profile inclined towards the subtle depression between the higher portions of the cut slope. The groundwater flow will tend to follow the weathered soil/rock profile towards the depression.

Between its formation in 1982 and March 1998 the cut slope does not appear to have been affected by significant instability, and there is no clear evidence for seepage. During this period vegetation appeared to be present within the majority of the surface drains suggesting a lack of slope maintenance.

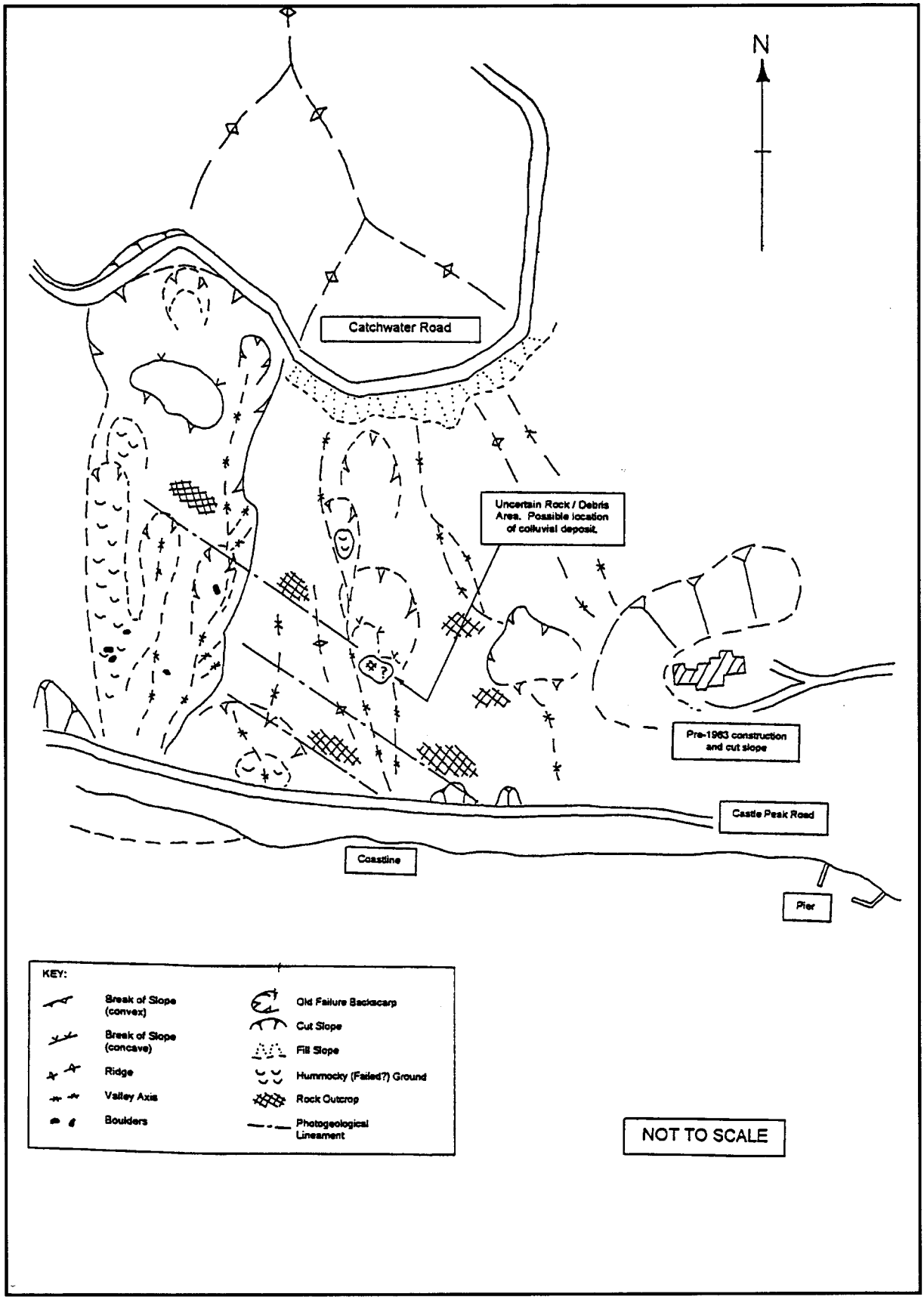


Figure A1 – Aerial Photograph Interpretation (API) from 1964 photographs

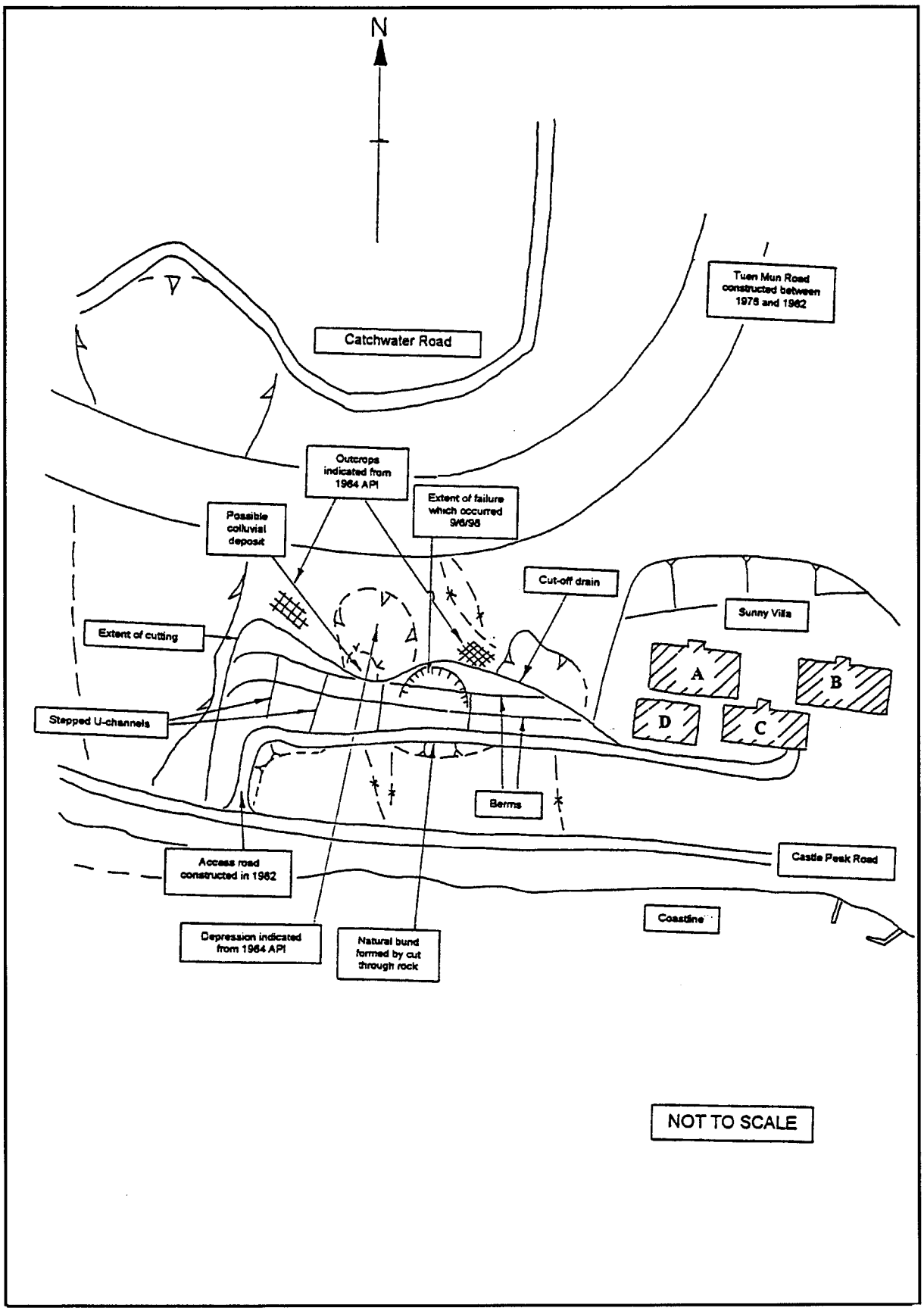
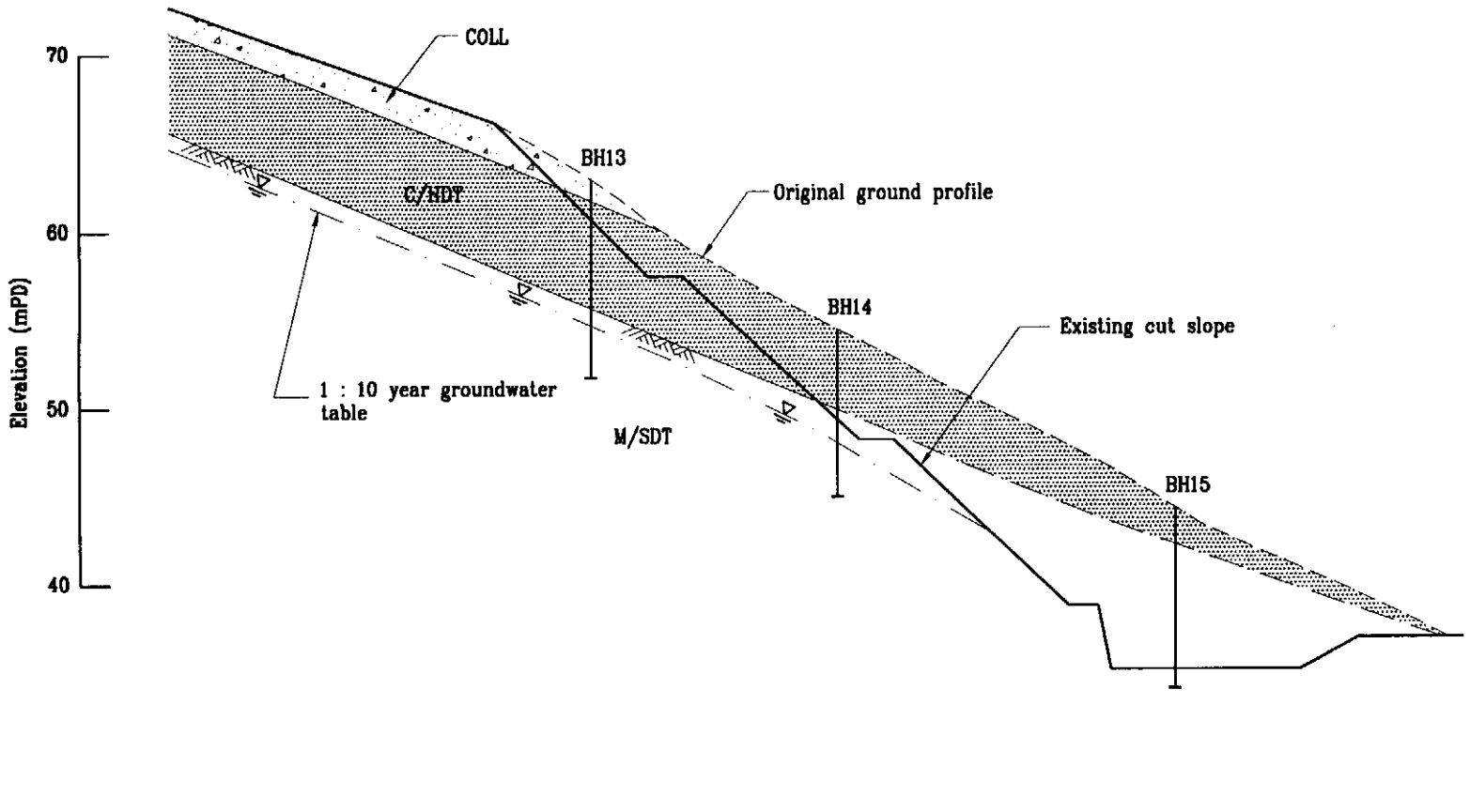


Figure A2 – Aerial Photograph Interpretation (API) from 1982 and 1996 photographs incorporating the salient geomorphological features from Figure A1

APPENDIX B

INFERRED GEOLOGICAL CONDITIONS AND GROUNDWATER TABLE AT CROSS-SECTION Y-Y



Legend : COLL Colluvium
C/HDT Completely to Highly Decomposed Tuff
M/SDT Moderately to Slightly Decomposed Tuff
— ▽ — Groundwater Level

Note : Information shown in this figure is based on drawing No. ESA/8000/02/14 of the Geotechnical Report dated 11 June 1980 prepared by ESA.

Inferred Geological Conditions and Groundwater Table at Cross-section Y-Y