INVESTIGATION OF SOME SELECTED LANDSLIDES IN 1998 (VOLUME 5)

GEO REPORT No. 112

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 two 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 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 SLOPE DISTRESS AT QUEEN'S HILL, BURMA LINES CAMP, FANLING

Fugro Scott Wilson Joint Venture

This report was originally produced in September 1999 as GEO Landslide Study Report No. LSR 10/99

FOREWORD

This report presents the findings of a detailed study of an area of instability in the natural terrain at Queen's Hill, Burma Lines Camp, Fanling. Instability in the form of localised landslides, tension cracks and disturbed ground were identified in December 1997 during upgrading works to Slope No. 3SW-B/C12 under the Landslip Preventive Measures (LPM) Programme. Two low-rise accommodation blocks at the toe of the slope were evacuated as a precautionary measure following recommendations made by the Geotechnical Engineering Office (GEO) in March 1998, with another two blocks being evacuated following further recommendations by the GEO in September 1998. There have been no casualties as a result of the observed instability.

The key objectives of the detailed study were to document the facts relating to the instability, present relevant background information and establish the probable causes of distress. The scope of the study involved site inspections, desk study, limited ground investigation and laboratory testing, 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 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 M Hughes 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

In December 1997, instability in the form of tension cracks, disturbed ground and localised landslips were identified in the natural terrain at Queen's Hill, Burma Lines Camp, Fanling, during upgrading works to Slope No. 3SW-B/C12, on the southern side of the hillside, under the Landslip Preventive Measures (LPM) Programme (Figure 1 and Plates 1 to 4). Two low-rise accommodation blocks at the toe of the slope were evacuated in March 1998 as a precautionary measure following recommendations made by the Geotechnical Engineering Office (GEO), and two more blocks were evacuated in September 1998. There have been no casualties as a result of the instability.

Following the identification of the signs of distress, Fugro Scott Wilson Joint Venture (FSW), the 1998 Landslide Investigation Consultants, commenced a study of the hillside for the GEO under Agreement No. CE 74/97. This is one of a series of reports produced during the consultancy by FSW.

The key objectives of the detailed study were to document the facts about the instability, present relevant background information and establish the probable causes of the distress. The scope of the study included site inspections, desk study, limited ground investigation as well as laboratory testing and stability analysis. Recommendations for follow-up actions are reported separately.

This report presents the findings of the study, which comprised the following key tasks:

(a) desk study, including a review of documentary records relating to the history of the site,

(b) aerial photograph interpretation (API),

(c) topographic survey, geological and geomorphological mapping and detailed observations and measurements along the hillside,

(d) limited ground investigation and laboratory testing,

(e) engineering analyses of the distressed hillside, and

(f) diagnosis of the probable causes of distress.

2. THE SITE

2.1 Site Description

The site comprises an area of unstable ground on the south-facing natural terrain of Queen's Hill, which lies on the edge of the Pat Sin Leng Country Park, Fanling (Figure 1). The instability potentially threatens a number of residential buildings within Burma Lines Camp, located at the base of the hillside (Figure 2).

The concerned natural terrain stands at an angle of between 25° and 35° (Figures 3 to 7). Two cut slopes, Nos. 3SW-B/C12 and 3SW-B/C242, have been formed at the base of the hillside to make room for a number of low-rise accommodation blocks (Block Nos. 13 to 15 and Block No. 17 respectively). These cut slopes have been formed roughly parallel to the direction of the main east to west trending ridgeline. The larger of the two cut slopes, No. 3SW-B/C12, is approximately 120 m long and comprises a steep (60°) lower batter with a maximum height of about 10 m, above which rises a shallower section, typically between 30° and 35°, that extends upslope for a distance of about 40 m. The smaller cut slope, No. 3SW-B/C242, is approximately 30 m long and 3.5 m high and stands at an angle of 70° to the horizontal. Between the two cut slopes a fill slope, No. 3SW-B/F30, has been formed to support the southeastern corner of Block 17. This slope is approximately 25 m long and about 3.5 m high and stands at an angle of about 30° to the horizontal. Slope Nos. 3SW-B/C12 and 3SW-B/F30 are both protected by shotcrete, while Slope No. 3SW-B/C242 is unprotected and in a poor condition with some localised signs of distress.

There is a prominent shallow depression on the western flank of the study area above Blocks 15 and 17. The mid to lower portion of this depression is where signs of instability were identified in December 1997. This area has since been covered with shotcrete (Figure 2 and Plate 2).

Another, less prominent, depression descends the hillside on the eastern flank of the study area. In the vicinity of this depression are two apparently recent landslide scars and an area of disturbed ground with tension cracks (Figure 2).

According to the "Systematic Identification of Maintenance Responsibility of Slopes in the Territory" (SIMAR) project undertaken by the Lands Department, the maintenance responsibility of both cut slopes and the fill slope lies with the Government Property Administrator. The District Lands Office (DLO) has advised that the natural terrain above the cut slopes lies within unallocated Government land.

2.2 Water-carrying Services

Private and Government utility owners were contacted for details of their installations. This revealed that no water-carrying services are present in the vicinity of the unstable area.

2.3 Site History

2.3.1 General

The history of development at the site has been determined from an interpretation of a series of aerial photographs (Table 1) as well as a review of the relevant available documentary records. The locations of the features referred to in this section are shown in Figures 8, 9 and 10.

2.3.2 History of Development

The earliest available photographs, taken in 1924, show that the study area comprises natural terrain. Burma Lines Camp (BLC) and the cut slopes at the base of Queen's Hill have not yet been formed. A number of depressions, interpreted as relict landslide scars, are present on the northern side of the ridgeline indicating a history of instability (Figure 8).

South of the ridgeline, a number of shallower and less pronounced depressions are observed. These are also interpreted as relict landslide scars. The westernmost depression, which is located behind Blocks 15 and 17, BLC, is about 15 m to 20 m wide, and appears to narrow at its mid-point giving it an hourglass plan shape. An ephemeral drainage line is thought to traverse this depression. Two smaller semi-circular depressions, about 5 m to 10 m wide respectively, are evident on the lower eastern side of this depression, above the area where Block 14 is currently located (Figure 9). These depressions are located next to each other and a broad (20 m to 25 m) fan-shaped deposit is evident further downslope. The lower edges of the fan are of a lighter shade than the adjacent hillside giving the impression that this is an area of recently disturbed ground. An area of apparently disturbed ground, approximately 30 m wide, is located at the northeastern corner of the study area above Block 13 (Figures 8 and 9).

The 1961 photographs show site formation works for the residential blocks of Burma Lines Camp in progress. The cut slopes, Nos. 3SW-B/C12 and 3SW-B/C242, and fill slope, No. 3SW-B/F30, were under construction at this time. Two laterally persistent linear features, approximately 120 m long, can be seen traversing the hillside in a direction roughly parallel to the ridgeline of Queen's Hill (Figure 9). These linear features form the upper and lower boundaries respectively to the relict instability noted within the upper part of the westernmost depression on the 1924 aerial photographs. These lines could represent the surface expression of instability across the hillside, possibly in the form of tension cracks and/or sharp breaks in the slope profile.

There is little change in the 1964 photographs, except for a series of regular, narrowly spaced linear features present towards the mid to lower portion of the hillside. These lines span the concerned hillside. A break in slope observed below the rounded ridgeline on these photographs appears to delineate approximately the upslope limit of instability on the hillside and may also represent the upslope limit of colluvium. Furthermore, a narrow discontinuous linear depression can be seen along the ridgeline of Queen's Hill (Figure 8), which has been identified on site as a series of man-made trenches.

The next noticeable change in the appearance of the hillside is in 1978, when areas of disturbed ground are apparent in the natural hillside above Blocks 13 and 14. The area of disturbed ground above Block 14 occurs adjacent to the two semi-circular features identified from the 1924 photographs.

In 1982 a prominent landslide scar is evident in the natural hillside to the northeast of Block 13. This semi-circular failure scar is about 10 m to 15 m wide and occurs in the vicinity of the scar identified on site by GEO in December 1997.

The next set of photographs, taken in 1984, show indications of instability in the natural terrain above the cut slopes. In the lower part of the depression above Blocks 15 and 17, an area of disturbed ground is visible and what appear to be tension cracks are evident along the upper eastern side. The laterally persistent lines seen crossing the hillside in the 1961 photographs are visible as are other similar linear features. The number and spacing of these lines possibly suggest "terracetting" across the hillside, i.e. shallow "creep-like" movement rather than deeper-seated instability. The shallow, semi-circular failure scar first noted on the 1982 aerial photographs is still evident to the northeast of Block 13. Above this feature a subtle depression can be seen descending from the ridgeline towards the crown of the landslide scar (Figure 9). Also evident across the hillside are areas of broken vegetation that appear to be disturbed ground, which could be possible indications of past and/or ongoing instability.

It is noticeable that the vegetation across the gully area above Blocks 15 and 17, which appears to comprise a light covering of grass, is distinctly different from that of the adjoining areas where the vegetation is denser and appears to comprise shrubs and small trees. This may indicate an area where movement is ongoing, thereby preventing the root systems of deeper-seated vegetation from establishing.

Between 1984 and 1992 there is little change in the appearance of the study area, except that there are more linear features across the natural terrain providing further indications of possible instability. Also, it appears that new surface protection has been applied to Slope No. 3SW-B/C12 (1988).

In the November 1993 photographs, there is an L-shaped failure scar close to the eastern boundary of the area of apparently disturbed ground identified on the 1924 aerial photographs. The mainscarp is quite linear, and runs roughly parallel to and directly below the laterally persistent linear feature that was first identified in the 1964 photographs.

The 1994 aerial photographs show that Slope No. 3SW-B/C12 has been extended further upslope by approximately 20 m. These modifications may be a result of remedial action following landslides in the natural terrain above the crest of the cut slope in October 1993 (Section 2.4).

In the October 1996 photographs, a large failure scar is evident to the north of the ridgeline, approximately coincident with the relict landslide scar to the north of Block 17 (Figure 8). The landslide is approximately 20 m wide and the debris trail extends downslope for about 100 m. The only visible change within the study area is that three slope strips are visible within the limits of Slope No. 3SW-B/C12.

No significant changes are evident within the study area in the 1997 aerial photographs, but in the May 1998 photographs it is evident that Slope No. 3SW-B/C12 has been further extended upslope by about 10 m to 15 m (Figures 9 and 10). Additionally, an area to the northeast of Block 13, and approximately coincident with the landslide scar identified in the 1982 photographs, has received a shotcrete covering. These photographs also show that the shallow depression above Blocks 15 and 17 has been cleared of vegetation.

The above observations are consistent with desk study records that show that Slope No. 3SW-B/C12 was modified as part of the LPM Programme under a Schedule of Rates Contract (No. GE/95/14), which commenced in late 1997. Under this contract the surface and sub-surface drainage of Slope No. 3SW-B/C12 was improved. Prescriptive soil nails were also installed at the locally steep cut slope behind Block 15 during the LPM works. During these works, signs of instability were noted in the natural hillside above the cut slope. These included several tension cracks in excess of 20 m long and various other indications of ground movement, including a past failure scar in the depression above Blocks 15 and 17, as well as a larger more prominent scar to the northeast of Block 13. As a result of these findings trial pitting and ground clearance works in addition to those proposed under the LPM contract were undertaken. Following these works areas of the hillside, including a large portion of the depression behind Blocks 15 and 17 and the failure scar to the northeast of Block 13, were cleared of vegetation and covered by shotcrete and limited additional surface water drainage provisions were installed. Soil nails and horizontal drains were also installed locally in the failure scar to the northeast of Block 13.

Due to the observed distress in the natural hillside Blocks 13 to 15 and Block 17 at the toe of the slopes are presently unoccupied. Also, the site is pending future development.

2.3.3 Previous Recorded Landslides

GEO's landslide database contains records of a 200 m^3 landslide (Incident No. ME 93/10/18), reported to have occurred on 26 September 1993, along the crest of Slope No. 3SW-B/C12, immediately behind Blocks 13 and 14. The incident involved two separate landslides that occurred adjacent to each other, but which were recorded as a single incident on the Incident Report (Figure 10). The smaller of the two landslides had a width of about 20 m and was located directly behind Block 14, whilst the larger landslide had a width of about 25 m and was located directly above Block 13. The failures were described as occurring in "colluvium stratum which is believed to be overlying CDV" and stated that "Perched water might be the possible cause of failure". The failure scars affected primarily the natural terrain and parts of the upper portion of Slope No. 3SW-B/C12. Slope No. 3SW-B/C12 was subsequently included in the 1995/96 LPM Programme.

GEO's Natural Terrain Landslide Inventory (NTLI) (Evans et al, 1997), indicates four previous landslides along the southern slopes of Queen's Hill and another along the eastern slopes. These failures were also identified during the API and field mapping for the current study, one of which is to the northeast of Block 13 (Figure 1).

2.4 Previous Inspections and Studies

Slope Nos. 3SW-B/C12, 3SW-B/C242 and 3SW-B/F30 were not registered in the 1977/78 Catalogue of Slopes.

The Geotechnical Control Office's (GCO, renamed as GEO in 1991) Geotechnical Area Studies Programme (GASP) Report V, North New Territories (GCO, 1988), produced at a scale of 1:20 000 for regional appraisal and outline and strategic planning purposes, designated the terrain in the vicinity of the distressed area as of moderate, high and extreme geotechnical limitation. In addition, a zone of general instability "associated predominantly with colluvial terrain" was noted on the western flank of the concerned hillside.

In mid-1992, the GEO initiated the consultancy agreement, entitled "Systematic

Inspection of Features in the Territory" (SIFT), to search systematically for features not included in the 1977/78 Catalogue of Slopes and to update information on previously registered features, based on studies of aerial photographs and limited site inspections. The two cut slopes were categorised as Class "C1" whilst the fill slope was assigned to Class "B1", i.e. all features having "been formed or substantially modified before 30th June 1978".

In June 1994, the Design Division of the GEO completed a Stage 1 Study for Slope No. 3SW-B/C12. The subsequent report noted that "The slope is covered with shotcrete. No signs of seepage were seen", but signs of distress and slip scars were recorded and recommendations for further study were made.

In May 1997, the Design Division of the GEO made a geotechnical submission for Stage 3 Study on Slope No. 3SW-B/C12 to the Mainland East Division of the GEO. The study comprised a detailed stability assessment based on two cross-sections. Ground investigation, comprising two trial pits and three chunam strips, was undertaken to assess the depth and nature of the slope-forming materials. This revealed that typically 2 m of colluvium was underlain by completely and moderately decomposed coarse ash crystal tuff (CDT and MDT respectively).

Shear strength parameters of $c' = 5$ kPa, $\phi' = 33^o$ and $c' = 6$ kPa and $\phi' = 36^o$ were adopted for the colluvium and CDT respectively. Parameters for CDT were determined from the results of laboratory tests undertaken on similar materials obtained during a ground investigation at a site approximately 250 m northwest of Slope No. 3SW-B/C12 in 1979. Parameters for colluvium were the average typical values given in Table 8 of GEO (1993).

It was also noted in the report that the 1993 failure of Slope No. 3SW-B/C12 appeared "to be caused by infiltration, which formed a perched water table at the colluvium/tuff interface". When assessing the stability of cross-section 2-2, a perched water table was modelled to consider failure within colluvium. For cross-section 3-3, the water table was assumed to be below the colluvium/tuff interface.

Furthermore, the report states that "The geology of the site as interpreted from the ground investigation is shown in Sections 2-2 and 3-3 ...". However the thickness of the colluvium shown in cross-section 2-2 increased from about 1.5 m at the crest of the cut slope to about 6 m some 40 m upslope and for cross-section 3-3, the colluvium was shown to increase from essentially nothing at the crest of the slope to about 4 m some 40 m upslope. The upslope thickness' would appear to be at odds with the GI information. The assumed geological model for the hillside above the cut slope was based on inference from the results of ground investigation carried out on Slope No. 3SW-B/C12.

No back analysis of the past failure was carried out. The report concluded that "both sections have a minimum FOS of 1.2 under wet conditions" as well as noting that the "slope has a Factor of Safety above the required standard and upgrading works are only necessary to improve the surface and sub-surface drainage in order to maintain the margin of safety". The recommended upgrading works included "minor trimming around the slope, installation of (2.5 m deep) cut off drains and (10 m long) raking drains in the colluvial layer, and the reconstruction of the deteriorated sprayed concrete surface protection".

An API was carried out by Scott Wilson Kirkpatrick and Partners on behalf of the

GEO in 1995 as part of the Stage 3 Study. The API, which was based on the limited number of photographs available at that time, identified possible localised instability in the immediate vicinity of Slope No. 3SW-B/C12 in 1984, 1986 and 1990, but did not record any signs of instability within the natural terrain above the cut slope. The report recommended that "a further API study is carried out if further photographs become available" as the photographs covering the period "between 1924 and 1984 were not available for this API report. During this time there were considerable changes within the area of interest which may affect the accuracy of this API".

A memo dated 16 May 1997 from the Mainland East Division to the Design Division noted that "The report concludes that the slope is up to current geotechnical standards (i.e. FOS > 1.2) and no upgrading works are necessary. However, the slope failure on 19.10.93, which involves about 200 m^3 of debris, implies that the minimum factor of safety of the slope should be below or equal to1.0". The memo also noted that soil strengths used in the stability analysis were derived from test results for a nearby site and stated that "It is advisable to carry out sensitivity analysis to determine the effect of any variation in strength parameters and groundwater conditions on the results of analysis".

The Design Division responded in a memo dated 24 June 1997 stating that "The factor of safety of slip surfaces emerging at the toe are in excess of 1.2 and no upgrading are necessary for such surfaces. However, there is concern that failures within the colluvial layer may continue to occur if a perched water table forms within this layer". Regarding the strength parameters, the Design Division commented that "The soil strength parameters from the nearby site are in similar material and are within the mid-range of typical values for CDV" and that "It is not considered necessary to do a sensitivity analysis for the dry slope condition". For failures in the natural hillside the Design Division stated in their "DESIGN ASSUMPTIONS & METHODOLOGY" attached with the memo that "The improvement to existing stability on the natural slope above the existing failure scar is considered only to the extent that they could conceivably affect the buildings at the toe. Failure in the natural slope above this are unlikely to affect the buildings". Attached with the memo were design calculations estimating the theoretical improvement in stability due to the installation of a cut-off drain at the crest of the cut slope. During construction the cut-off drain was replaced by 2 rows of raking drains at the request of Works Division.

In July 1994, the GEO initiated the 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 the area on 26 June 1997. Slope No. 3SW-B/C12 was identified as being in a fair condition with only "minor" signs of distress (based on a grading system comprising the categories "severe", "reasonable", "minor" and "none"). Seepage was, however, noted within the slope.

3. DESCRIPTION OF THE DISTRESS

Based on API and site observations, it is evident that instability, comprising widespread ground distress in conjunction with discrete localised landslides, has been ongoing on the hillside for many years (API indicates signs of instability as early as 1924). Cross-sections of the site are shown in Figures 3 to 7 whilst details of the field mapping are presented in Figures 11 and 12.

The natural terrain within the study area is moderately sloping (25^{o} to 35^{o}), with a series of concave and convex breaks of slope. These comprise several prominent breaks as well as a greater number of smaller less obvious breaks that give the hillside a generally hummocky appearance. The prominent breaks of slope (Plate 5) form laterally persistent bands across the hillside and appear to occur where bedrock (taken to be Grade III or better rock) outcrops at the ground surface. The smaller less obvious breaks of slope are narrowly-spaced and occur with increasing frequency towards the base of the hillside (Plate 6).

Along the western side of the study area, above Blocks 15 and 17, a shallow depression descends from the ridgeline. This depression, which would appear to form an ephemeral drainage line, has an undulating profile with several rounded convex features and some localised sharp breaks of slope (Plates 7 and 8). Signs of instability were identified by the Design Division during the LPM works in December 1997 in the mid to lower portion of this depression. A prominent failure scar, approximately 25 m long, and disturbed ground with tension cracks are present along the upper eastern side of the depression (Plates 9 and 10). A maximum vertical displacement of about 1 m was evident at the western end of the feature. The material exposed in the backscar comprises colluvium, which had some vegetation growing from it indicating that the failure was at least a few years old.

Much of the depression was covered by mesh reinforced shotcrete following the observation of distress in this area during the LPM works. Site inspections undertaken by FSW in August 1998 noted cracks through the shotcrete (that was applied to the unstable portion of the depression in about May/June 1998). In general these are hairline cracks, but over the mid to upper eastern side of the depression, below the prominent backscar, the hairline cracks have developed into 2 mm to 3 mm wide cracks, which indicates possible continued movement in this locality.

Another less prominent depression, which also appears to form an ephemeral drainage line, descends the eastern side of the hillside. In the vicinity of this depression are two landslide scars and disturbed ground with tension cracks (Plates 4, 11 and 12). The crown of the northernmost landslide scar lies approximately 15 m to 20 m downslope from the ridgeline and occurs in the vicinity of one of the prominent breaks in slope observed across the hillside. The scar is approximately L-shaped in plan with the landslide backscarp, which runs roughly parallel to the ridgeline, being about 20 m long, and varying in height up to a maximum of about 2.5 m. The estimated volume of this failure is of the order of 150 m^3 to 200 m^3. A layer of colluvium of variable thickness overlying highly and highly to moderately decomposed tuff is exposed in the mainscarp. The corresponding debris trail extends downslope for a distance of about 25 m (Plates 11 and 13). The profile of the debris trail appears to have been accentuated by erosion.

The second failure scar is located further downslope and was identified during the LPM works to Slope No. 3SW-B/C12 (Plate 4). This scar is about 10 m to 15 m wide with a semi-circular plan profile, and has been covered with shotcrete and surface water drainage provided. In addition, soil nails and raking drains have been installed locally in the landslide scar.

The volume of the unstable section of the southern hillside investigated in this study is estimated to be between 1 500 m^3 and 2 000 m^3.

Both cut slope No. 3SW-B/C12 and fill slope No. 3SW-B/F30 appear to be in good condition based on the visual inspection of the shotcreted slope surface by FSW, but the 3.6 m high cut slope above Block 17 (No. 3SW-B/C242) is in a poor condition with no surface protection covering the slope and localised detachments from the slope surface. Also, the northerly upstand of the crest channel of this cut slope has failed over approximately a 10 m-long length, indicating ground movement (Figure 2).

Evidence of instability is also present to the east of the study area as well as over the northern side of Queen's Hill. This takes the form of recent landslides and tension cracks within relict landslide scars (Figure 11 and Plates 14 to 18). Observations on site suggest that this instability involves a thin colluvial layer sliding on top of the underlying decomposed tuff.

Recent hillfires (April 1999) across Queen's Hill have exposed some of the tension cracking, sharp breaks of slope and relict landslides observed during the API for the current study. Also, several discontinuous man-made trenches were observed along the ridgeline of Queen's Hill (Figure 8 and Plate 19). These occur in sections of varying length covering an overall distance of about 50 m and are between 0.65 m and 1.45 m deep, and 0.65 m and 2.3 m wide. There are also other smaller isolated man-made trenches elsewhere across the hillside. There is no apparent relationship between the trenches and the extensive instability identified across the hillside, although ponding within the trenches could have locally affected the stability of the hillside.

4. SUBSURFACE CONDITIONS

4.1 Geology

The Hong Kong Geological Survey Memoir 5 (Lai et al, 1996) indicates that the local geology of the area comprises slightly metamorphosed coarse ash crystal tuff of the Tai Mo Shan formation of the Tsuen Wan Volcanic Group (Figure 13). No geological structures are shown as crossing the study area, but foliations within the bedrock are shown to dip in a northwesterly direction (into the slope) at angles of between 40° and 50°.

4.2 Previous Ground Investigations

A plan showing the location of previous ground investigation works is presented in Figure 14.

Ground investigation works, comprising two shallow trial pits and three chunam strips, were carried out during March and April 1996 as part of the Stage 3 Study for Slope No. 3SW-B/C12. Colluvium, typically 1.6 m to 1.8 m deep, overlying moderately decomposed coarse ash crystal tuff, was encountered in both trial pits whilst colluvium and completely decomposed tuff were encountered in the three chunam strips excavated down the cut face.

More extensive works, comprising fifteen trial pits, were undertaken following the discovery of instability along the hillside in December 1997 during the LPM works. These works were located predominantly in areas where signs of instability were evident, namely along the shallow depression behind Blocks 15 and 17 on the western side of the study area. Typically, colluvium between 0.5 m and 1 m thick was found to overlie residual soil of varying thickness, which in turn was underlain by completely decomposed tuff (CDT). Fill material was also encountered locally towards the base of the depression. Cracking and voids were identified in the following trial pits:

(a) TP2 - about a 1 m long crack was seen to extend from the ground surface to a shallow depth (less than 0.5 m) within the colluvium in the western and eastern faces of the trial pit. No width to the crack was specified,

(b) TP3 - about a 1 m long and 50 mm to 200 mm wide crack was seen to extend from the ground surface at a shallow depth (less than 0.5 m) through the colluvium towards the base of a collapsed upstand to a drainage channel above which the trial pit had been excavated,

(c) TP6 - a short 150 mm to 200 mm wide crack was noted in the western and eastern faces of the trial pit extending from the ground surface to a shallow depth (less than 0.5 m) within the colluvium layer,

(d) TP8 - about a 0.5 m long and 25 mm wide crack was noted in the eastern face of the trial pit at a depth of between 0.8 m and 1.0 m, roughly along the interface between the colluvium and the underlying tuff,

(e) TP9 - about a 1 m long and 15 mm crack was noted in the eastern face of the trial pit running through the CDV and arcing up into the colluvium layer where it merged with a 300 mm wide void just below the ground surface at the downslope end of the trial pit,

(f) TP14 - Voids between 65 mm to 200 mm wide and cracking between 20 mm and 100 mm were noted at the ground surface to a depth of about 0.7 m within the colluvium and in the upper layer of the tuff in all faces of the trial pit. These formed a continuation of an open crack, about 100 mm to 200 mm wide, immediately above the upper northern face of the trial pit, and

(g) TP15 - a single main crack between 150 mm to 200 mm wide was identified in the western and eastern faces of the trial pit, which was excavated across an existing open crack at the ground surface. The crack had an overall length of about 1.2 m and descended through the colluvium into the underlying tuff. Several smaller cracks and voids up to 200 mm wide were noted in the western face of the trial pit.

Insitu density tests were carried out in the majority of the trial pits, with compaction tests being performed on bulk samples taken at these depths. The results showed that the insitu dry density of the colluvium layer ranged from 1.17 Mg/m^3 to 1.73 Mg/m^3 (with a mean of about 1.5 Mg/m^3), while relative compactions varied between 74% and 99%, with a mean of about 84% (Table 2). No distinction was made between upper and lower layers of colluvium as identified under the current investigation (Section 4.3). The CDT had a dry density varying from 1.46 Mg/m^3 to 1.91 Mg/m^3 (with a mean of about 1.7 Mg/m^3).

4.3 Current Investigation

4.3.1 Field Mapping

Six strips of hillside within the site (S1 to S6) were cleared of vegetation in September 1998 to allow a closer inspection of the ground profile. S1 was undertaken along the prominent failure scar at the upper eastern side of the depression above Blocks 15 and 17. The remaining five were cut downslope from the ridgeline at intervals of approximately 30 m across the hillside (Figure 14 and Plate 1). Based on information arising from these clearance works it was also decided to clear the vegetation on the hillside between strips S4 and S5 along the eastern side of the site.

Following clearance works, detailed field mapping and a topographic survey were undertaken to identify the locations of past failures, tension cracks and sharp breaks of slope along the hillside, as well as to plot details of rock outcrops to establish whether there was a relationship between these features. The field mapping revealed a pervasive cover of colluvium over much of the hillside. Over the upper portion of the hillside, approximately 15 m downslope from the ridgeline, moderately decomposed tuff (MDT) was exposed in a relatively persistent continuous exposure across the study area forming a convex break of slope below which the ground profile was locally steeper (Figure 14). Further downslope another laterally persistent outcrop of MDT was observed but the area of exposed MDT was much greater towards the southeastern portion of the hillside. This MDT outcrop also formed a convex break of slope beneath which the ground profile was locally steeper. The lateral extent and alignment of these exposures were consistent with observations made from the API.

It was noted that the surface of the outcropping bedrock was heavily iron stained and had a 'baked' appearance. The staining had penetrated the surface of the rock by about 10 mm, forming a hardened outer layer (Plate 20). When holding a rock sample in the hand it appeared heavy, suggesting that these rocks were iron rich. Also, a distinct foliation was visible within the fabric of the exposed material that dipped at an angle of between 35^o and 55^o into the slope in a northwesterly direction (Section 4.1).

Mapping of the landslide scar over the upper eastern portion of the study area identified colluvium in the backscar, generally at least 1 m thick, but locally thinner or absent where the underlying tuff was near (or at) the surface. Measurements within the exposed tuff identified a number of joints. In particular, a smooth undulating locally persistent joint plane dipping in a southeasterly direction at an angle of between 50^o and 65^o was prominent in the backscar and elsewhere across the hillside (Plate 21)

4.3.2 Ground Investigation Fieldwork

Investigative works comprising one trial pit, eight trial trenches, instrumentation and field and laboratory testing were undertaken between March and April 1999 as part of the current study. Trial trenches TT1, TT2, TT8 and TT9 were located along the prominent backscars, while trial pit TP7 and the remaining trial trenches were located within areas of hummocky ground or at sharp breaks in the ground profile (Figure 14). Detailed logs are included in Appendix A.

This investigation encountered colluvium, overlying fine to coarse ash crystal meta-tuff (Section 4.1). Zones of residual soil were also identified at the boundary between the colluvium and tuff.

The colluvium was typically between 1 m and 1.5 m thick along the upper portion of the hillside (trial trenches TT1, TT2, TT8 and TT9), where the underlying tuff comprised extremely weak, pale pinkish grey, spotted red brown, stained yellow and orangish brown near discontinuity surfaces, completely and completely to highly decomposed fine to coarse ash crystal tuff (CDT and C-HDT respectively). Further downslope the colluvium was thinner, typically between 0.5 m and 1 m thick, and was underlain by weak to moderately weak, pinkish grey, spotted red brown, highly to moderately and moderately decomposed fine to coarse ash crystal tuff (H-MDT and MDT respectively), with localised areas of more decomposed material. Tuff-derived residual soil was encountered in most of the trial excavations, being typically described as a firm, orangish brown, mottled red, slightly sandy clayey silt with some fine to medium gravel of moderately (typically) decomposed tuff.

Measurements within the tuff revealed a variety of medium to closely-spaced joint sets at different orientations. In particular, an undulating joint set dipping in a southeasterly direction at an angle between 50^o and 80^o was common in all the trial excavations (Plate 22). This joint set was also exposed in the backscar at the northeastern corner of the study area and in exposures elsewhere across the hillside (Figure 12). In the trial excavations, this joint plane was generally interrupted by other joints to give the surface of the tuff a stepped profile, but in trial trench TT5 and to a lesser extent TT6, a relatively continuous plane dipped adversely out of the slope (Plate 22).

On inspection of the CDT and C-HDT, it was evident that the rock had a slightly porous texture, with certain minerals having been leached out (i.e. eluviation) leaving open pores. In some of the pores the material around the inside of the pore had decomposed to a clayey silt. This localised decomposition is believed to have led to adjacent pores "collapsing" into each other, thereby increasing the pore size, this process possibly resulting in the formation of erosion pipes with time. This porous texture was also observed within the outcrops across the hillside, but was not obvious in the H-MDT and MDT within the trial excavations.

In line with observations made during detailed mapping, a distinct foliation was visible within the fabric of the less decomposed tuff that dipped at a similar angle and direction into the slope, as observed in the surface exposures. In trial trench TT4 a block of tuff could be identified where the foliation dipped at a shallower angle into the slope (Figure 15). Either side of this block were apparent joint openings that were filled by a combination of colluvium and intact rock fragments, suggesting a locally disturbed zone.

Localised quartz and iron rich veins dipping into the slope at a similar angle and direction as the foliation were also evident within the fabric of the tuff. These formed less decomposed bands within the tuff and residual soil layers. In some of the trial excavations it was noticeable that the dip of these veins flattened towards the boundary of the tuff and colluvium (Figure 16), suggesting a disturbed interface where movement had occurred (Section 4.4).

The colluvium identified on site could be categorised into two types, forming an upper and lower layer respectively, which were both present to varying degrees within all the trial excavations (see also Section 4.4). Based on field observations the upper layer generally contained more fines (including a higher clay content), whilst the lower layer was more gravelly. Limited laboratory testing confirmed the visual observations as discussed in Section 4.3.3.

The upper layer generally comprised a desiccated, loose, pale brownish yellow, slightly sandy, slightly gravelly, clayey to very clayey silt with occasional boulders of moderately decomposed fine to coarse ash crystal tuff, and occasional to some angular to subangular cobbles of highly to completely decomposed tuff (Plate 23). This layer was encountered directly below the ground surface and contained many rootlets. Its colour graded to a darker greyish brown towards the surface, which may represent a gradation to an immature topsoil layer. In trial trenches TT5 and TT6, this material occurred as a "lobe" overlying the lower colluvium (Plate 24). It also was seen forming a "lobe" directly above outcrops of bedrock across the study area (Plate 25). The thickness of this upper colluvial layer was generally greater over the western portion of the site, where it was between 0.4 m and 0.6 m, as identified in trial trenches TT1 and TT2 respectively. Over the central and eastern portions of the site the upper colluvial layer was thinner, being typically between 0.1 m and 0.3 m thick.

The lower colluvium layer comprised a slightly moist, visually more compact, orangish brown, slightly sandy, slightly gravelly to gravelly, clayey silt with some subangular cobbles of highly to completely decomposed fine to coarse ash crystal tuff, and some angular to subangular boulders of highly decomposed tuff. This colluvium type generally formed a lower layer beneath the upper colluvium, but in trial trench TT6 it outcropped at the ground surface. The lower colluvial layer was typically between 0.8 m and 1.2 m thick, but in trial pit TP7 and trial trench TT5, over the mid to lower eastern portion of the natural hillside, it was thinner, being typically between 0.4 m and 0.8 m.

Open cracks related to the mainscarps visible over the western and eastern portions of the study area were present only to shallow depths, typically less than 1 m, in trial trenches TT2, TT8 and TT9 (Plates 23 and 26). These cracks varied in width between 20 mm and 30 mm, but were locally up to 50 mm wide, and could be traced from the ground surface to a depth of 1 m to 1.5 m through the colluvium, finishing at the interface between the colluvium and the underlying tuff. A disturbed zone of loose material was identified either side of these cracks. The cracks were not seen to penetrate into the underlying tuff, but there were zones of material beneath these open cracks where it is apparent that the underlying tuff is more decomposed. This feature could relate to an opening of joints within the near-surface tuff, which have subsequently decomposed due to concentrated water flows or they have been infilled with material washed in from above. In trial trench TT1, where the vertical displacement at the ground surface across the mainscarp was about 1 m, no openings were observed, but a zone of decomposed material similar to that described above was present beneath the mainscarp (Appendix A).

A number of small to medium-sized voids, ranging from a few millimetres to several centimetres in width, were identified within both the colluvium and the decomposed tuff (Plates 27 to 30). These may be soil pipes and/or burrows /decayed rootlets. Also, in some of the trial excavations narrow, typically less than 2 mm wide, root-filled sub-vertical cracks were present throughout the upper colluvium layer.

Lateral cracks were observed within the CDT and C-HDT in the downhill face (the southern face) of trial excavations TT2, TT6, TP7 and TT8 (Plate 31). In trial pit TP7 and trial trench TT6 open joints, approximately 3 mm to 5 mm wide, were observed within the H-MDT (Plate 32) suggesting previous movement. A typically thin, but up to about 3 mm, reddish brown clayey silt infill was noted along some of the cracked surfaces (Plate 33).

4.3.3 Testing and Instrumentation

Insitu density tests undertaken within the different soil types at various locations across the site gave fairly consistent results as shown in Table 3. The test results indicated that the upper colluvial layer had a dry density that ranged typically between 1.33 Mg/m^3 and 1.37 Mg/m^3 whilst the lower colluvial layer had dry densities up to 1.47 Mg/m^3. The dry densities of the tuff-derived residual soil varied from 1.46 Mg/m^3 to 1.53 Mg/m^3. These results are generally in line with the data from the previous investigation, as presented in Table 2 and discussed in Section 4.2.

Particle size distribution and Atterberg Limit tests were undertaken on a variety of soil samples. The upper colluvium exhibited plastic behaviour and contained 11% to 27% of clay-sized material, 21% to 27% sand and 10% to 31% gravel. The lower colluvium was generally non-plastic with 8% to 17% clay-sized material, 15% to 22% sand and 28% to 48% gravel. The residual soil was shown to have a much greater silt content (65%), but only one sample was tested.

The blow counts recorded for GCO probe test results were less consistent, probably due to the effects of the variable coarse fraction within the different soil types. Nevertheless, they indicate that the colluvial layers had a typical blow count in the range of 5 to 15, with no significant distinction between the two types, while the residual soil and CDT typically had blow counts in excess of 20.

Instrumentation installed on site comprised eight tensiometers and four standpipes with Halcrow buckets at 0.5 m intervals (Figure 14). This equipment was monitored on a weekly basis after installation at the end of March 1999. Four tensiometers were installed to a depth of about 0.6 m, three to a depth of about 1.5 m and the remaining one at 0.85 m. Allowing for local variation, initial readings indicate that there is a greater degree of pore suction within the lower colluvial layer, with peak pore suctions of about 90 kPa compared to peak pore suctions of about 60 kPa in the upper colluvium. The standpipes were installed in trial trenches TT1, TT2, TT4 and TT8 to a typical depth of 2.5 m below the ground surface.

4.4 Deduced Ground Conditions

Two principal material types, namely colluvium overlying a fine to coarse ash crystal meta-tuff, were encountered. The colluvium forms a thin layer, typically between 0.5 m and 1.5 m thick, that can be divided into two sub-units, comprising a loose, desiccated, upper layer overlying a slightly more compact, slightly moist, lower layer. In places the upper colluvium is considered to occur as localised "lobes" of material rather than a continuous layer. This could be due to a change in depositional conditions during a particular landslide event or represent a different period of landslide activity. Alternatively, it could possibly be an indication of localised movement/detachment of the lower colluvial layer since deposition. However, no obvious shear plane or topsoil layer was identified beneath the upper colluvial layer in any of the trial excavations to corroborate movement at this interface.

The lower colluvium layer has been shown to be a coarser grained material with a higher gravel content. This may have been due to eluviation arising from concentrated groundwater flows within this material either prior to or after deposition of the upper colluvium layer. The numerous sub-vertical hairline cracks and the smaller number of larger and more open cracks observed within the upper colluvium layer may have contributed to this process by allowing surface water to penetrate readily into the sub-soil. Furthermore, the small to medium-sized voids identified in both the upper and lower colluvium could act as soil pipes, forming preferential flow paths for groundwater, which may also promote infiltration into the sub-soil thereby exacerbating eluviation. Accordingly, the colluvium, in particular the lower colluvium, is considered to have a relatively high mass permeability.

The degree of decomposition of the tuff varied across the site, with C-HDT, with a rock mass weathering zone rating between PW 0/30 and PW 30/50, typically encountered over the upper portion of the hillside and H-MDT and MDT, with a rock mass weathering zone rating of between PW 50/90 and PW 90/100, encountered further downslope. The more decomposed tuff appears to have had certain mineral types leached from the rock leaving a porous texture and possibly leading to the formation of soil pipes. Field observations suggested that this grade of rock was relatively light by weight, reflecting the slightly 'honeycombed' nature of the material. Subsequent test results have confirmed this observation (Table 4).

Typically, the tuff appears to have an irregular surface profile, but some locally persistent planes with an adverse component of dip were observed to daylight out of the slope.

The cracks observed in trial trenches TT2, TT8 and TT9 can only be traced over a short distance through the colluvium before stopping at the boundary with the tuff. In trial trenches TT8 and TT9 the cracks tend to flatten out in a direction roughly parallel with the ground surface as they approach the interface between the colluvium and tuff, suggesting that movement is shallow and occurs at or near the colluvium/tuff interface. However, there are possible indications in the trial pits and elsewhere across the hillside to suggest a mechanism of failure that is not entirely confined to the colluvium, these being:

(a) evidence of laterally persistent convex breaks of slope as observed on site and from API exposing moderately decomposed tuff of PW 90/100. These breaks of slope may represent a relict form of deeper seated instability,

(b) zones of completely decomposed material/residual soil occurring below open cracks in the trial pits, as discussed in Section 4.3.2, that could be an indication that movement extends into the underlying tuff,

(c) in trial pit TP7 and trial trench TT6 there was some evidence, in the form of open joints and hairline cracks in the tuff, to suggest that movement has extended into the tuff (Plate 34), and

(d) in trial trench TT4, the dip of a quartz and iron rich seam within the decomposed tuff has been flattened out and blocks of decomposed tuff have apparently rotated within the rock mass. These features probably reflect drag forces generated by the colluvium moving relative to the tuff and indicate that movement has occurred locally within the upper horizon of the tuff.

4.5 Groundwater Conditions

It is considered that the setting of locally detached/disturbed loose colluvium with an open structure which overlies decomposed tuff is favourable to direct infiltration and a build-up of transient water pressures within the colluvium, and possibly within the upper region of the CDT. Little information has been obtained during this study concerning the main groundwater table in the tuff. However, field observations suggest that there is no permanent high ground water table in the hillside.

5. ANALYSIS OF RAINFALL RECORDS

Due to the nature of instability in the hillside i.e. predominantly intermittent movement, it is not possible to establish a specific time for a landslide event (or events). Consequently, it is not possible to undertake a meaningful analysis of the rainfall records.

6. SLOPE STABILITY ANALYSIS

Limit equilibrium slope stability analyses based on the Morgenstern & Price (1965) rigorous solution were carried out to assist in the diagnosis of the probable causes of instability in the hillside. The effects of different transient elevated water pressure conditions in the colluvium on the factor of safety (FOS) of the hillside, assuming a range of likely mass shear strength parameters, were considered. A postulated slip surface located in the upper part of Section D-D (Figure 17) was used for the purposes of analysis to model the instability in the eastern part of the hillside.

Based on information obtained from the trial excavations and detailed field mapping, the instability across the hillside appears to be shallow in nature and predominantly involves movement along the colluvium/tuff interface. Transient elevated water pressure in the colluvium (either perched above the colluvium/tuff interface or within the colluvium layer) is considered to be a key factor in the cause of the instability in the hillside. For the purposes of analysis the surface of the CDT was modelled as an impermeable boundary.

Based on visual inspections of the nature of the colluvium, it is also possible that minor permeability contrasts may exist between the upper and lower colluvium, which could result in localised elevated water pressures in the upper colluvial layer.

Field measurements have shown that pore suctions up to 90 kPa can exist within the colluvium of the hillside during dry periods. Low suctions were recorded following recent (June 1999) relatively heavy rainfall, and this suggests that pore suctions can reduce rapidly to zero or near zero values in response to heavy rainfall. Accordingly, the effects of pore suction have been ignored and shear strength parameters ranging from c' = 0 kPa, $\phi' = 30^{o}$ to c' = 6 kPa, $\phi' = 30^{o}$ have been assumed in the analyses to represent the likely range of operational mass shear strength of the colluvium under saturated conditions. These are in line with field observations and "typical" ranges of values given in GEO (1993).

The results of the stability analyses are summarised in Figure 18. These show that under the condition of no build-up in positive water pressure in the colluvium the hillside should be stable. However, as water pressures build up within the colluvium the factor of safety falls below/towards unity for the range of shear strength parameters considered. The probable mass shear strength of the colluvium appears to be lower than that adopted in the LPM design for Slope No. 3SW-B/C12, which is consistent with the visual assessment of the material.

In practice, the actual groundwater regime is likely to be complex and may involve localised build-up of elevated water pressure within the colluvium, filling-up of open joints or cracks etc. Nevertheless, the simplified calculations serve to illustrate that under transient elevated water pressure conditions shallow instability within the hillside is possible given typical shear strength parameters for the relatively loose colluvium. Hence, the instability is unlikely to be associated with particularly weak materials, and this is corroborated by the findings of the field mapping and subsequent ground investigation.

7. PROBABLE MODE AND CAUSES OF THE DISTRESS

API and field mapping have revealed that a thin mantle of colluvium is pervasive across the hillside above Slope No. 3SW-B/C12 and elsewhere across Queen's Hill and that there have been extensive signs of shallow instability within the near-surface material since at least 1924. These observations are in line with the findings of Evans & King (1998), which suggest that natural terrain comprising fine to coarse ash tuff, including a thin (less than 2 m) colluvium cover, with a slope angle between 25^{o} and 50^{o} has a high degree of susceptibility to shallow failure. The NTLI, which is based on high-level aerial photographs, contains records of five landslides on this hillside, but does not indicate overall general instability as observed on site.

Significant pore suctions that contribute to stability have been shown to exist within the colluvium in the dry season. However, if water pressure builds up in the colluvium it is liable to achieve limiting equilibrium conditions, as shown by the major failure in 1993 and the theoretical calculations presented in this report. This is corroborated by the nature of the material, which was observed to be in a loose state with a probable high mass permeability, particularly in the upper colluvium layer. Consequently, direct surface infiltration during rainfall could quickly lead to saturated conditions within the colluvium. The tension cracks and erosion pipes observed on site may locally exacerbate the process. The significant drop in pore suction following rainfall as measured by the tensiometers demonstrates the susceptibility of the colluvium to rapid infiltration.

The adverse hydrogeological setting involving a thin colluvium layer overlying tuff is favourable to the development of a perched water table within the colluvium. Transient elevated water pressures would build up as water fills open joints and cracks, perched conditions develop or as a result of groundwater flow. The instability of the hillside is most probably caused by infiltration of rainfall into the ground resulting in loss of suction and build-up of positive water pressures in the near-surface material.

The mode of instability identified to date primarily involves limited slope movement giving rise to tension cracking of the near-surface material and sharp breaks of slope, with occasionally discrete landslides locally, probably during heavy rainfall, with runout of debris and formation of landslide scars. Evidence of detachment has also been identified at the northeastern corner of the study area and on the southern hillside further to the east of the study area as well as on the northern side of the hillside (Section 2.3.2).

Localised instability is extensive over a large part of the hillside, suggesting that the generic cause may be of a 'regional' nature. The form deformation suggests a relatively shallow landsliding process that involves mainly the upper and lower colluvium, but the prominent landslide scar at the northeastern corner of the site indicates that detachments can involve the weathered tuff as well. Also, some of the tension cracks in the trial excavations were observed to have extended into the upper horizon of the CDT, which locally shows signs of movement as evidenced by the rotation of the foliation within sections of the tuff. Furthermore, site observations suggest a mechanism of instability that is not locally confined to the colluvium. The possibility that the laterally persistent convex break of slope exposing moderately decomposed tuff of PW90/100 may represent a relict form of a deeper-seated instability cannot be ruled out, but this would have been of a much greater time-scale that is not considered to be a direct factor in the context of the more recent extensive instability of the near-surface material.

Hence, the hillside instability problem and possible deterioration of the ground conditions are not confined to the surface colluvium alone, but also involve the weathered tuff. The practical implication of this observation is that if instability of surface colluvium is not attended to the potential scale and mode of further instabilities on the hillside could be affected by the process of deterioration that may extend into the underlying material.

The nature of the upper and lower colluvium suggests that they could be of different origin. The upper colluvium, which occurs in places as localised lobes, appears to be landslide debris probably derived from discrete failures in the past. On the other hand, the lower colluvium is not as loose as that of the upper colluvium and locally it incorporates disturbed CDT. The insitu density of the lower colluvium is higher than that of the upper colluvium and is close to that of the tuff. It is postulated that the lower colluvium could represent a zone of intermittent movement within the upper part of the CDT due to progressive development and deterioration of the near-surface instability into the underlying material without global detachment of material (see Figure 15). This intermittent ground movement, which was probably comparatively limited given the relatively small relief of the hillside, probably occurred over a fairly long timescale. Superimposed on this ongoing process is the opening up of the ground due to the intermittent movement and possible disturbance to subsurface water flow (e.g. blockage of erosion pipes or cracks extending into the CDT). Also, the occasional detachments observed across the hillside have resulted in local steepening of the ground and surcharge of other areas by the debris. This could promote further local instability of the hillside, which may affect the underlying weathered tuff.

If the postulation regarding the origin of the lower colluvium were correct, then there are likely to be some geological factors specific to this hillside that have contributed to the instability. The porous nature of the more weathered tuff and the distinct foliation of the fabric could be possible factors for consideration. The presence of a zone of more porous rock overlying less porous rock may promote preferential water flow and differential weathering. Likewise the foliation, which was a result of thrusting, could possibly have some controlling influence on the flow of water, thereby influencing the weathering process. However, the actual engineering geological implications of the foliation are not fully understood and further work is needed to examine the significance of this. It may be possible that the combination of the above two factors could increase the susceptibility of the tuff to deterioration and enable the surface instability to extend into the underlying material over a period of time. This process may involve the formation of tension cracks that promote surface infiltration and build-up of water pressure, leading to discrete failures and further hillside instability, with oversteepening at the crown of landslide scars and surcharging of downslope areas with debris, which in turn could trigger further instability.

A large part of the distressed material remains on the slope without complete detachment. The limited mobility of the material could be due to the following:

(a) dissipation of elevated water pressure by drainage through the cracks (because the ground has opened up),

(b) the rough, and occasionally interlocking, nature of the interface between the lower colluvium and the tuff (Figure 15) resulting in increased resistance during shearing displacement due to dilation effects (there is a general lack of a well-defined slip surface at the colluvium/tuff interface), and

(c) the relatively planar nature of the slope surface with no significant drainage concentration or potential for concentrated surface water flow.

A further consideration is that the limited overall displacement of the colluvium could be the result of the small relief and moderate gradient of the natural hillside. This is likely to be different to the setting of thin colluvium derived from instabilities from very high hillsides, such as that involved in many of the failures during the November 1993 rainstorm on Lantau Island (Wong et al, 1996). It is not certain as to whether this latter factor has also contributed to the limited mobility of the hillside instability.

The main cut slope (No. 3SW-B/C12) at the toe of the hillside is unlikely to have been the cause of instability within the upper portion of the hillside, which appears to have been ongoing since at least 1924. However, there is probably some interaction between the cutting and the lower portion of the hillside. This is reflected by the distress and failure in this locality since formation of the cut slope in the early 1960's, including the major failures in 1993, which affected the crest area of the cutting and a significant portion of the hillside.

The extensive instability of the concerned hillside is evidently 'active' and the problem is not of a geological time scale. The various forms of distress observed from API were essentially 'recent' and some of the detachments were fairly mobile. There are also areas where the instability has 'matured' to a stage that the tuff is also involved instead of being confined to the surface colluvium.

8. CONCLUSIONS

It is concluded that the widespread instability on the natural hillside above Slope No. 3SW-B/C12 was probably triggered by rainfall.

The instability, which has been identified in aerial photographs dating back to 1924, predominantly involved limited slope movement giving rise to tension cracks and sharp breaks of slope together with localised detachments with debris runout. Based on evidence recovered during the study, these features probably reflect intermittent shallow movements within the surface mantle of colluvium, which is pervasive across the hillside, as well as locally in the upper horizon of the decomposed tuff. There is evidence over parts of the hillside to suggest that the progressive ground movements could develop into more mobile failure, probably during severe rainfall.

The tuff was observed to contain a distinct foliation, as well as having a porous structure in the more decomposed deposits. It is not certain whether these were significant contributory factors to the widespread instability of the hillside.

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LIST OF TABLES

Table 1 – Summary of Site Development from Aerial Photograph Interpretation

Year	Photograph Reference No.	Altitude (feet)	Observations (refer to Figures 8 and 9)
1924	Y00190 Y00191	21352	The study area comprises natural hillside. Burma Lines Camp (BLC) and the cut slopes towards the toe of Queen's Hill have not yet been formed. A track traverses the toe of the hillside between the area currently occupied by Blocks 13 to 15 of BLC, and the western part of the hill. The low-lying areas along the valley floor at the toe of Queen's Hill appear to be cultivated. Five large, well-defined depressions are present on the northern side of the main east-west trending ridgeline. Although affected by erosion, they appear to be relict landslide scars. Several smaller landslide scars are observed within these larger features. In general, they are located on the steeper portion of the slope below the rounded, main ridgeline. South of the main ridgeline, a number of shallow depressions are observed and interpreted as landslide scars. All of the scars are covered with thin vegetation, similar in tone to the adjacent terrain. The westernmost depression, located above the area currently occupied by Block 17 BLC, is about 20 m to 30 m wide, and several smaller depressions are apparent within this area. The central axis of the main depression appears to form a natural drainage line, and towards the toe a fan-shaped area is observed. In plan, the depression has an hourglass shape. Two small semi-circular depressions are observed at the base of and to the east of this depression, above the area currently occupied by Block 14 BLC. A broad fan-shaped deposit is evident below these depressions, the lower edges of which are lighter in colour than the surrounding terrain giving the impression that this is an area of recently disturbed ground. On the hummocky slope between the ridgeline and the area currently occupied by Block 13 BLC, a series of lobe-shaped features, covering an area approximately 30 m wide, are indicated

Year	Photograph Reference No.	Altitude (feet)	Observations (refer to Figures 8 and 9)
			by a lighter tone, which may represent colluvial deposits. A series of depressions are also located on the southeast-facing slope, northeast of the area currently occupied by Blocks 12 and 13 BLC. An area above Block 20 BLC, to the west of the shallow depression above Block 17, appears disturbed and may therefore represent an area of shallow instability and/or colluvium. Along, and on either side of the main ridgeline, a series of patches characterised by a lighter tone, are observed, which may have been formed by quarrying activities.
1961	F42/81A/RAF0035 F42/81A/RAF0036	30000	The site formation works for the residential blocks of Burma Lines Camp at the toe of the south-facing slope, cut slopes, Nos. 3SW-B/C12 and 3SW-B/C242, and fill slope No. 3SW-B/F30, are in progress. Immediately above the cut slopes, a narrow strip of vegetation has been cleared in an east-west direction, probably in preparation for fencing and/or drainage works. Several linear features are observed, which traverse the south-facing slope above the site formation works roughly parallel to the ridgeline. Two of these lines are laterally persistent (in excess of 100 m long) across the slope and may represent the surface expression of shallow instability and/or sharp breaks in the slope profile. Vegetation is generally thin over the hillside with some trees covering the east-facing slopes, north of the ridgeline. The depressions interpreted as landslide scars across the hillside in the 1924 photographs are still visible.
1964	Y12291 Y12292	1800	Cut slopes Nos. 3SW-B/C12 and 3SW-B/C242, and fill slope No. 3SW-B/F30, have been formed and the residential blocks at the toe of Queen's Hill have been completed. A

Year	Photograph Reference No.	Altitude (feet)	Observations (refer to Figures 8 and 9)
			catchwater drainage channel is present above the crest of the cut slopes, which traverses the hillside roughly parallel to the ridgeline. The linear features that were observed traversing the hillside in the 1961 photographs are still evident, as are a series of regular, closely spaced lines towards the mid to lower portion of the south-facing slope. These generally span the entire width of the study area, and give the hillside a stepped/hummocky appearance. Several linear features are observed traversing the upper portion of the drainage line above Block 17 BLC, which may represent cracking of the slope surface. A concave break in slope is observed below the rounded ridgeline and may represent the upslope limit of the colluvium on the hillside. The linear features described above generally occur below this line. An area of apparently disturbed ground is visible to the east of Block 13 BLC. Several small depressions are observed in the broad depressions north of the ridgeline (all are vegetated but were not identified in the 1924 photographs). A depression is also observed on the west-facing slope, west of the main ridgeline above Blocks 29 to 32 BLC. Again, this was not visible in the 1924 photographs. Debris, not vegetated, is observed towards the toe of the depression on the north-facing slope opposite Block 17. The source of this relatively fresh debris is not clear.
1974	10057 10058	12500	A small scar is observed to the east of Block 13 BLC in the area where disturbed ground was noted in 1964. From the high-level photography it is unclear as to the origin of this feature. The debris noted towards the toe of the north-facing slope in 1964, is now fully vegetated.

Year	Photograph Reference No.	Altitude (feet)	Observations (refer to Figures 8 and 9)
1978	23416 23417	4000	The scar to the east of the catchwater drain and Block 13 BLC, noted above, is now vegetated. The origin and nature of the scar are still unclear. Two areas of possible instability are noted on the slope above Blocks 13 and 14 respectively. The two areas are rectangular in shape and are both characterised by having thinner vegetation cover.
1979	28361 28362	10000	No significant changes apparent.
1981	38040 38041	10000	A narrow landslide and/or erosion scar are observed along the centre of the depression on the north-facing slope opposite Block 17 BLC. The source area is located at about the mid-point of the slope. Site formation works are ongoing above Blocks 46 to 50 BLC, on the western side of Queen's Hill.
1982	44759 44760	10000	A landslide scar, about 20 m in width, is observed to the northeast of Block 13 BLC. Debris does not appear to have reached the residential blocks below. Vegetation on the south-facing slopes comprise denser shrubs and small trees above Burma Lines Camp, which thins to grasses and low shrubs closer to the ridgeline. On the north-facing slopes, the vegetation comprises grasses and low shrubs, with trees located in the depression to the east. Residential Blocks 46 to 50 BLC on the western side of Queen's Hill are complete.
1984	55845 55846	4000	As in 1964, several linear features are observed traversing the south-facing slopes above the residential blocks. The location of one such line coincides with a small backscarp observed on site during the current investigation. Another more extensive and prominent line,

Year	Photograph Reference No.	Altitude (feet)	Observations (refer to Figures 8 and 9)
			estimated at over 100 m in length, traverses the hillside and the shallow depression above Block 17 BLC in a predominantly east-west direction. The origin and nature of this feature is unclear. Several other linear features are observed below this line within the shallow depression and may indicate cracking of the slope surface. What appear to be tension cracks are evident along the upper eastern side of the depression above Block 17 (tension cracks and instability were observed on site in a similar location in December 1997). Most of the linear features traverse the hillside in an east southeast to west northwest direction and may represent cracking and/or breaks in the slope profile. A disturbed area of vegetation noted above Blocks 13 and 14 BLC in approximately the same location as that identified in 1978 suggests similar instability. A fence has been erected close to the catchwater drainage channel.
1985	67329 67330	10000	Two areas of instability and/or erosion are observed on the slope above the landslide scar first noted in 1982 (i.e. the scar to the northeast of Block 13 BLC).
1986	A07276 A07277	4000	The vegetation covering the natural hillside appears to be less dense, particularly towards the crest of Queen's Hill. The prominent failure scar to the northeast of Block 13 BLC is still visible, and the area above this scar has several lighter patches visible through the vegetation cover, giving the appearance that the ground is disturbed. The area of broken vegetation identified above Block 14 appears more extensive than in the 1984 photographs. The fence line identified behind the residential blocks in the 1984 photographs appears to have been renewed. An irregular linear feature can be seen

Year	Photograph Reference No.	Altitude (feet)	Observations (refer to Figures 8 and 9)
			descending the western side of the shallow depression at the rear of Blocks 15 and 17. This line traverses the toe of the depression and drainage line, and may represent a footpath. The lines identified across the natural hillside in 1984 are still evident.
1987	A09742 A09743	4000	No significant changes apparent.
1988	A15516 A15517	4000	New surface protection has been applied to slope No. 3SW-B/C12 above Blocks 13 to 15 BLC. A linear feature is observed traversing the hillside to the east of the western depression noted in 1924.
1989	A19120 A19121	10000	No significant changes apparent.
1990	A23492 A23493	4000	No significant changes apparent.
1992 (29.01)	CN2883 CN2884	2000	Possible cracks are observed on the slope towards the upper portion of the shallow depression above Block 17 BLC and to the east of the depression in the area currently affected by cracking.
1992 (07.10)	A32163 A32164	4000	A new landslide scar is observed in the area identified as a relict landslide scar on the 1924 and 1964 photographs, on the southeast-facing slope about 100 m northeast of Block 13 BLC.
1993 (29.05)	A34438 A34439	4000	No significant changes apparent.
1993 (09.11)	A36412 A36413	4000	A landslide scar is observed below the ridgeline above Blocks 12 and 13 BLC. The scar is an inverted 'L'-shape and appears to be located along part of the concave break of slope below the main ridgeline, i.e. the possible upslope limit of the colluvium. A non-vegetated area is observed above Block 14 which may represent an area of instability and/or erosion, or may be the result of slope and/or fence works.

Year	Photograph Reference No.	Altitude (feet)	Observations (refer to Figures 8 and 9)
			A new landslide scar is observed below that described in 07.10.92. The scar appears to be larger than before, but is partly obscured by trees and shadow. A new landslide scar is also noted in the east-facing depression on the eastern side of the hill.
1994 (14.05)	A38279 A38280 A38281	4000	The cut slope above Blocks 13 to 15 BLC has been extended further up slope and new surface protection has been applied. The cut slope appears to have been extended partly into the two areas identified as possible instability in 1978. Several trees have been retained on the slope and between the two areas described above. A small area of instability and/or erosion is evident towards the toe of the shallow depression above Block 17.
1994 (21.10)	A39330 A39331	10000	A fresh scar is observed in the area above Block 17 BLC described above. Fresh scars are also observed in the area described as unstable in the October 1992 and November 1993 photographs, i.e. about 100 m northeast of Block 13.
1994 (07.11)	CN8697 CN8698	4000	The hillside has been affected by fire. Otherwise no significant changes apparent.
1995	CN10571 CN10572	3000	A surface crack and/or a small backscar is observed in the area to the east of the upper portion of the shallow depression above Block 17 BLC in part of the area currently under investigation.
1996 (15.05)	CN13602	3500	The scars described earlier, between 1992 and 1994 are now partly vegetated. No further significant changes are observed.
1996 (29.10)	A43602 A43603	3500	A small scar is observed above Block 20 BLC. This scar occurs in the area of possibly disturbed ground identified in the 1924 photographs. The inverted ‘L’-shaped scar is now mostly vegetated.

Year	Photograph Reference No.	Altitude (feet)	Observations (refer to Figures 8 and 9)
			Several slope strips have been excavated and re-covered on the cut slope above Blocks 13 to 15. A small scar representing instability and/or erosion is observed on the west-facing slope on the western portion of the hillside above Blocks 48 and 49. A new landslide scar is observed towards the top of the depression on the north-facing slope to the north of Block 17. The scar is about 25 m wide and over 100 m long.
1997 (15.05)	CN16834 CN16835	3500	Soil is exposed towards the top of the shallow depression above Block 17 BLC, which may indicate shallow instability and/or erosion. The surface crack and/or small backscar noted in 1995 is now prominent and similar features are observed at a similar elevation further east, in locations also currently under investigation.
1998 (07.05)	CN19593 CN19594	3300	The shallow depression above Block 17 BLC has been mostly cleared of vegetation. However, no surface protection has been applied. The cut slope above Blocks 13 to 15 has been extended and covered with surface protection. A new boundary fence has been erected along the crest of the new cut slope. An area to the northeast of Block 13 has also been covered with surface protection. The area appears to correspond with that identified in 1982 as a landslide scar. The hillside is generally covered with low shrubs with trees concentrated along the lower portions of the slope and in the north-facing depression at the eastern end of the hill.

Table 2 - Summary of Laboratory Soil Test Results for Field Works Undertaken in January 1998

Trial Pit Location	Material Type	Depth below ground level (m)	Particle Size Distribution				Liquid Limit (%)	Plastic Limit (%)	Natural Moisture Content (%)	Maximum Dry Density (Mg/m^3)	Insitu Dry Density (Mg/m^3)	Relative Compaction (%)	Optimum Moisture Content (%)
			Gravel (%)	Sand (%)	Silt (%)	Clay (%)							
TP7	Colluvium	0.52	47	19	24	10	48	26	13	1.96	1.55	79.1	12
		1.04	25	25	32	18	53	28	14	1.81	1.45	80.1	16
TP8	Colluvium	0.25	40	21	33	6	36	20	11	1.92	1.73	90.1	13
		0.74	24	25	44	7	37	21	14	1.92	1.57	81.8	14
TP9	Colluvium	0.55	7	26	57	10	43	26	15	1.77	1.68	94.9	16
	CDT	0.96	19	32	42	7	43	27	20	1.77	1.46	82.5	17
TP10	Colluvium	0.3	14	25	45	16	49	28	19	1.76	1.47	83.5	18
	CDT	0.96	8	26	54	12	43	27	13	1.73	1.91	110.4	19
TP10A	Colluvium	0.27	20	26	40	14	51	30	20	1.75	1.49	85.1	18
TP11A	Colluvium	0.24	7	36	44	13	59	38	25	1.56	1.32	84.6	24
	CDT	0.5	7	32	48	3	45	28	14	1.79	1.80	100.6	17
TP12A	Colluvium	0.24	11	31	43	15	54	34	24	1.62	1.21	74.7	21
	CDT	0.4	9	30	50	11	48	30	18	--	1.55	--	--
TP14	Colluvium	0.07	18	39	32	11	61	39	22	1.45	1.44	99.3	28
TP15	Colluvium	0.4	17	30	36	17	58	41	26	1.59	1.17	73.6	21

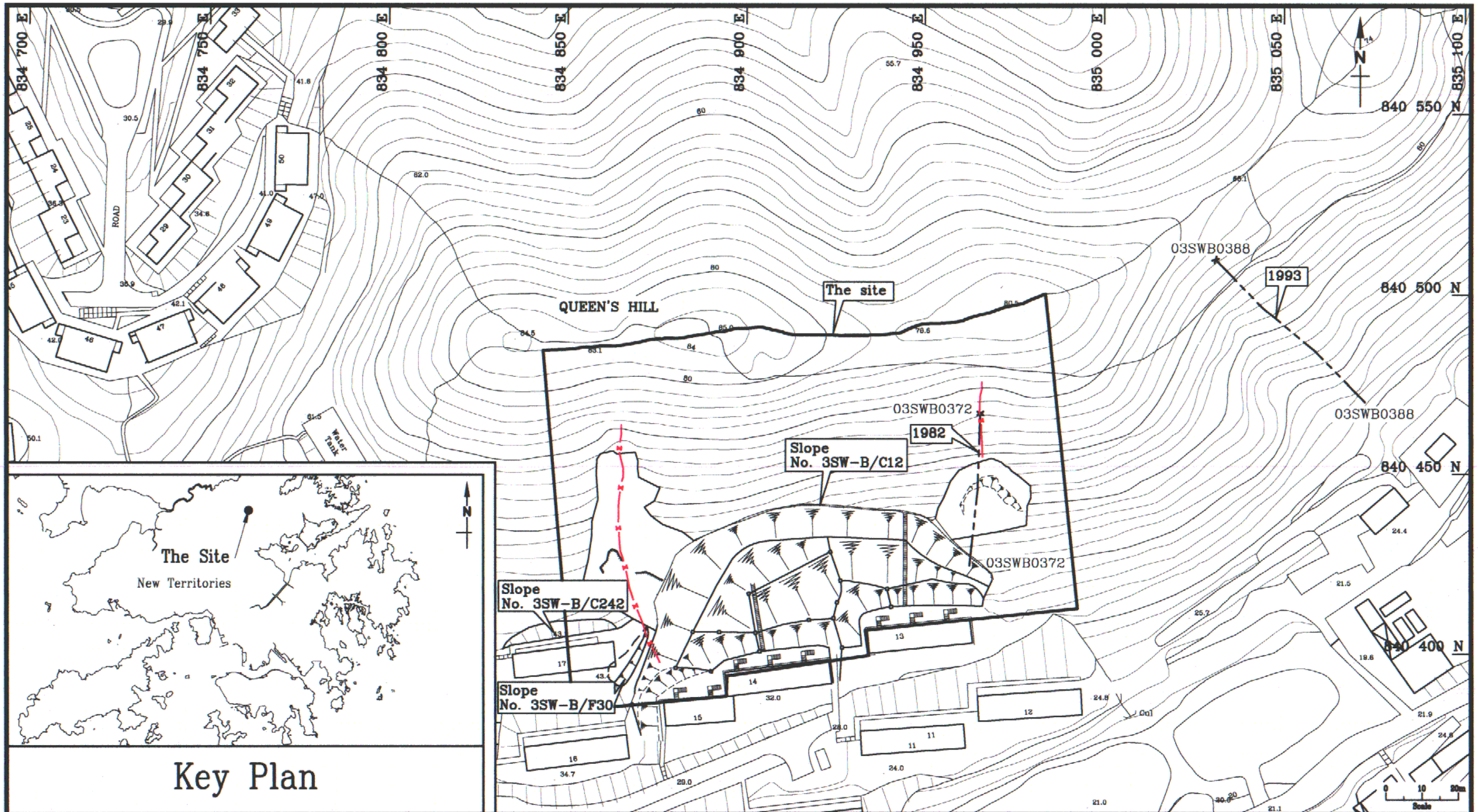
Table 3 - Summary of Laboratory Soil Test Results for Field Works Undertaken as Part of the Detailed Study

Trial Tench/Pit Location	Material Type	Depth Below Ground Level (m)	Particle Size Distribution				Liquid Limit (%)	Plastic Limit (%)	Insitu Density (Mg/m^3)	Natural Moisture Content (%)
			Gravel (%)	Sand (%)	Silt (%)	Clay (%)				
TT1	Upper Colluvium	0.1	--	--	--	--	--	--	1.37	11
		0.5	31	21	31	17	50	30	--	--
		0.7	--	--	--	--	--	--	1.36	12
	Lower Colluvium	1.1	28	19	39	14	--	--	1.47	13
	Residual Soil	1.5	7	22	65	6	--	--	--	--
TT2	Upper Colluvium	0.4	10	22	41	27	53	32	1.35	20
		0.5	--	--	--	--	--	--	1.33	15
	Lower Colluvium	1.0	38	17	28	17	--	--	1.46	19
	CDT	2.0	24	21	43	12	--	--	--	--
TT4	Lower Colluvium	0.8	--	--	--	--	--	--	1.35	14
	Residual Soil	1.6	--	--	--	--	--	--	1.46	18
TT5	Lower Colluvium	0.5	48	15	23	14	56	30	--	--
TT6	Lower Colluvium	0.5	--	--	--	--	--	--	1.46	12
TT8	Upper Colluvium	0.1	--	--	--	--	--	--	1.34	12
TT9	Upper Colluvium	0.5	20	27	42	11	41	24	--	--
	Lower Colluvium	0.7	--	--	--	--	--	--	1.36	14
		1.0	32	22	38	8	--	--	--	--
	Residual Soil	1.7	--	--	--	--	--	--	1.53	14
	CDT	2.0	26	22	39	13	--	--	--	--

Table 4 - Summary of Laboratory Rock Test Results for Field Works Undertaken in March 1999

Trial Trench/Pit Location	Rock Type	Bulk Density (Mg/m^3)	Water Content (%)	Dry Density (Mg/m^3)	Specific Gravity	Porosity (%)
TT1	HDT	1.92	2.20	1.88	2.73	31.30
	HDT	1.83	2.50	1.79	2.74	34.80
TP7	HDT	1.90	1.30	1.87	2.70	30.70
TT8	M/SDT	2.33	0.70	2.31	2.80	17.50
N/A	M/SDT	2.49	4.20	2.39	2.80	14.40

LIST OF FIGURES



Legend:
× Landslide crown
03SWB0372 Landslide reference number on NTLI
— - - — Landslide debris trail on NTLI
—x—x— Axis of shallow depression (possible ephemeral drainage line)

Notes: (1) Base Map is extracted from Survey Sheet No. 3SW-9A, scale 1 : 1 000.
(2) Landslides shown on this figure are based on the information in the Natural Terrain Landslide Inventory (NTLI).

Figure 1 - Site Location Plan

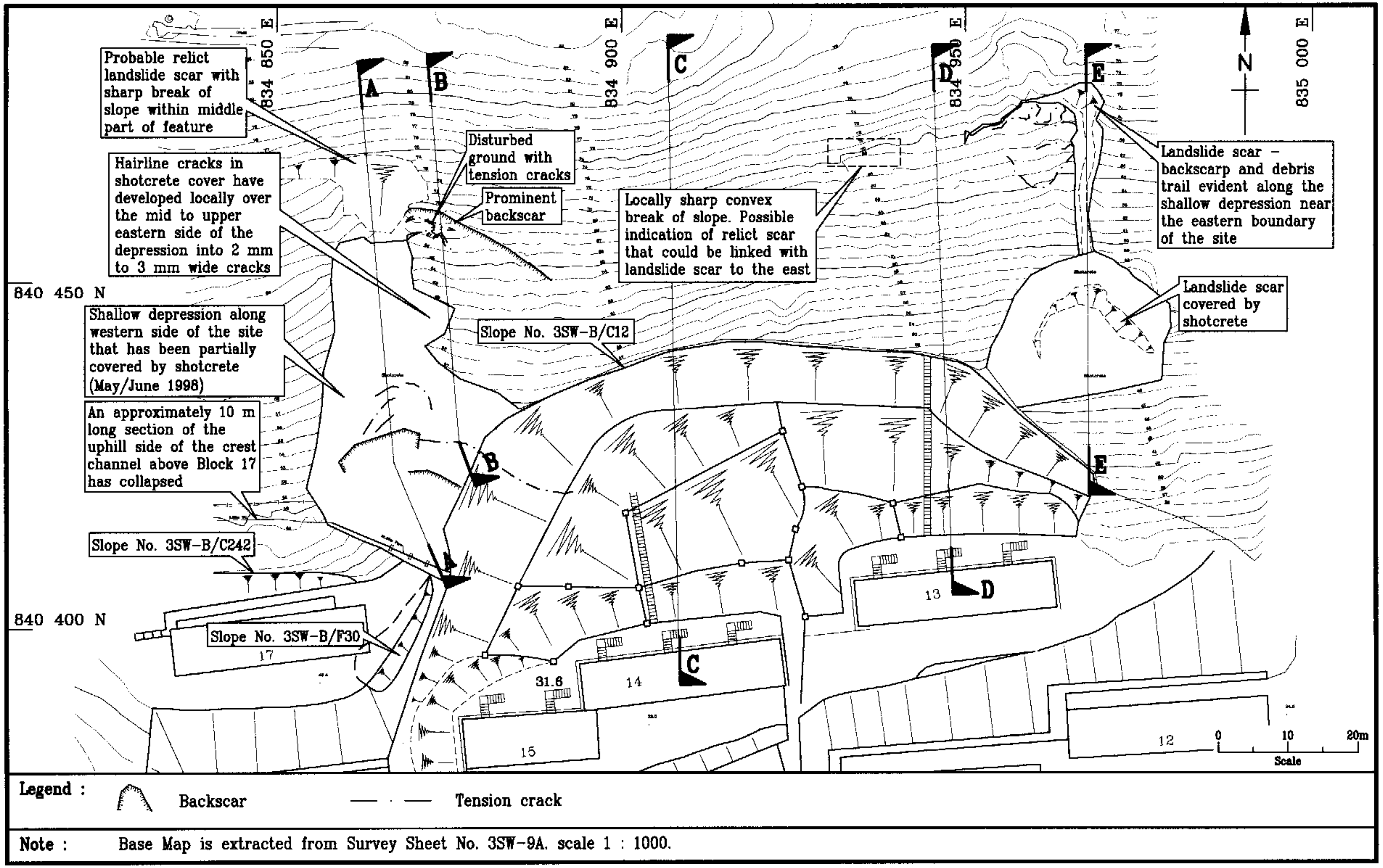
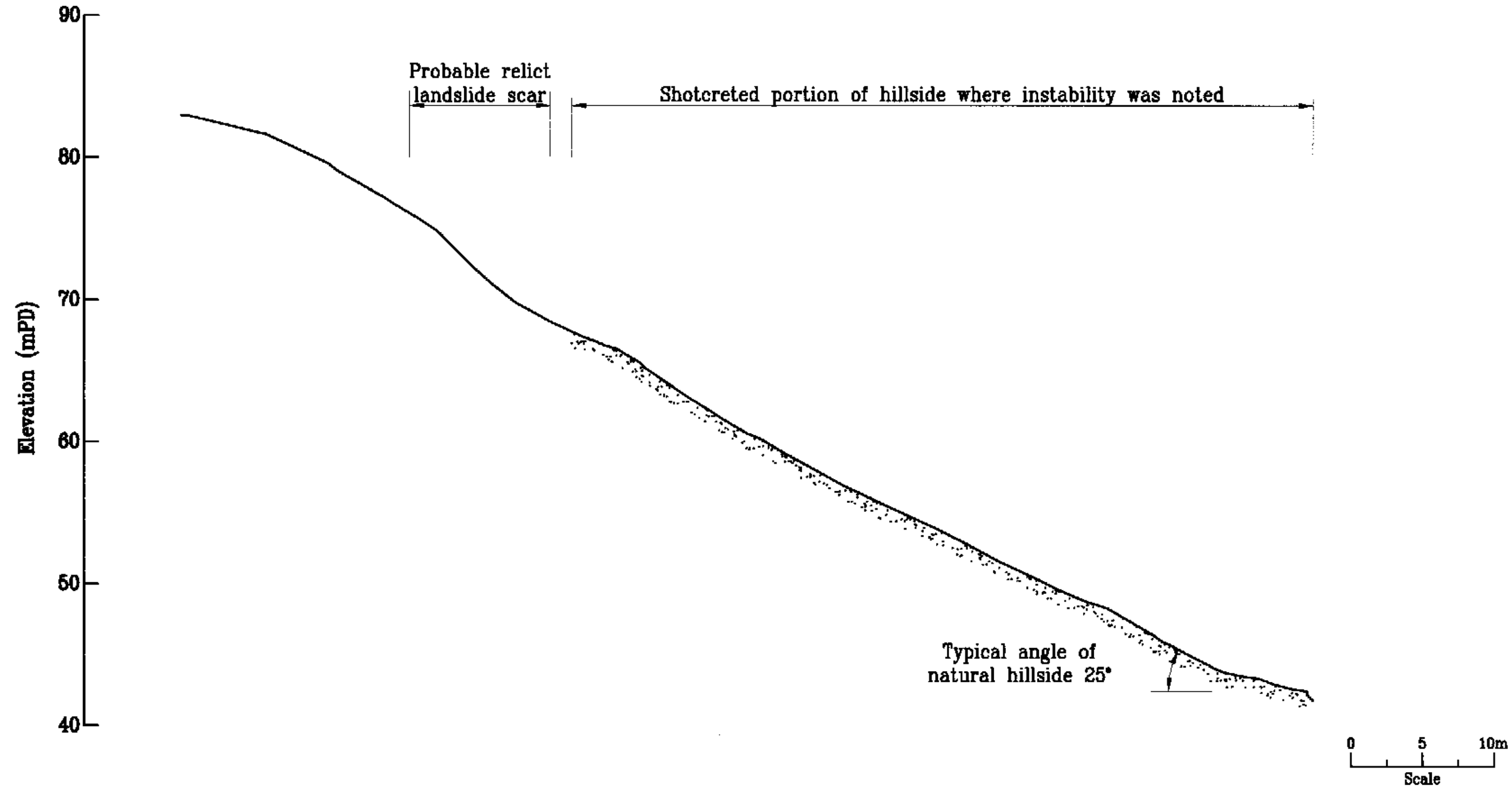


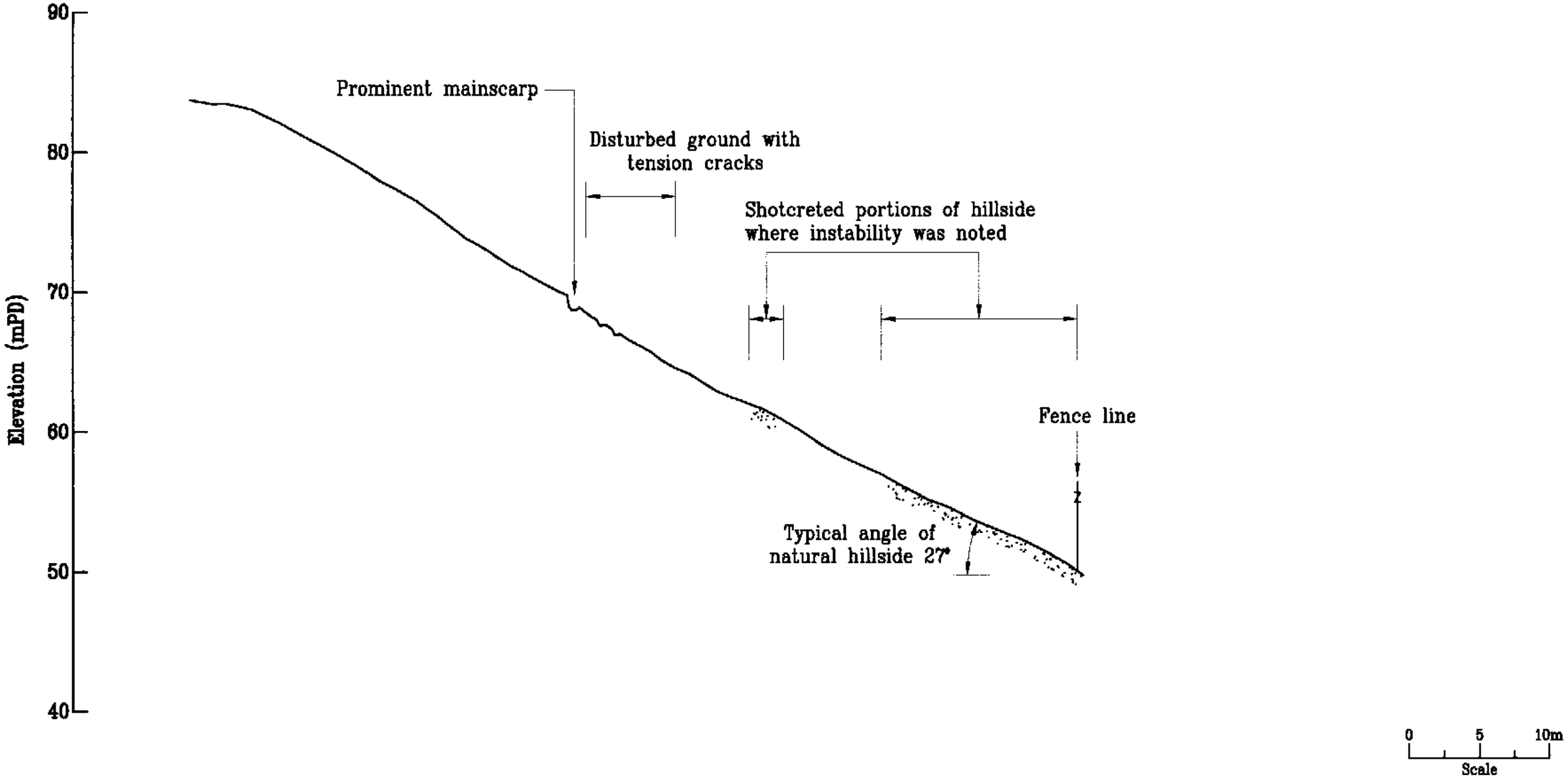
Figure 2 - Site Plan



Legend : Shotcrete covered portion of the hillside

Notes : (1) Information shown in this figure is based on topographic survey, geological mapping and documentary records.
(2) For location of section see Figure 2.

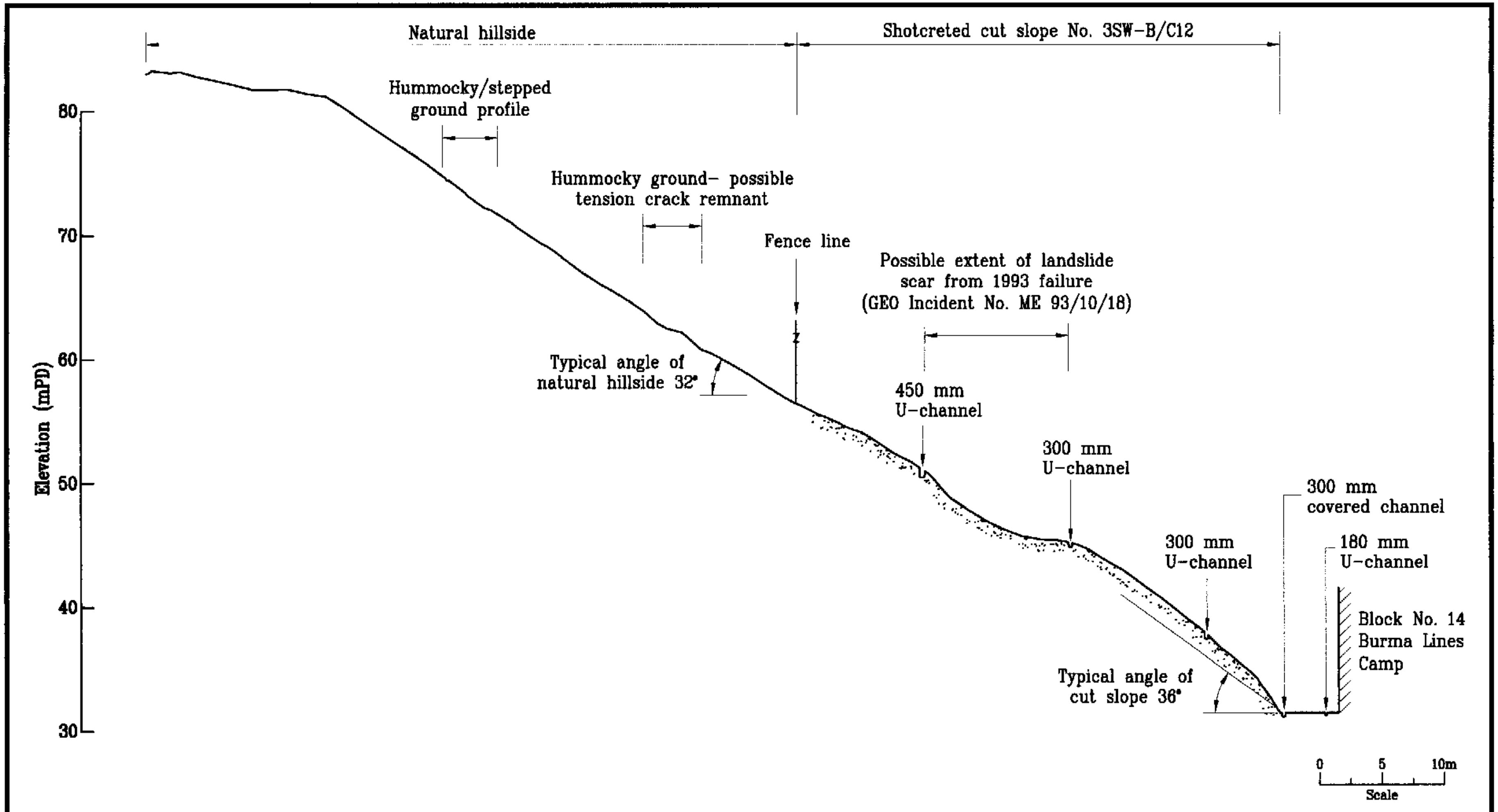
Figure 3 - Section A-A



Legend : Shotcrete covered portion of the hillside

Notes : (1) Information shown in this figure is based on topographic survey, geological mapping and documentary records.
(2) For location of section see Figure 2.

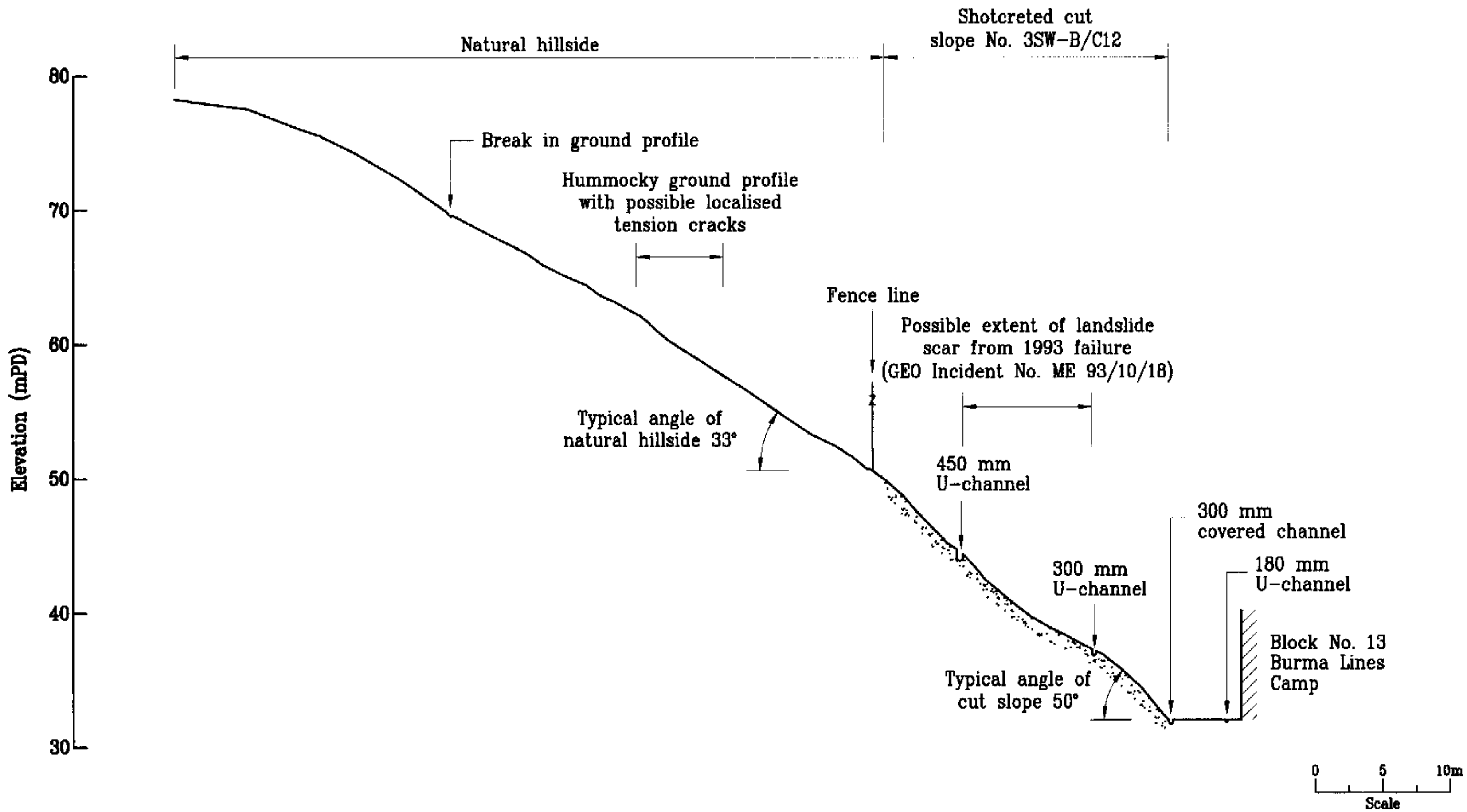
Figure 4 - Section B-B



Legend : Shotcrete covered portion of the hillside

Notes : (1) Information shown in this figure is based on topographic survey, geological mapping and documentary records.
(2) For location of section see Figure 2.

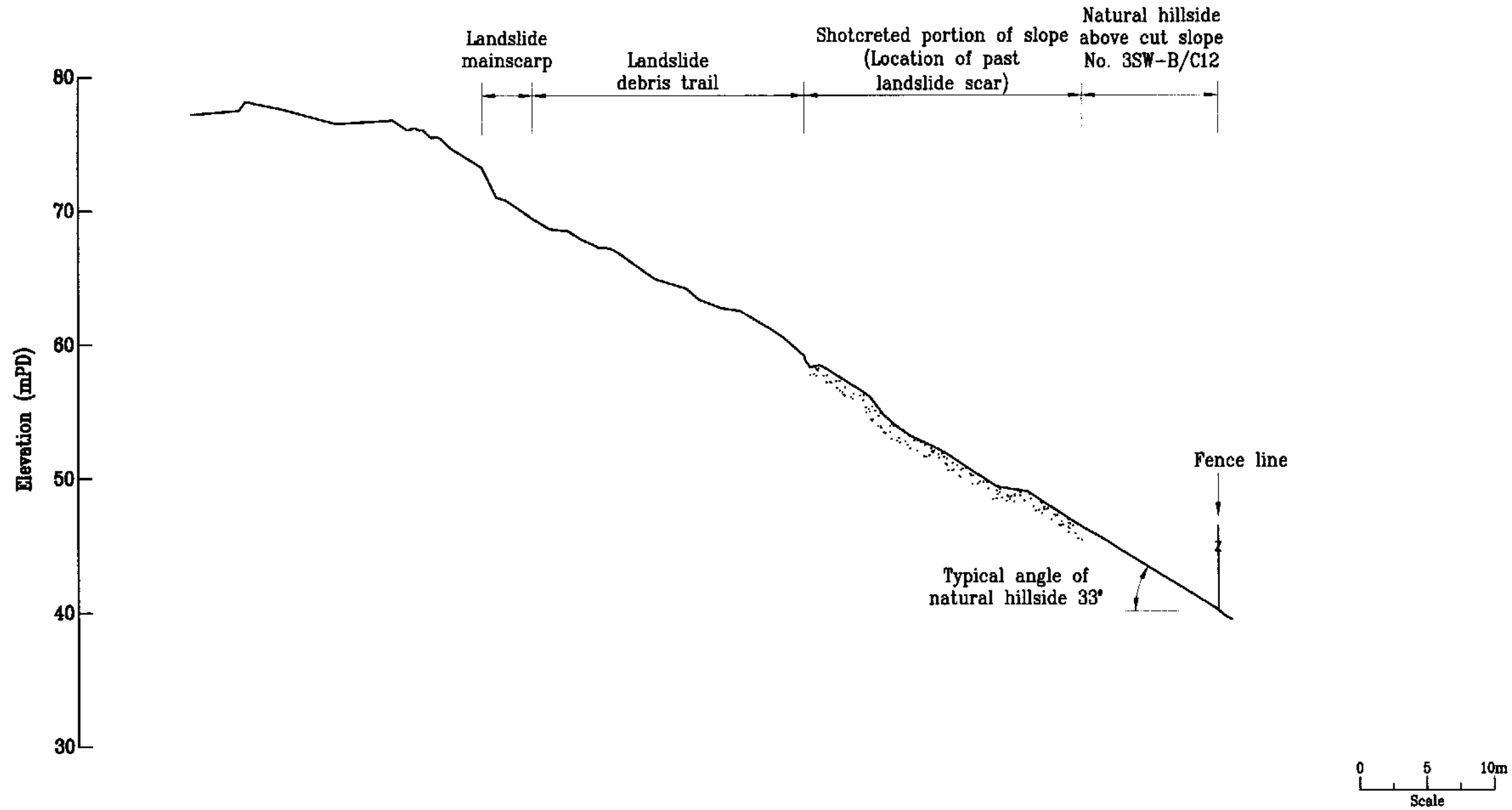
Figure 5 - Section C-C



Legend : Shotcrete covered portion of the hillside

Notes : (1) Information shown in this figure is based on topographic survey, geological mapping and documentary records.
(2) For location of section see Figure 2.

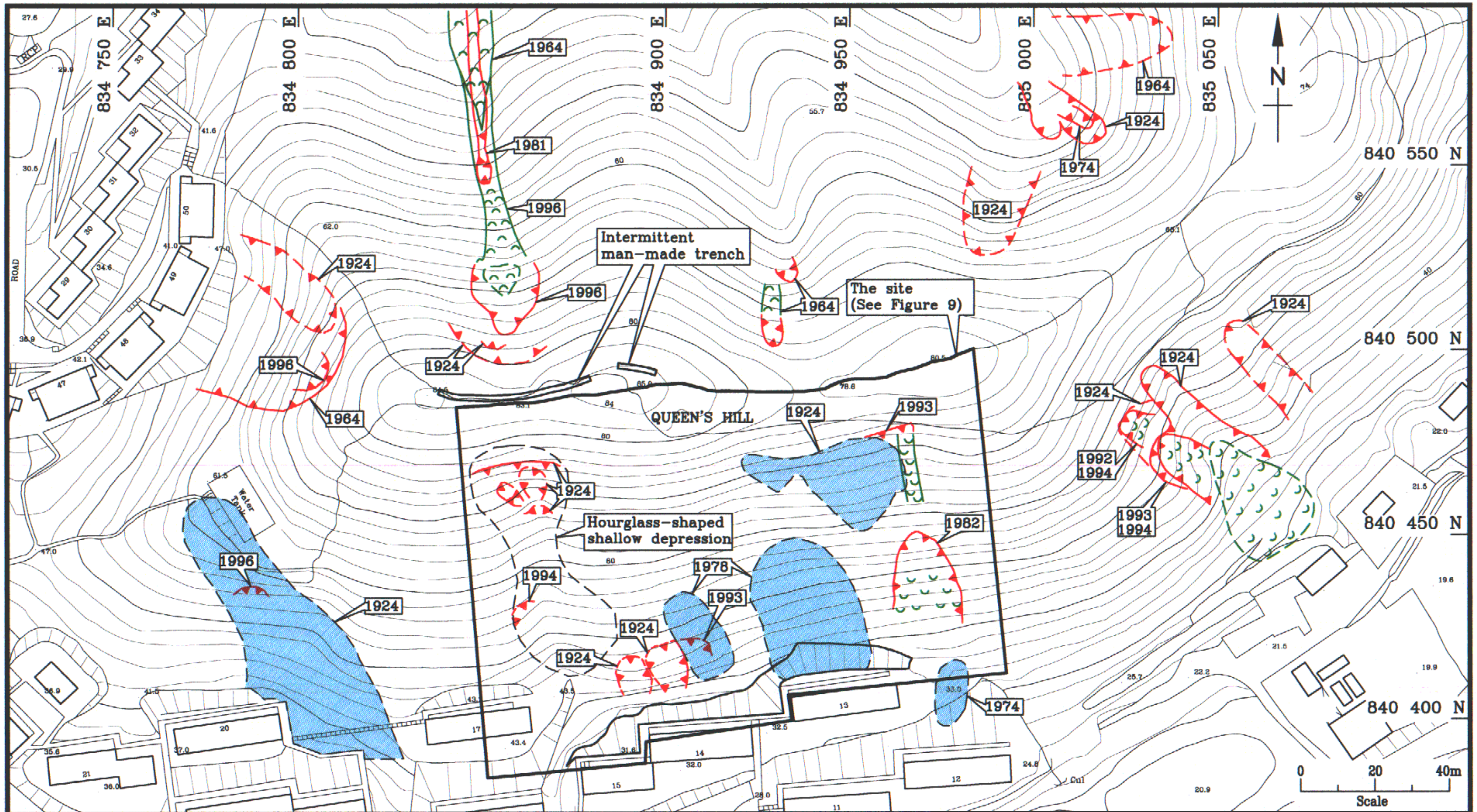
Figure 6 - Section D-D



Legend : Shotcrete covered portion of the hillside

Notes : (1) Information shown in this figure is based on topographic survey, geological mapping and documentary records.
(2) For location of section see Figure 2.

Figure 7 - Section E-E



Legend: 1984 Landslide scar and year of first observation; Main body of landslide debris; 1978 Area of possible instability (mainscarp not observed) and year of first observation

Notes: (1) Base Map is extacted from Survey Sheet No. 3SW-9A, scale 1 : 1 000.
(2) Dashed line denotes uncertainty.

Figure 8 - Site History and Development (Sheet 1 of 3)

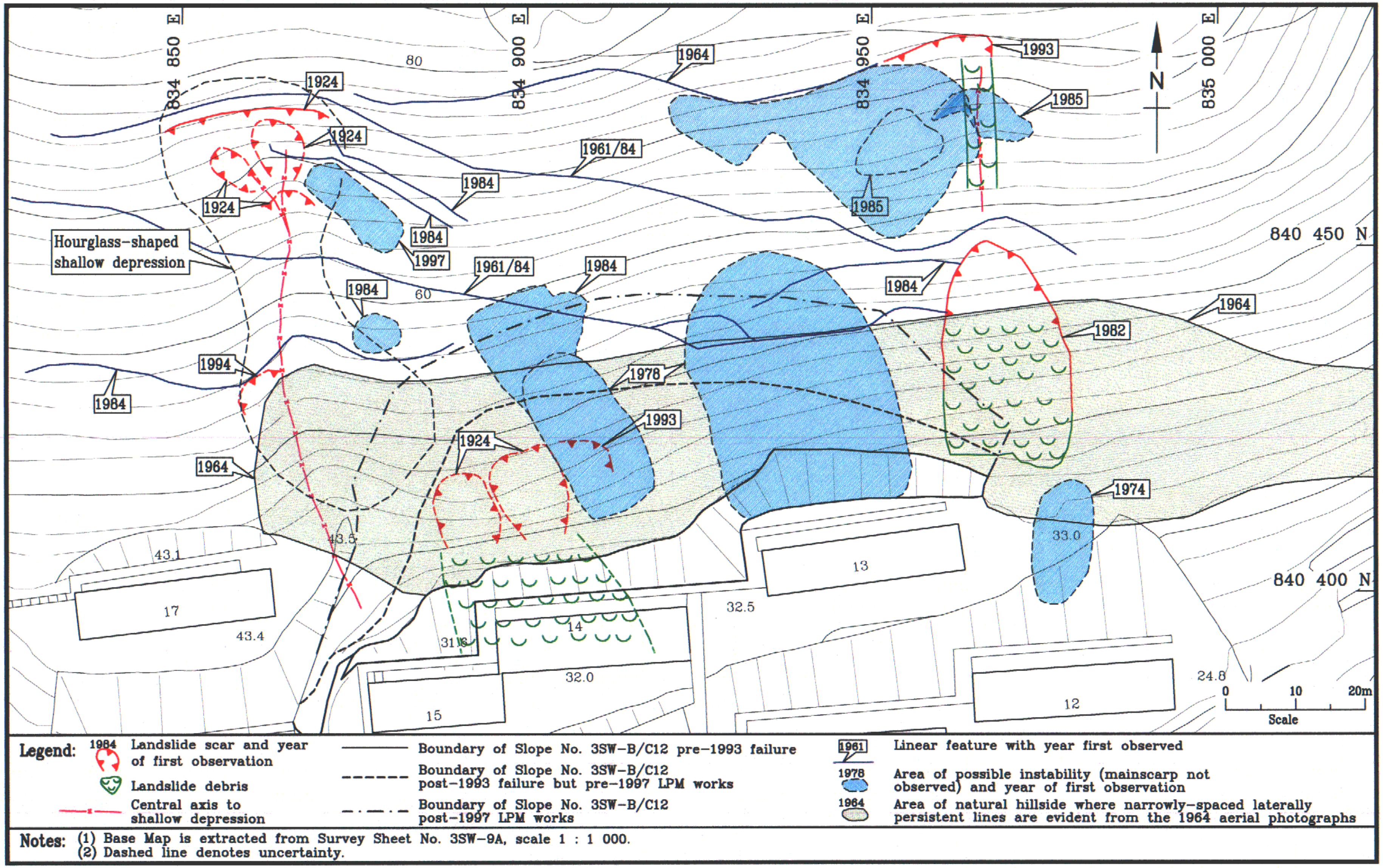
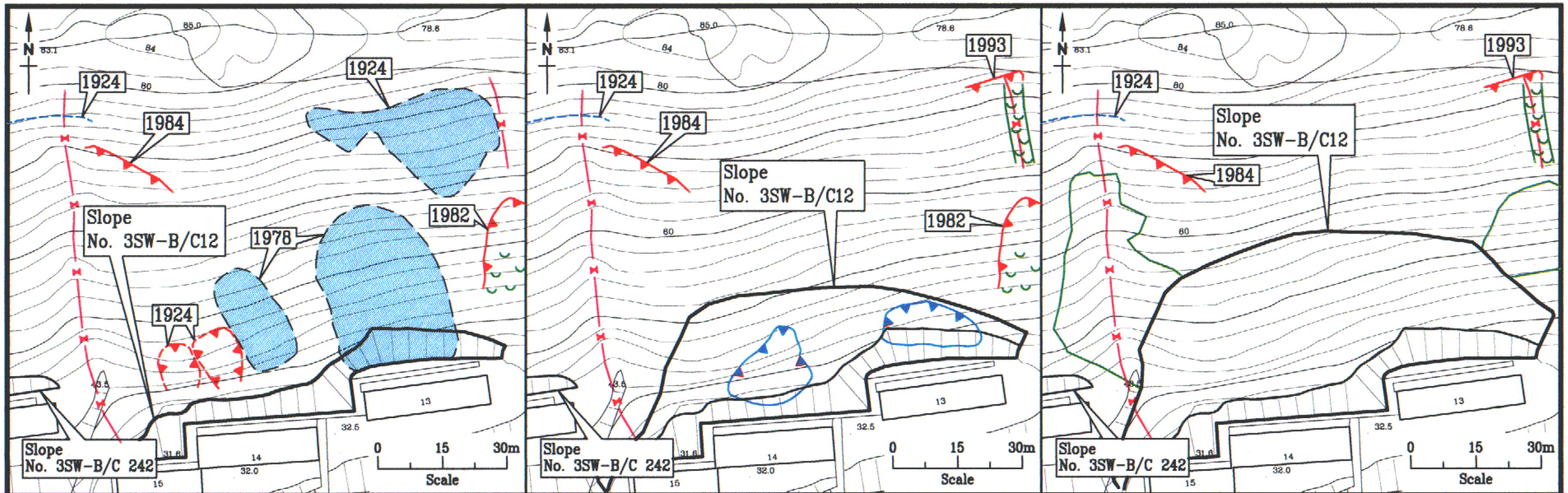
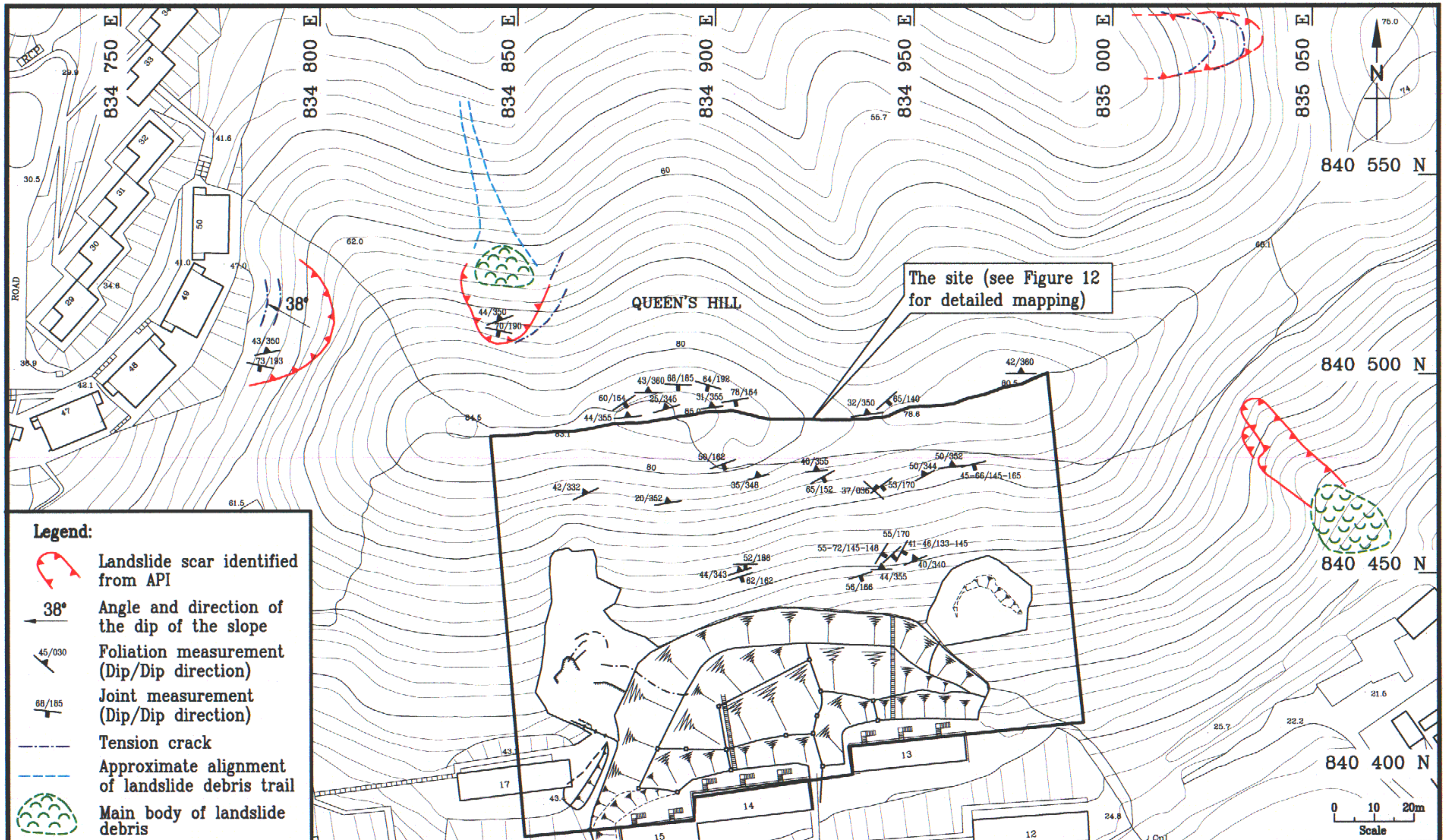


Figure 9 - Site History and Development (Sheet 2 of 3)



a) Layout of the Site Pre-1993 Failure	b) Layout of the Site Post-1993 Failure, and Pre-LPM Works	c) Layout of the Site Post-1997 LPM Works
Legend : Boundary of Slope No. 3SW-B/C12; Axis of shallow depression; 1924 Possible relict mainscarp with year of identification from API; 1984 Prominent mainscarp observed on site, with year of identification from API; 1978 Area of possible instability with year of identification from API; Landslide debris	**Legend :** Boundary of Slope No. 3SW-B/C12; Axis of shallow depression; Backscar of 1993 Failures; 1924 Possible relict mainscarp with year of identification from API; 1984 Prominent mainscarp observed on site, with year of identification from API; Landslide debris	**Legend :** Boundary of Slope No. 3SW-B/C12; Axis of shallow depression; Approximate boundary of shotcreted areas adjoining Slope No. 3SW-B/C12; 1924 Possible relict mainscarp with year of identification from API; 1984 Prominent mainscarp observed on site, with year of identification from API; Landslide debris
Notes : (1) The area of interest comprises the natural hillside above Slope Nos. 3SW-B/C12 and 3SW-B/C242 behind Accommodation Blocks 13 to 15 and Block 17 respectively. (2) Dashed lines denote uncertainty.	**Notes :** (1) Two landslides occurred behind Blocks 13 and 14, which were reported on 19 October 1993 (GEO Incident No. ME 93/10/18). (2) Following the landslides, the slope was cleared and new shotcrete applied, extending the boundary of Slope No. 3SW-B/C12 further upslope. (3) Dashed lines denote uncertainty.	**Notes :** (1) Slope No. 3SW-B/C12 was upgraded as part of the LPM programme. The works were carried out in late 1997, during which time the slope boundary was extended upslope. (2) During the LPM works, signs of instability were identified along the shallow depression above Block 15. An old landslide scar was also identified to the northeast of Block 13. These areas of past/ongoing instability were subsequently covered with shotcrete. (3) Dashed lines denote uncertainty.

Figure 10 - Site History and Development (Sheet 3 of 3)



Notes : (1) Base Map is extracted from Survey Sheet No. 3SW-9A, scale 1 : 1000.
(2) Information shown in this figure is based on topographic survey, geological mapping and documentary records.

Figure 11 - Field Mapping Details (Sheet 1 of 2)

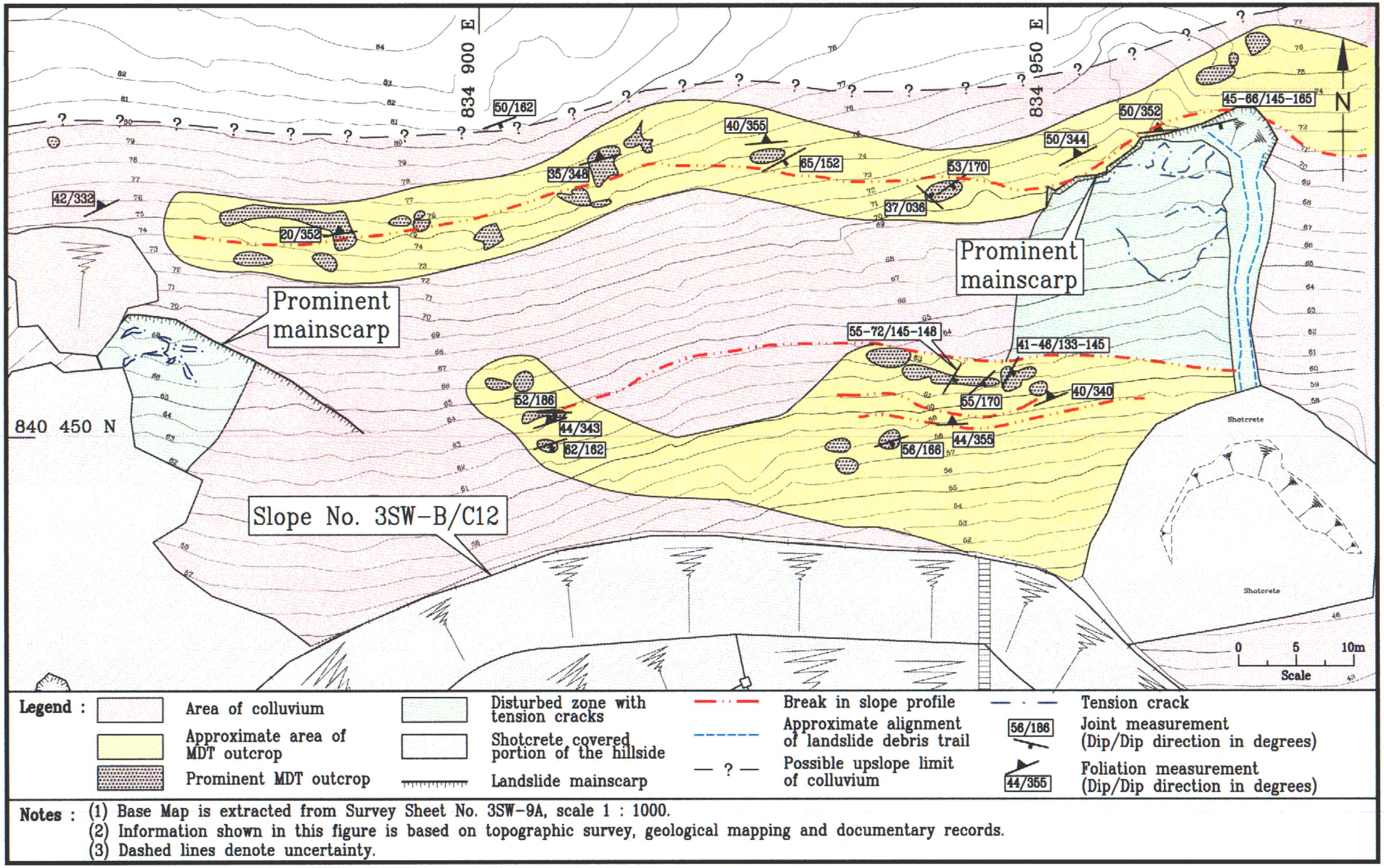
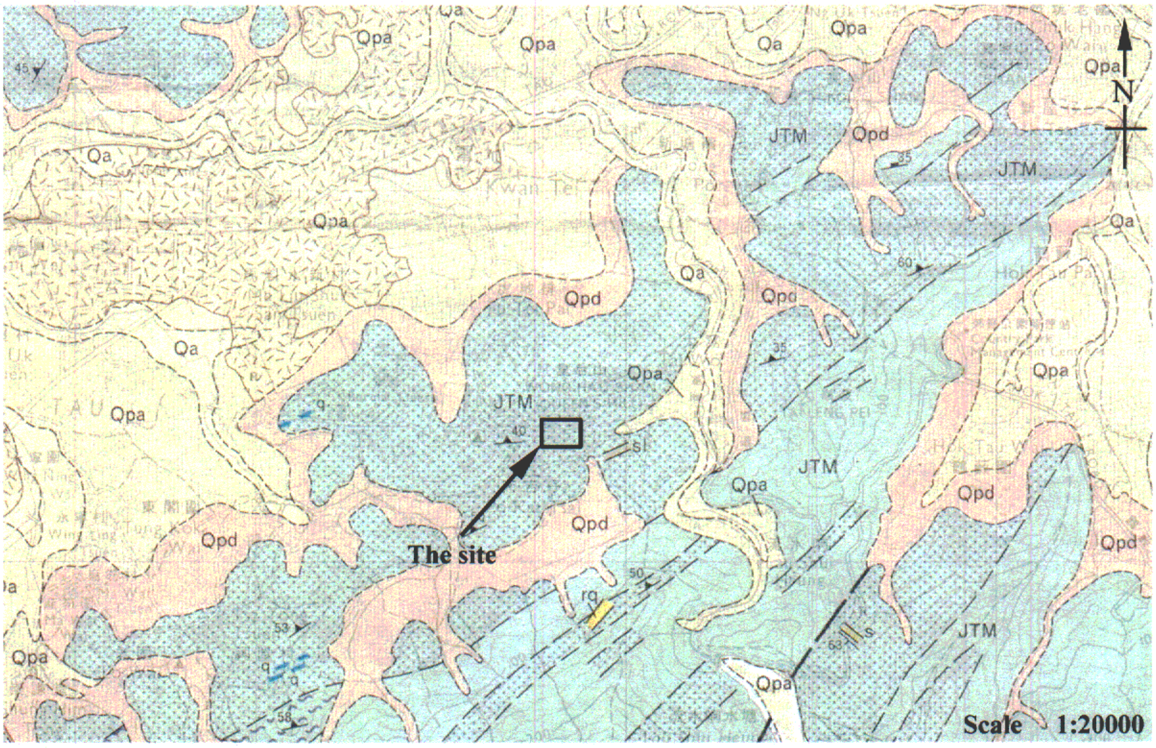


Figure 12 - Field Mapping Details (Sheet 2 of 2)



Legend :

QUARTERNARY SUPERFICIAL DEPOSITS (Onshore)

- Fill – Natural earth and waste
- Qa — Alluvium – Clay/silt, sand and gravel; well-sorted to semi-sorted
- Qpa — Terraced alluvium – Clay/silt, gravelly sandy; well-sorted to semi-sorted
- Qpd — Debris flow deposits – Silt/sand, gravelly, clayey with cobbles and boulders: unsorted

SOLID GEOLOGY

- JTM — Undivided, coarse ash crystal tuff
- s — Sandstone
- sl — Siltstone and mudstone
- rq — Quartzphyric rhyolite
- Schist
- Slightly metamorphosed

GEOLOGICAL LINES

- Geological boundary, superficial deposits
- Geological boundary, solid rock (* Broken lines denote uncertainty)
- Photogeological lineament
- * Broken lines denote uncertainty

STRUCTURAL SYMBOLS

Inclined

- 20 Bedding
- 20 Foliation
- 20 Jointing

MINERAL SYMBOL

q Quartz

Note: Extract from Sheet 3 of the Hong Kong Geological Survey 1:20,000 Scale Map Series HGM20 (GCO, 1991)

Figure 13 – Solid and Superficial Geology of the Site

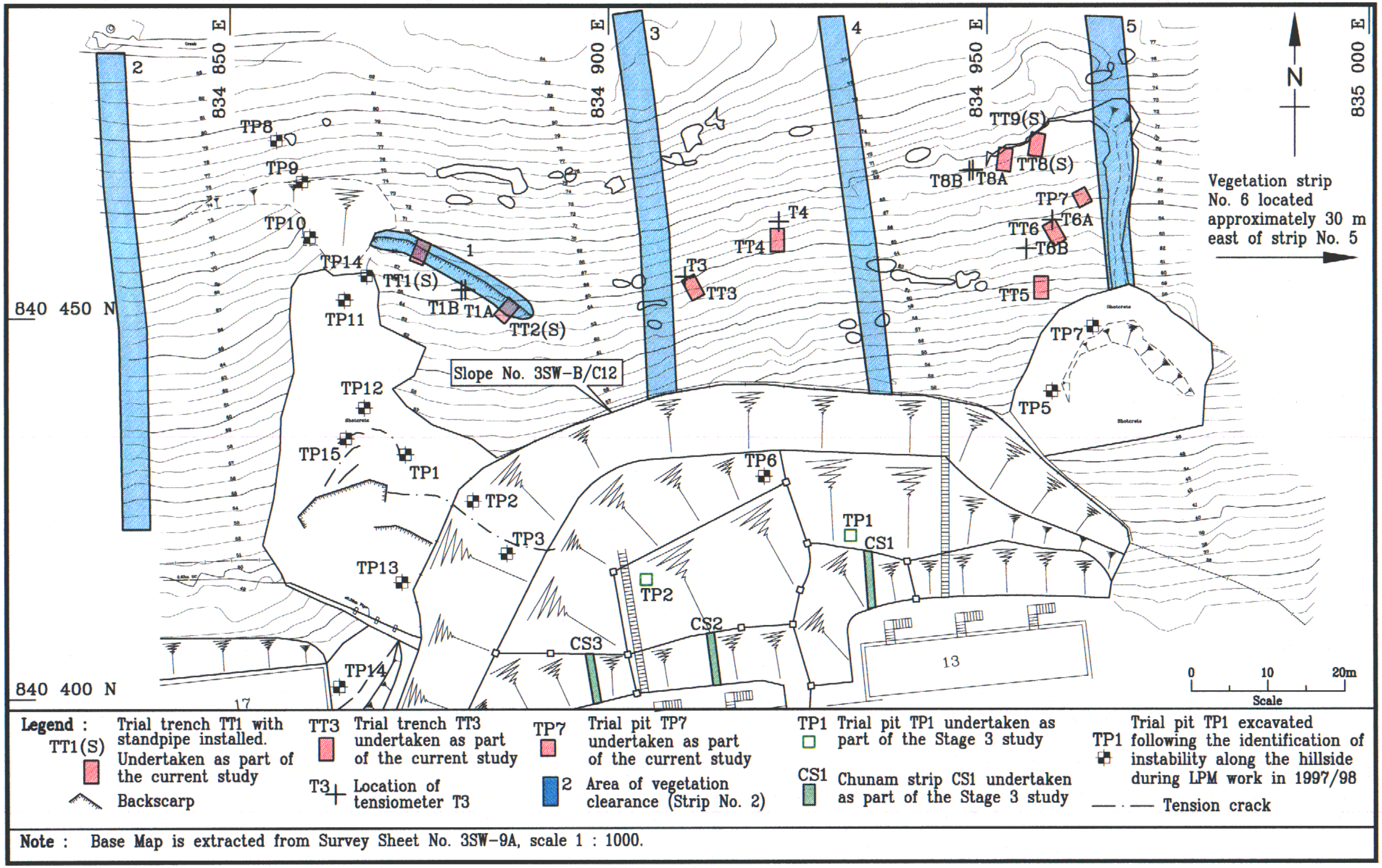
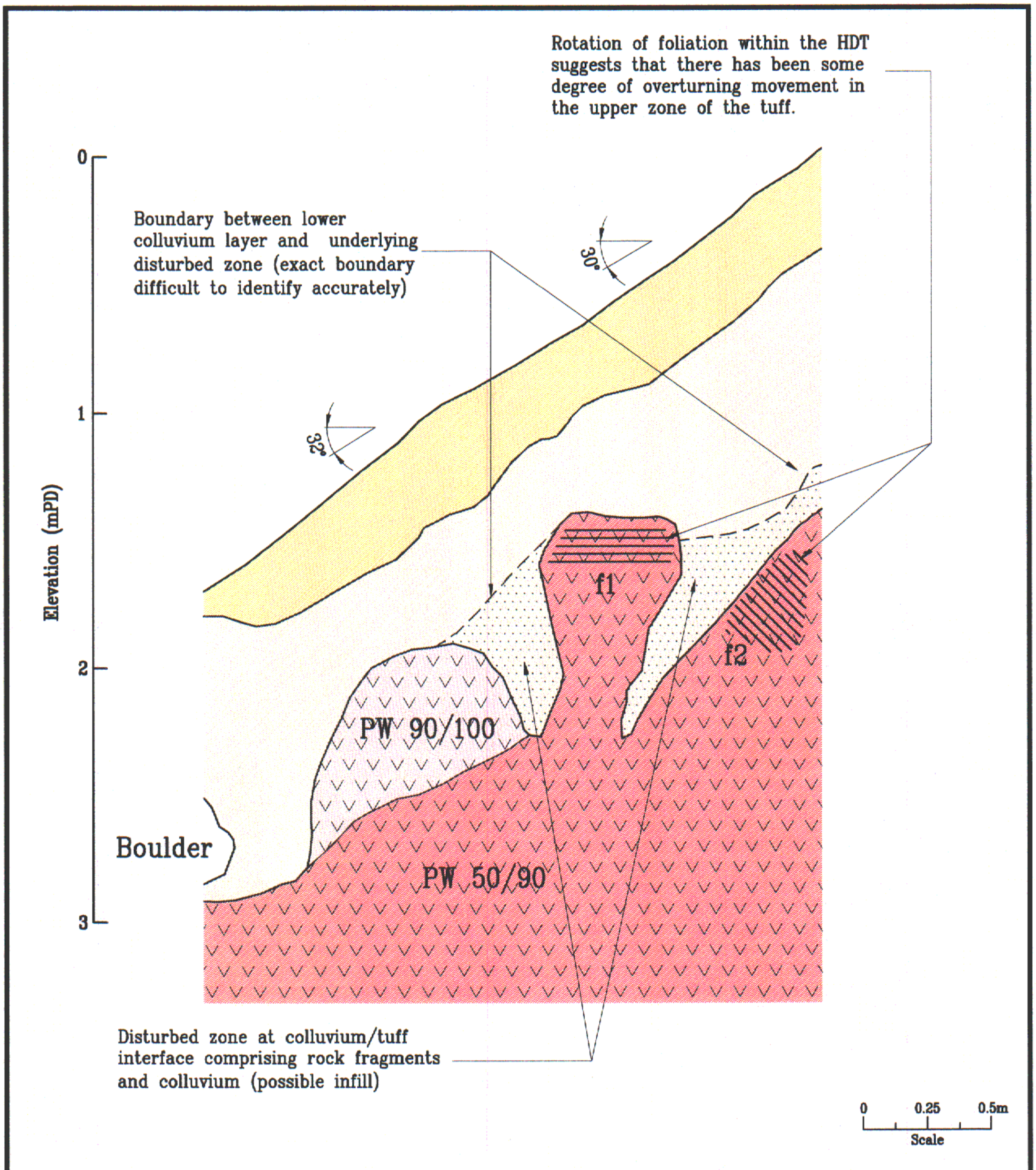


Figure 14 - Ground Investigation and Vegetation Clearance

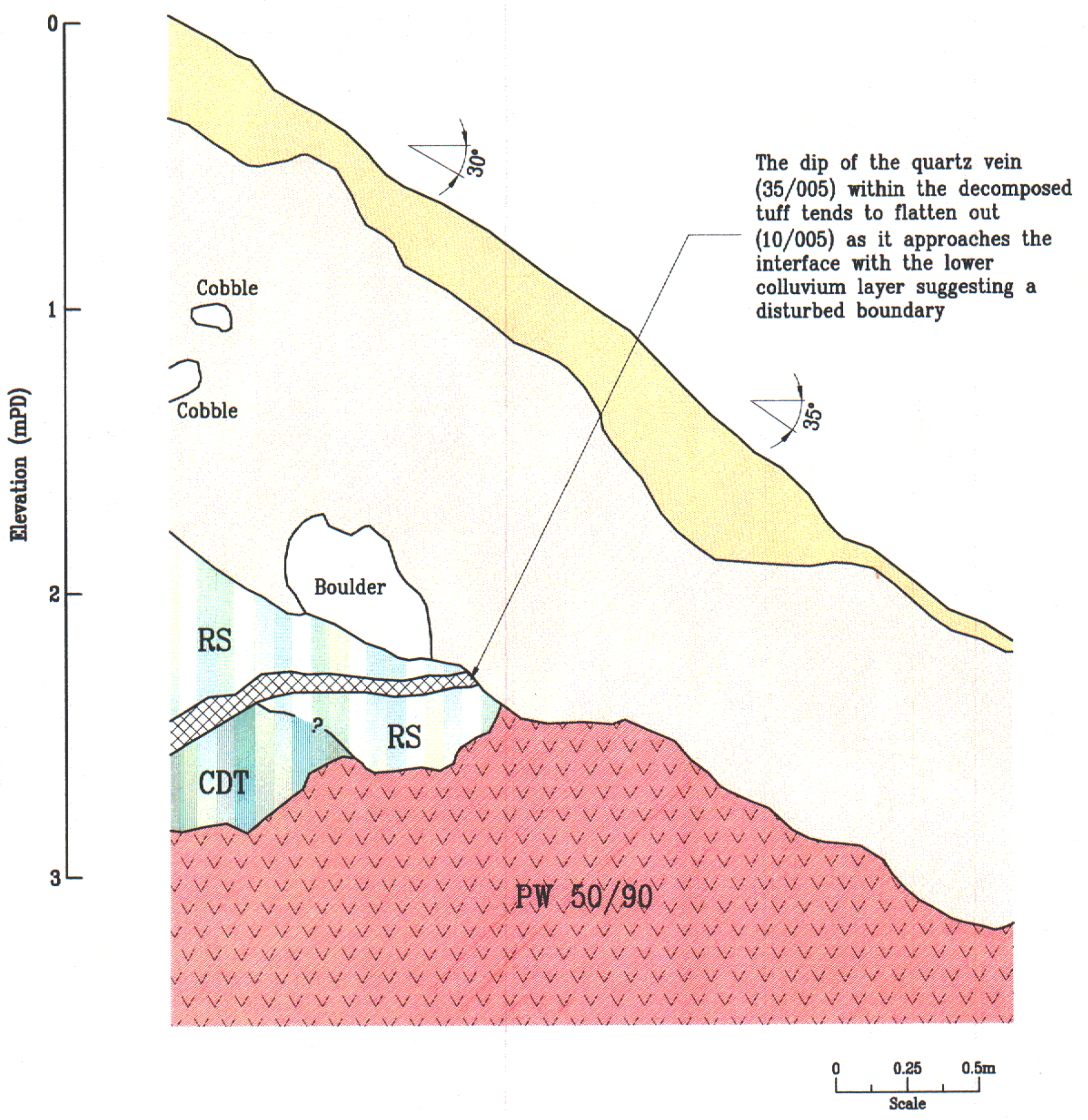


Legend:

- Upper colluvium layer
- Lower colluvium layer
- Highly decomposed fine to coarse ash crystal meta-tuff (HDT)
- Moderately decomposed fine to coarse ash crystal meta-tuff (MDT)
- f1 — Foliation locally at a flatter angle suggesting movement within the upper layer of the tuff
- f2 — Foliation within main body of tuff dips at an angle of between 35° and 55° into the slope in a northwesterly direction which is consistent with foliations identified elsewhere across the hillside
- PW 50/90 — 50% to 90% rock. Interlocked structure
- PW 90/100 — Greater than 90% rock. Small amount of the material converted to soil along discontinuities

Note : For complete trial trench log see Appendix A.

Figure 15 - Enlarged View of Face D of Trial Trench TT4

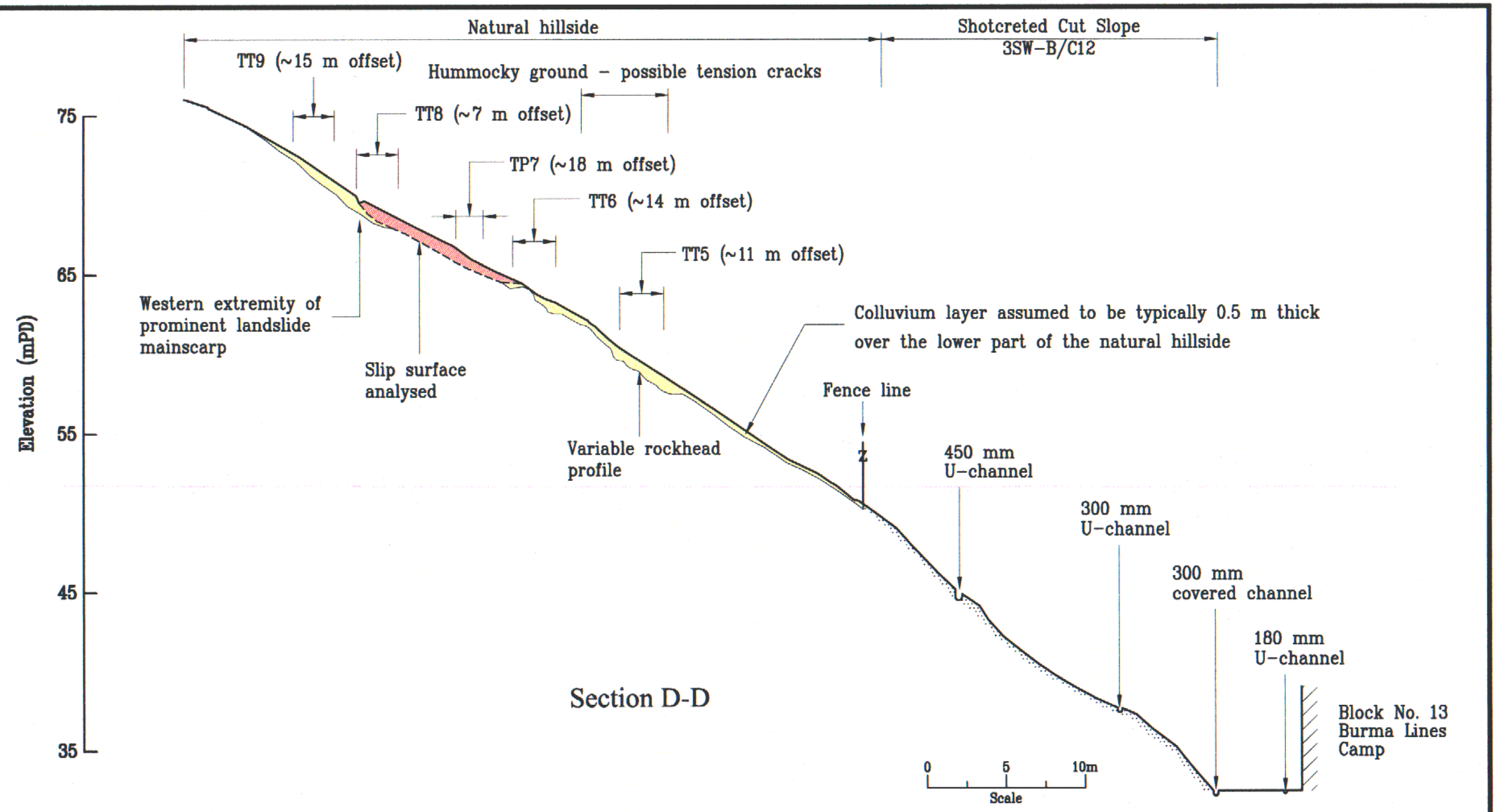


Legend:

(yellow)	Upper colluvium layer	RS	Residual soil
(white)	Lower colluvium layer	(cross-hatch)	Quartz vein
(red, V)	Highly decomposed fine to coarse ash crystal meta-tuff	PW 50/90	50% to 90% rock Interlocked structure
CDT	Completely decomposed fine to coarse ash crystal meta-tuff	PW 90/100	Greater than 90% rock Small amount of the material converted to soil along discontinuities

Note : For complete trial trnch log see Appendix A.

Figure 16 - Enlarged View of Face B of Trial Trench TT4



Legend :

- Colluvium layer
- Shotcrete covered portion of the hillside
- Extent of slip surface analysed
- ------ Postulated slip surface

Notes : (1) Information shown in this figure is based on topographic survey, ground investigation and documentary records.
(2) For location of section see Figure 2.

Figure 17 - Theoretical Stability Analysis

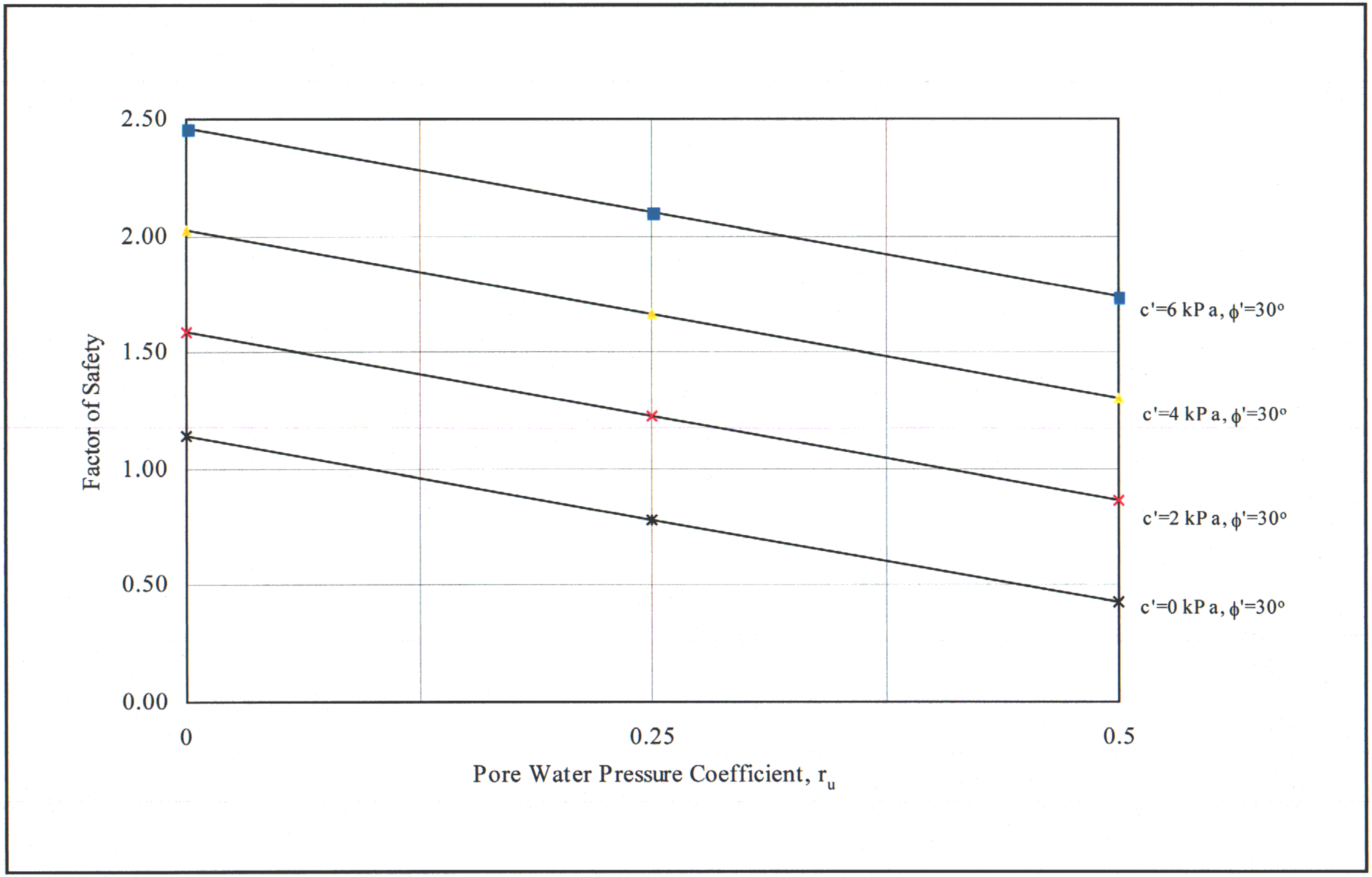
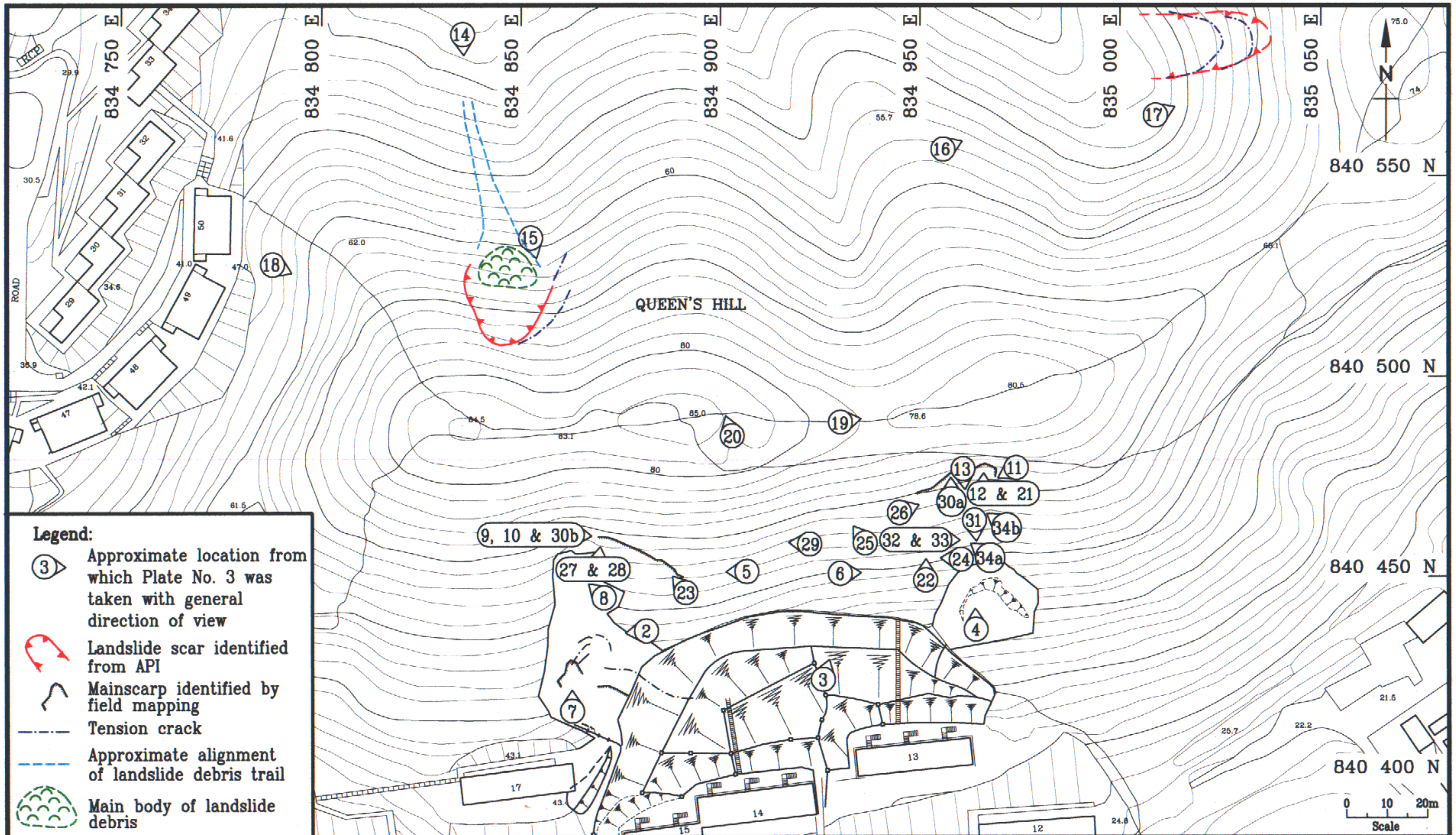


Figure 18 – Summary of Results of Stability Analyses



Notes: (1) Base Map is extracted from Survey Sheet No. 3SW-9A, scale 1 : 1000.
(2) Plate No. 1 was taken from a helicopter.
(3) Dashed lines denote uncertainty.

Figure 19 - Location and Direction of Photographic Plates

LIST OF PLATES

Plate 1 – View of Queen's Hill Showing the Layout of the Site and Location of Vegetation Strips
(Photograph taken on 10 September 1998)

Note : See Figure 19 for Location of Photograph.

Plate 2 – View of Extensive Cracking and Bulging Visible in the Shallow Depression above Blocks 15 and 17
(Photographs taken on 23 January 1998)

Note : See Figure 19 for Locations of Photographs.

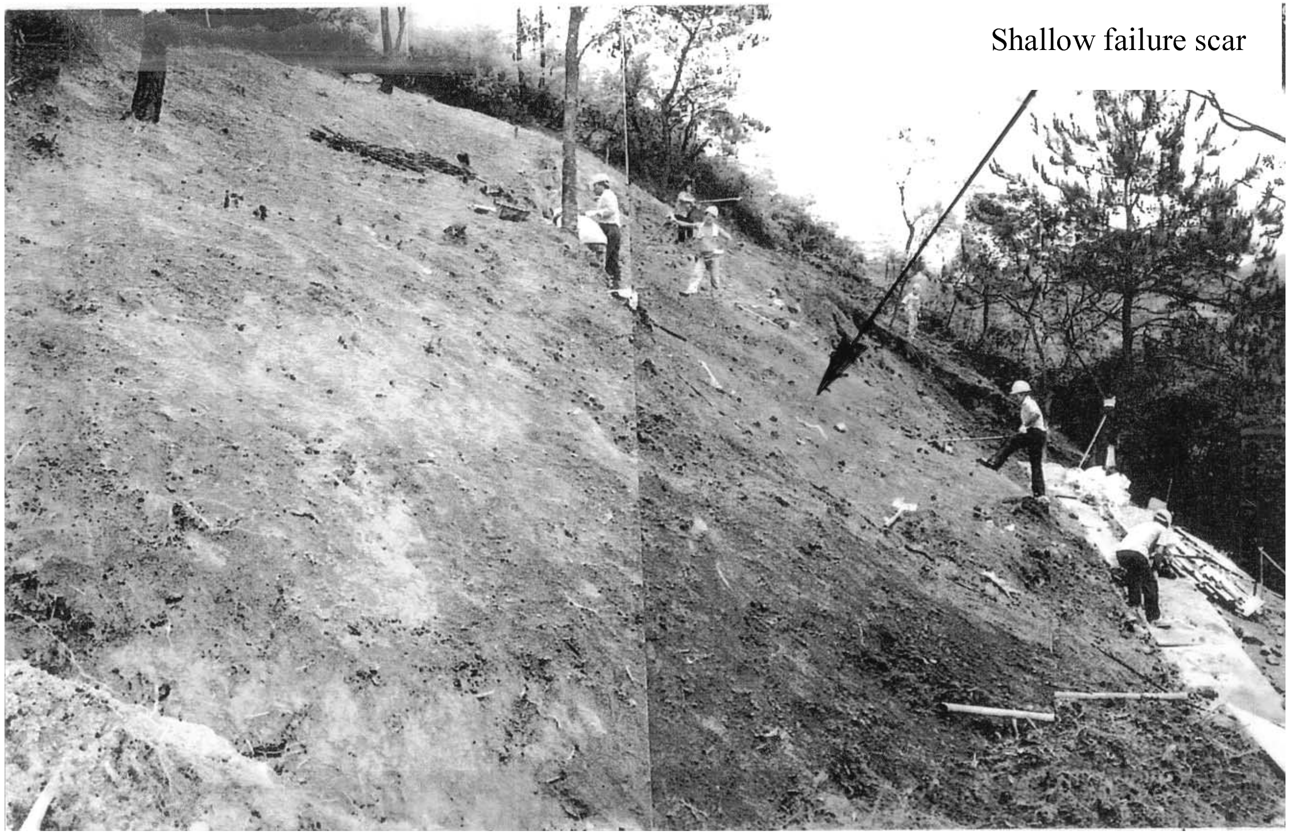


Plate 3 – View of Shallow Failure Scar Identified in the Hillside above Block 13
(Photographs taken on 29 April 1998)

Note : See Figure 19 for Locations of Photographs.

Plate 4 – View of Old Landslide Scar Identified above Block 13
(Photographs taken on 9 March 1998)

Note : See Figure 19 for Locations of Photographs.

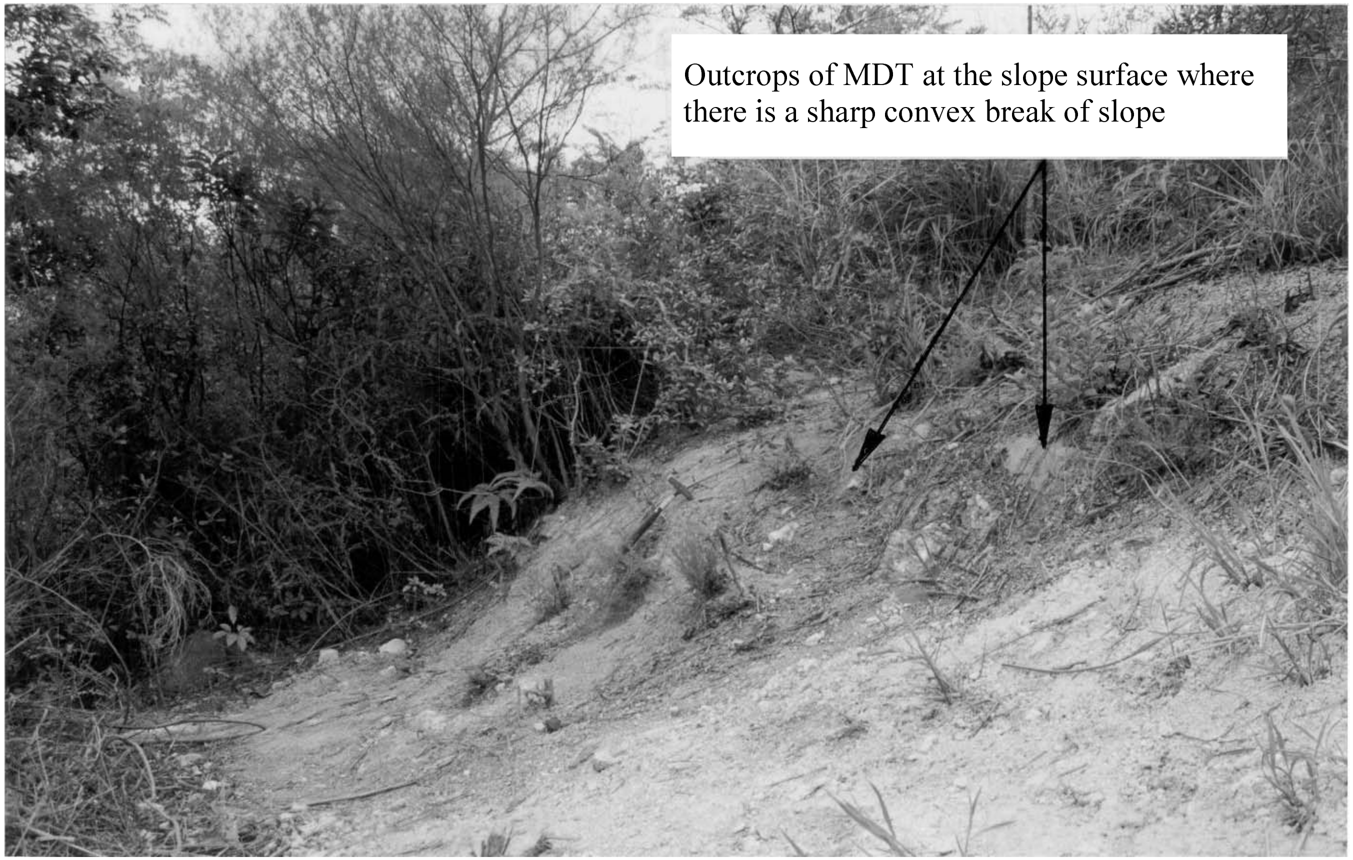


Plate 5 – View of Prominent Convex Break of Slope
(Photograph taken on 14 April 1999)

Note : See Figure 19 for Location of Photograph.

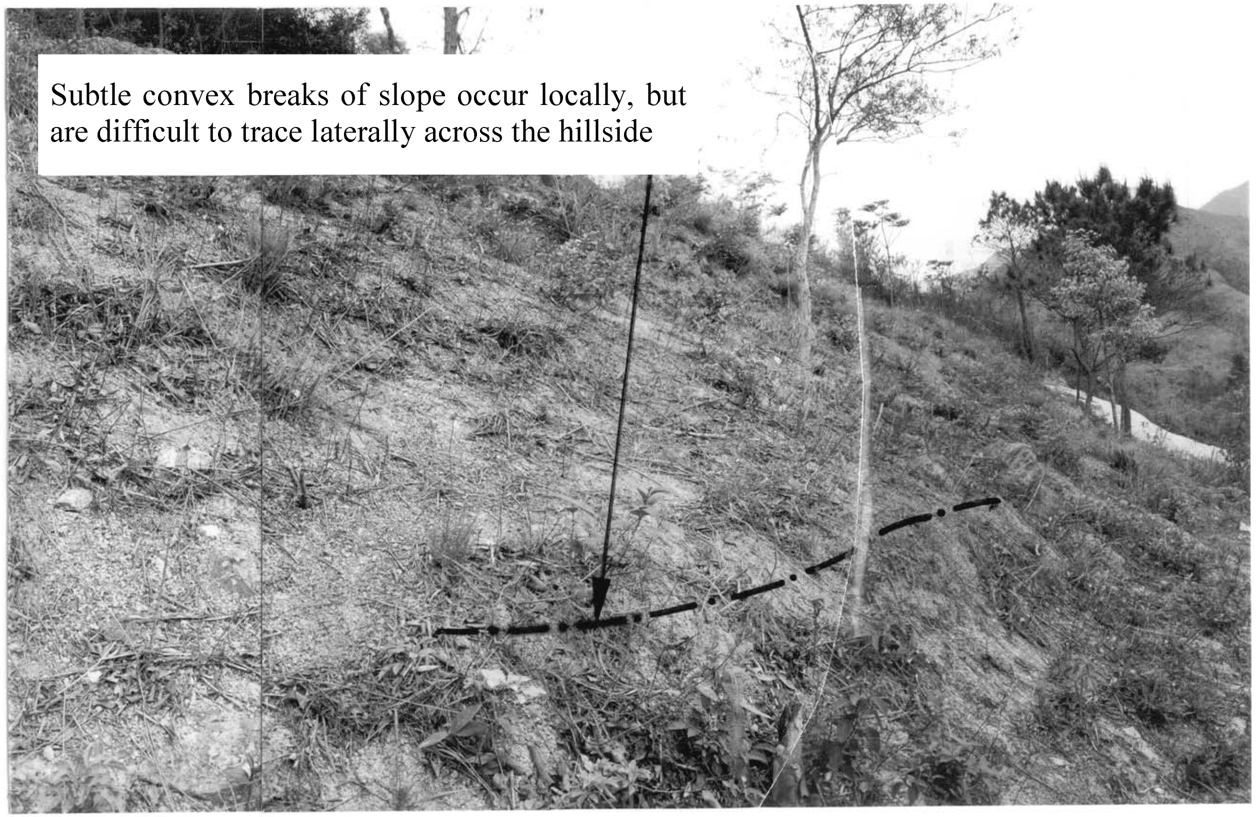


Plate 6 – View across the Lower Eastern Portion of the Site Showing the Hummocky Nature of the Ground (Photographs taken on 14 April 1999)

Note : See Figure 19 for Locations of Photographs.

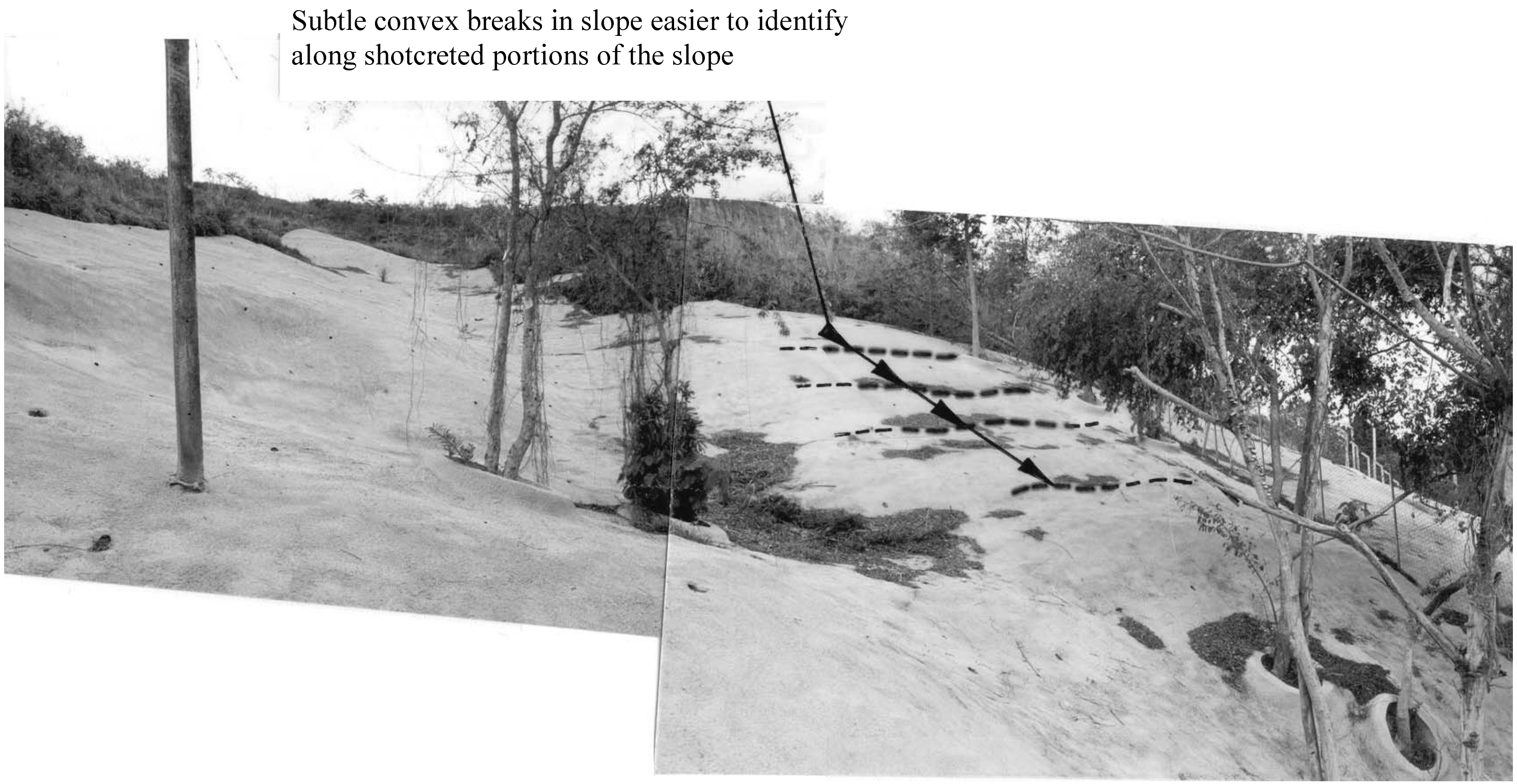


Plate 7 – General View of the Shallow Depression in the Western Half of the Site
(Photographs taken on 14 April 1999)

Note : See Figure 19 for Locations of Photographs.

Plate 8 – View of Upper Portion of the Shallow Depression in the Western Half of the Site
(Photographs taken on 14 April 1999)

Note : See Figure 19 for Locations of Photographs.

Plate 9 – View of Prominent Mainscarp in the Western Half of the Site
(Photographs taken on 14 April 1999)

Note : See Figure 19 for Locations of Photographs.

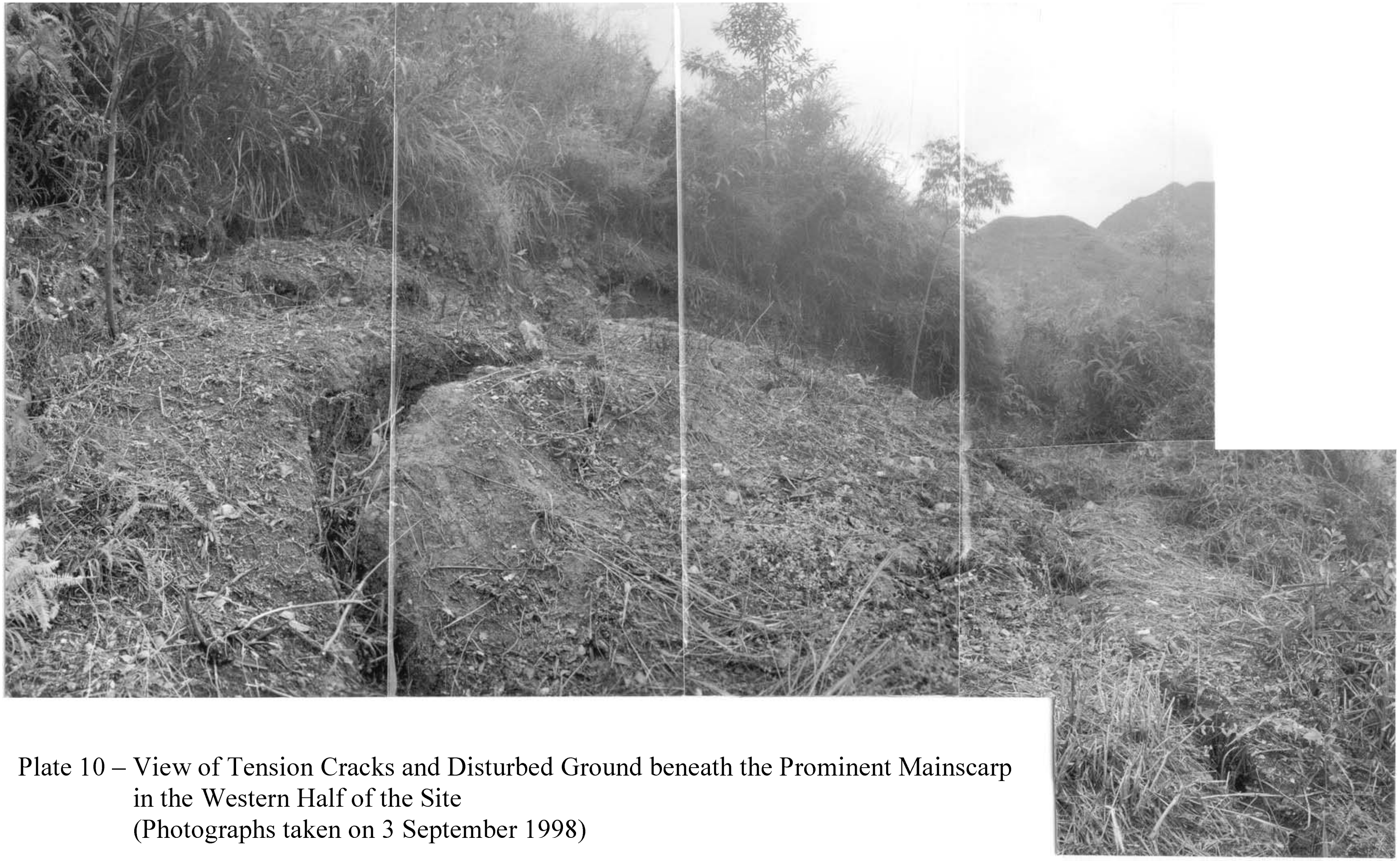


Plate 10 – View of Tension Cracks and Disturbed Ground beneath the Prominent Mainscarp in the Western Half of the Site
(Photographs taken on 3 September 1998)

Note : See Figure 19 for Locations of Photographs.

Plate 11 – General View of Mainscarp and Disturbed Ground in the Eastern Half (Upper Part) of the Site
(Photographs taken on 23 September 1998)

Note : See Figure 19 for Locations of Photographs.

Plate 12 – View of Mainscarp in the Eastern Half (Upper Part) of the Site
(Photographs taken on 17 September 1998)

Note : See Figure 19 for Locations of Photographs.

Erosion has excentuated the profile of
the debris trail below the mainscarp

Plate 13 – Debris Trail of L-shaped Landslide Scar
(Photographs taken on 23 September 1998)

Note : See Figure 19 for Locations of Photographs.

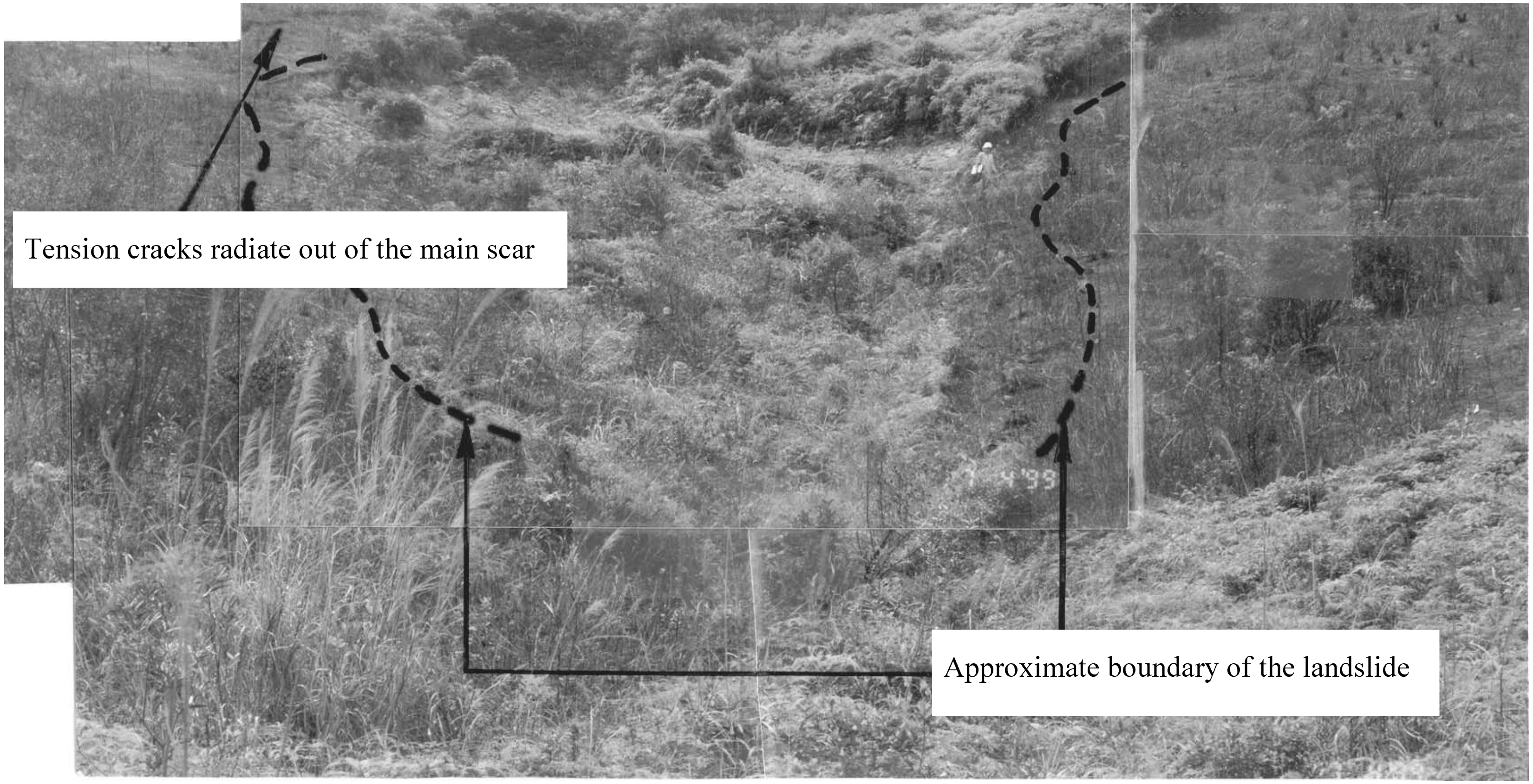


Plate 14 – General View of Apparently Recent Instability within a Relict Landslide Scar on the Northern Side of Queen's Hill (Photographs taken on 7 April 1999)

Note : See Figure 19 for Locations of Photographs.

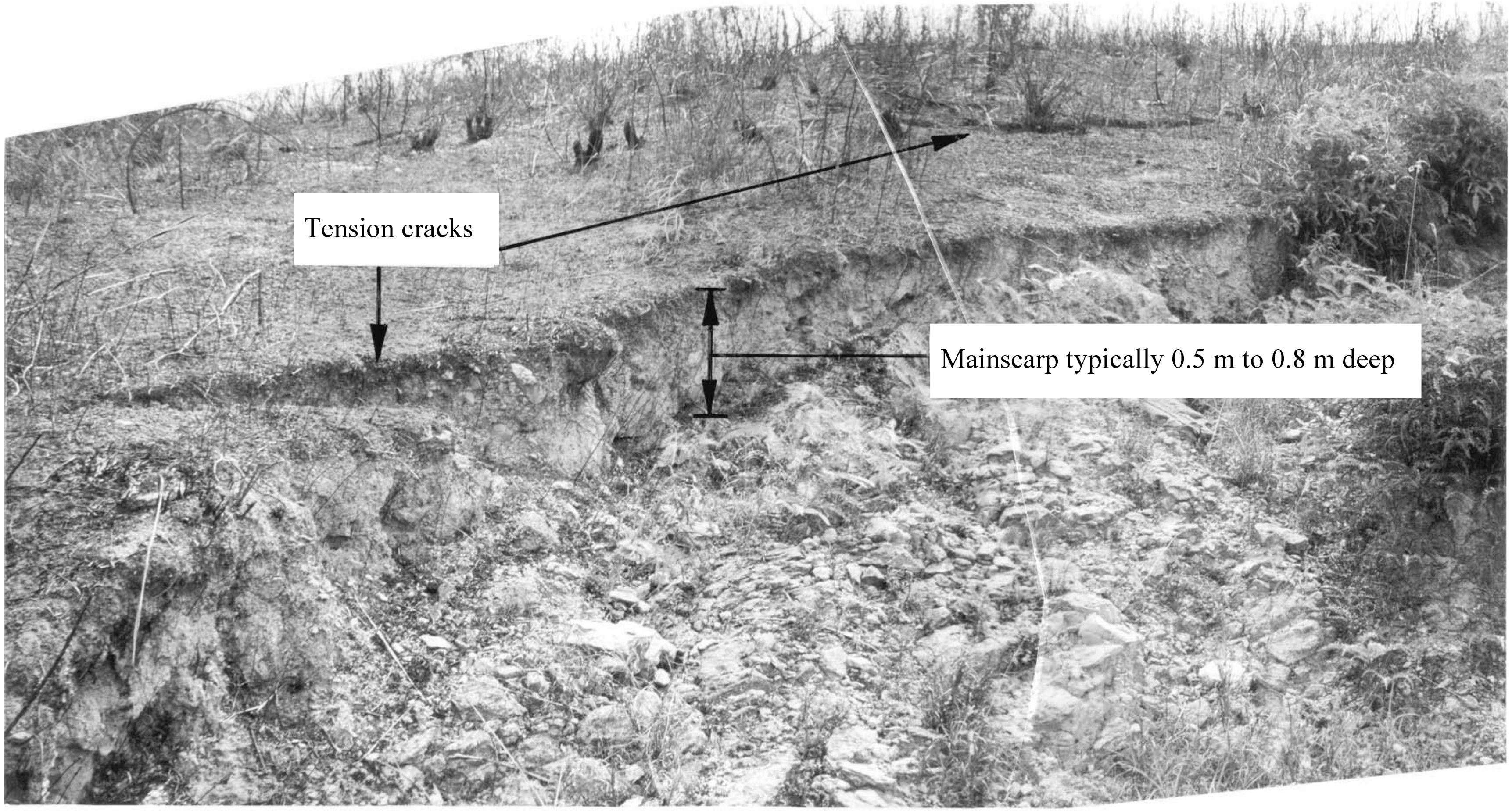


Plate 15 – Close-up View of Mainscarp from Plate 13 Showing the Shallow Nature of the Instability
(Photographs taken on 7 April 1999)

Note : See Figure 19 for Locations of Photographs.

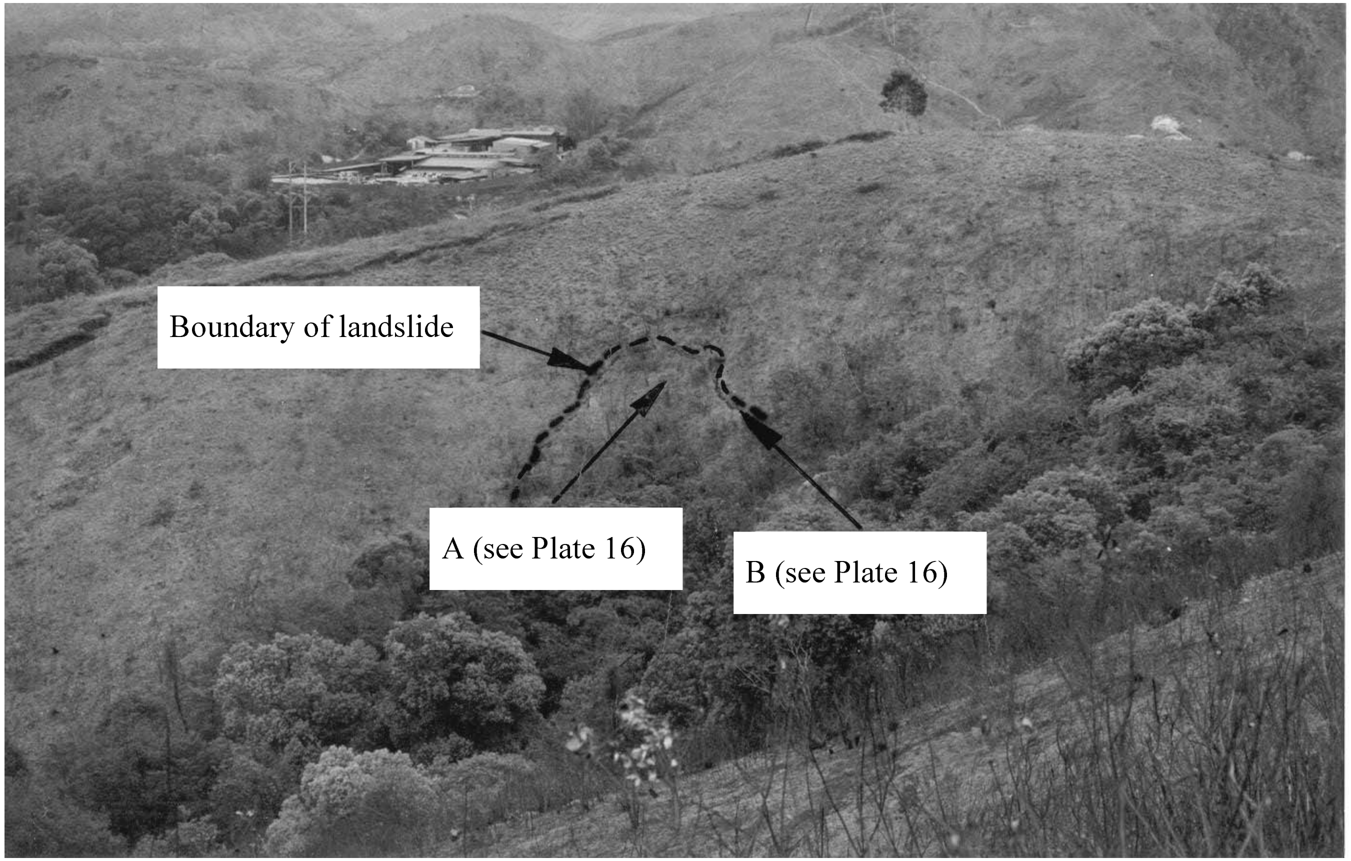


Plate 16 – View of Further Shallow Instability along the Flank of a Relict Landslide Scar on the Northern Side of Queen's Hill (Sheet 1 of 2)
(Photographs taken on 14 April 1999)

Note : See Figure 19 for Locations of Photographs.

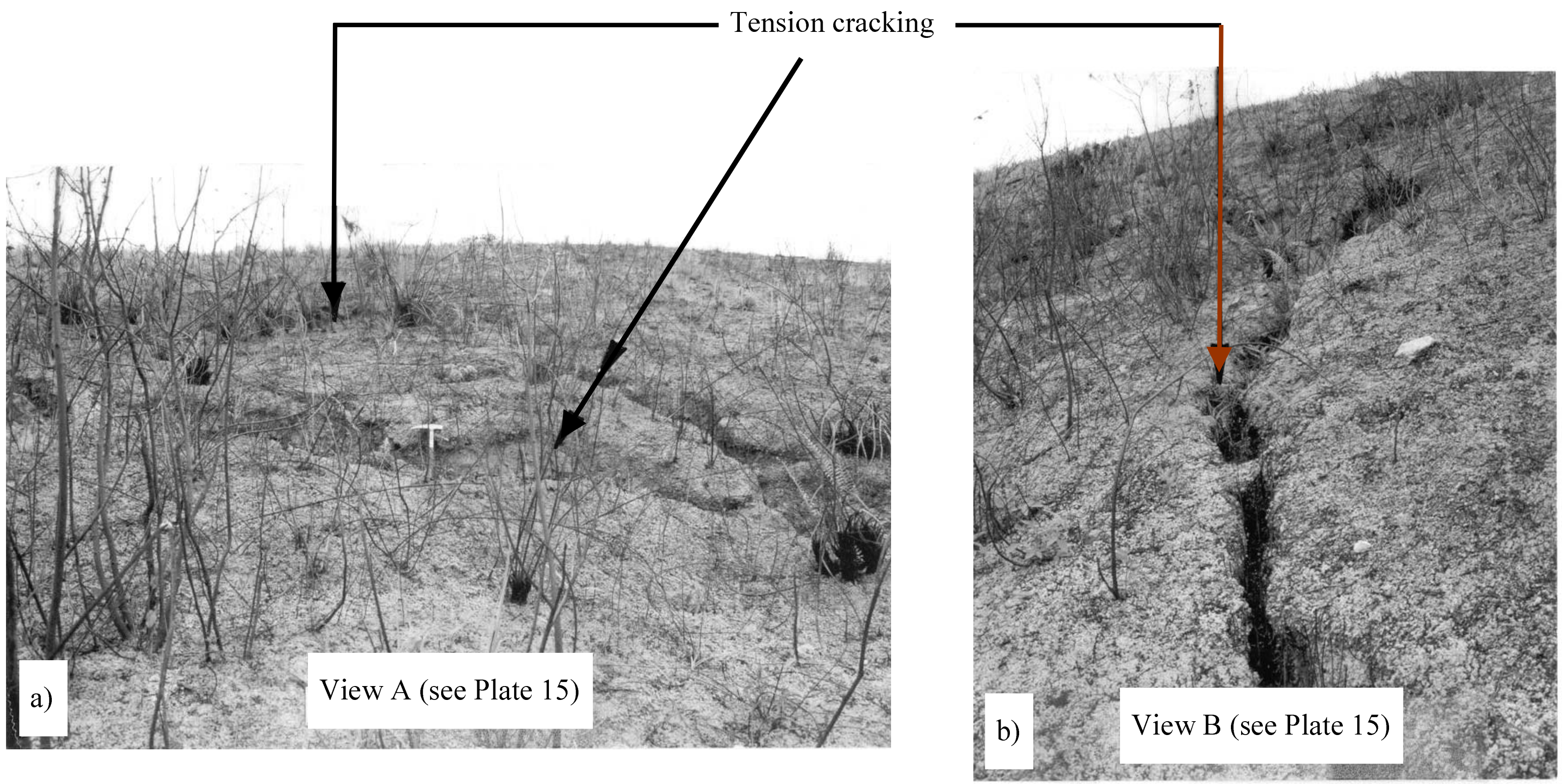


Plate 17– View of Further Shallow Instability along the Flank of a Relict Landslide Scar on the Northern Side of Queen's Hill (Sheet 2 of 2)
(Photographs taken on 14 April 1999)

Note : See Figure 19 for Locations of Photographs.

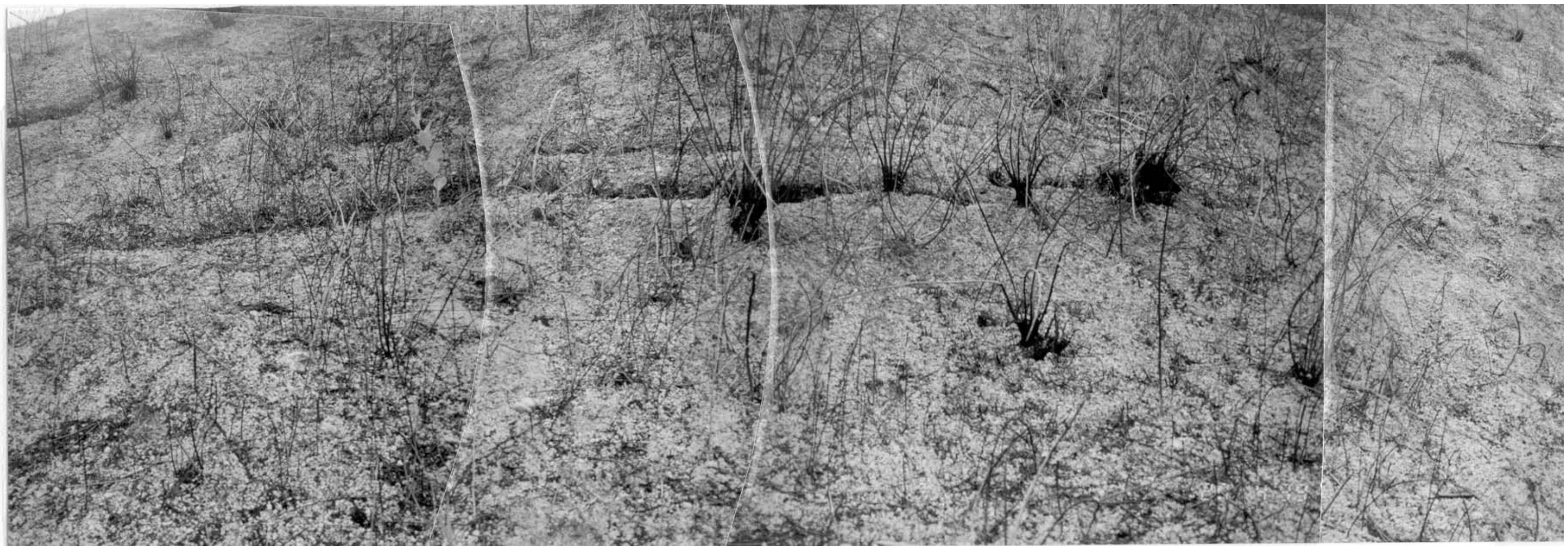


Plate 18 – Tension Cracking and Relict Landslides Observed on Western Side of Queen's Hill Following Recent (April 1999) Hillfires
(Photographs taken on 27 April 1999)

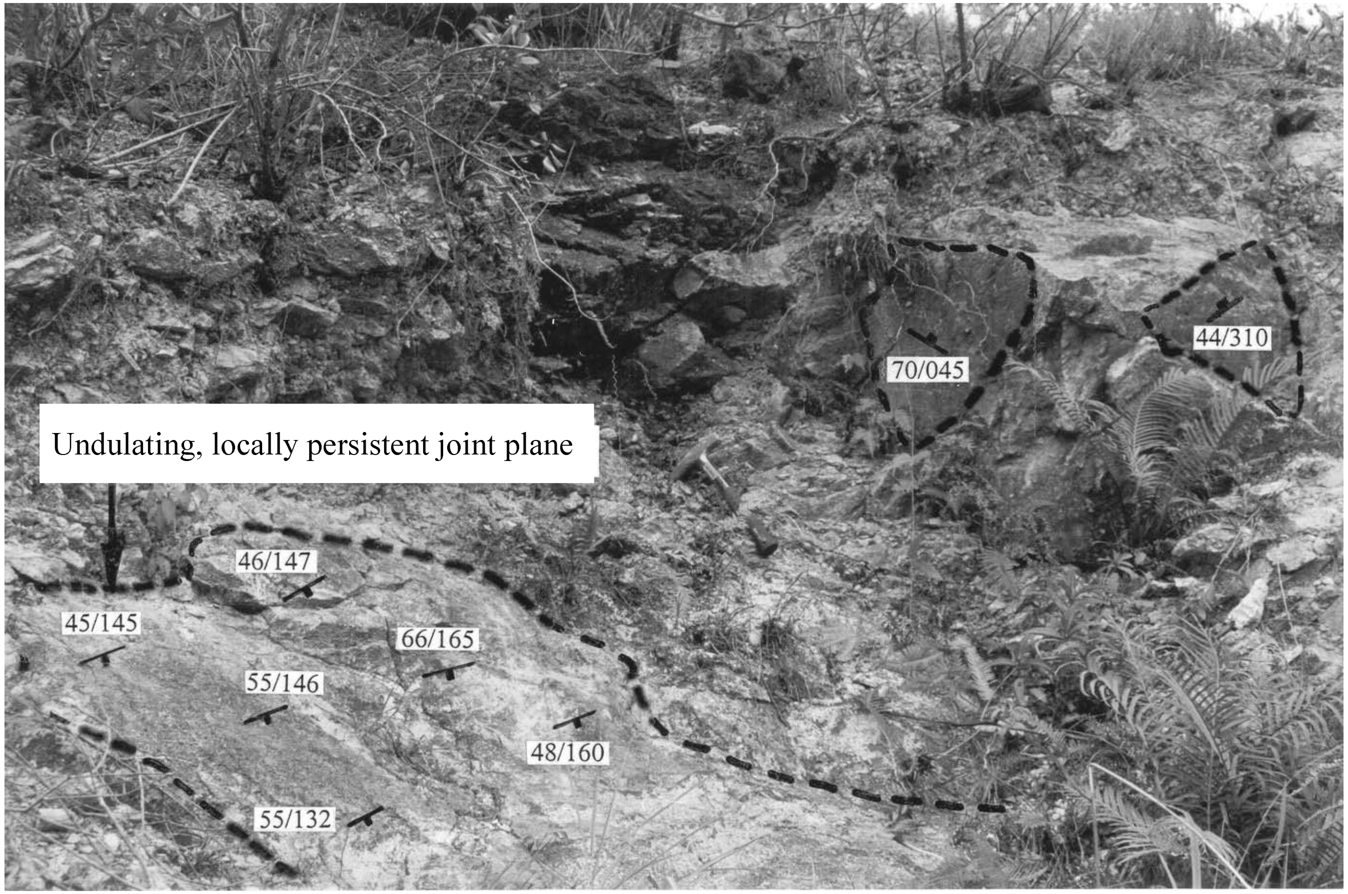
Note : See Figure 19 for Locations of Photographs.

Plate 19 – Man-made Trench Running along Queen's Hill Ridgeline
(Photographs taken on 9 June 1999)

Note: See Figure 19 for Locations of Photographs.

Plate 20 – View of Iron Stained Outer Layer Exposed along MDT Outcrops
(Photographs taken on 14 April 1999)

Note: See Figure 18 for Location of Photograph.



Legend:

Joint measurement
48/160 (Dip angle/Dip direction)

Plate 21 – View of Mainscarp Exposed in the Northeastern Corner of the Site Showing Adverse Jointing
(Photograph taken on 14 April 1999)

Note : See Figure 19 for Location of Photograph.

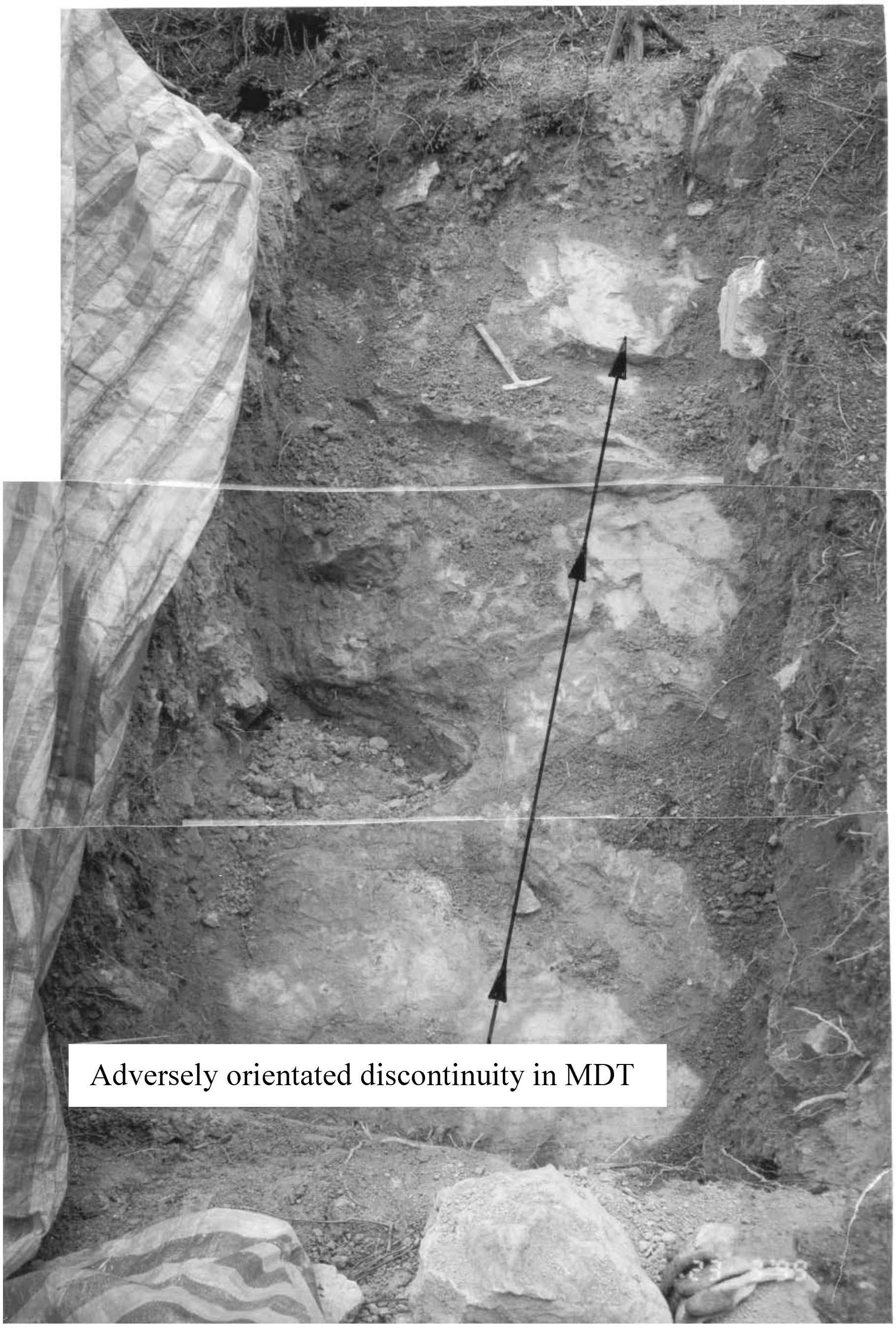


Plate 22 – General View of Trial Trench TT5
(Photographs taken on 23 March 1999)

Note: See Figure 19 for Location of Photograph.

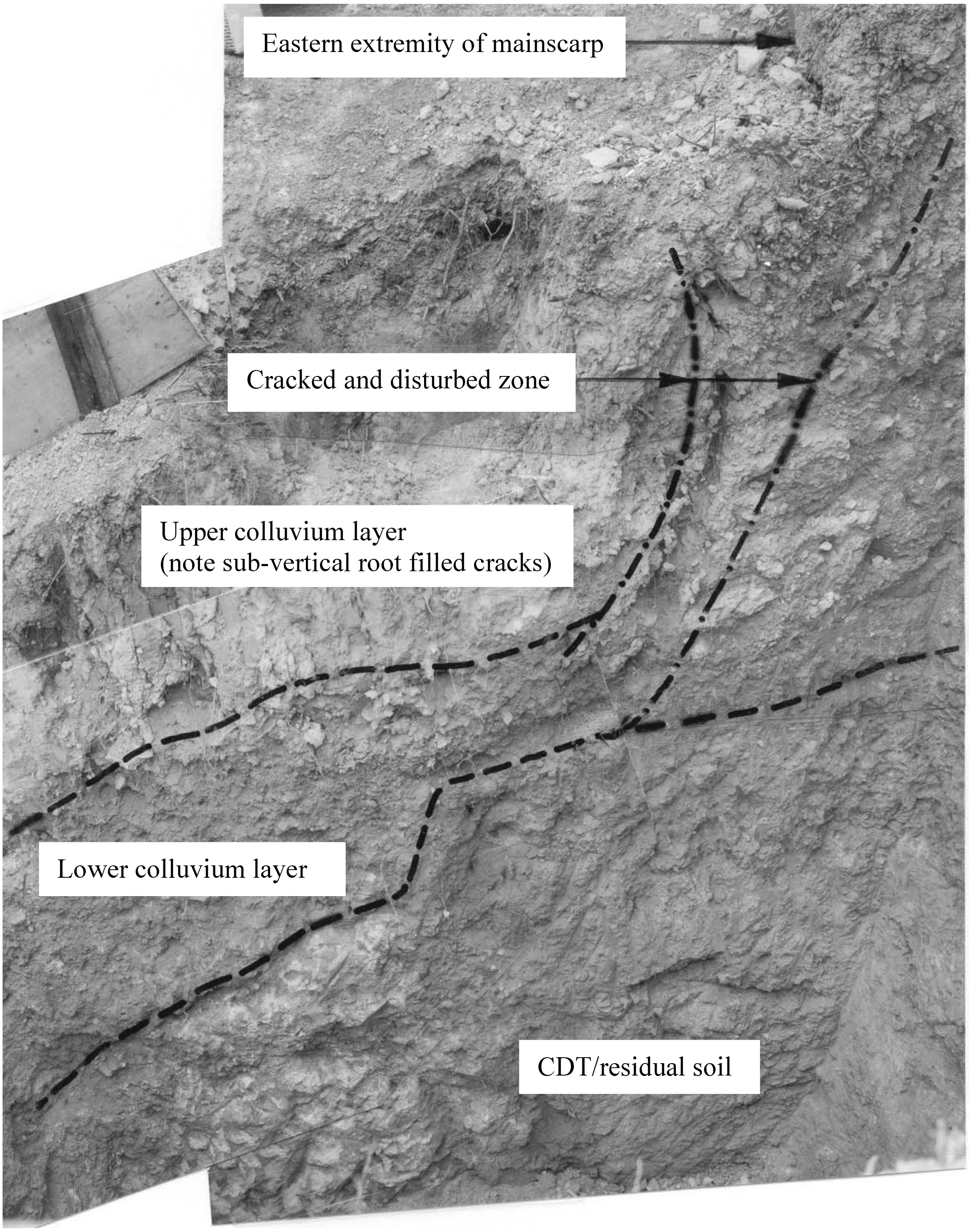


Plate 23 – View of Face D, Trial Trench TT2
(Photographs taken on 23 March 1999)

Note: See Figure 19 for Locations of Photographs.

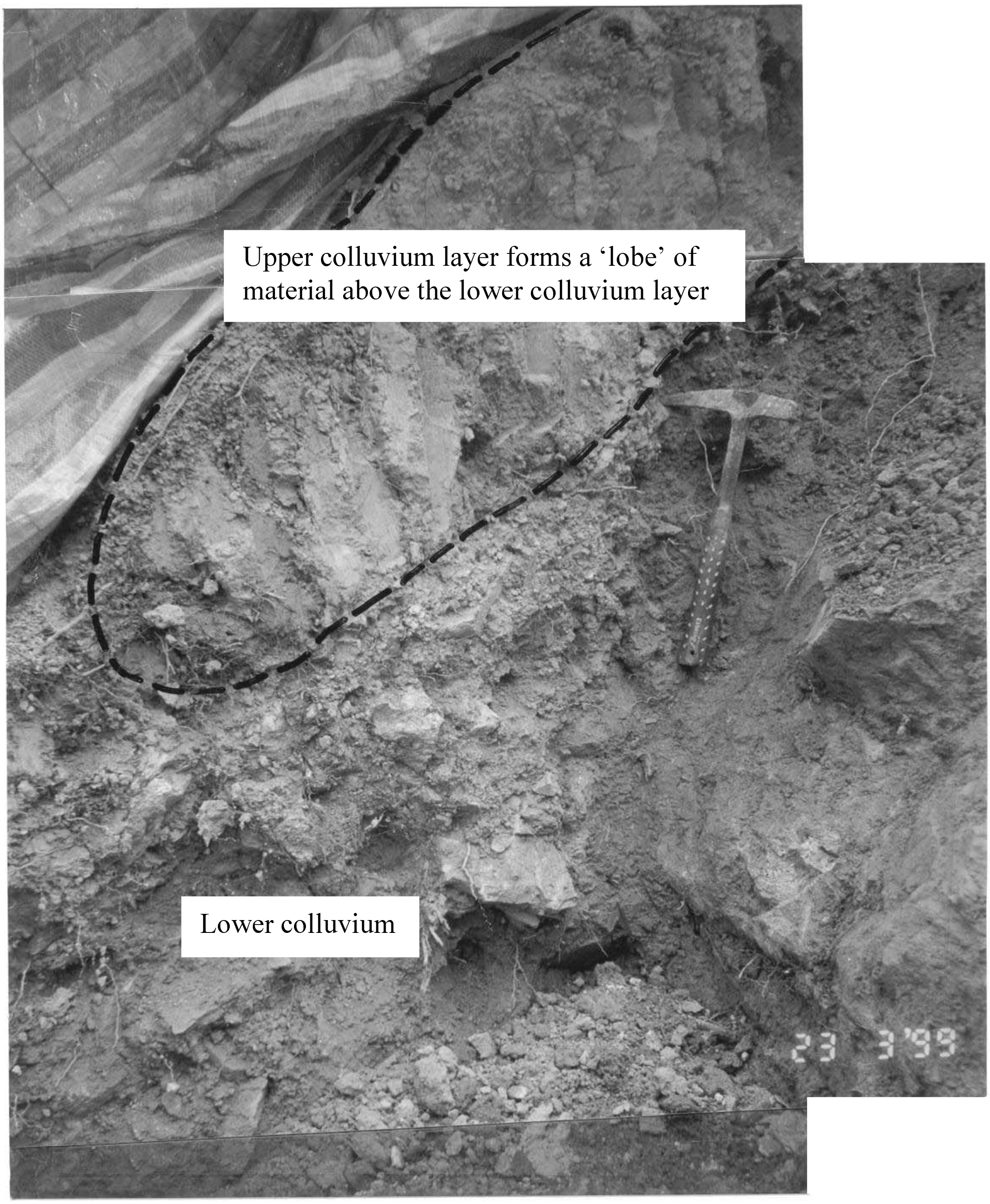


Plate 24 – View of Face D of Trial Trench TT5 Showing Upper Layer of Colluvium Forming a "Lobe" of Material above the Lower Colluvium Layer (Photographs taken on 23 March 1999)

Note: See Figure 19 for Locations of Photographs.

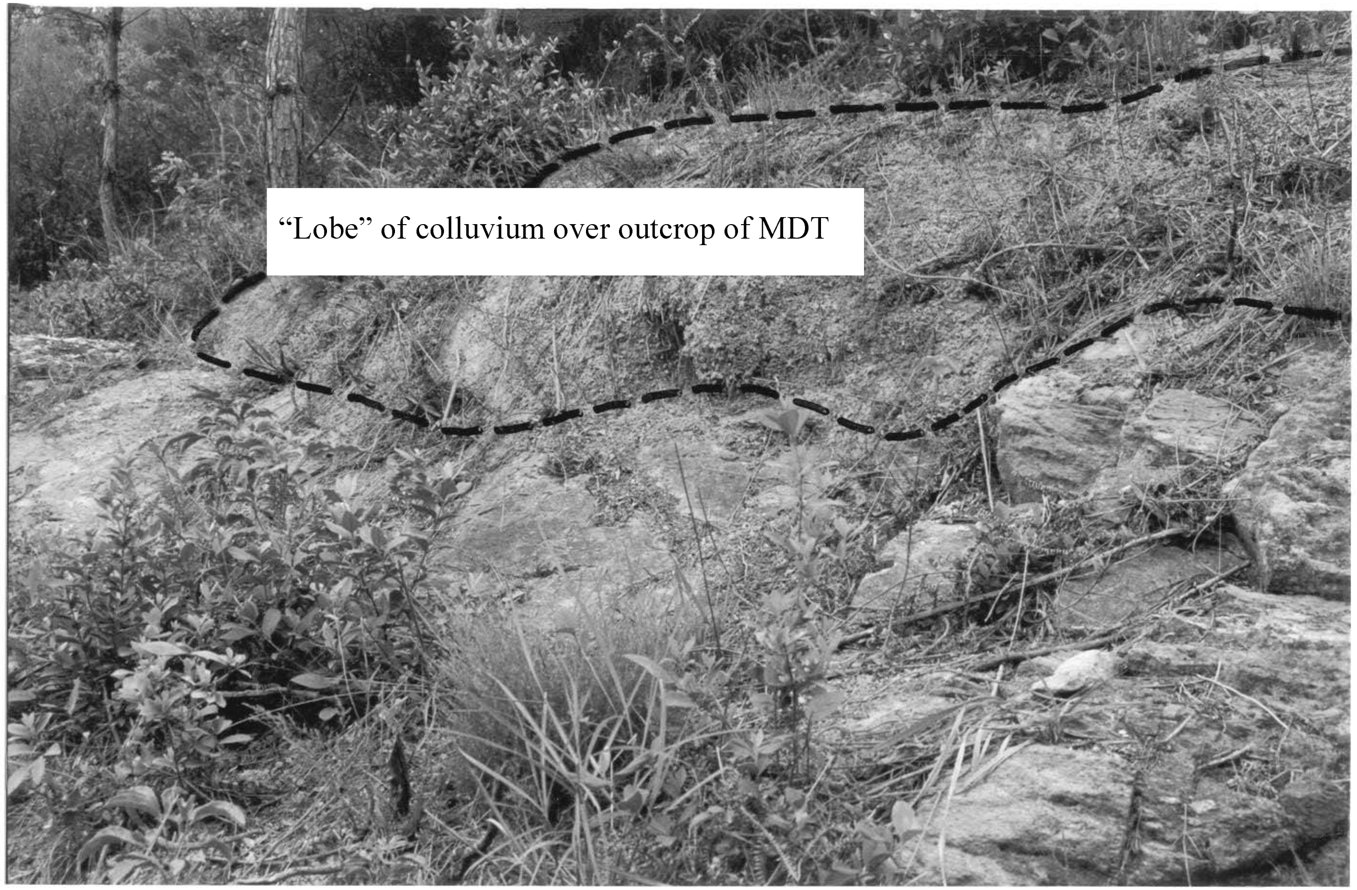


Plate 25 – View of MDT Outcrop. Note "Lobe" of Colluvium Overlying this Surface (Photograph taken on 14 April 1999)

Note : See Figure 19 for Location of Photograph.

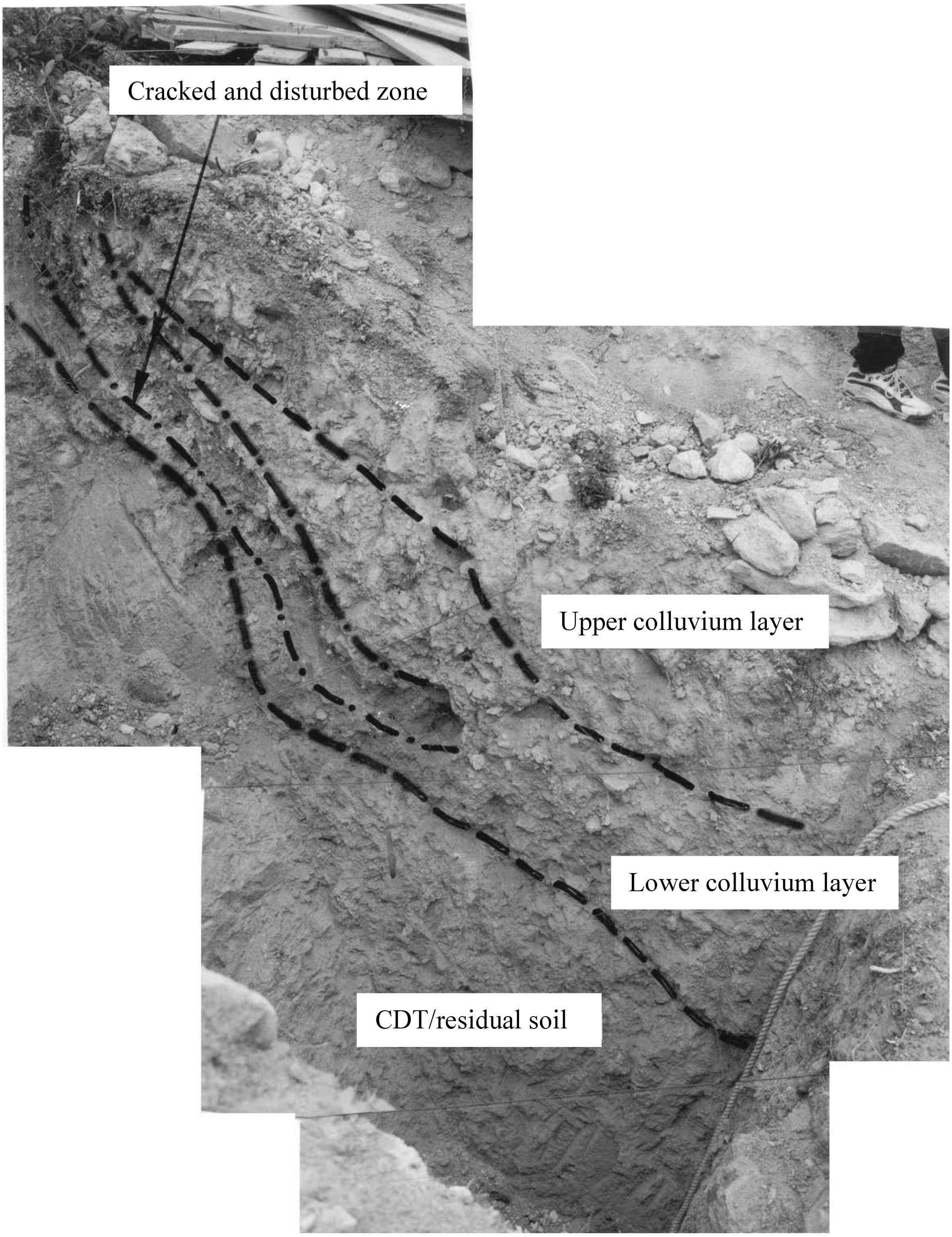


Plate 26 – View of Voided Shear Zone Exposed in Face A, Trial Trench TT8
(Photographs taken on 23 March 1999)

Note: See Figure 19 for Locations of Photographs.

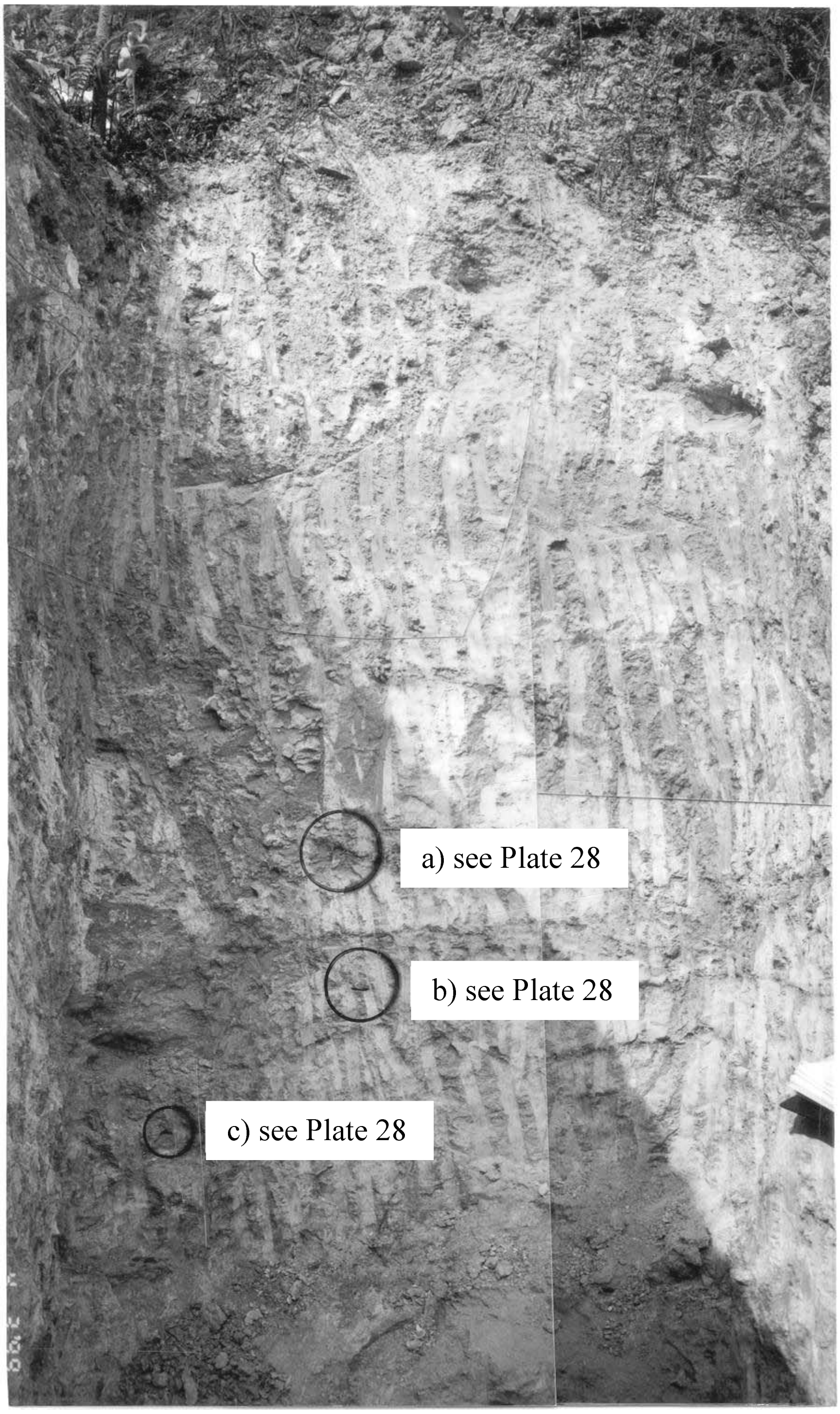


Plate 27 – View of Face A, Trial Trench TT1, Showing Location of Voids/Soil Pipes within the C-HDT
(Photographs taken on 4 March 1999)

Note: See Figure 19 for Locations of Photographs.

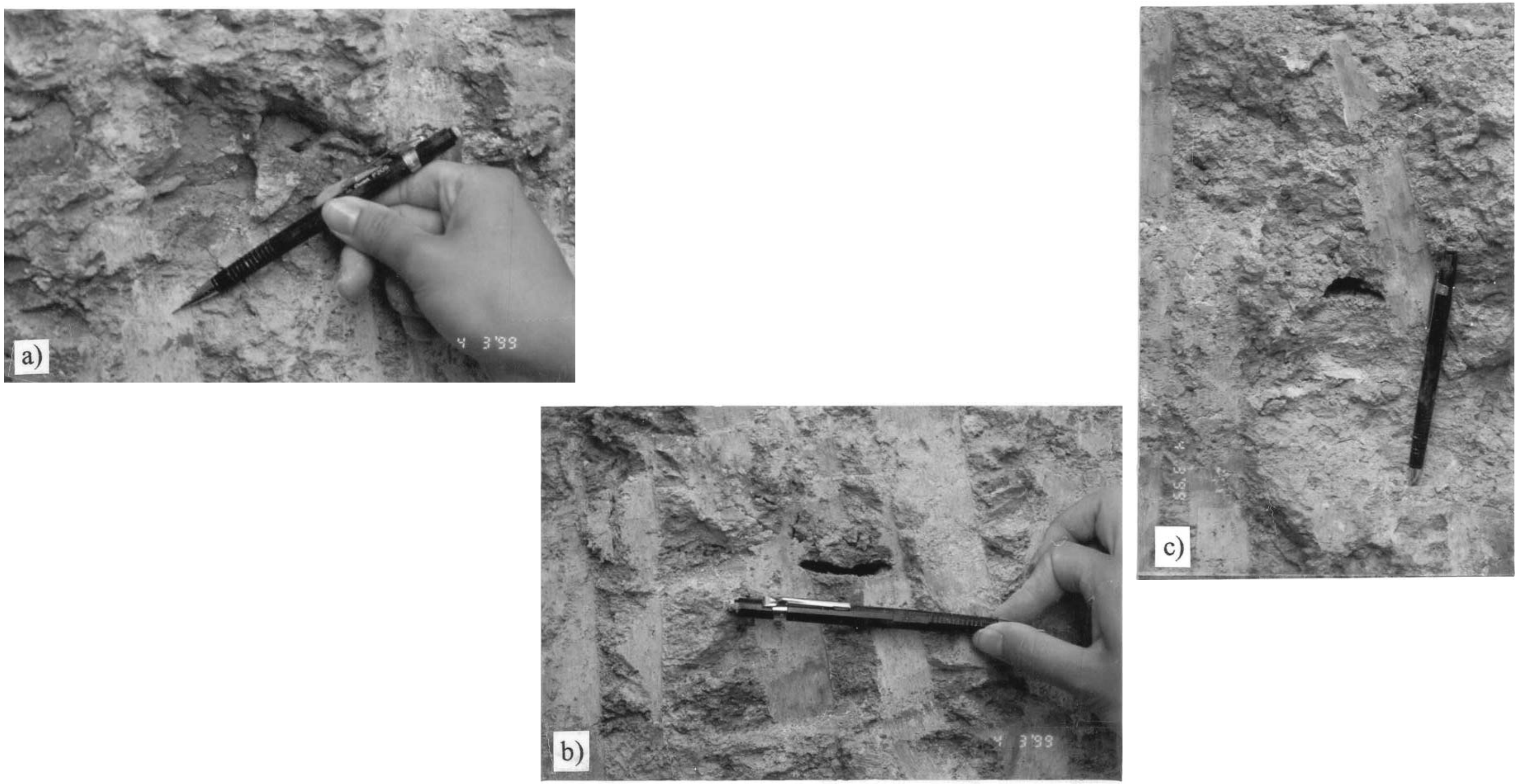


Plate 28 – Close-up Views of Voids/Soil Pipes Exposed in Trial Trench TT1
(Photographs taken on 4 March 1999 - see Plate 27 for locations)

Note : See Figure 19 for Locations of Photographs.

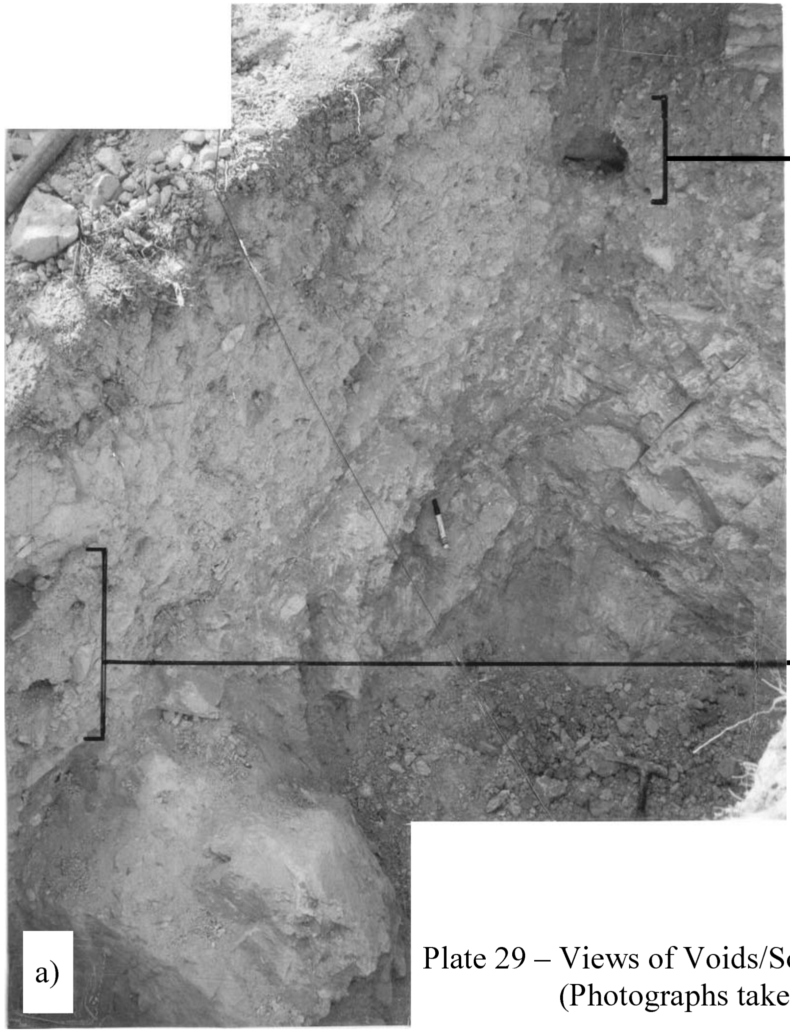
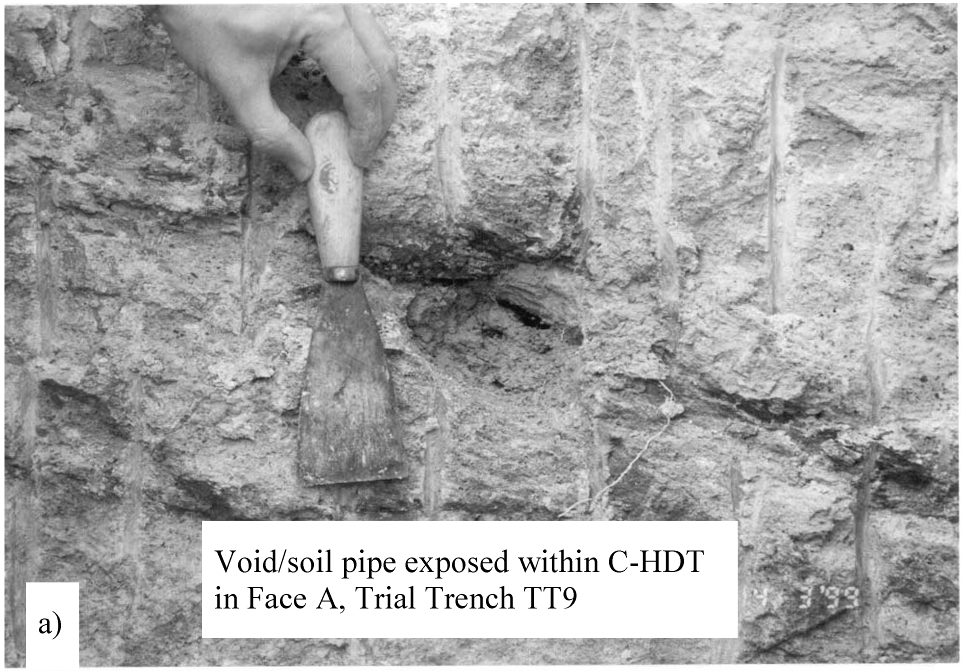


Plate 29 – Views of Voids/Soil Pipes Exposed in Trial Trench TT4
(Photographs taken on 4 March 1999)

Note : See Figure 19 for Locations of Photographs.



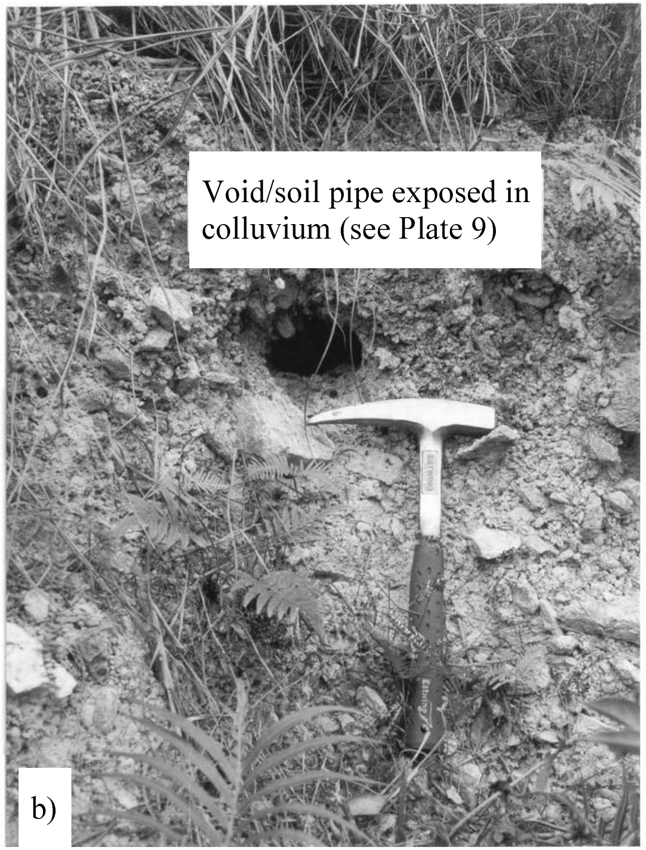


Plate 30 – Views of Voids/Soil Pipes Identified within the Site
(Photographs taken on 4 March 1999)

Note : See Figure 19 for Locations of Photographs.

Plate 31 – Views of Face C, Trial Pit TP7 Showing Lateral Cracking/Voiding within CDT
(Photographs taken on 4 March 1999)

Note : See Figure 19 for Locations of Photographs.

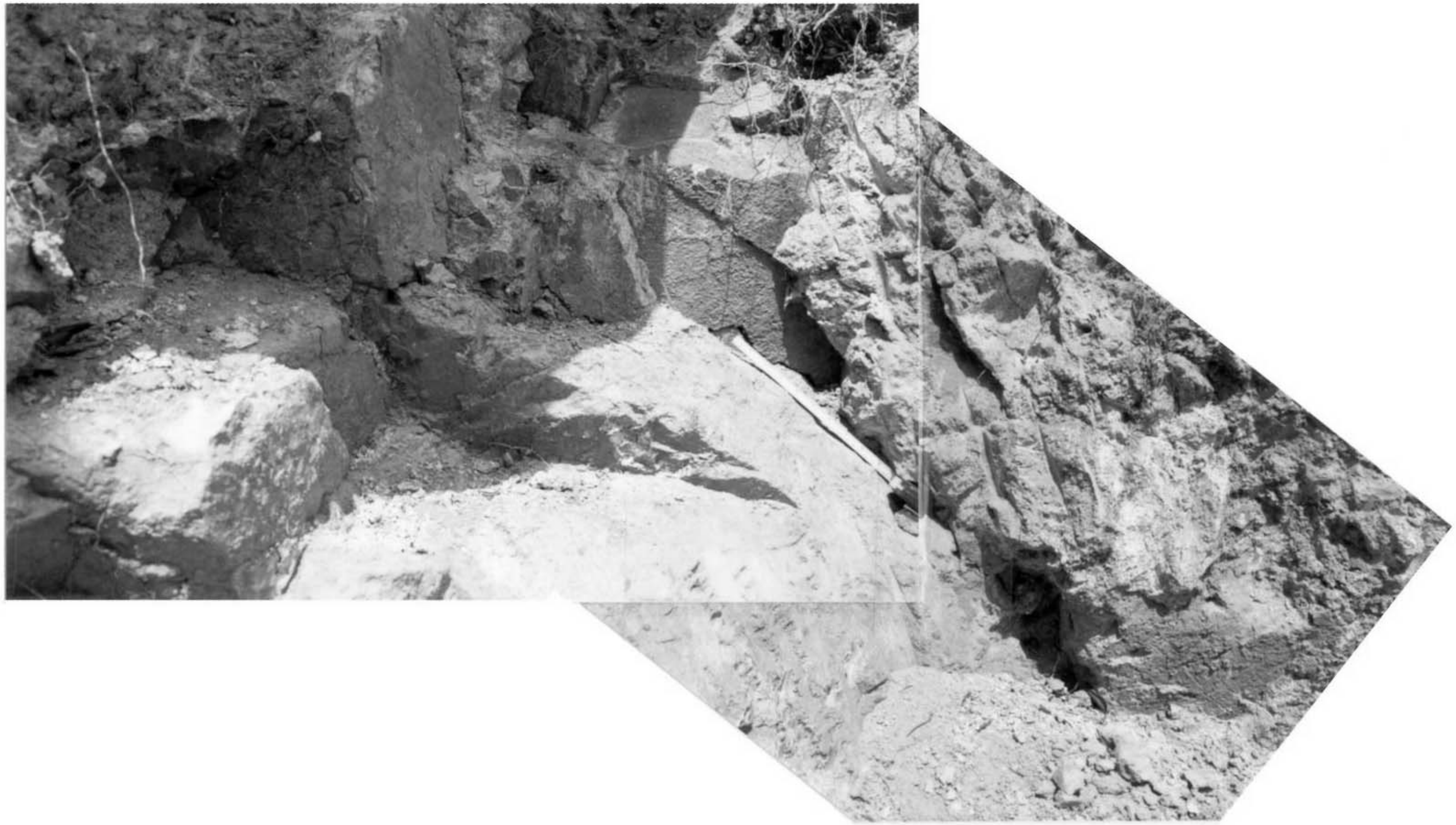


Plate 32 – View of Face B, Trial Pit TP7 Showing Cracking within H-MDT
(Photographs taken on 23 March 1999)

Note : See Figure 19 for Locations of Photographs.

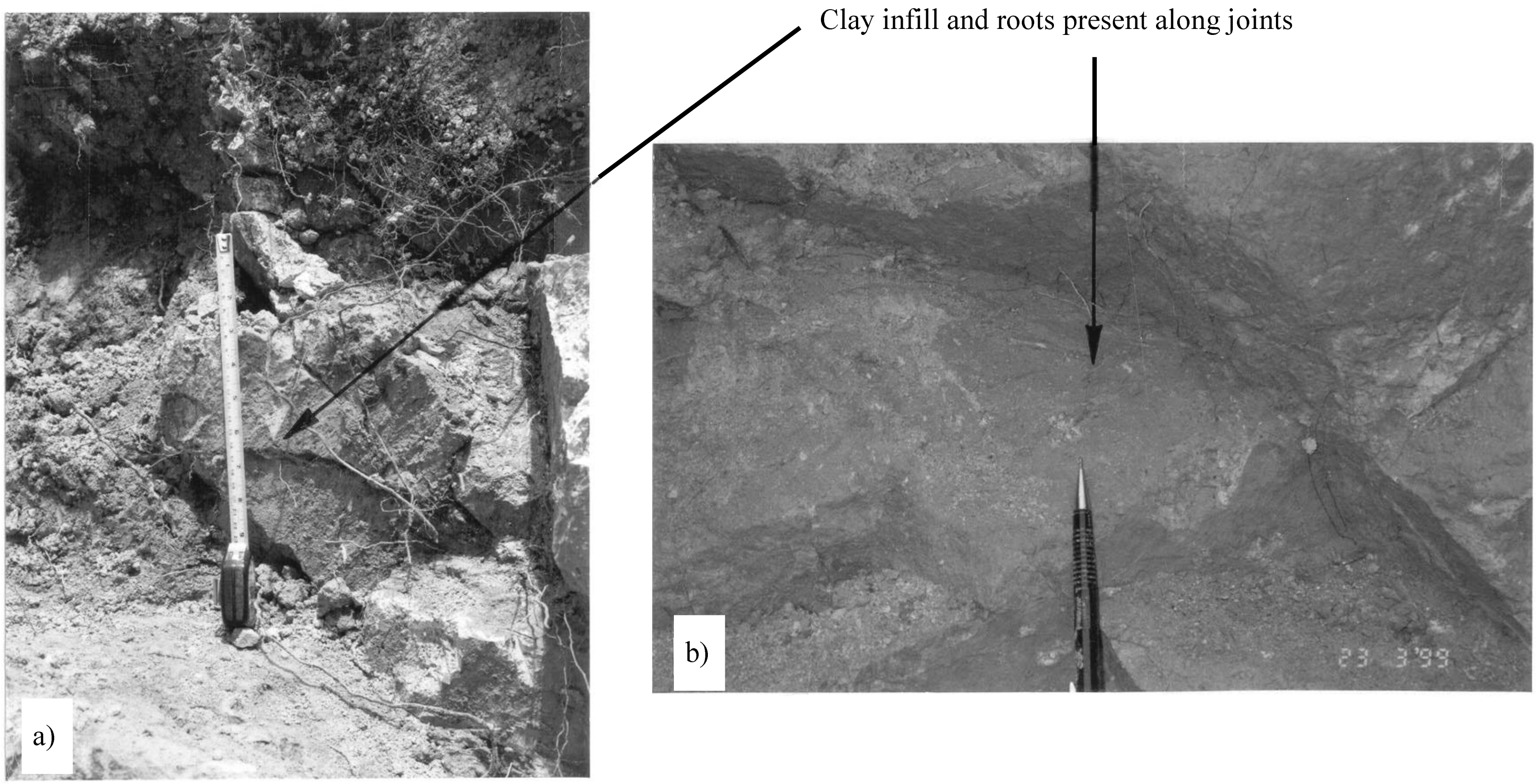


Plate 33 – Views Showing Infilling to Joints/Cracks within H-MDT
(Photographs taken on 23 March 1999)

Note : See Figure 19 for Locations of Photographs.

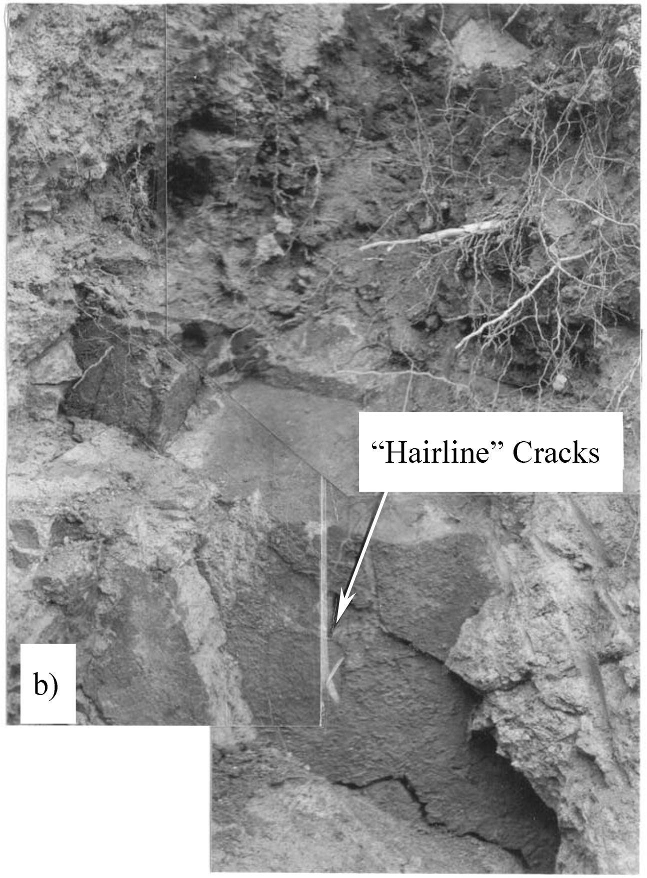


Plate 34 – Open Joints and "Hairline" Cracks Observed in the Tuff in Trial Trench TT6 and Trial Pit TP7
(Photographs taken on 23 March 1999)

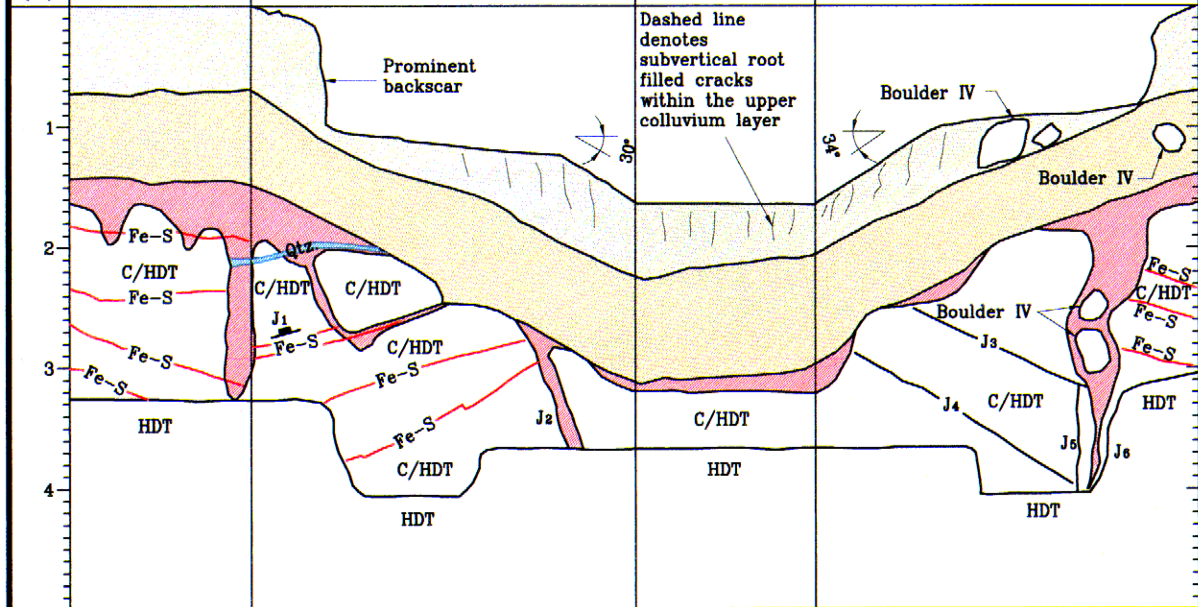
Note : See Figure 19 for Locations of Photographs.

APPENDIX A

TRIAL PIT AND TRENCH LOGS

Fugro Scott Wilson Joint Venture **Agreement No. CE 74/97** **The 1998 Landslide Investigation Consultancy** **Detailed Study No. 17** **Burma Lines Camp, Queen's Hill, Fanling**	TRIAL TRENCH RECORD		Sheet 1 of 1
	TRIAL TRENCH No. TT1	EXCAVATION DATE: from 02-03-99 BACKFILL DATE: 05-03-99	
	CO-ORDINATES 834876.74E 840457.88N GROUND LEVEL 68.50mPD	LOGGED BY: P.H. Chan DATE: 04-03-99 CHECKED BY: J. Hart DATE: 04-03-99	

Depth (m)	FACE A: 1.50m	FACE B: 3.20m	FACE C: 1.50m	FACE D: 3.20m	Legend	Grade	Description



Description:

Loose, dry (dessicated), greyish and yellowish brown, slightly sandy, clayey SILT with some subangular fine to coarse gravel-sized rock fragments and occasional cobble and boulders. (COLLUVIUM). Many sub-vertical root filled cracks are present within the colluvium.

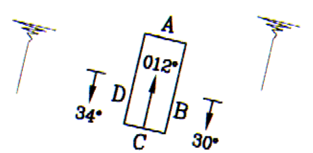
Loose to medium dense, slightly moist, orangish brown, slightly sandy, clayey, gravelly SILT with some angular to subangular cobbles and occasional boulders (COLLUVIUM). Some roots are present within the colluvium.

Firm, orangish brown, mottled red, slightly clayey, slightly sandy, SILT with some fine to medium gravel-sized rock fragments. (RESIDUAL SOIL)

Extremely weak to very weak, light yellowish grey, completely to highly decomposed fine to coarse ash crystal meta-TUFF. (Slightly sandy, clayey SILT with some fine to coarse gravel and cobble sized rock fragments and occasional boulders.)

Very weak to weak, yellow to yellowish grey, highly decomposed fine to coarse ash crystal meta-TUFF.

PLAN (NOT TO SCALE)



KEY

NORTH ARROW

REMARKS

Dip/dip direction of relict joints –

J_1:	88°/252°	J_5:	35°/310°
J_2:	76°/176°	J_6:	90°/360°
J_4:	25°/005°	J_7:	86°/158°

Legend

- Upper colluvium
- Lower colluvium
- Residual soil
- —Fe-S— Iron (Fe) rich seam
- Qtz. Quartz vein
- J_1 Relict joint No.1 (See remarks for dip/dip direction)
- 34° Angle of the sloping ground surface

Figure A1 - Investigation Trial Trench TT1

Fugro Scott Wilson Joint Venture
Agreement No. CE 74/97
The 1998 Landslide Investigation Consultancy
Detailed Study No. 17
Burma Lines Camp, Queen's Hill, Fanling

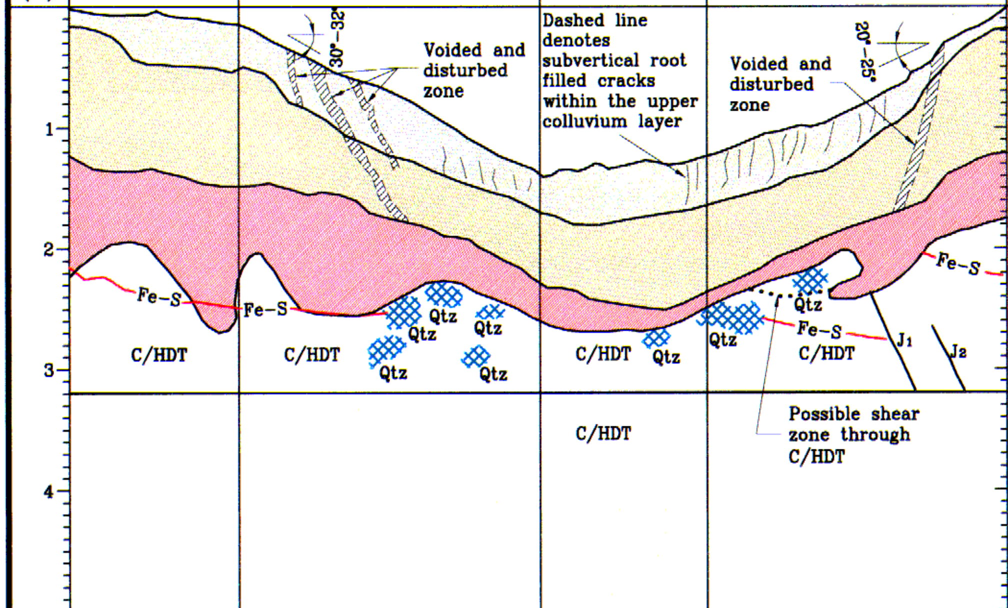
TRIAL TRENCH RECORD

TRIAL TRENCH No. TT2

Sheet 1 of 1

CO-ORDINATES	834887.85E 840452.06N
GROUND LEVEL	65.08mPD
EXCAVATION DATE:	from 03-03-99
BACKFILL DATE:	07-03-99
LOGGED BY: P.H. Chan	DATE: 05-03-99
CHECKED BY: J. Hart	DATE: 06-03-99

Depth (m)	FACE A: 1.40m	FACE B: 2.50m	FACE C: 1.40m	FACE D: 2.50m	Legend	Grade	Description



Description

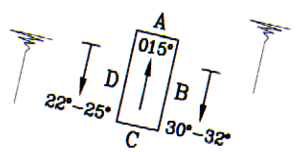
Loose, dry (dessicated), greyish and yellowish brown, slightly sandy clayey SILT with occasional subangular fine to coarse gravel-sized rock fragments (COLLUVIUM). Many sub-vertical root filled cracks are present within the colluvium.

Loose to medium dense, slightly moist, orangish brown, slightly sandy, clayey, gravelly SILT with occasional angular to subangular cobbles (COLLUVIUM). Some roots are present within the colluvium.

Firm, orangish brown, mottled red, slightly clayey, slightly sandy, SILT with some fine to medium gravel-sized rock fragments. (RESIDUAL SOIL)

Extremely weak to very weak, light yellowish grey, completely to highly decomposed fine to coarse ash crystal meta-TUFF. (Slightly sandy, clayey SILT with some fine to coarse gravel and cobble-sized rock fragments and occasional boulders.)

PLAN (NOT TO SCALE)



KEY

NORTH ARROW

REMARKS

Dip/dip direction of relict joints –

J_1: 70°/305°
J_2: 70°/312°

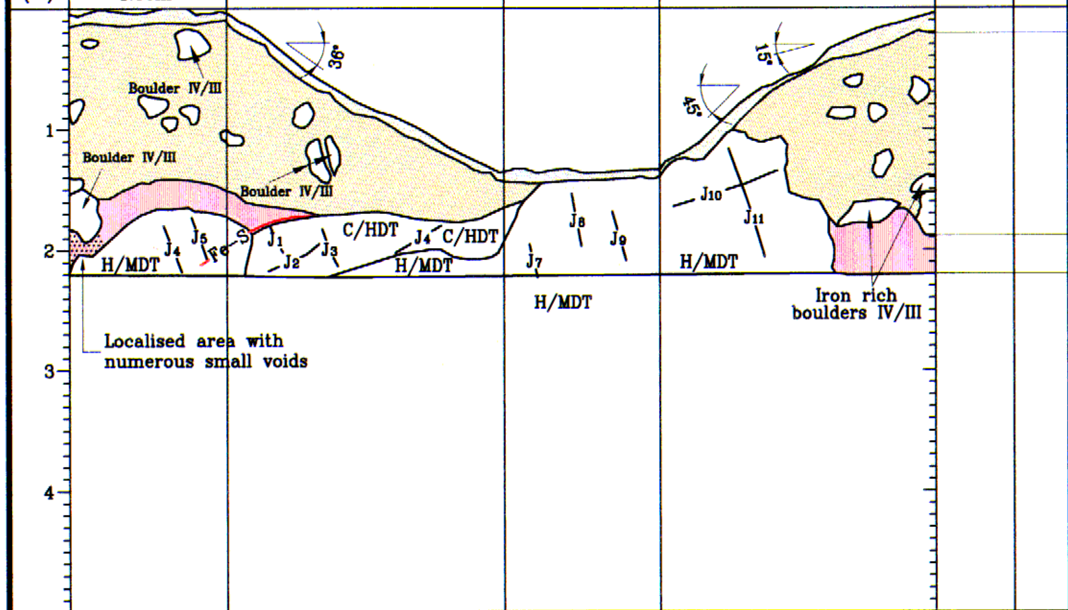
Legend

- Upper colluvium
- Lower colluvium
- Residual soil
- —Fe–S— Iron (Fe) rich seam
- Qtz. Accumulation of Quartz
- J_1 Relict joint No.1 (See remarks for dip/dip direction)
- 34° Angle of the sloping ground surface

Figure A2 - Investigation Trial Trench TT2

Fugro Scott Wilson Joint Venture **Agreement No. CE 74/97** **The 1998 Landslide Investigation Consultancy** **Detailed Study No. 17** **Burma Lines Camp, Queen's Hill, Fanling**	TRIAL TRENCH RECORD TRIAL TRENCH No. TT3 CO-ORDINATES 834909.59E 840454.01N GROUND LEVEL 64.34mPD	Sheet 1 of 1 EXCAVATION DATE: from 04-03-99 BACKFILL DATE: 08-03-99 LOGGED BY: P. H. Chan DATE: 06-03-99 CHECKED BY: J. Hart DATE: 07-03-99

Depth (m)	FACE A: 1.30m	FACE B: 2.30m	FACE C: 1.30m	FACE D: 2.30m	Legend	Grade	Description



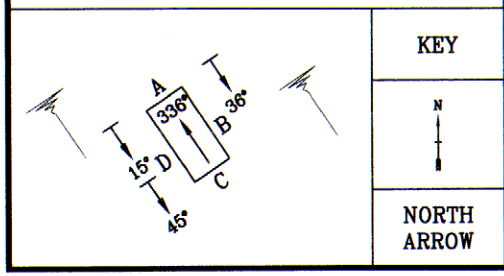
Loose, dry (dessicated), greyish and yellowish brown, slightly sandy, clayey SILT with occasional subangular fine to coarse gravel-sized rock fragments. (COLLUVIUM). Many plant roots are present within the colluvium.

Loose to medium dense, slightly moist, orangish brown, slightly sandy, clayey, gravelly SILT with some to many angular to subangular cobbles and occasional boulders. (COLLUVIUM)

Firm, orangish brown, mottled red, slightly clayey, slightly sandy, SILT with some fine to medium gravel-sized rock fragments and some cobbles and boulders. (RESIDUAL SOIL)

Very weak to moderately weak, yellow to yellowish grey, highly to moderately decomposed fine to coarse ash crystal meta-TUFF.

PLAN (NOT TO SCALE)



REMARKS

Dip/dip direction of relict joints –

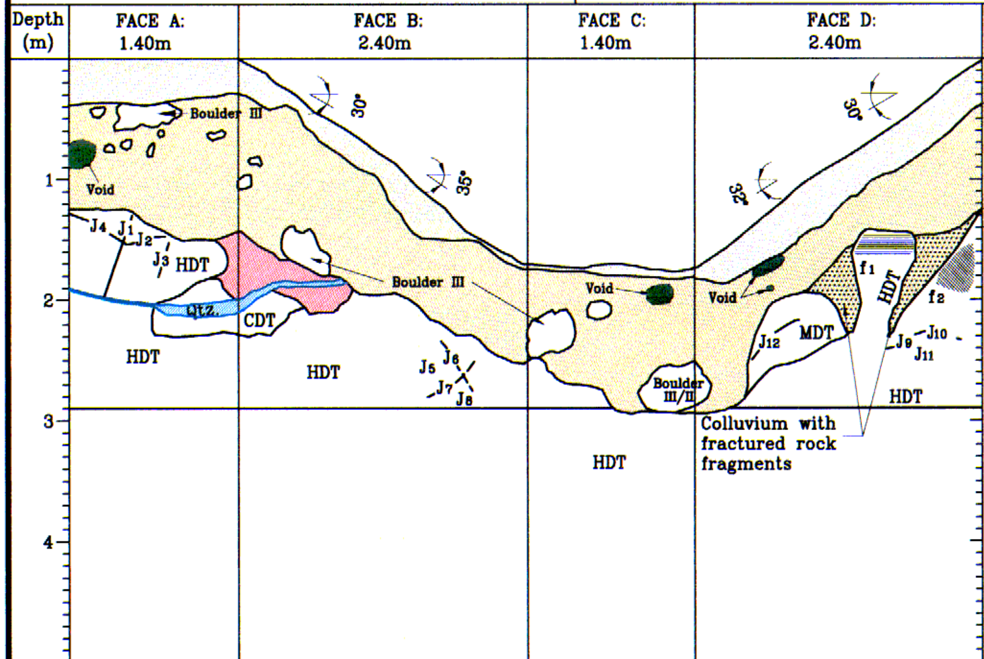
J_1:	88°/210°–218°	J_3:	80°/090°
J_2:	62°–66°/060°–064°	J_5:	64°/034°
J_4:	70°–80°/030°–055°	J_7:	90°/072°
J_6:	80°–82°/060°–082°		
J_8:	82°–90°/038°–050°		
J_9:	85°–88°/202°–234°		
J_{10}:	68°–89°/216°–232°		
J_{11}:	76°–80°/314°–316°		

Legend

- Upper colluvium
- Lower colluvium
- Residual soil
- —Fe–S— Iron (Fe) rich seam
- J_1 Relict joint No.1 (See remarks for dip/dip direction)
- 34° Angle of the sloping ground surface

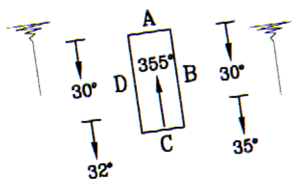
Figure A3 - Investigation Trial Trench TT3

Fugro Scott Wilson Joint Venture Agreement No. CE 74/97 The 1998 Landslide Investigation Consultancy Detailed Study No. 17 Burma Lines Camp, Queen's Hill, Fanling	TRIAL TRENCH RECORD		Sheet 1 of 1
	TRIAL TRENCH No. TT4	EXCAVATION DATE: from 04-03-99 BACKFILL DATE: 06-03-99	
	CO-ORDINATES 834923.14E 840459.52N GROUND LEVEL 65.34mPD	LOGGED BY: P. H. Chan DATE: 05-03-99 CHECKED BY: J. Hart DATE: 06-03-99	



Description
Loose, dry (dessicated), greyish and yellowish brown, slightly sandy, clayey SILT with occasional to some subangular fine to coarse gravel-sized rock fragments. (COLLUVIUM). Many plant roots are present within the colluvium.
Loose to medium dense, slightly moist, orangish brown, slightly sandy, clayey, gravelly SILT with some to many angular to subangular cobbles and occasional boulders. (COLLUVIUM)
Firm, orangish brown, mottled red, slightly sandy, clayey SILT with some fine to medium gravel-sized rock fragments. (RESIDUAL SOIL)
Very weak to weak, yellow to yellowish grey, highly decomposed fine to coarse ash crystal meta-TUFF.

PLAN (NOT TO SCALE)



KEY

NORTH ARROW

REMARKS

Dip/dip direction of relict joints –

J1:	60°–62°/244°–258°	J7:	56°/004°
J2:	36°–38°/160°–186°	J8:	88°/066°
J3:	60°–218°	J9:	44°/256°
J4:	40°/026°	J10:	76°/233°
J5:	70°–245°	J11:	90°/063°
J6:	56°–148°	J12:	50°/212°

Dip/dip direction of foliation –

f1: 18°/345° f2: 34°/345°

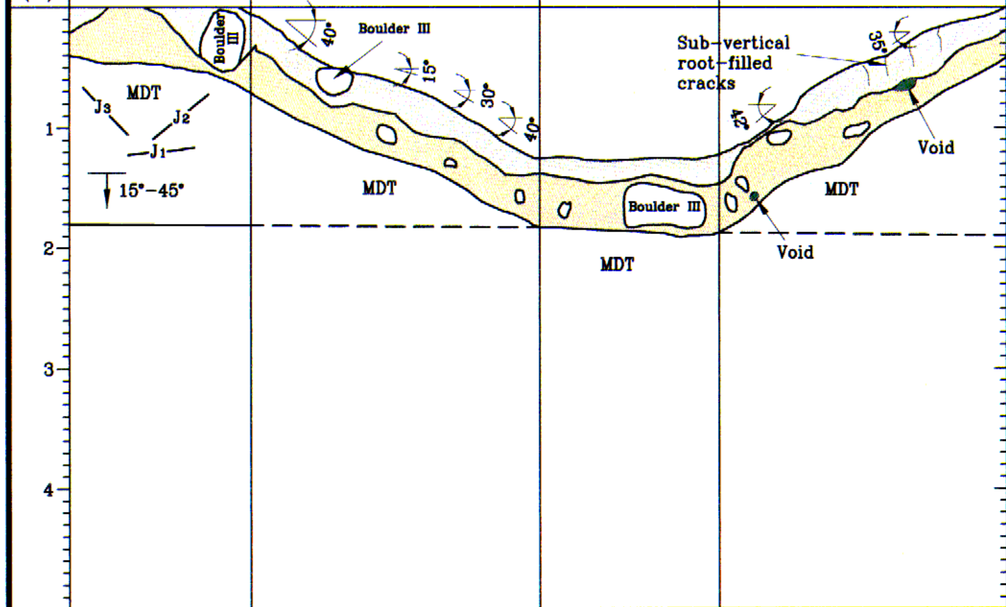
Legend

- Upper colluvium
- Lower colluvium
- Residual soil
- Qtz. Quartz Vein
- J1 Relict joint No.1 (See remarks for dip/dip direction)
- f1 Foliation No.1 (See remarks for dip/dip direction)
- 34° Angle of the sloping ground surface

Figure A4 - Investigation Trial Trench TT4

Fugro Scott Wilson Joint Venture **Agreement No. CE 74/97** **The 1998 Landslide Investigation Consultancy** **Detailed Study No. 17** **Burma Lines Camp, Queen's Hill, Fanling**	TRIAL TRENCH RECORD		Sheet 1 of 1
	TRIAL TRENCH No. TT5	EXCAVATION DATE: from 06-03-99 BACKFILL DATE: 09-03-99	
	CO-ORDINATES 834956.39E 840454.92N GROUND LEVEL 59.96mPD	LOGGED BY: P. H. Chan DATE: 08-03-99 CHECKED BY: J. Hart DATE: 09-03-99	

Depth (m)	FACE A: 1.50m	FACE B: 2.40m	FACE C: 1.50m	FACE D: 2.40m	Legend	Grade	Description
							Loose, dry (dessicated), greyish and yellowish brown, slightly sandy clayey SILT with occasional to some subangular fine to coarse gravel-sized rock fragments and occasional cobbes and boulders (COLLUVIUM). Many plant roots are present within the colluvium.
							Loose to medium dense, slightly moist, orangish brown, slightly sandy, clayey, gravelly SILT with some to many angular to subangular cobbles and occasional boulders. (COLLUVIUM)
							Moderately strong, pinkish grey and yellowish brown, moderately decomposed fine to coarse ash crystal meta-TUFF.



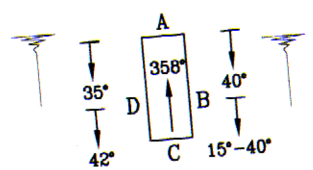
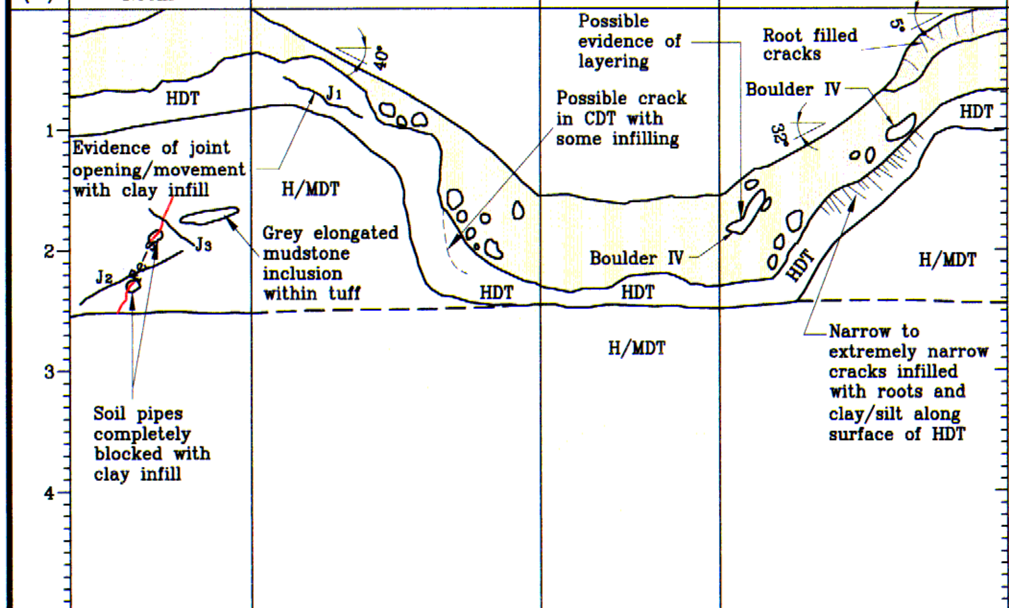
PLAN (NOT TO SCALE)	KEY	REMARKS	Legend
	NORTH ARROW	Dip/dip direction of relict joints – J1: 45°/176° J2: 80°/147° J3: 64°/215°	Upper colluvium Lower colluvium J1 Relict joint No.1 (See remarks for dip/dip direction) 34° Angle of the sloping ground surface 30° Angle of the sloping face

Figure A5 - Investigation Trial Trench TT5

Fugro Scott Wilson Joint Venture Agreement No. CE 74/97 The 1998 Landslide Investigation Consultancy Detailed Study No. 17 Burma Lines Camp, Queen's Hill, Fanling	TRIAL TRENCH RECORD TRIAL TRENCH No. TT6 CO-ORDINATES 834959.18E 840461.29N GROUND LEVEL 63.41 mPD	Sheet 1 of 1 EXCAVATION DATE: from 07-03-99 BACKFILL DATE: 09-03-99 LOGGED BY: P. H. Chan DATE: 08-03-99 CHECKED BY: J. Hart DATE: 09-03-99

Depth (m)	FACE A: 1.50m	FACE B: 2.40m	FACE C: 1.50m	FACE D: 2.40m	Legend	Grade	Description



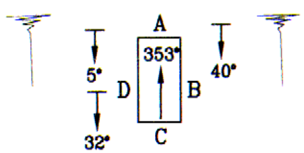
Loose, dry (dessicated), greyish and yellowish brown, slightly sandy clayey SILT with occasional subangular fine to coarse grave-sized rock fragments. (COLLUVIUM). Many plant roots are present within the colluvium.

Loose to medium dense, slightly moist, orangish brown, slightly sandy, clayey, gravelly SILT with some to many angular to subangular cobbles and occasional boulders. (COLLUVIUM)

Very weak to weak, yellow to yellowish grey, highly decomposed fine to coarse ash crystal meta-TUFF.

Very weak to moderately weak, yellow to yellowish grey, highly to moderately decomposed fine to coarse ash crystal meta-TUFF.

PLAN (NOT TO SCALE)



KEY

NORTH ARROW

REMARKS

Dip/dip direction of relict joints –

J_1: 36°/156°
J_2: 75°/145°
J_3: 85°/205°

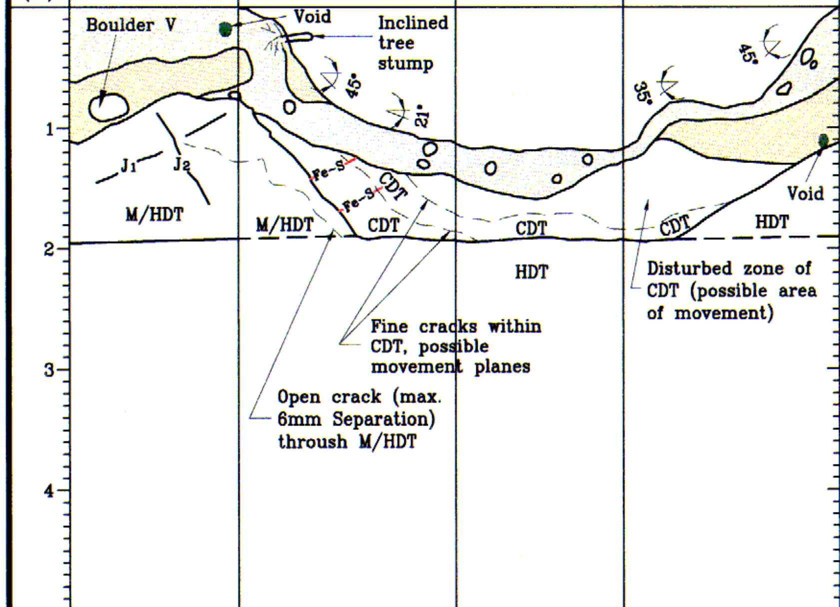
Legend

- ☐ Upper colluvium
- ☐ Lower colluvium
- —Fe–S— Iron (Fe) rich seam
- J_1 Relict joint No.1 (See remarks for dip/dip direction)
- 34° Angle of the sloping ground surface

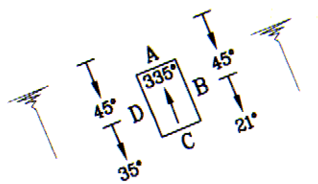
Figure A6 - Investigation Trial Trench TT6

Fugro Scott Wilson Joint Venture **Agreement No. CE 74/97** **The 1998 Landslide Investigation Consultancy** **Detailed Study No. 17** **Burma Lines Camp, Queen's Hill, Fanling**	TRIAL PIT RECORD		Sheet 1 of 1
	TRIAL PIT No. TP7	EXCAVATION DATE: from 08-03-99 BACKFILL DATE: 09-03-99	
	CO-ORDINATES 834963.22E 840465.82N GROUND LEVEL 64.98mPD	LOGGED BY: PHC DATE: 08-03-99 CHECKED BY: JH DATE: 09-03-99	

Depth (m)	FACE A: 1.40m	FACE B: 1.80m	FACE C: 1.40m	FACE D: 1.80m	Legend	Grade	Description
							Loose, dry (dessicated), dark brownish grey, slightly sandy, clayey SILT with occasional subangular fine to coarse gravel-sized rock fragments (COLLUVIUM). Many plant roots are present within the colluvium.
							Loose to medium dense, slightly moist, orangish brown, slightly sandy, clayey, gravelly SILT with some to many angular to subangular cobbles and occasional boulders. (COLLUVIUM)
							Very weak to weak, yellow to yellowish grey, highly decomposed fine to coarse ash crystal meta-TUFF.



PLAN (NOT TO SCALE)



KEY

NORTH ARROW

REMARKS

Dip/dip direction of relict joints –

J_1: 65°–89°/310°–320°
J_2: 60°–80°/025°–036°

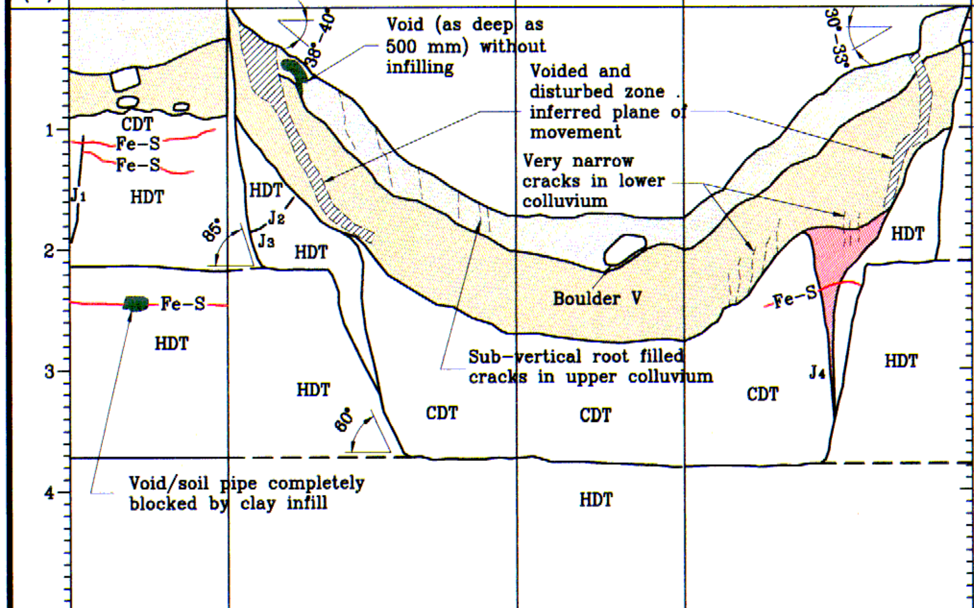
Legend

- ☐ Upper colluvium
- ☐ Lower colluvium
- —Fe–S— Iron (Fe) rich seam
- J_1 Relict joint No.1 (See remarks for dip/dip direction)
- 34° Angle of the sloping ground surface

Figure A7 - Investigation Trial Pit TP7

Fugro Scott Wilson Joint Venture Agreement No. CE 74/97 The 1998 Landslide Investigation Consultancy Detailed Study No. 17 Burma Lines Camp, Queen's Hill, Fanling	TRIAL TRENCH RECORD		Sheet 1 of 1
	TRIAL TRENCH No. TT8	EXCAVATION DATE: BACKFILL DATE: 07-03-99	from 03-03-99
	CO-ORDINATES 834952.00E 840471.93N GROUND LEVEL 69.77mPD	LOGGED BY: P. H. Chan CHECKED BY: J. Hart	DATE: 05-03-99 DATE: 06-03-99

Depth (m)	FACE A: 1.30m	FACE B: 2.40m	FACE C: 1.40m	FACE D: 2.40m	Legend	Grade	Description
							Loose, dry (dessicated), greyish and yellowish brown, slightly sandy, clayey SILT with occasional to some subangular fine to coarse gravel-sized rock fragments and occasional cobbles and boulders (COLLUVIUM). Many plant roots are present within the colluvium.
							Loose to medium dense, slightly moist, orangish brown, slightly sandy, clayey, gravelly SILT with some to many angular to subangular cobbles and occasional boulders. (COLLUVIUM)
							Very weak to weak, yellow to yellowish grey, highly decomposed fine to coarse ash crystal meta-TUFF.



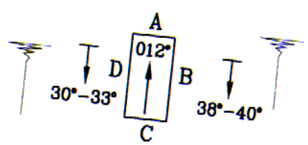
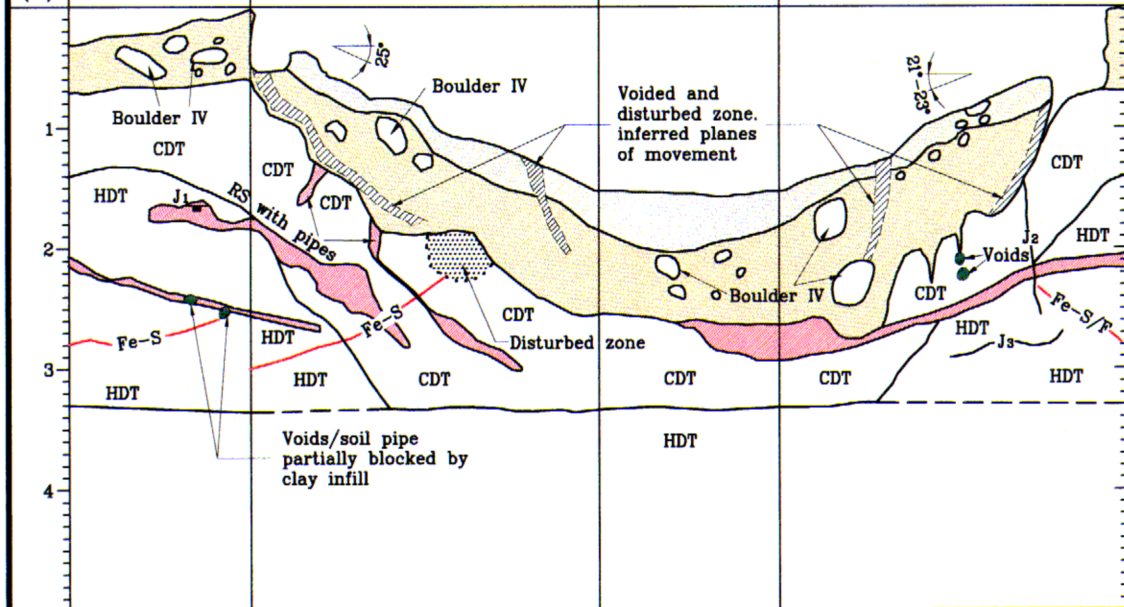
PLAN (NOT TO SCALE)	KEY	REMARKS	Legend
	NORTH ARROW	Dip/dip direction of relict joints – J1: 86°-88°/214°-240° J2: 50°/310° J3: 70°/234° J4: 80°/014°	Upper colluvium Lower colluvium Residual soil —Fe-S— Iron (Fe) rich seam J1 Relict joint No.1 (See remarks for dip/dip direction) 34° Angle of the sloping ground surface

Figure A8 - Investigation Trial Trench TT8

Fugro Scott Wilson Joint Venture Agreement No. CE 74/97 The 1998 Landslide Investigation Consultancy Detailed Study No. 17 Burma Lines Camp, Queen's Hill, Fanling	TRIAL TRENCH RECORD TRIAL TRENCH No. TT9 CO-ORDINATES 834957.90E 840475.22N GROUND LEVEL 71.85 mPD	Sheet 1 of 1 EXCAVATION DATE: from 25-02-99 BACKFILL DATE: 03-03-99 LOGGED BY: P. H. Chan DATE: 28-02-99 CHECKED BY: J. Hart DATE: 01-03-99

Depth (m)	FACE A: 1.50m	FACE B: 2.90m	FACE C: 1.50m	FACE D: 2.90m	Legend	Grade	Description



Loose, dry (dessicated), greyish and yellowish brown, slightly clayey, slightly sandy SILT with occasional subangular fine to coarse gravel-sized rock fragments. (COLLUVIUM). Many plant roots are present within the colluvium.

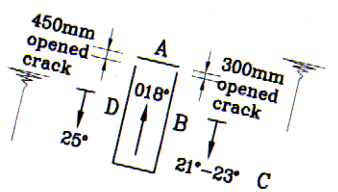
Loose to medium dense, slightly moist, orangish brown, slightly sandy, clayey, gravelly SILT with some to many angular to subangular cobbles and occasional boulders. (COLLUVIUM)

Extremely weak to very weak, light yellowish grey, completely to highly decomposed fine to medium coarse ash crystal meta-TUFF. (Slightly sandy, clayey SILT with some fine to coarse gravel and cobble-sized rock fragments and occasional boulders.)

Firm, orangish brown, mottled red, slightly sandy, clayey SILT with some fine to medium gravel-sized rock fragments. (RESIDUAL SOIL)

Very weak to weak, yellow to yellowish grey, highly decomposed fine to coarse ash crystal meta-TUFF.

PLAN (NOT TO SCALE)	KEY	REMARKS	Legend



KEY

N

NORTH ARROW

Dip/dip direction of relict joints –

J1: 44°/146°
J2: 87°/030°
J3: 44°/020°

Legend

- Upper colluvium
- Lower colluvium
- Residual soil
- —Fe-S— Iron (Fe) rich seam
- J1 Relict joint No.1 (See remarks for dip/dip direction)
- 34° Angle of the sloping ground surface

Figure A9 - Investigation Trial Trench TT9