DETAILED STUDY OF THE 20 AUGUST 2005 LANDSLIDE ON SLOPE NO. 11NE-A/C153 AT PING TING ROAD, NGAU CHI WAN

GEO REPORT No. 215

T.M.F. Lau & K.K.S. Ho

GEOTECHNICAL ENGINEERING OFFICE
CIVIL ENGINEERING AND DEVELOPMENT 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. The GEO Reports can be downloaded from the website of the Civil Engineering and Development Department (http://www.cedd.gov.hk) on the Internet. Printed copies are also available for some GEO Reports. For printed copies, a charge is made to cover the cost of printing.

The Geotechnical Engineering Office also produces documents specifically for publication. These include guidance documents and results of comprehensive reviews. These publications and the printed GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the second last page of this report.

R.K.S. Chan
Head, Geotechnical Engineering Office
December 2007

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FOREWORD

This report presents the findings of a review of a landslide (Incident No. 2005/08/0299) that occurred at the rock portion of a 47 m high soil/rock cut slope No. 11NE-A/C153 at Ping Ting Road, Ngau Chi Wan, at about 2:37 a.m. on 20 August 2005. The landslide involved the detachment of a total of about 36 m^3 of rock blocks and soil, and the displacement of a rock wedge, about 12 m wide and 14 m high. Both lanes of Ping Ting Road were temporarily closed. No casualties were reported as a result of the landslide.

In the early morning of 13 September 2005, further instability of slope No. 11NE-A/C153 occurred at the location of the 20 August 2005 landslide. Another 10 m^3 of rock blocks and soil detached and an unstable rock wedge displaced forward further. Both lanes of Ping Ting Road, together with the playground at the Buddhist Hung Sean Chau Memorial College on the opposite side of the road, were temporarily closed. No casualties were reported as a result of the landslide.

The key objectives of the review were to document the facts about the incident, past geotechnical input provided to the slope and pertinent site observations made under this review. Recommendations for follow-up actions are reported separately.

Mr T. M. F. Lau of the Landslip Preventive Measures Division 1 assisted in preparing the report. Maunsell Geotechnical Services Limited, the 2005 landslide investigation consultants, provided general support. All contributions are gratefully acknowledged.

K.K.S. Ho
Chief Geotechnical Engineer/ LPM Division 1

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1. INTRODUCTION

At about 2:37 a.m. on 20 August 2005 when the Landslip Warning was in effect, a landslide (Incident No. 2005/08/0299) occurred on a soil/rock cut slope No. 11NE-A/C153 at Ping Ting Road, Ngau Chi Wan (Figure 1 and Plates 1 and 2). The landslide involved the detachment of about 36 m³ of rock blocks and soil, and the displacement of a rock wedge of about 120 m³ in volume and about 12 m wide by 14 m high (Figure 2). The debris was deposited on the footpath and the southbound lane of Ping Ting Road (Plates 1 and 2). As a result of the incident, both lanes of Ping Ting Road were temporarily closed. No casualties were reported.

In the early morning of 13 September 2005, the August 2005 landslide was re-activated. Another 10 m³ of rock blocks and soil detached and were deposited again on the footpath and the southbound lane of Ping Ting Road (Plates 3 and 4). The rock wedge had displaced up to about 0.5 m. The total volume of the detached and displaced ground mass was estimated to be about 170 m³. Consequently, both traffic lanes and footpaths of Ping Ting Road and the playground at the Buddhist Hung Sean Chau Memorial College on the opposite side of the road below the slope were temporarily closed. No casualties were reported.

Following the landslide incident, Maunsell Geotechnical Services Limited (MGSL), the 2005 Landslide Investigation Consultants for Kowloon and the New Territories, carried out a review of the landslide for the Geotechnical Engineering Office (GEO), Civil Engineering and Development Department (CEDD), under Agreement No. CE 15/2004 (GE).

This report documents the facts about the landslide incident, a review of the relevant documentary records and pertinent site observations made by MGSL. The scope of this report also included a review of the recent ground investigation, which was carried out as part of the Stage 3 Study (S3R 20/2006) for slope No. 11NE-A/C153. Recommendations for any necessary follow-up actions will be reported separately.

2. THE SITE

2.1 Site Description

Slope No. 11NE-A/C153 is a west facing soil/rock cut slope situated on the east side of Ping Ting Road and the west side of Hammer Hill, Ngau Chi Wan. A site location plan is shown in Figure 1. Ping Ting Road is a two-lane cul-de-sac that provides access to the Buddhist Hung Sean Chau Memorial College (Plate 5), and other residential areas on On Ting Road and Wing Ting Road to the south of slope No. 11NE-A/C153. Pedestrian walkways of 2 m and 3.5 m wide are located on the east and west sides of Ping Ting Road respectively. Above the cut slope is a natural hillside that extends about 150 m to the east.

Slope No. 11NE-A/C153 is approximately 295 m long, with a maximum height of about 47 m. For ease of reference, the slope is divided into three parts, namely the northern, middle and southern parts in this report (Figures 3 and 4). In the northern part of the slope, the mixed rock and soil cut portion is about 180 m long and up to 47 m high, reaching an elevation of about 74 mPD at the crest (Plate 6). This part of the slope comprises three to six batters, with the lowermost batter inclined at about 67°, and the other batters inclined at about

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40°. The batters are separated by approximately 1.5 m wide berms. A geological section through the slope is shown in Figure 5. The rock cut portion is located on the two lowermost batters up to about 15 m high. Most of the two uppermost batters are covered with erosion control mat and vegetation. The rest of the northern part is covered with shotcrete (Figure 3). Surface drainage provisions on the northern part mainly comprise 200 mm wide U-channels on the berms, a 200 mm to 350 mm wide U-channel along the crest, and 350 mm to 400 mm stepped channels connecting to catchpits along the roadside.

The middle part of slope No. 11NE A/C153 is about 70 m long and up to about 34 m high with an average inclination of 37° (Figure 4 and Plate 7). This part of the slope has no berm and the slope surface is vegetated. Chevron drains, comprising 250 mm to 400 mm wide U-channels, are present.

The southern part of the slope is about 45 m long and up to about 8 m high, and is inclined at approximately 34° (Plate 8). This part of the slope is also vegetated and is overlooking Block 1 of Bay View Garden (Figure 4). Approximately 300 mm wide U-channels have been provided at the crest and toe of this part of the slope.

2.2 Regional Geology

The Hong Kong Geological Survey (HKGS) 1:20 000 Solid and Superficial Geology Map Sheet No. 11 - Hong Kong and Kowloon (GCO, 1986), indicates that medium-grained Granite underlies the site at the location of the August 2005 landslide (Figure 6). Debris flow deposits are shown to be approximately 60 m to the west of the landslide. A minor intrusion of pegmatite is shown approximately 400 m to the east of the landslide site.

3. SITE HISTORY AND PAST INSTABILITY

3.1 Site History

The history of site development has been determined from an interpretation of the available aerial photographs between 1949 and 2003, together with a review of relevant documentary information and site observations. Detailed observations from the Aerial Photograph Interpretation (API) are summarized in Appendix A.

Slope No. 11NE-A/C153 was formed by cutting into the natural hillside of Hammer Hill. The slope was constructed in three stages between 1980 and 1988 in conjunction with the extension of Ping Ting Road and the developments on the west side of the road (Figure 7).

Prior to the construction of slope No. 11NE-A/C153, the extent of Ping Ting Road was at the southernmost boundary of the East Kowloon Polyclinic, which was developed prior to 1976. The northern part of the slope was constructed between 1980 and 1981 as part of the site formation for the Buddhist Hung Sean Chau Memorial College. The associated section of Ping Ting Road fronting the College was also completed at around the same time to provide access to this development. The construction of Hammer Hill Road Sports Ground, which is situated to the west of the East Kowloon Psychiatric Centre and the College, commenced in 1984. To provide access to the sports ground, the middle part of slope No. 11NE-A/C153 was constructed in 1986 and Ping Ting Road was extended further to the

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south. The southern part of the slope was constructed between 1987 and 1988 in connection with the private development of Bay View Garden.

3.2 Past Instability

According to the GEO's landslide database, a landslide occurred on the northern part of slope No. 11NE-A/C153 on 27 September 1993 (Incident No. K93/9/13). The incident involved a detachment of about 10 m³ of colluvium at the uppermost batter of the slope, about 65 m to the south of the August 2005 landslide site (Figure 7). The failure undermined some boulders immediately above the landslide. In the GEO's landslide inspection record, this was taken to be a washout incident.

Following the September 1993 landslide, GEO advised HyD to carry out emergency repair works, which comprised diversion of the surface runoff from the landslide area, fencing off the area in danger, provision of additional drainage measures, together with reconstruction and clearance of all existing channels. The works were completed in March 1994.

Based on the API, repeated re-surfacing of parts of the slope was carried out between 1984 and 2001 (see also Section 5.6). It is not certain whether or not the re-surfacing was required as a result of local instabilities (Figure 8).

4. MAINTENANCE RESPONSIBILITY AND LAND STATUS

The northern and middle parts of slope No. 11NE-A/C153 are located on unleased unallocated government land, and the southern part lies within lot No. NKIL 6028. According to the Slope Maintenance Responsibility Information System of the Lands Department, slope No. 11NE-A/C153 has mixed maintenance responsibility. Highways Department (HyD) is responsible for the northern and middle parts of the slope, while the owners of private lot NKIL 6028 are responsible for the southern part.

5. PAST STABILITY ASSESSMENTS AND SLOPE WORKS

5.1 Geotechnical Submissions

In November 1978, C Y Wong Architect and Associates (CYWAA), on behalf of the Hong Kong Buddhist Association, submitted a site formation proposal for the Buddhist Hung Sean Chau Memorial College at Lot No. NKIL 5753 to the Building Authority (BA) (Buildings Department file No. 6/4153/78). The site formation works included the formation of the northern part of slope No. 11NE-A/C153.

A report entitled "NKIL No. 5753, Ping Ting Road, Kowloon, Site Formation and Foundation Study", which was prepared by Fugro (HK) Limited (FHK) in October 1978, was submitted as a supporting document (FHK, 1978). The report contained the results of a ground investigation and stability analyses for the proposed cutting. The calculated minimum factor of safety for the soil cut for a 10 year return period rainstorm was 1.4. The report noted that the measurement of joint orientations was not possible since, at the time of its preparation, there were no rock outcrops present. The report recommended that "the

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orientation of joints should be investigated by a geotechnical engineer to check overall stability", during excavation of the rock face.

In January 1979, following the comments made by the BA, CYWAA revised and re-submitted the site formation proposal, which was approved by the BA in February 1979. In the Buildings Department file records (Ref. 6/4153/78), it was evident that the site formation proposal was checked by the Geotechnical Control Office (GCO was renamed GEO in 1991).

In the approved site formation drawings (Nos. 7817/02A, 7817/03A and 7817/04A), the design angles for the soil and rock cut portions of the slope were 42° and 70° respectively. The soil cut portion of the slope was to be covered with 50 mm thick chunam and a 2 m high no fines concrete filter panel was to be installed immediately above the soil/rock interface. The notes on the drawings indicated that "the specified rock cutting angle is provisional only" and that the "the final rock profile will be the subject of a stage II site formation submission which shall include a report on the detailed study of the rock slope". No information relating to the further assessment of the rock-cut could be found. No as-built record plan was located in the BD and GEO files.

In September 1984, Ove Arup & Partners HK Limited (OAP), on behalf of the Architectural Office of the then Building Development Department, submitted to the GCO via the Building Development Department a report entitled "Geotechnical Report, Hammer Hill Sports Ground" on the site formation design for the Hammer Hill Sports Ground and an extension of Ping Ting Road. As part of the proposed extension of Ping Ting Road, the present-day middle part of slope No. 11NE-A/C153 was to be constructed by cutting into the natural hillside. The design angle of the soil cut was 39° and the slope surface was to be vegetated. In November 1984, the GCO confirmed that they had no adverse geotechnical comments on OAP's report.

In June 1987, MGSL, on behalf of Henderson Real Estate Agency Ltd., submitted to the Buildings Ordinance Office (BOO) of the then Buildings and Lands Department a geotechnical report and site formation plans for the private development at NKIL 6028 (BDfile No. 6/4122/86). The plan proposed site formation works for the development of Bay View Garden and the formation of the southern part of slope No. 11NE-A/C153 (Drawing No. 52787/202). The maximum design angle for the soil cut portion of the slope was 40°. The site formation plan was checked by the GCO and approved by the BOO in August 1987. The as-built site formation plan of August 1989 (Drawing No. 52787/202H) indicated no change to the slope angle.

5.2 SIFT, SIRST and Stage 1 Studies

The northern part of slope No. 11NE-A/C153 was originally registered as slope No. 11NE-A/C154 in 1994. In February 1994, under GEO's "Systematic Inspection of Features in the Territory" (SIFT) project, slope No. 11NE-A/C154 was classified as SIFT Class 'C1', i.e. a slope that had "been formed or substantially modified before 30.6.78".

In September 1994, the Design Division of the GEO carried out a Stage 1 Study on slope No. 11NE-A/C154 to assess the need for any further action. The entire slope

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No. 11NE-A/C154 (except the northern end) was covered with chunam at the time and no signs of distress were observed. No further action was recommended.

In November 1999, under the GEO's "Systematic Identification and Registration of Slopes in the Territory" (SIRST) project, slope No. 11NE-A/C153 was inspected by the SIRST consultants. The slope surface was shotcreted and the surface condition was assessed as "fair". No signs of distress or seepage were noted.

5.3 Slope Status Review

The subject slope was included in the GEO District Divisions' Slope Status Review carried out in 2003. The purpose of the review was to identify GEO's checking status of post-1978 government slopes through a review of the relevant files within the GEO.

The records of the review indicated that "Part 1" of slope No. 11NE-A/C153, i.e. the southern part, had been checked by the GCO under the Hammer Hill Sports Ground & Swimming Pool - Stage I Project in November 1984 and that HyD had installed prescriptive soil nails in the northern part (within "Part 2") of the government portion of the slope in 2001. The checking status for both parts was assigned as category "A1 - No outstanding comments", which denotes that the slope was "processed by GEO with no outstanding comments".

5.4 Engineer Inspections and Routine Maintenance Inspections

In September 1999, MGSL carried out an Engineer Inspection (EI) of slope No. 11NE-A/C153 for HyD. The overall state of maintenance was classified as "Fair". According to the EI report, "no recent movement, no tension crack and no other signs of instability" were observed. Recommendations on routine maintenance works included: "clear debris, undesirable vegetation and other obstructions from surface drainage systems", "rebuild severely cracked catchpit" and "rebuild severely cracked channels". MGSL also recommended the provision of a cat ladder, raking drains, soil nails and a shotcrete cover on part of the slope as preventive maintenance works. Some of the identified slope defects are reproduced in Plate 9. Other recommendations included "Priority Stability Assessment is recommended due to the feature without previous Stability Assessment and failure of the feature may have major consequence to public (i.e. consequence to life) and soil cut slope is steeper than 45 degree".

The EI consultant noted that according to CEDD/Survey Division feature boundary plan, slope Nos. 11NE-A/C153 and 11NE-A/C154 were actually a single feature, and accordingly recommended the re-registration of slopes Nos. 11NE-A/C153 and 11NE-A/C154 as one feature. This was subsequently agreed with the Slope Safety Division of the GEO and the slope is now designated slope No. 11NE-A/C153.

In January 2003, MGSL carried out a further EI of the slope for HyD. Defects observed on slope included "cracked surface cover", "blocked channel & weephole", "undermined channel due to erosion or wash-out", "rubbish on the feature surface", "undesirable vegetation on rigid surface", "damaged channel" and "cracked surface cover with signs of seepage". The EI consultant reported no recent movement, no tension cracks

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at the crest but recent seepage was noted. Some of the identified slope defects are shown in Plate 10. The overall state of maintenance was classified as "1", i.e. the overall state of maintenance of the slope was considered to be satisfactory in general. The routine maintenance works were considered to be satisfactorily carried out and no routine maintenance works were recommended. The EI report indicated that no stability assessment or upgrading works has been carried out previously on the slope (based on a file search by MGSL) and a stability assessment was therefore recommended.

According to HyD's records, HyD carried out Routine Maintenance Inspections of the slope No. 11NE-A/C153 in June 1994, March 1995, March 1996, March 1997, March 1998, October 1999, January 2000, January 2002 and November 2003. The HyD's records of the Routine Maintenance Inspections carried out between 1994 and 2000 cover the present-day middle and southern parts of slope No. 11NE-A/C153. Minor maintenance works were recommended, including clearing drainage channels and catchpits, repair of cracked/damaged drainage channels and slope surface, unblocking weepholes and re-hydroseeding. No information relating to Routine Maintenance Inspections on slope No. 11NE-A/C154 could be found during the present study.

Both 1999 and 2003 EI carried out by MGSL did not identify the previous stability assessment in 1979 and 1984.

5.5 Slope Maintenance Works

Based on the API, the northern part of the slope was stripped and re-surfaced with shotcrete in 1988 and 1996. Re-surfacing of parts of the slope had been carried out between 1984 and 2001 (Figure 8). It was also noted that a small local area immediately adjacent to the 2005 landslide was re-surfaced, probably between February 2000 and September 2000 (Figure 8 and Plate 11). To date, no records relating to this re-surfacing could be found.

In 2001, HyD carried out preventive maintenance works, which were broadly in accordance with those recommended in the 1999 EI (Section 5.4). Based on HyD's records, the works comprised the installation of 498 Nos. of 10 m long soil nails, at 2 m and 1 m centre-to-centre spacing horizontally and vertically, at the two uppermost soil cut batters of the northern part of slope No. 11NE-A/C153. Most of the original hard cover on the slope surface where soil nails were installed was removed and replaced with hydroseeding. The preventive maintenance works also included the installation of 13 Nos. 8 m long raking drains at 6 m centres above the lowermost berm of the northern part of the slope (Figure 8).

5.6 LPM Works

Following the August and September 2005 landslides, slope No. 11NE-A/C153 was injected into the LPM Programme and a Stage 3 Study (S3R 20/2006) was undertaken by MGSL under Agreement No. 75/2001 (GE). The fast tracked LPM works commenced in February 2006 under Contract No. GE/2004/11 and are on-going at the time of preparing this report. The fieldworks of the ground investigation under the LPM Programme were completed in April 2006 and the results have been reviewed in this report.

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6. THE AUGUST 2005 LANDSLIDE AND POST-FAILURE OBSERVATIONS

6.1 The 20 August 2005 Landslide

At 2:37 a.m. on 20 August 2005, the GEO received a notification of a landslide from the Police. The Landslip Warning was in effect at the time. MGSL, GEO's landslide investigation consultant, first inspected the landslide on the afternoon of 20 August 2005.

About 36 m³ of debris was deposited on the footpath and the southbound lane of Ping Ting Road (Plates 1 and 2). The travel angle was about 49°. The debris comprised mainly boulders, with reddish brown, silty sand and fragments of shotcrete. The landslide scar was about 10 m wide by 10 m long with a maximum depth of about 1 m. The slope surface immediately adjacent to the landslide scar was inclined at about 67°. The landslide scar exposed a partially weathered rock mass (approximately PW 50/90), containing thick seams of completely decomposed granite between discrete intact moderately to slightly decomposed granite blocks (Plate 12).

Persistent cracking of the shotcrete surface adjacent to the landslide scar was also observed (Plate 1). The pattern of shotcrete cracking indicated that movement had occurred within a rock wedge about 12 m wide (at the top) and about 14 m high. Seepage from the nearby weepholes and cracked shotcrete surface was observed (Plate 13). The raking drains located above the lowermost batter and to the north of the landslide scar also show significant seepage (Plate 14).

As a result of the landslide, both lanes of Ping Ting Road were temporarily closed. The northbound lane was later re-opened at 1:00 a.m. on 22 August 2006. Emergency works were recommended to the HyD by the GEO on 23 August 2006, which included temporary closure of the southbound lane, provision of barriers and removal of the unstable rock mass and landslide debris.

The rock joints exposed within the landslide scar were mapped and their orientations measured on 25 August 2005 (Figure 9), and a kinematic analysis was carried out. In the analysis, a friction angle of 35° was adopted for the rock joints taking cognizance of the presence of very thin coating of limonite in the joints. The stereoplot of the rock joints indicates that two of three joint sets identified fall just within the daylighting envelope for wedge failure (Figure 10).

6.2 Re-activated Landslide on 13 September 2005

On the morning of 13 September 2005, further instability of slope No. 11NE-A/C153 occurred at the location of the 20 August 2005 landslide following relatively light rainfall (Figure 11). MGSL inspected the landslide on the morning of 14 September 2005.

The unstable rock wedge, as defined by the persistent cracking in the shotcrete, had displaced further with significant widening (up to about 0.5 m) of the cracks (Plate 15). MGSL observed a sub-vertical tension crack, about 0.5 m wide and more than 1 m deep, at the top of the displaced rock wedge (Plate 16). The back-release surface of the rock wedge was steeply inclined (almost sub-vertical) and by inference, based on the observed exposed joint surfaces, the wedge appeared to be approximately 4 m deep. Another 10 m³ of debris

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detached from the August 2005 landslide scar and was deposited onto the debris from the previous landslide resting on the footpath and the southbound lane of Ping Ting Road (Plates 3 and 4). The footpath and the southbound lane of Ping Ting Road were still fenced off at that time following the 20 August 2005 landslide. The travel angle of the landslide debris was again about 49°. It is estimated that the displaced rock wedge had a volume of about 120 m^3.

Beneath the shotcrete surface, a suspected void about 2 m wide by 1 m long was identified near the top of the displaced rock wedge (Plate 17). Several old cracks, about 2 mm wide, were also observed on the shotcrete surface above the displaced rock wedge (Plate 18). Debris and vegetation were found in these cracks, which suggest that the cracks had existed for quite some time.

As a result of the further instability following relatively light rainfall, both the traffic lanes and the pedestrian walkways of Ping Ting Road, together with the playground at the Buddhist Hung Sean Chau Memorial College, were temporarily closed. The northbound lane and the playground were subsequently re-opened at 9:00 a.m. on 16 September 2005.

Between 13 and 16 September 2005, HyD carried out emergency works at the recommendation of the GEO, including the removal of landslide debris and loose rock blocks, to allow re-opening of the northbound lane of Ping Ting Road. During the emergency works, some of the loose rock blocks were observed to exhibit further displacement. Struts were erected by HyD to support the overhanging rock blocks (Plate 19). In mid-September 2005, the Mainland East Division of the GEO advised HyD to construct a mass concrete buttress to support the displaced rock wedge. The buttress was completed by the end of January 2006 (Plate 20).

Five surface markers were installed on the soil cut portion of the slope above the displaced rock wedge by the GEO. Movement monitoring of these surface markers was carried out by CEDD Survey Division between 17 September 2005 and 26 January 2006. No obvious movements were noted during this period.

7. GROUND CONDITIONS

7.1 General

The geological conditions in the area of the August 2005 landslide were inferred from a review of the available ground investigation (GI) records, API and field mapping by MGSL.

7.2 Ground Investigations

According to the geotechnical report prepared by FHK (1978), ten boreholes were drilled at the development site for the Buddhist Hung Sean Chau Memorial College, including five boreholes at slope No. 11NE-A/C153, as part of the ground investigation works for the development (see Figure 3 for the locations of the boreholes).

Bachy Soletanche (1984) drilled another seven boreholes at the development site for the Hammer Hill Road Sports Ground and at the middle part of slope No. 11NE-A/C153 (Figure 4).

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Another ground investigation was carried out by Fugro Geotechnical Services Limited (FGS) as part of the LPM Stage 3 Study (under Agreement No. CE 75/2001 (GE)). In total, six boreholes (DH 1 to DH6) were sunk (Figures 3 and 4).

7.3 Geology

Slope No. 11NE-A/C153 was formed by cutting into the western flank of a minor spur. Rock outcrop and corestones were observed on the natural hillside. The northern part of slope No. 11NE-A/C153, where the August 2005 landslide occurred, traversed an east-northeast to west-southwest trending spur exposing rock at the lower portion of the slope.

According to the GI information given in FHK (1978), the natural hillside prior to cutting in the vicinity of the August 2005 landslide site comprised approximately 7 m of completely to highly weathered granite with occasional "boulders", overlying slightly weathered granite. The slightly weathered granite was described as "Pinkish light grey, medium to coarse-grained, moderately widely spaced joints, slightly weathered GRANITE, very strong". An inferred geological cross-section of the hillside was presented in FHK (1978) as Section 1-1, which showed a 7 m to 10 m thick layer of completely weathered granite overlying moderately to slightly weathered granite. After forming the slope, the completely weathered granite would have been trimmed and the moderately to slightly weathered granite exposed at the lowermost batter. The extent of the cutting as depicted in Section 1-1 in FHK (1978) is reproduced in Figure 12.

The logs of the boreholes (FGS, 2006) indicate that the rock mass underlying the completely to highly decomposed granite was partially weathered, which is consistent with the findings of MGSL's field mapping of the scar of the August 2005 landslide (Section 6.1). Borehole DH 3, which is closest to the August and September 2005 landslides, was sunk on the third berm of the slope about 20 m to east of the landslides. A rock mass of moderately to slightly decomposed granite was encountered at a depth of 2 m. Between 2 m and 18 m depths, the rock mass was partially weathered with the presence of completely to highly decomposed sub-horizontal granite seams of about 0.1 m to 0.7 m thick. The moderately weathered granite was described as "Moderately strong, light yellowish brown, spotted white, moderately decomposed, medium-grained GRANITE", whereas the slightly weathered granite was described as "Strong to very strong, pinkish grey, spotted black, slightly decomposed, fine- to medium-grained GRANITE". The rock joints in the moderately and slightly decomposed granite were medium to closely spaced, rough planar, extremely narrow and limonite and manganese stained.

Televiewer survey was carried out at borehole DH3 within the moderately to slightly decomposed granite (at depths between 14 m and 25 m). Kinematic analysis was carried out on the rock joints obtained from televiewer survey. The results indicate that the joint sets there are marginally daylighting (Figure 15).

FHK (1978) carried out groundwater monitoring between August and September 1978 prior to the formation of slope No. 11NE-A/C153. Groundwater in the northern part of the slope was about 12 m below ground surface. The highest recorded groundwater levels close to the August 2005 landslide site were about 5 m above the toe of the present-day slope. The recent groundwater monitoring carried out between April and June 2006 as part of the

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LPM Stage 3 Study, indicated that the groundwater table was approximately at the toe level.

8. ANALYSIS OF RAINFALL RECORDS

Rainfall data were obtained from GEO automatic raingauge No. K09, which is the nearest raingauge to the landslide site and is located at Robert Black Health Centre, Prince Edward Road West, San Po Kong, approximately 1.45 km to the southwest of the landslide (Figure 1). The raingauge records and transmits rainfall data at 5-minute intervals via a telephone line to the Hong Kong Observatory and the GEO.

The landslide was reported to the GEO at 2:37 a.m. on 20 August 2005. At that time, the Landslip Warning had been in effect since the evening of 19 August 2005. The Amber Rainstorm Warning, which was in effect between 7:25 p.m. on 19 August 2005 and 12:55 a.m. on 20 August 2005, was terminated about 1½ hours before the landslide.

The daily rainfall recorded by raingauge No. K09 over the month preceding the 20 August 2005 landslide, together with the hourly rainfall readings for the period of 18 to 21 August 2005, are presented in Figure 13. A rainstorm started on the afternoon of 18 August 2005 and heavy rainfall was recorded until the evening of 20 August 2005. The maximum 24-hour and 48-hour rolling rainfall before the landslide was 255 mm and 307 mm respectively. The maximum 1-hour rolling rainfall was recorded as 44.5 mm between 7:25 p.m. and 8:25 p.m. on the evening of 19 August 2005 (Table 1).

Table 1 presents the estimated return periods for the maximum rolling rainfall for various durations recorded by raingauge No. K09 with reference to the historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994). The results show that the 31-day rolling rainfall of 918 mm before the landslide was the most critical, with a corresponding return period of 8 years.

The return periods of the rainstorms were also assessed based on the statistical parameters derived by Evans & Yu (2001) for rainfall data recorded by local raingauge No. K07, which is located approximately 1.7 km to the northwest, between 1984 and 1997. The return periods for rainfall durations over 4 hours were about 2 years to 4 years.

The maximum rolling rainfall for the August 2005 rainstorm has been compared with the past major rainstorms between 1983 and 2004 recorded by raingauges Nos. K07 and K09, which came into operation in March 1983 and October 1999 respectively (Figure 14). The maximum rolling rainfall for the 19 August 2005 rainstorm is less severe than the past rainstorms recorded between 1983 and 2004.

The daily rainfall recorded by raingauge No. K09 over the month preceding the landslide on 13 September 2005, together with the hourly rainfall readings for the period of 11 to 14 September 2005, are presented in Figure 11. A short duration rainstorm started on the early morning of 13 September 2005 and rainfall was recorded for less than 3 hours. The maximum 24-hour rolling rainfall before the landslide was 21 mm. The maximum 1-hour rolling rainfall was 13.5 mm between 2:00 a.m. and 3:00 a.m. in the early morning of 13 September 2005 (Table 2). Table 2 presents the estimated return periods for the maximum rolling rainfall for various durations. It can be seen that for rainfall durations

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between 5 minutes and 31 days, the corresponding return periods are less than 2 years.

9. DISCUSSION

This failure incident involved a slope that had previously been subjected to engineering input in the late 1970's and the 1980's. The northern part of the slope, where the 2005 landslides occurred, had previously gone through the geotechnical checking process in 1979. However, the submission on the detailed study and stability assessment of the rock slope during site formation as required by BA/GCO, together with the as-built plans, could not be located in the available file records.

The other parts of the slope were also processed by the geotechnical checking system in 1984 and 1987 respectively.

Two EIs were carried out on the slope in 1999 and 2003 respectively. Both EIs did not identify the previous geotechnical submissions and hence recommended stability assessment to be carried out on the slope. Signs of distress in local areas (viz. severely cracked catchpit and channels) were observed in the 1999 EI report and routine/preventive maintenance works were recommended by the EI consultants. Local re-surfacing of the shotcrete cover adjacent to the 2005 landslides was carried out in 2000. It is not certain whether or not this reflected progressive deterioration of the rock mass condition in the locality.

Prescriptive measures were carried out on the northern part of the slope by HyD in 2001. The works comprised the installation of about 500 soil nails and replacement of the hard surface cover by hydroseeding on the two uppermost batters of the soil portion, and 13 raking drains on the lower rock cut portion.

The rock mass at the location of the 2005 landslides contains sub-horizontal weathered seams at various depths, which may influence the hydrogeology and subsurface seepage. Field mapping of the landslide scarp identified the presence of potentially adverse jointing. The kinematic analysis of the rock joints exposed in the landslide scarp and interpreted from the post-failure televiewer survey shows that some of the joint sets identified fall just within the daylight envelope for planar and wedge failures. This suggests that the rock cut was probably only marginally stable prior to the August 2005 landslide.

Rain continued for a period of 12 days preceding the August 2005 landslide incident. The observation of localised seepage issuing from the nearby weepholes and raking drains following the August 2005 landslide suggests that the transient groundwater table was high in the locality at the time of failure and the landslide was likely to have been rain-induced. Despite the persistent rainfall, the maximum rolling rainfall preceding the instability was less severe than the past intense rainstorms recorded by the nearest automatic raingauge between 1983 and 2004, during which time no instability was reported. This may suggest that the slope may have been subjected to progressive deterioration (as possibly reflected by the need for repeated re-surfacing of parts of the slope between 1984 and 2001, and the observation of local major distress during the past EI), and/or adverse changes in the environmental setting (e.g. replacement of the hard surface cover with hydroseeding in the uppermost soil portion, which could have allowed enhanced surface infiltration).

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The presence of the shotcrete cover on the rock face had meant that it was not possible to assess the nature and condition of the rock joints during the EI. The soil portion of the slope was treated with Type 2 and Type 3 prescriptive measures (i.e. raking drains and soil nails respectively), but not the rock portion. Because of the shotcrete and due to lack of simple GI such as local slope surface stripping, there was probably some uncertainty about the location of the soil/rock interface, and hence the installations and effectiveness of the raking drains might be affected to a certain degree.

The past GI findings indicate that the transient groundwater condition could be quite high close to the 2005 landslide site. The local development of cleft water pressure in rock joints probably caused the detachment of rock blocks and instability of a large rock wedge. The fact that the rock wedge did not detach completely might be related to the kinematics of the joints defining the wedge. Cracking of the shotcrete surface had probably increased infiltration into the joints, rendering the rock mass more susceptible to further movement or instability even given moderate rainfall, as reflected by the September 2005 failure. Furthermore, the likely reduction in joint shear strength due to shear movement along the joints and less tight interlocking of the rock blocks, coupled with a reducing operational rock mass strength, are liable to make the rock cut more vulnerable to sudden major detachments given sufficient build-up of groundwater pressures.

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Table 1 - Maximum Rolling Rainfall at GEO Raingauge No. K09 for Selected Durations Preceding the Landslide on 20 August 2005 and Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years)	
			Based on Lam & Leung (1994)	Based on Evans & Yu (2001)
5 Minutes	5.0	8:10 p.m. on 19 August 2005	< 2	< 2
15 Minutes	14.0	8:10 p.m. on 19 August 2005	< 2	< 2
1 Hour	44.5	8:25 p.m. on 19 August 2005	< 2	< 2
2 Hours	73.5	8:45 p.m. on 19 August 2005	< 2	< 2
4 Hours	131.0	10:25 p.m. on 19 August 2005	3	3
12 Hours	179.5	2:15 a.m. on 20 August 2005	2	2
24 Hours	254.5	1:55 a.m. on 20 August 2005	3	3
48 Hours	307.0	2:30 a.m. on 20 August 2005	3	2
4 Days	392.0	2:30 a.m. on 20 August 2005	4	3
7 Days	527.5	2:30 a.m. on 20 August 2005	7	4
15 Days	639.5	2:30 a.m. on 20 August 2005	5	3
31 Days	918.0	2:30 a.m. on 20 August 2005	8	3

Notes:
(1) Maximum rolling rainfall was calculated from 5-minute rainfall data.
(2) Return periods were derived from Table 3 of Lam & Leung (1994), and using data from Evans & Yu (2001).
(3) According to GEO records, the landslide occurred at about 2:37 a.m. on 20 August 2005.
(4) The nearest GEO raingauge to the site is raingauge No. K09 located about 1.45 km to the southwest. GEO raingauge No. K07 is located about 1.7 km to the northwest.
(5) GEO raingauges Nos. K07 and K09 operates since 22 March 1983 and 1 November 1999 respectively.

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Table 2 - Maximum Rolling Rainfall at GEO Raingauge No. K09 for Selected Durations Preceding the Re-activated Landslide on 13 September 2005 and Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years)	
			Based on Lam & Leung (1994)	Based on Evans & Yu (2001)
5 Minutes	5.5	2:10 a.m. on 13 September 2005	< 2	< 2
15 Minutes	11.0	2:15 a.m. on 13 September 2005	< 2	< 2
1 Hour	13.5	3:00 a.m. on 13 September 2005	< 2	< 2
2 Hours	16.0	3:05 a.m. on 13 September 2005	< 2	< 2
4 Hours	21.0	4:20 a.m. on 13 September 2005	< 2	< 2
12 Hours	21.0	4:20 a.m. on 13 September 2005	< 2	< 2
24 Hours	21.0	4:20 a.m. on 13 September 2005	< 2	< 2
48 Hours	21.0	4:20 a.m. on 13 September 2005	< 2	< 2
4 Days	21.0	4:20 a.m. on 13 September 2005	< 2	< 2
7 Days	36.0	4:20 a.m. on 13 September 2005	< 2	< 2
15 Days	61.5	3:05 p.m. on 12 September 2005	< 2	< 2
31 Days	61.5	3:05 p.m. on 12 September 2005	< 2	< 2

Notes:
(1) Maximum rolling rainfall was calculated from 5-minute rainfall data.
(2) Return periods were derived from Table 3 of Lam & Leung (1994), and using data from Evans & Yu (2001).
(3) According to the eye-witness account, the landslide occurred in the early morning of 13 September 2005. For the purpose of rainfall analysis, the time of the re-activated landslide is assumed to be at 7:00 a.m. on 13 September 2005.
(4) The nearest GEO raingauge to the site is raingauge No. K09 located about 1.45 km to the southwest. GEO raingauge No. K07 is located about 1.7 km to the northwest.
(5) GEO raingauges Nos. K07 and K09 operates since 22 March 1983 and 1 November 1999 respectively.

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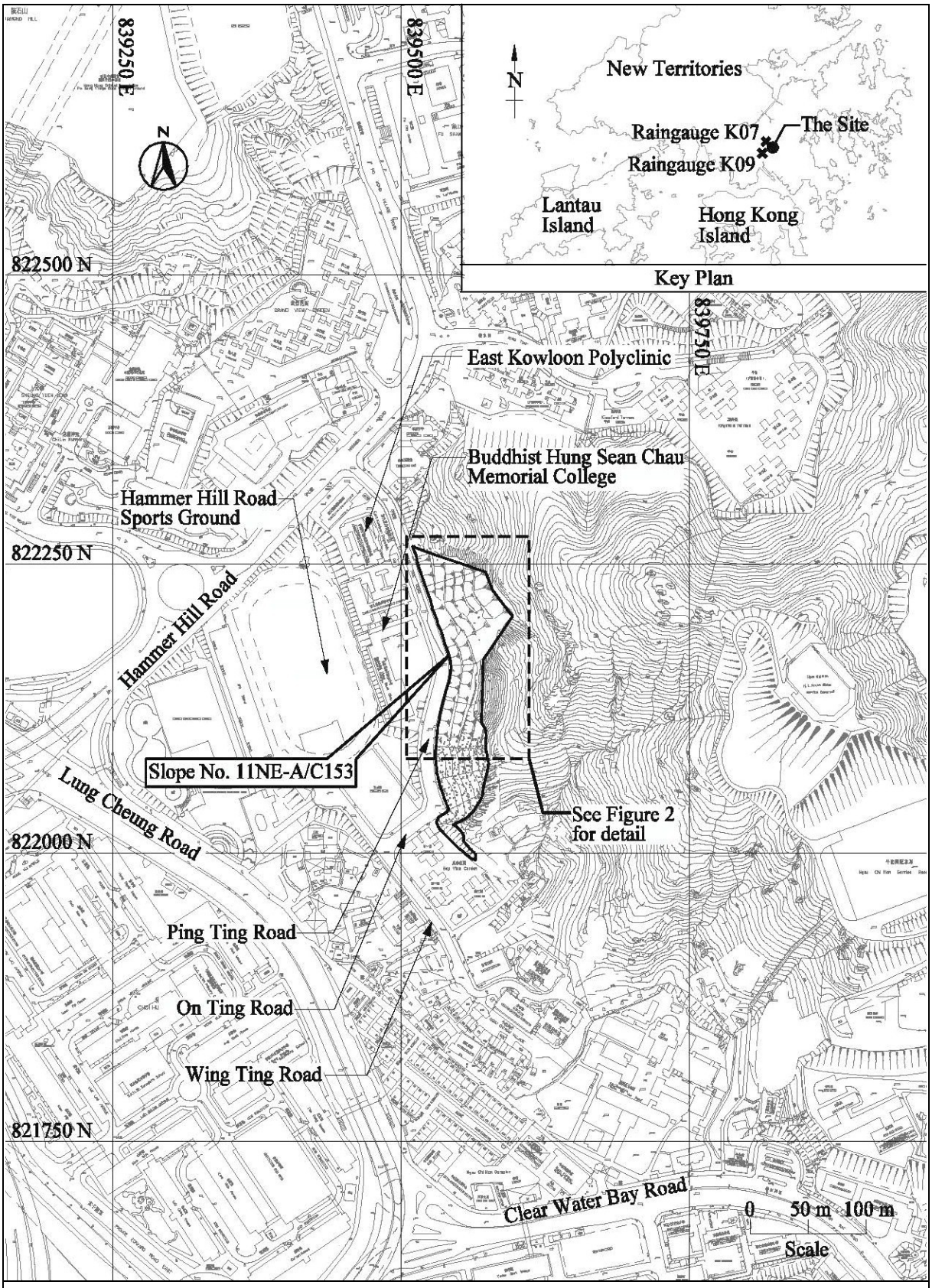

Note: Base plan is extracted from 1:1000 survey sheets Nos. 11NE-7A, 11NE-7B, 11NE-7C and 11NE-7D dated March 2004.

Figure 1 - Location Plan

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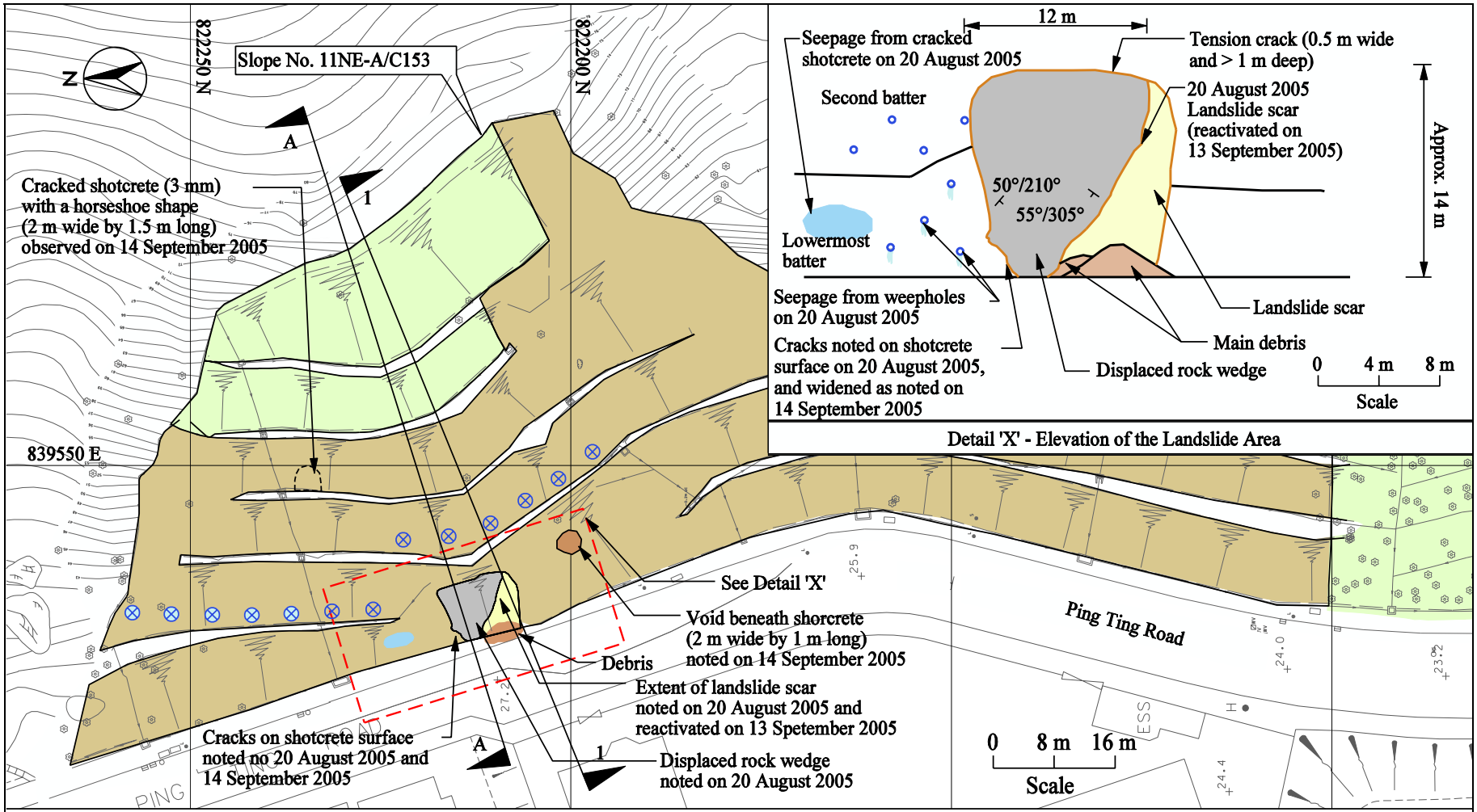

Note: Base plan is extracted from 1:1000 survey sheets Nos. 11NE-7A and 11NE-7C dated March 2004.

Figure 2 - Site Observation

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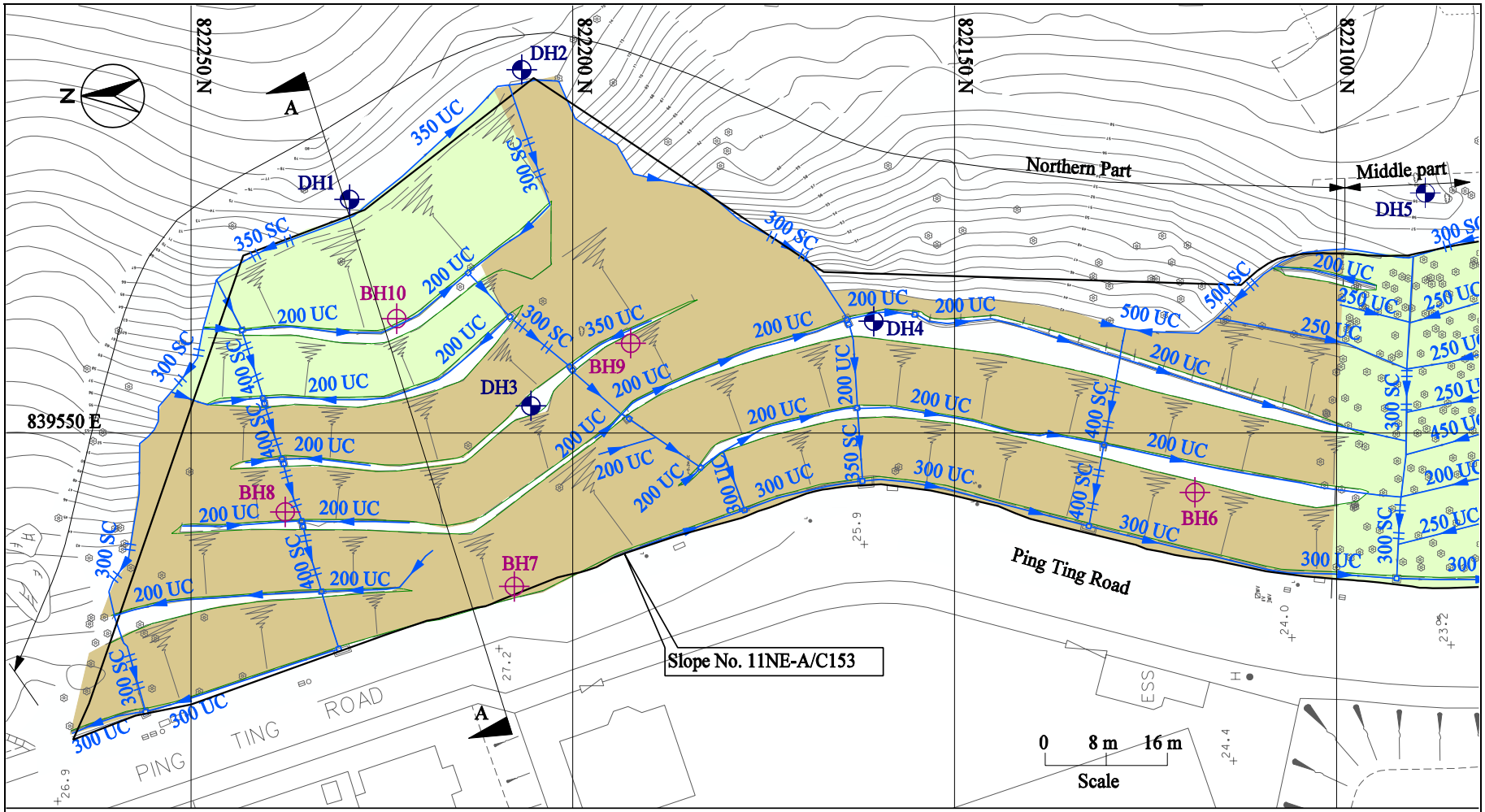
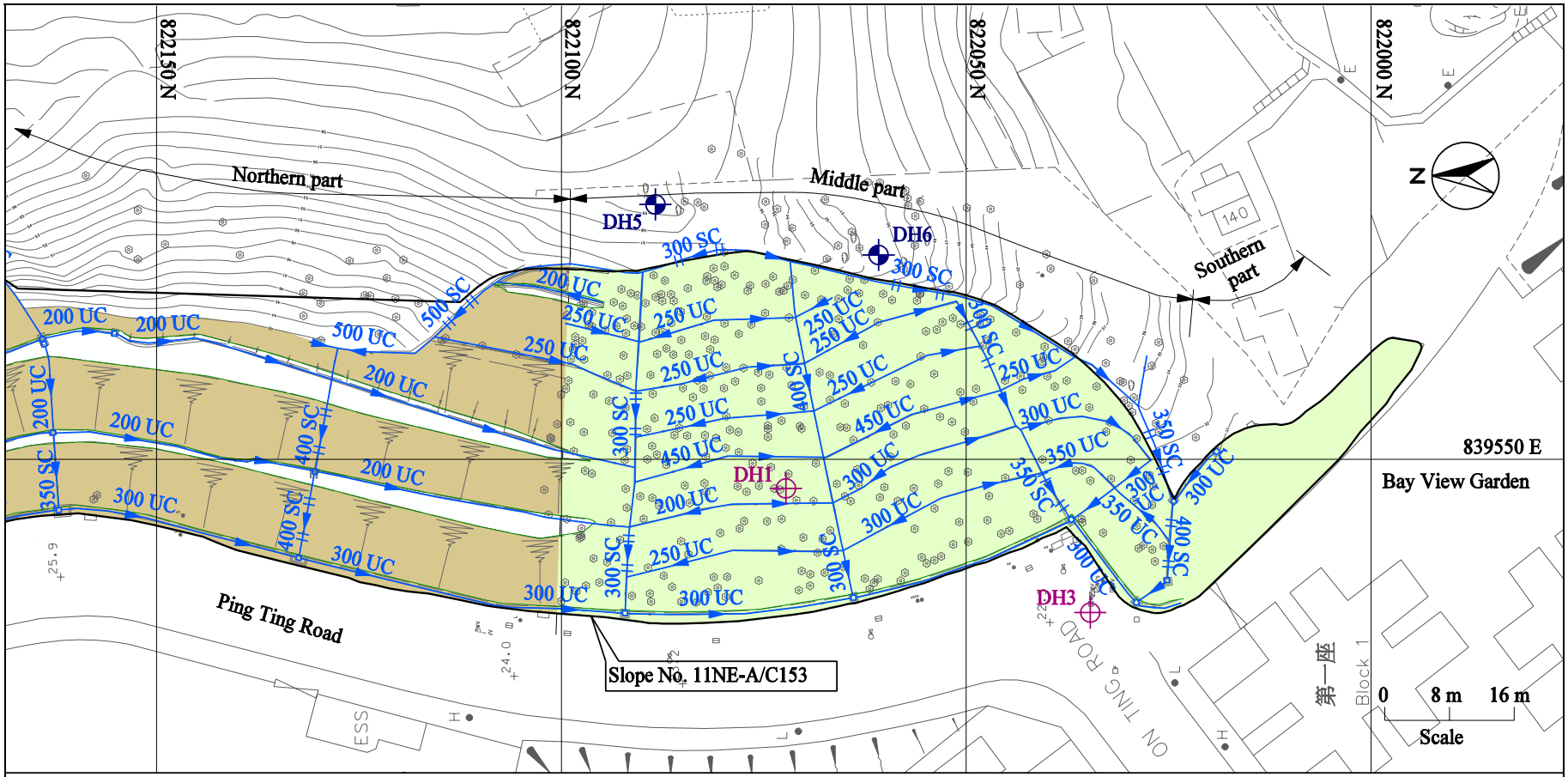


Note: Base plan is extracted from 1:1000 survey sheets Nos. 11NE-7A and 11NE-7C dated March 2004.

Figure 3 - Site Layout Plan (Sheet 1 of 2)



Note: Base plan is extracted from 1:1000 survey sheets Nos. 11NE-7C dated March 2004.

Figure 4 - Site Layout Plan (Sheet 2 of 2)

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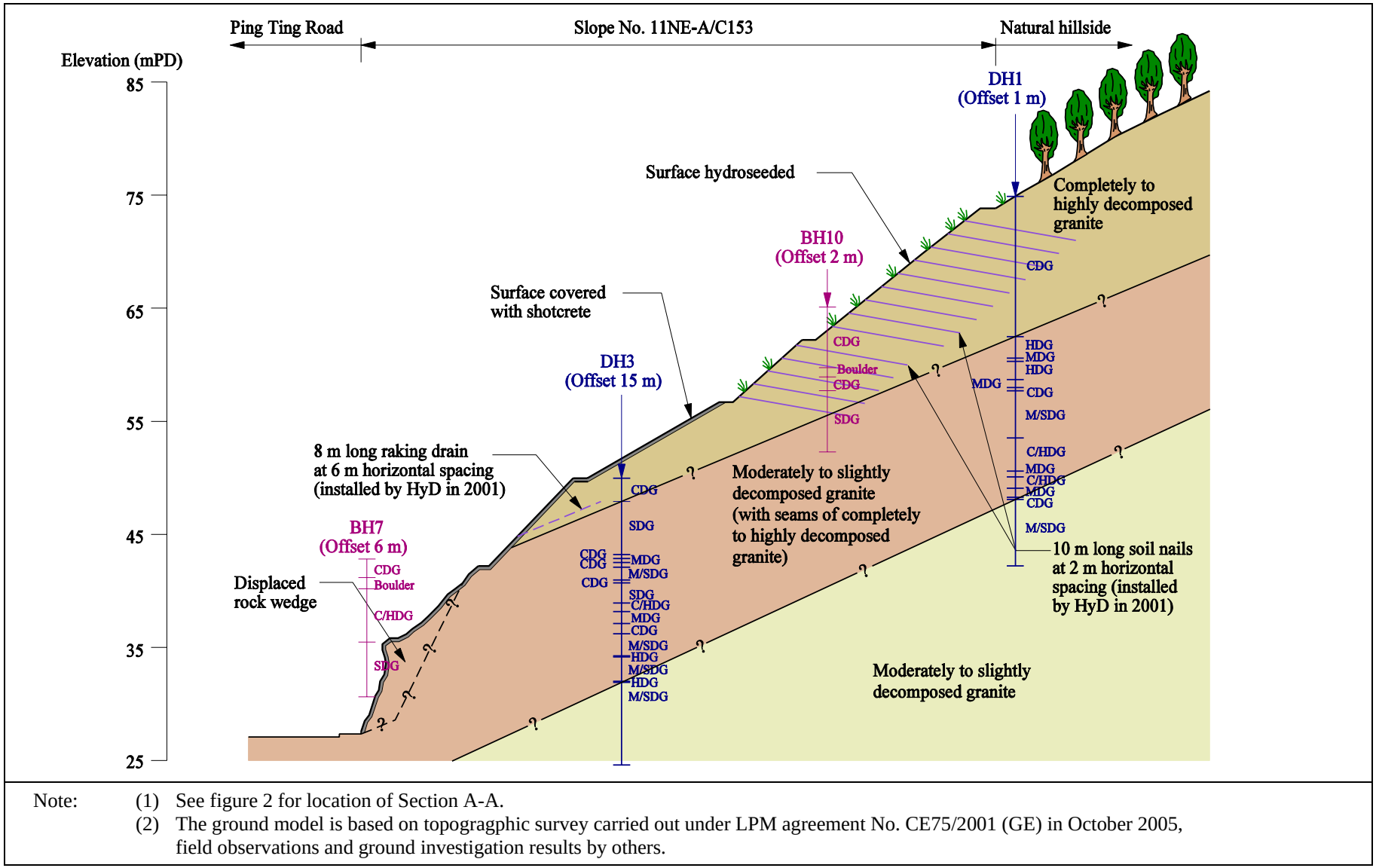
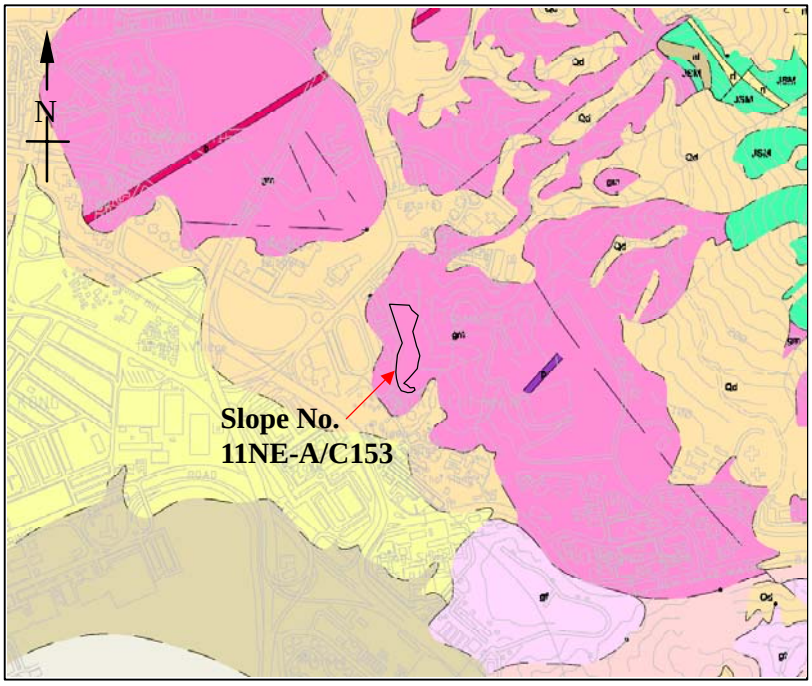


Note: (1) See figure 2 for location of Section A-A.
(2) The ground model is based on topogragphic survey carried out under LPM agreement No. CE75/2001 (GE) in October 2005, field observations and ground investigation results by others.

Figure 5 - Section A-A



Legend:

Superficail Deposits

Qa	Clay/silt, sand and gravel (Alluvium)	Qd	Sand, gravel, cobbles and boulders in clay/silt matrix (Debris Flow Deposits)
Qb	Sand	HHH	Undivided, mainly dark grey marine mud

Solid Geology

b	Basalt	JSM	Crystal and lithic tuff, tuff-breccia and tuffite
rf	Feldsparphyric rhyolite	sl	Siltstone and mudstone
gm	Medium-grained granite	gf	Fine-grained granite
p	Pegmatite	gfm	Fine- to medium-gained granite

Geological Lines

- Geological boundary, superficial deposits
- Geological boundary, solid rock
- Fault (crossmark indicates downthrow side)
- Mineral vein
- Photogeological lineament

Structural Symbols

- 22 Intrusive contact
- Jointing for vertical

Note: Extracted from Hong Kong Geological Survey, Map Series HGM20, Sheets No. 11, 1:20 000 scale (GCO, 1986)

Figure 6 - Regional Geology

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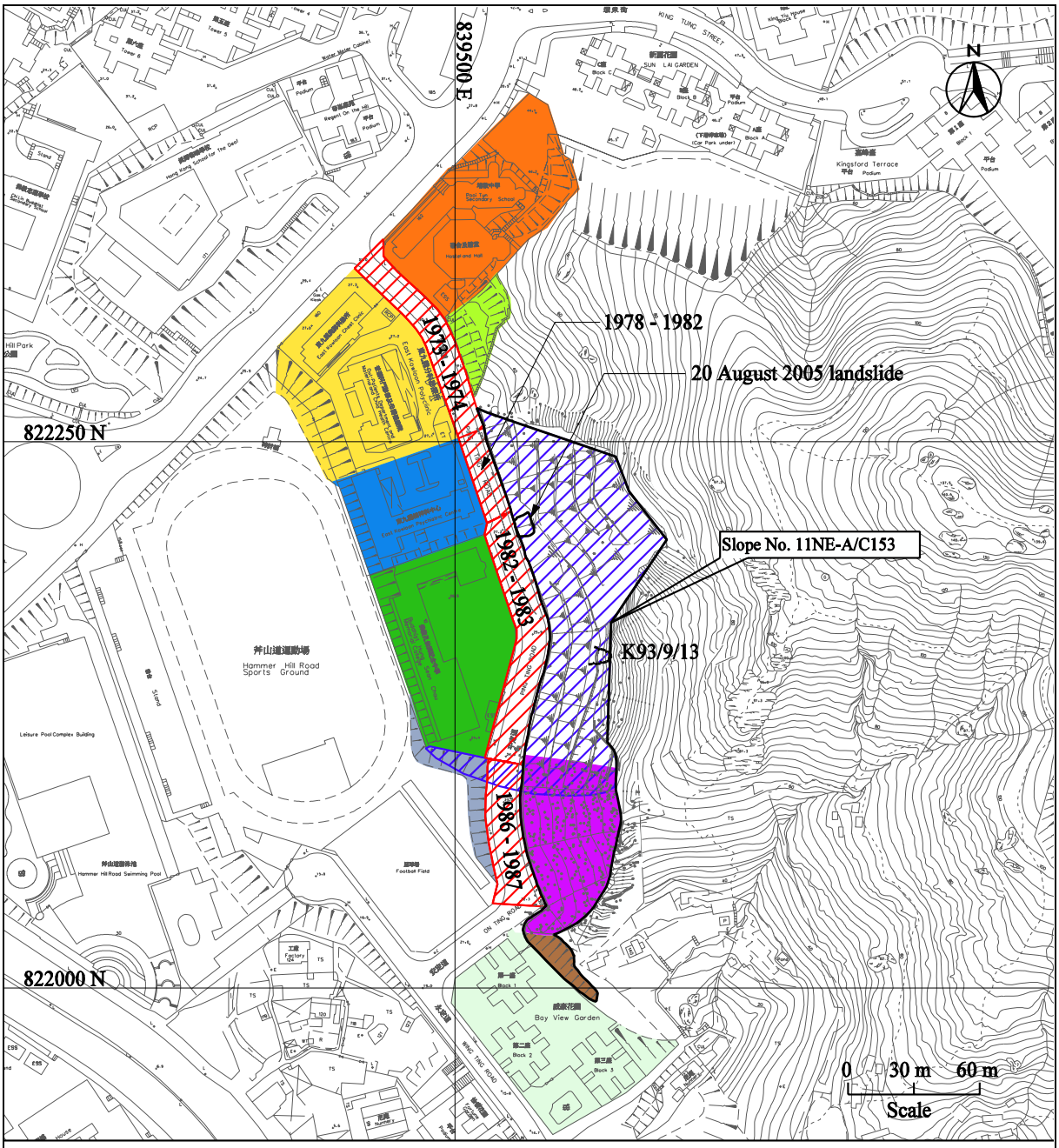

Legend :

- K93/9/13 — Previous instability in 1993 (No. K93/9/13)
- 1973 - 1974 — Part of Ping Ting Road constructed 1973 - 1974
- Pooi Tun Secondary School constructed 1973 - 1975
- East Kowloon Polyclinic constructed 1973 - 1976
- Slope No. 11NE-A/CR47 constructed 1975
- Buddhist Hung Sean Chau Memorial College constructed 1978 - 1983
- East Kowloon Psychiatric Centre constructed 1978 - 1983
- Part of Slope No. 11NE-A/C153 constructed 1980 - 1981
- Part of Slope No. 11NE-A/C153 constructed 1986
- Slope No. 11NE-A/C843 constructed 1986 - 1987
- Part of Slope No. 11NE-A/C153 constructed 1988
- Private development 1988 - 1989

Note: Base plan is extracted from 1:1000 survey sheets Nos. 11NE-7A, 11NE-7B, 11NE-7C and 11NE-7D dated March 2004.

Figure 7 - Site History and Past Instabilities

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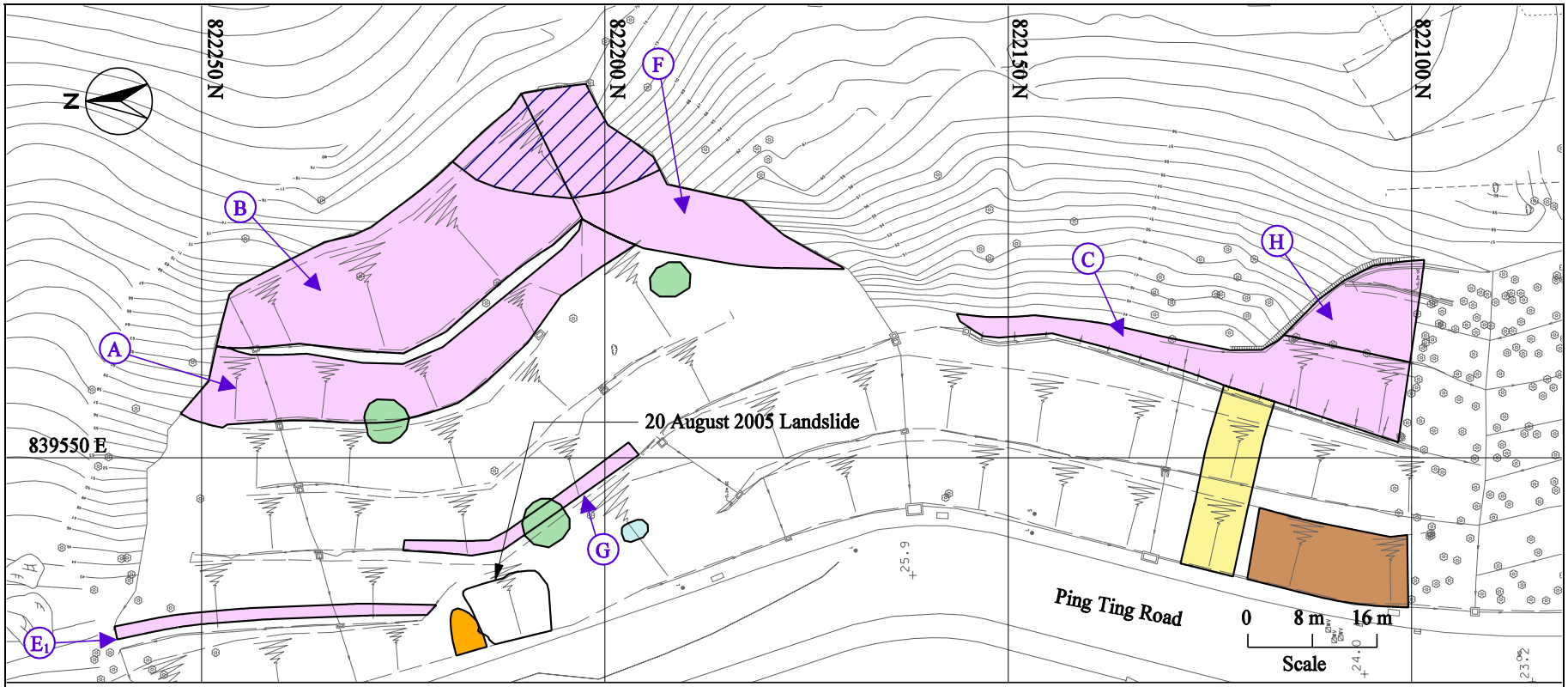

Figure 8 - Previous Works Carried Out at the Northern Part of Slope No. 11NE-A/C153

Figure 9 - Rock Joint Mapping of Landslide Scar

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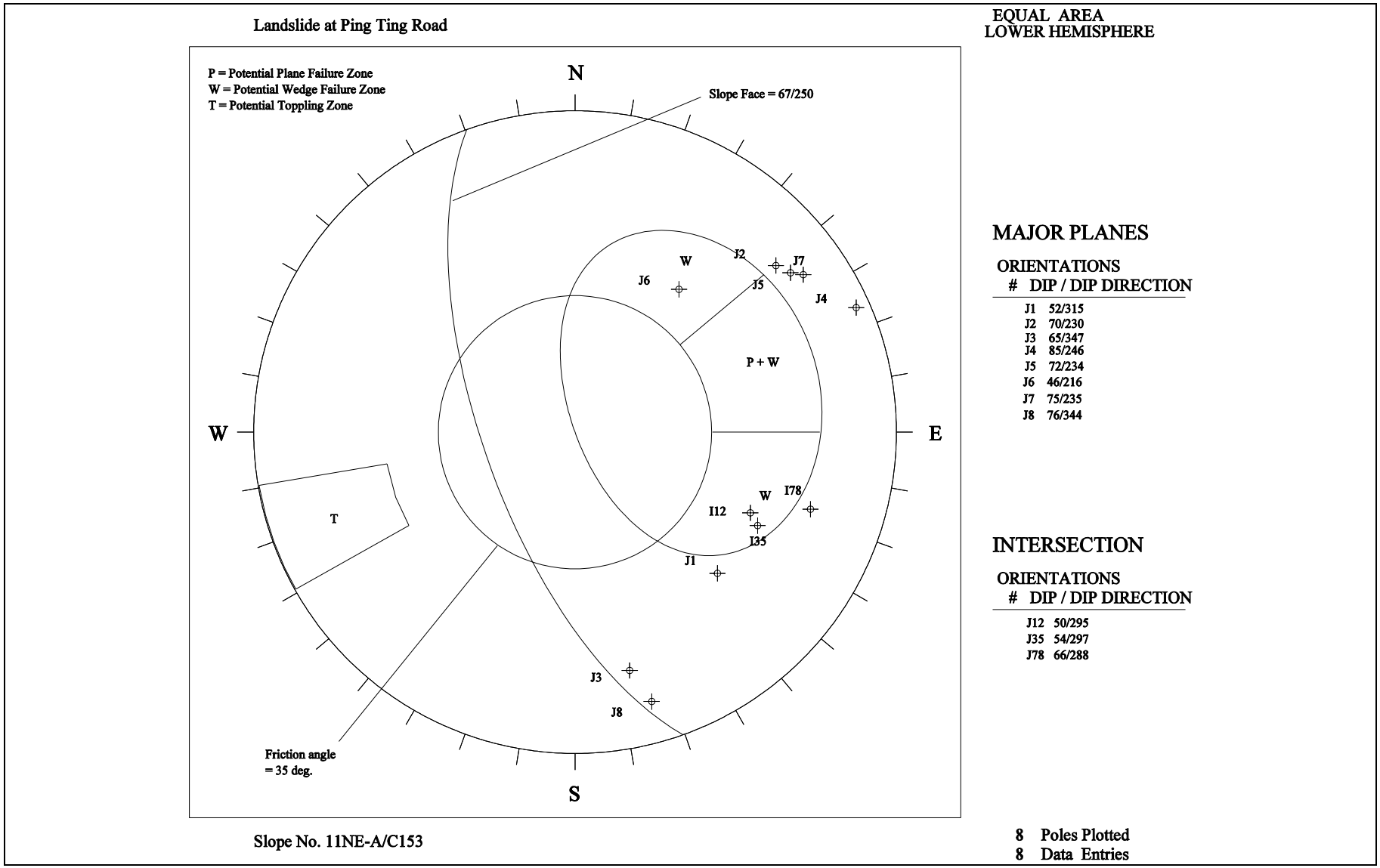
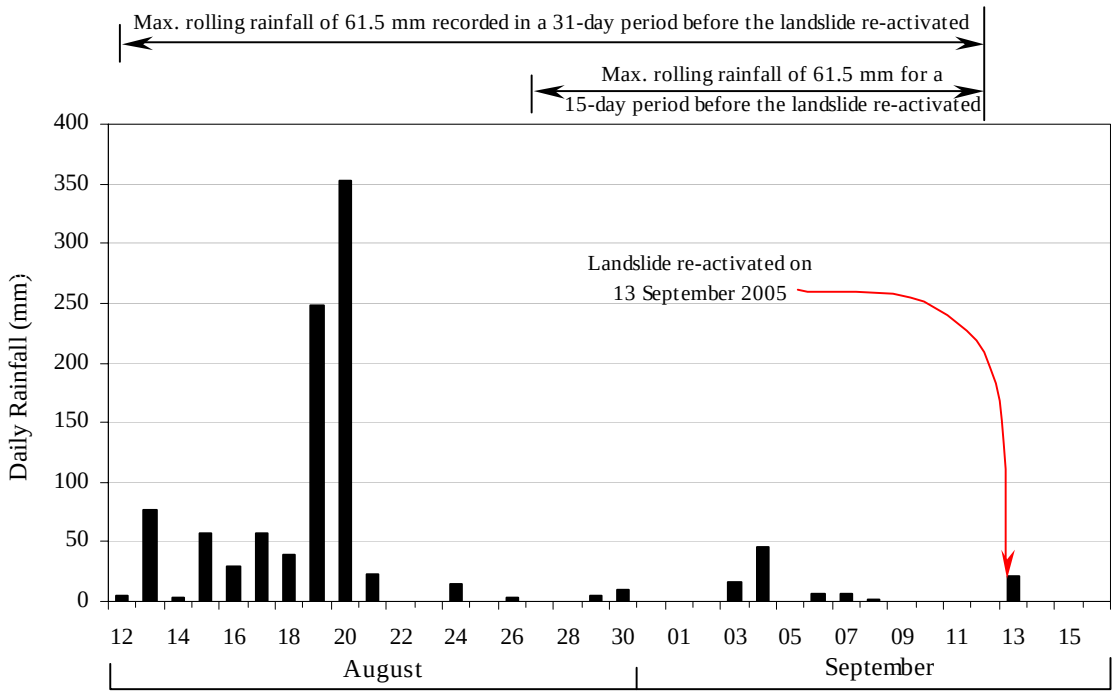
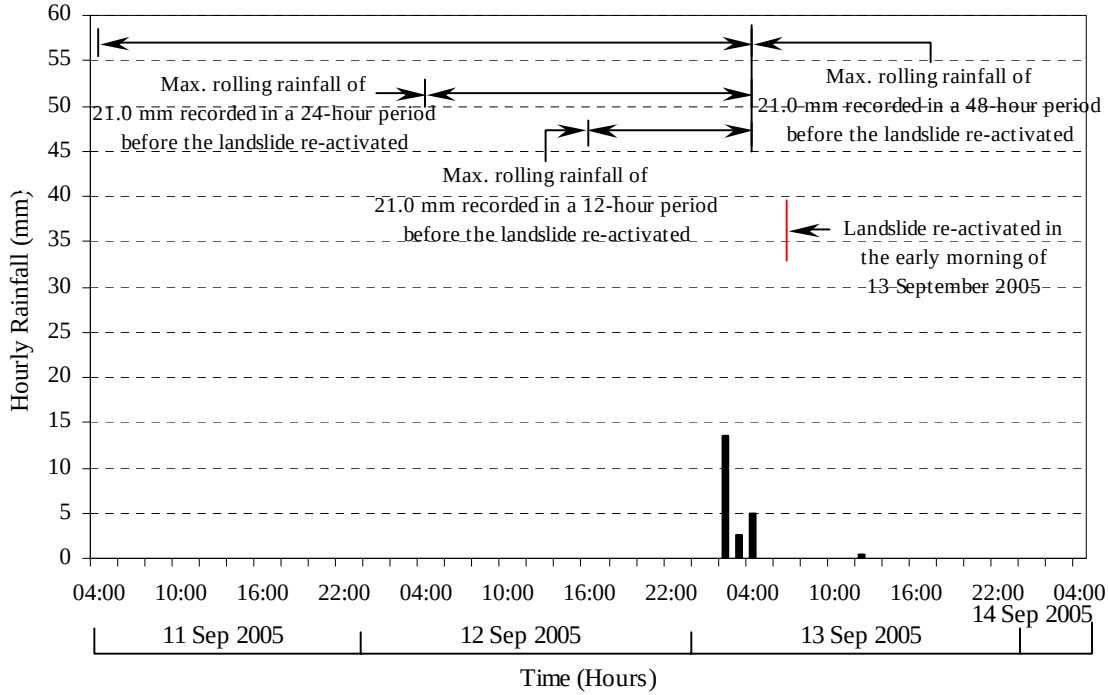


Figure 10 - Strereograph of Rock Joints at Landslide Scar



(a) Daily Rainfall Recorded at GEO Raingauge No. K09 between 12 August 2005 and 16 September 2005



(b) Hourly Rainfall Recorded at GEO Raingauge No. K09 between 11 September 2005 and 14 September 2005

Figure 11 - Daily and Hourly Rainfall Recorded at GEO Raingauge No. K09 Preceding the Re-activated Landslide on 13 September 2005

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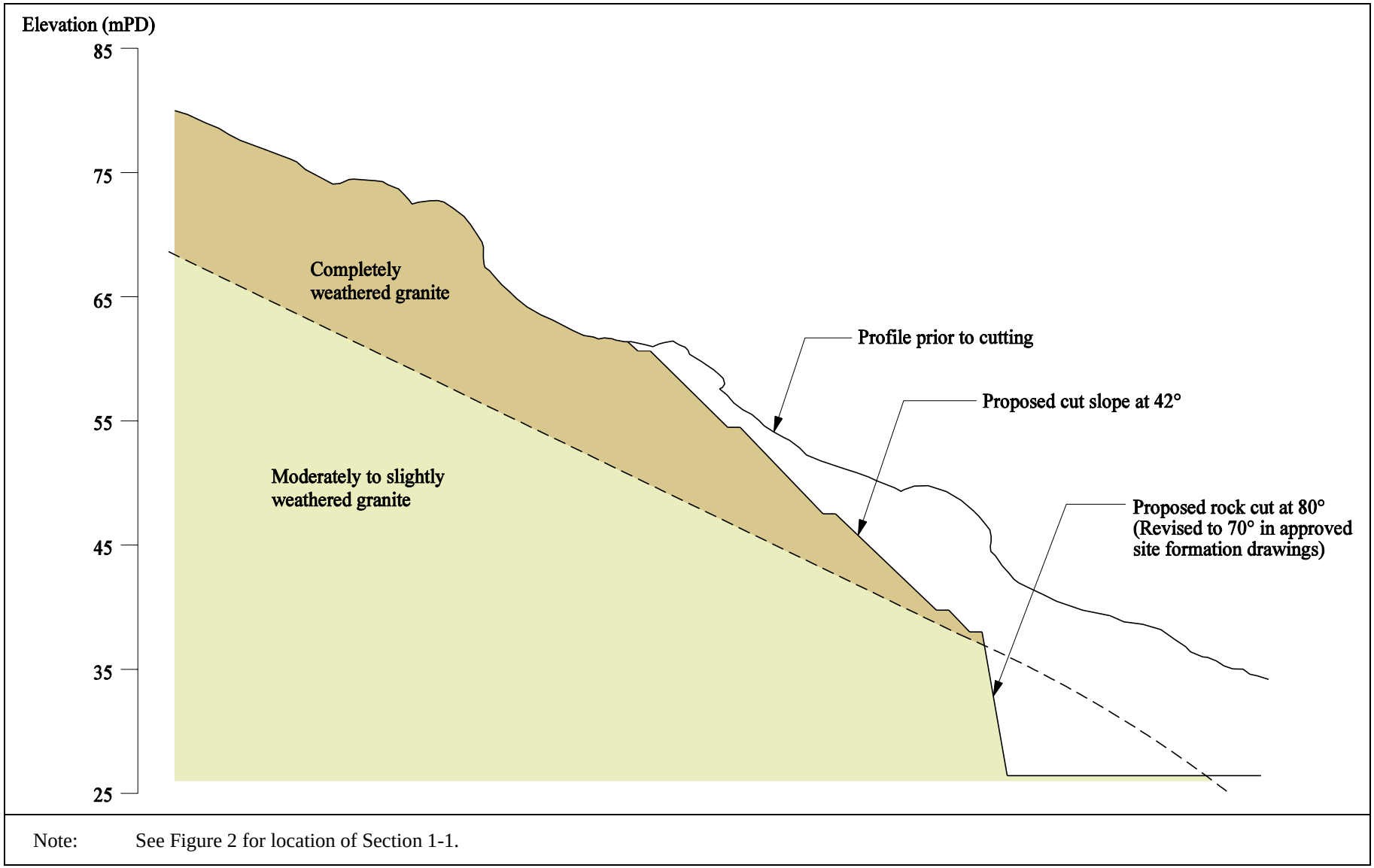

Note: See Figure 2 for location of Section 1-1.

Figure 12 - Geological Section 1-1 Extracted from FHK Design Report (1978)

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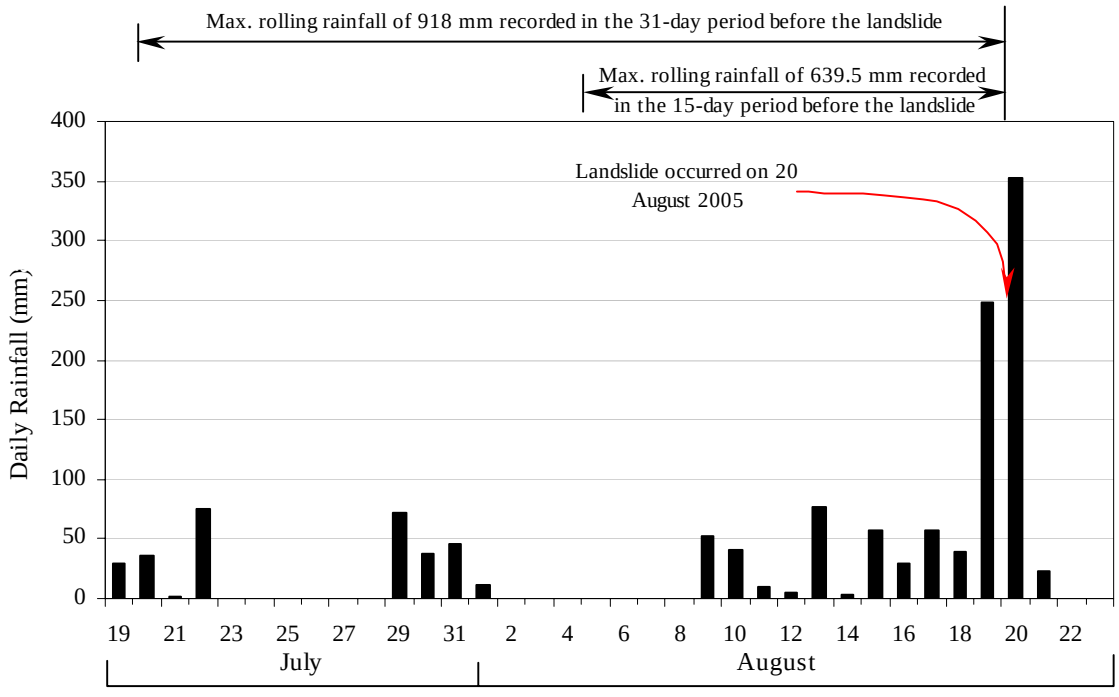
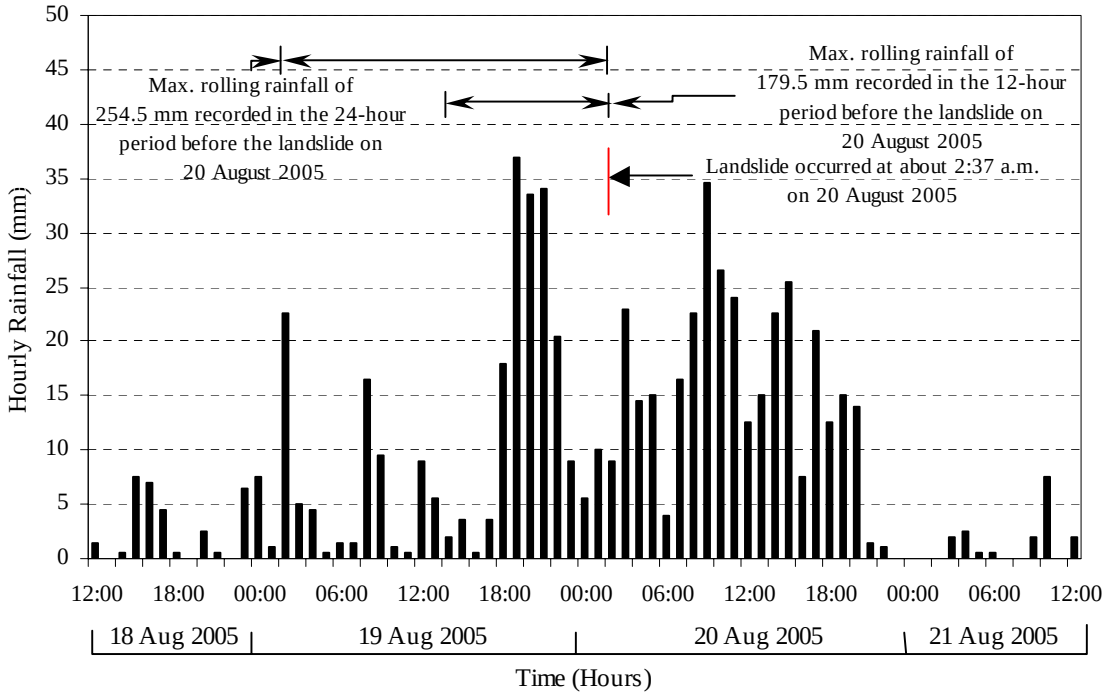


(a) Daily Rainfall Recorded at GEO Raingauge No. K09 between 18 July 2005 and 23 August 2005



(b) Hourly Rainfall Recorded at GEO Raingauge No. K09 between 18 August 2005 and 21 August 2005

Figure 13 - Daily and Hourly Rainfall Recorded at GEO Raingauge No. K09 Preceding the Landslide on 20 August 2005

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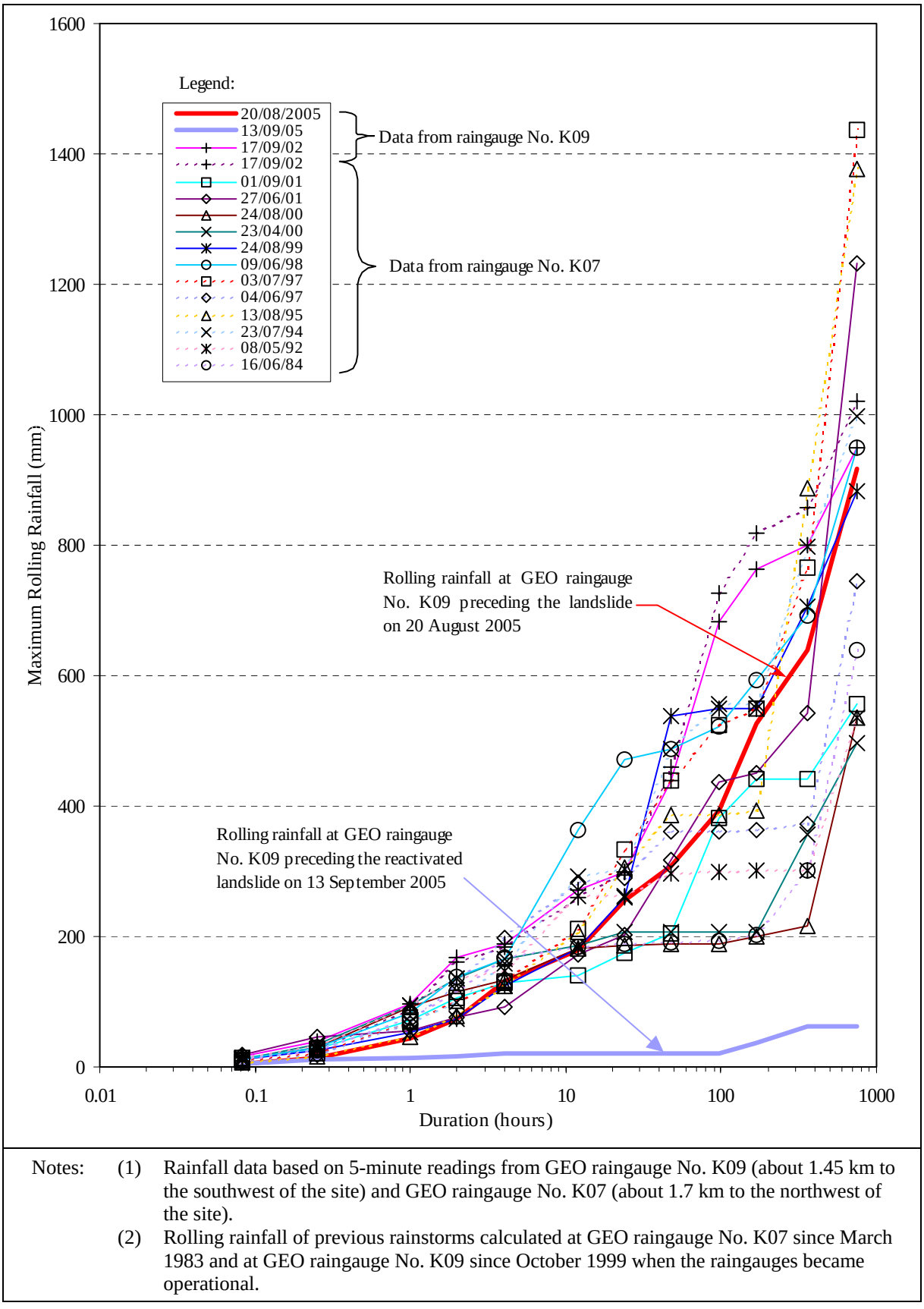

Notes: (1) Rainfall data based on 5-minute readings from GEO raingauge No. K09 (about 1.45 km to the southwest of the site) and GEO raingauge No. K07 (about 1.7 km to the northwest of the site).

(2) Rolling rainfall of previous rainstorms calculated at GEO raingauge No. K07 since March 1983 and at GEO raingauge No. K09 since October 1999 when the raingauges became operational.

Figure 14 - Maximum Rolling Rainfall for Previous Major Rainstorms at GEO Raingauge Nos. K07 and K09

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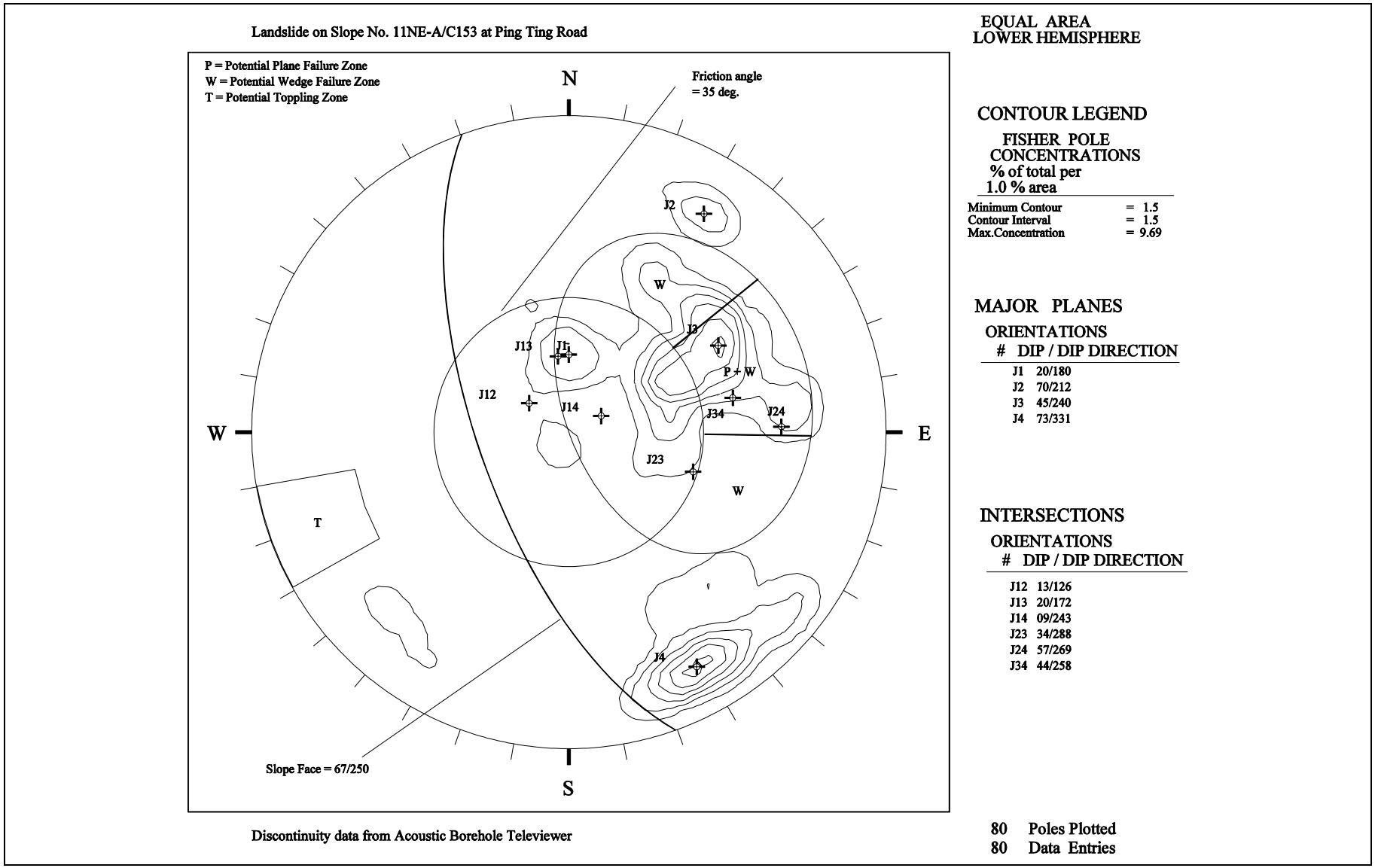

Figure 15 - Strereograph of Rock Joints at Borehole DH3

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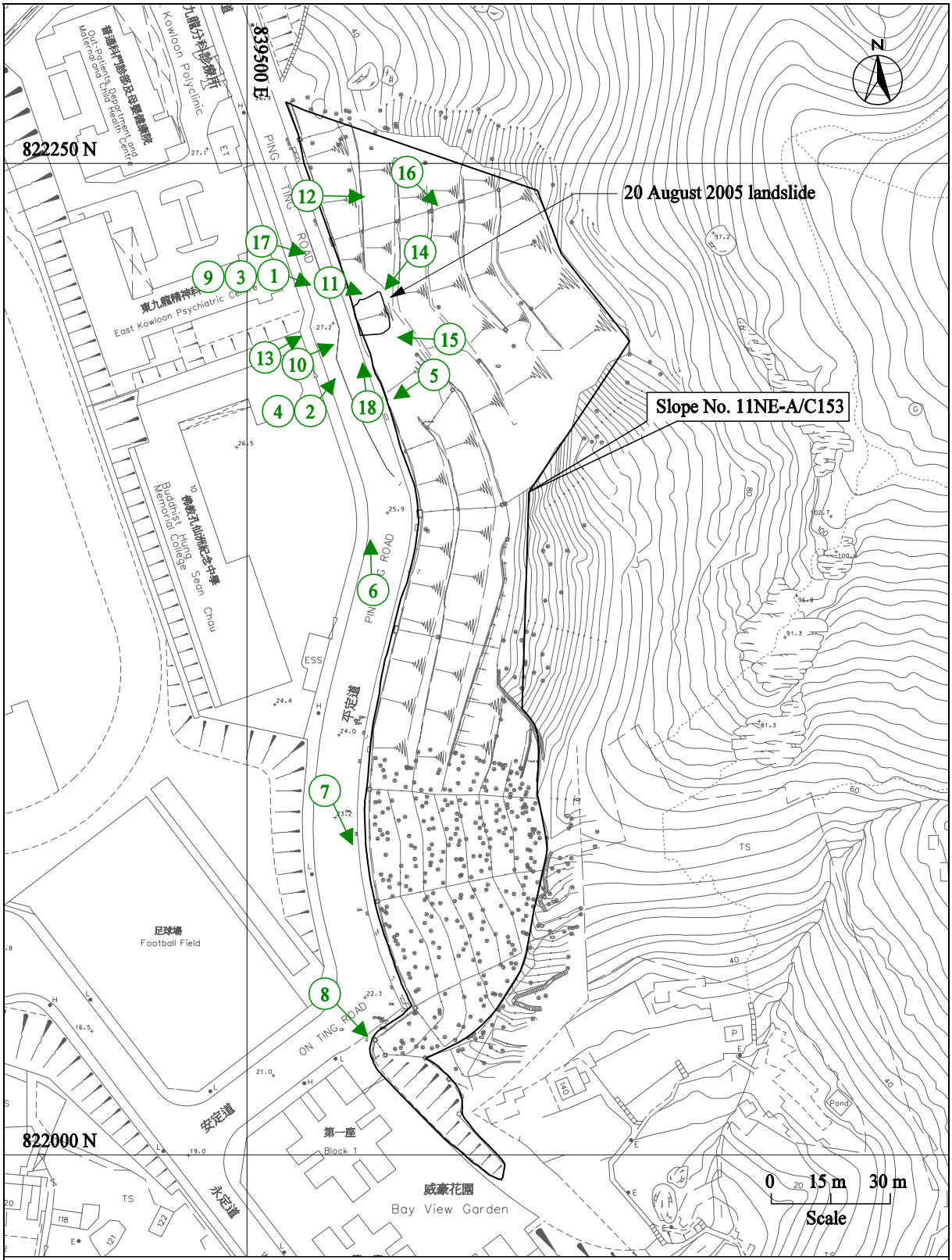

Figure 16 - Locations and Directions of Photographs Taken

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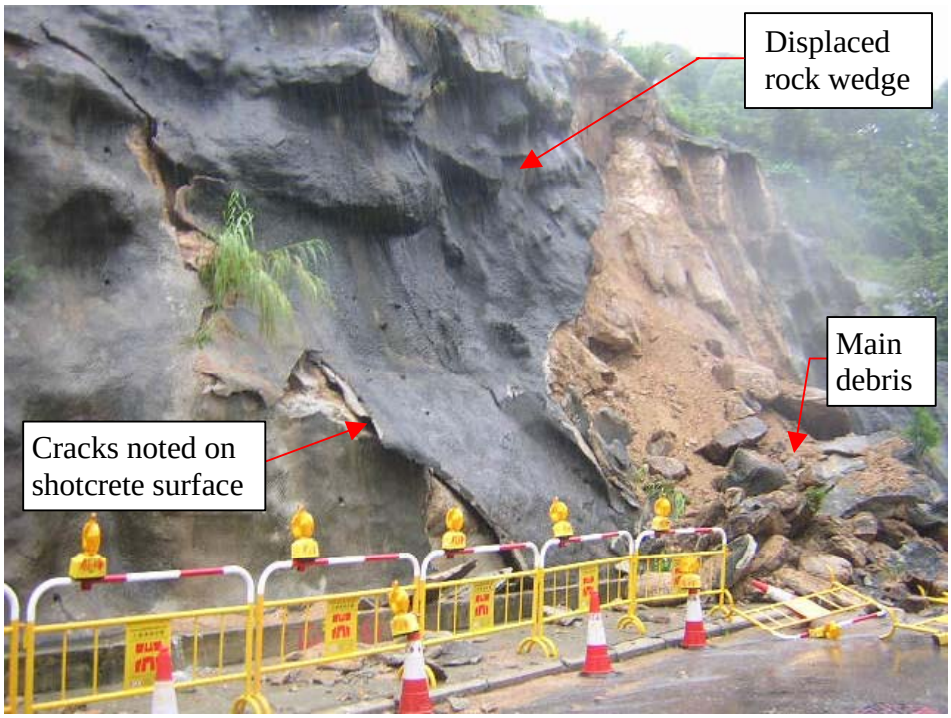

Plate 1 - View of the 20 August 2005 Landslide on Slope No.11NE-A/C153 Looking Southeast (Photograph taken on 20 August 2005)

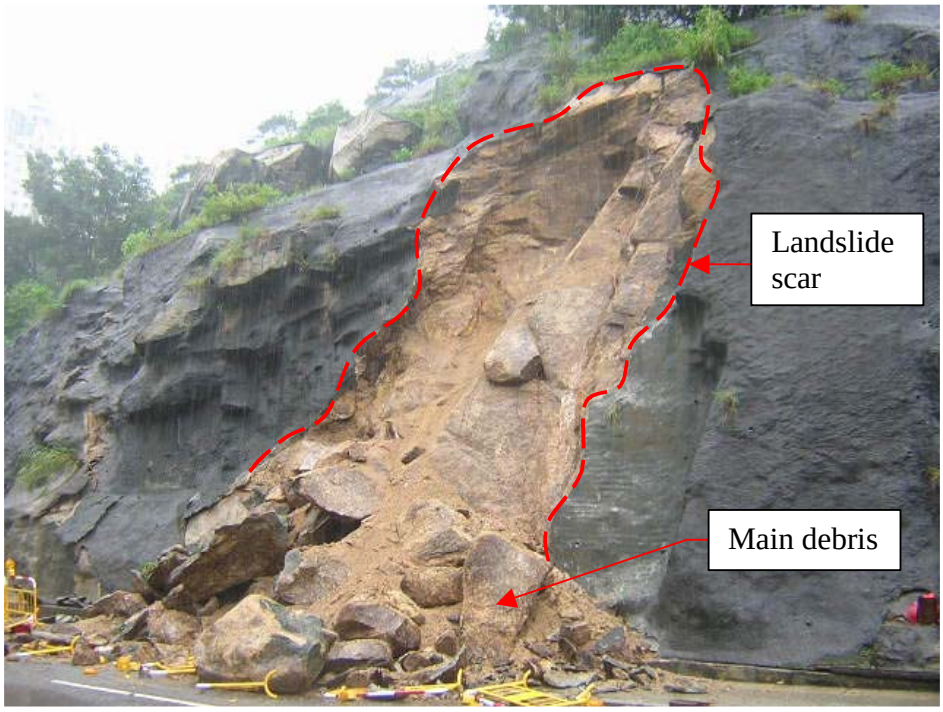

Plate 2 - View of the 20 August 2005 Landslide on Slope No.11NE-A/C153 Looking North (Photograph taken on 20 August 2005)

Note: See Figure 16 for locations and directions of photographs taken.

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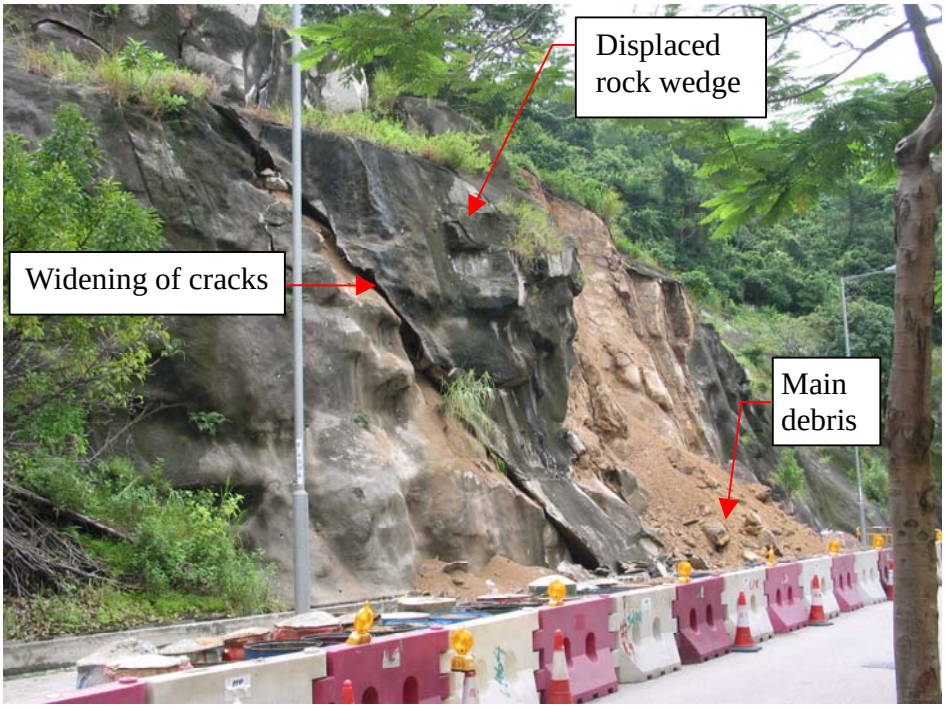

Plate 3 - View of the Reactivated Landslide on Slope No. 11NE-A/C153 on 13 September 2005 Looking Southeast (Photograph taken on 13 September 2005)

Plate 4 - View of the Reactivated Landslide on Slope No.11NE-A/C153 on 13 September 2005 Looking North (Photograph taken on 13 September 2005)

Note: See Figure 16 for locations and directions of photographs taken.

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Plate 5 - View of Ping Ting Road and Buddhist Hung Sean Chau Memorial College at toe of Slope No. 11NE-A/C153 Looking Southwest (Photograph taken on 19 December 2005)

Plate 6 - General View of Northern Part of Slope No.11NE-A/C153 Looking North (Photograph taken on 20 August 2005)

Note: See Figure 16 for locations and directions of photographs taken.

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Plate 7 - General View of Middle Part of Slope No. 11NE-A/C153
Looking South (Photograph taken on 14 September 2005)

Plate 8 - General View of Southern Part of Slope No.11NE-A/C153
Looking Southeast (Photograph taken on 14 September 2005)

Note: See Figure 16 for locations and directions of photographs taken.

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Cracked stepped channel and seepage

Cracked catchpit

Cracked channel at slope toe

Plate 9 - Some of the Slope Defects Identified in 1999 EI (Extracted from the 1999 EI Report for Slope No. 11NE-A/C153)

Note: See Figure 16 for locations and directions of photographs taken.

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Cracked surface cover

Blocked channel

Plate 10 - Some of the Slope Defects Identified in 2003 EI (Extracted from the 2003 EI Report for Slope No. 11NE-A/C153)

Note: See Figure 16 for locations and directions of photographs taken.

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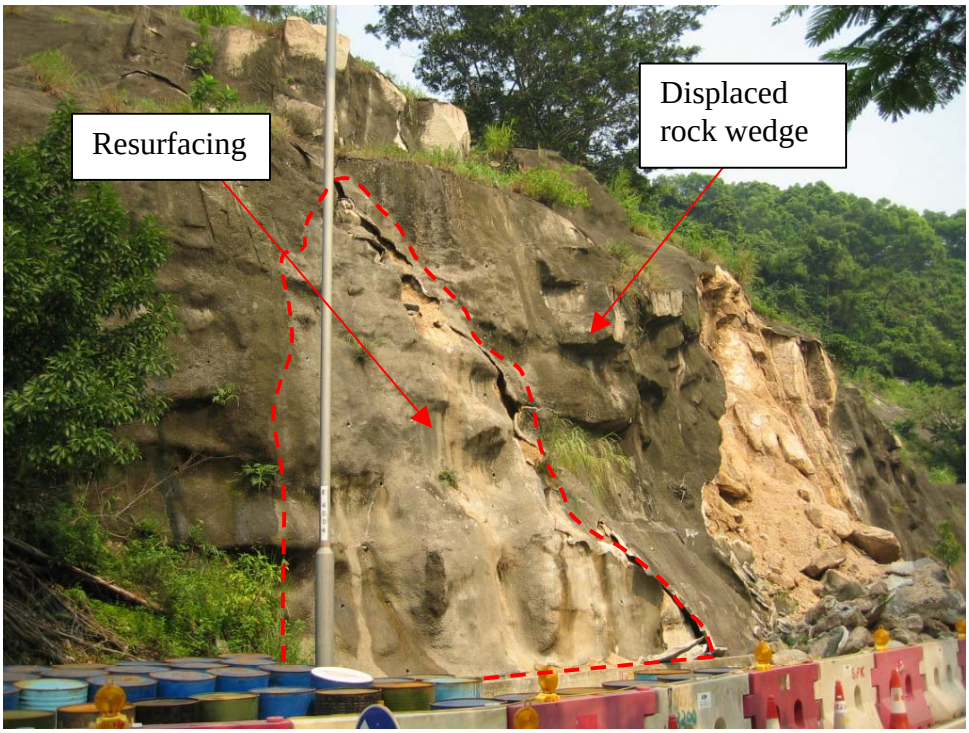

Plate 11 - View of Localised Re-surfacing Immediately Adjacent to the Displaced Rock Wedge (Photograph taken on 31 August 2005)

Note: See Figure 16 for locations and directions of photographs taken.

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Plate 12 - General View of 20 August 2005 Landslide Scar
(Photograph taken on 25 August 2005)

Note: See Figure 16 for locations and directions of photographs taken.

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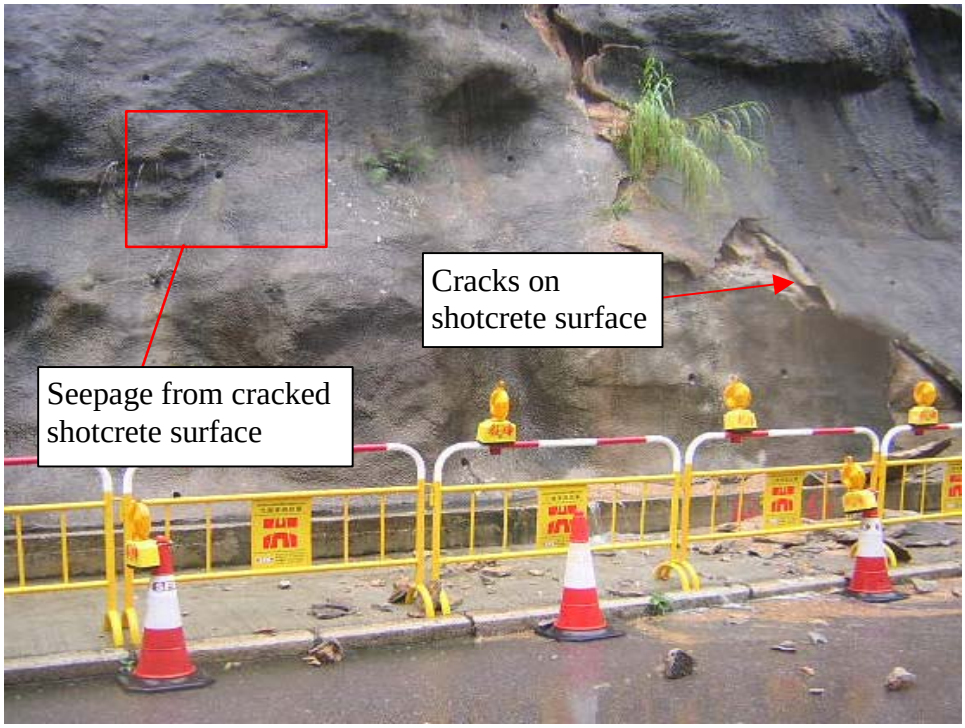

Plate 13 - Seepage from Cracked Shotcrete
(Photograph taken on 20 August 2005)

Plate 14 - Seepage from Raking Drain above the Lowest Batter of the Northern Part of Slope No. 11NE-A/C153
(Photograph taken on 24 August 2005

Note: See Figure 16 for locations and directions of photographs taken.

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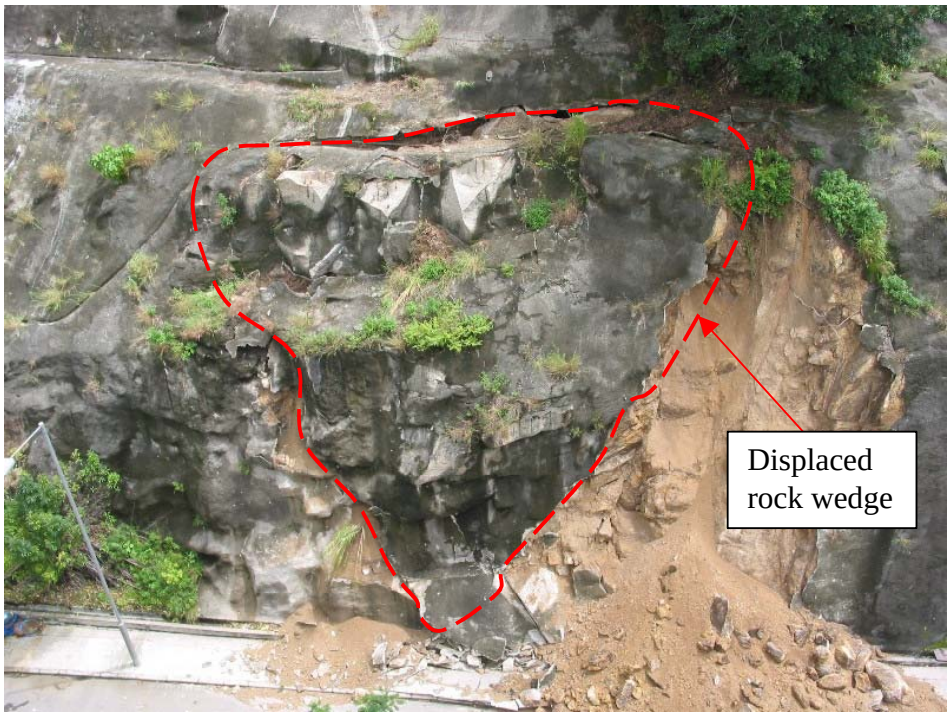

Plate 15 - General View of Displaced Rock Wedge on Northern Part of Slope No. 11NE-A/C153 (Photograph taken on 13 September 2005)

Plate 16 - Tension Crack at Top of the Displaced Rock Wedge (Photograph taken on 13 September 2005)

Note: See Figure 16 for locations and directions of photographs taken.

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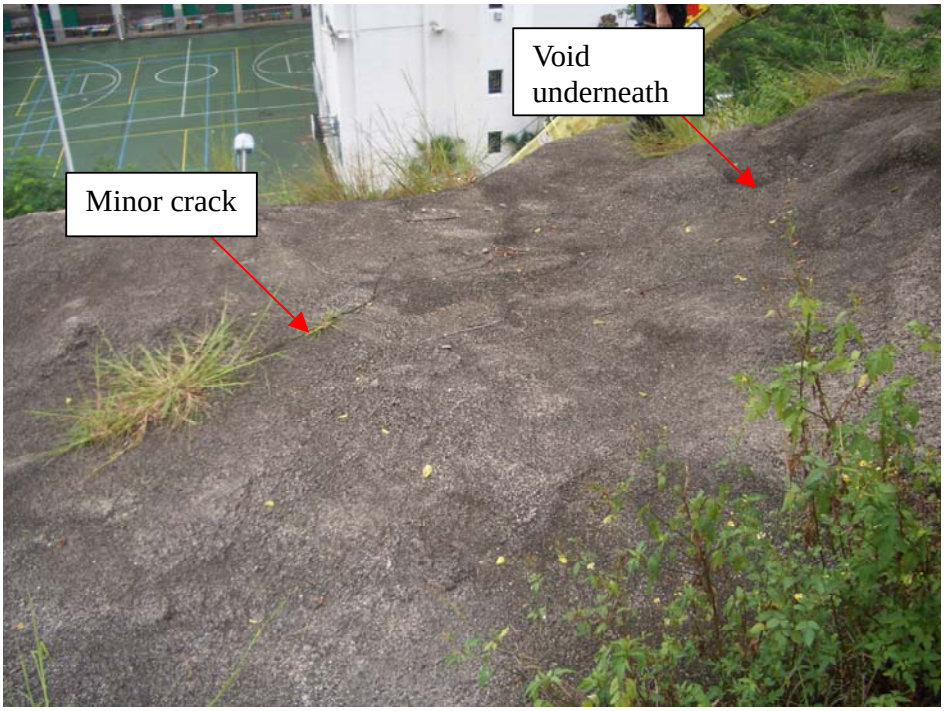

Plate 17 - Void near the Top of Displaced Rock Wedge
(Photograph taken on 14 September 2005)

Plate 18 - Cracked Shotcrete Surface above the Displaced Rock Wedge
(Photograph taken on 14 September 2005)

Note: See Figure 16 for locations and directions of photographs taken.

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Plate 19 - General View of Urgent Repair Works as at 16 September 2005 Looking Southeast

Plate 20 - General View of Urgent Repair Works as at 1 February 2006 Looking Northeast

Note: See Figure 16 for locations and directions of photographs taken.

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APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

CONTENTS

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A.1 SUMMARY OF OBSERVATIONS

This appendix sets out the detailed observations made from an interpretation of aerial photographs taken between 1949 and 2003. A list of the aerial photographs studied is presented in Table A1 and the main observations of API are shown in Figure A1.

Formation History of Slope

Construction of the northern part of slope No. 11NE-A/C153 was carried out between 1980 and 1981. Formation of the slope had required the excavation and removal of the lower footslope terrain, with the excavated materials used to from elevated platforms at the present-day Buddhist Hung Sean Chau Memorial College. The middle part of the slope was constructed in 1986. The excavated materials were deposited on the lower-lying alluvial toeslope terrain. The southern part of the slope was formed by cutting between 1987 and 1988, probably in association with the development of Bay View Garden.

Past Instability

The lower batter of the northern part of the slope (opposite to the Buddhist Hung Sean Chau memorial College) appeared to have been locally resurfaced but in ad hoc manner in the 1993 aerial photographs. An area of recently resurfaced slope can also be observed within the third batter. The configuration of this area suggests that the location has been recently affected by localised instability. The landslide is likely to correspond to the location of reported incident K93/9/13. Extensive slope works appear to be currently underway on the northern part area in the 1994 aerial photographs, incorporating the location recently affected by landsliding. These slope works appear to have been completed in the same year.

Local resurfacing was also observed in the 1984, 1988, 1989, 1992 and 2000 aerial photographs, which might be related to localized instabilities.

Natural Terrain

Prior to the formation of slope No. 11NE-A/C153 and the adjacent development, the study catchment comprised the western flank of a minor foothill. The upper catchment area predominantly comprises exposed rock outcrop with scattered corestones, whilst the central and lower catchment areas have decreasing quantities of exposed rock outcrop but increased concentrations of corestones. A relatively thick blanket of colluvium is present within the central catchment.

Several southeast-draining ephemeral streamcourses can be observed emanating from the upper catchment area and extending to the lower footslope area. The footslope is located adjacent to an alluvial toeslope terrain.

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A2. DETAILED OBSERVATIONS

YEAR	OBSERVATIONS
1949	Excellent quality, low-flight aerial photographs.

The study area comprises predominantly natural terrain. Slope No. 11NE-A/C153 has not yet been constructed and no development is currently evident at the toe of the study area.

The study catchment comprises the western flank of a minor foothill. The upper catchment area predominantly comprises exposed rock outcrop with scattered corestones, whilst the central and lower catchment areas have decreasing quantities of exposed rock outcrop and increased concentrations of corestones. Rock jointing can be clearly discerned within the rock outcrop and corestone areas and generally consists of east-west, northeast-southwest and north-south trending joint sets. The corestones generally appear to be in situ, although several detached boulders are visible at the toe of the footslope terrain.

Several southeast-draining ephemeral streamcourses can be observed emanating from the upper catchment area and extending to the lower footslope area. Some localised incision along these streamcourses can be discerned and is likely to relate to preferential weathering of pre-existing joints.

The footslope is located adjacent to an alluvial toeslope terrain, currently utilized for agricultural terracing. Scattered minor dwellings can also be discerned. A streamcourse can be observed extending through the alluvial toeslope terrain, draining to the southwest.

Some minor sheet erosion can be identified affecting the ridgeline extending across the upper study catchment. This erosion appears to be associated with the presence of numerous minor access trails traversing the terrain.

Numerous graves are visible within the lower catchment area and the terrain also appears to have been locally affected by anthropogenic modification, as discerned from the subtle lineaments extending across the terrain (possibly relating to the passage of grazing animals).

A relatively thick blanket of colluvium is present within the central catchment, within a general topographic depression area associated with the ephemeral streamcourse channels. The colluvium appears to be generally vegetated by small shrubs (heather) with the adjacent spurlines (comprising degraded granite saprolite) appearing to be generally bare from vegetative cover. The vegetation on the colluvium is also likely to be due to the presence of thicker superficial deposits and subsurface water.

1963 Excellent quality, low-light aerial photographs.

No significant changes to the study area are apparent.

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YEAR	OBSERVATIONS
1964	Excellent quality, high-flight aerial photographs.
	Reconstruction of Hammer Hill Road to the northwest of the study area is currently underway. The road elevation appears to have been modified by the incorporation of significant volumes of fill materials supporting the elevated road sections. Elevation of the road is likely to have been carried out to remove the possibility of flooding from the streamcourse channel presently located along its southern flank.
	No significant changes to the study area are apparent.
1967	Excellent quality high-flight aerial photographs.
	Reconstruction of Hammer Hill Road has been completed.
	The southern section of the study catchment and the upper ridgeline area has been affected by hillfire with the complete removal of all vegetative cover.
	An increased number of minor dwellings are now visible within the agricultural terraces at the toe of the footslope terrain.
1969	Excellent quality, low-flight aerial photographs.
	The density of vegetation within the drainage depression area located in the lower catchment has increased, with scattered trees now visible. The previously observed hillfire appears to have removed most of the grass and shrub cover from the remainder of the study catchment area.
	Further minor dwellings have been constructed on the agricultural terraces immediately downslope from the study catchment.
1973	Emplacement of extensive fill materials to form the platform for the East Kowloon Polyclinic to the northwest of the study catchment is presently underway. The level of the platform is consistent with that of Hammer Hill Road and is several meters higher than the previous alluvial toeslope terrain.
	Modification to the lower footslope terrain immediately to the north of the study catchment is also underway as part of these site formation works.
	Construction of the excavated platform for the Pooi Tun Secondary School to the north of the study catchment is also underway.
1974	Construction of the Pooi Tun Secondary School Buildings is presently underway. Construction of Slope No. 11NE-A/CR47 in association with these works appears to have been completed.

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YEAR	OBSERVATIONS
1974 (Cond't)	Construction of the platform for the East Kowloon Polyclinic has been completed together with the construction of the slopes located along the western (downslope) side of the platform. The northernmost section of Ping Ting Road has also been constructed in association with the East Kowloon Polyclinic works, to provide access. No significant changes to the study area are apparent.
1975	Single aerial photograph precludes detailed interpretation. Construction of the Pooi Tun Secondary School buildings appears to have been completed. Construction of the East Kowloon Polyclinic buildings appears to be currently underway.
1976	Slopes associated with the Pooi Tun Secondary School appear to have been generally constructed. Construction of the East Kowloon Polyclinic building is continuing in the earlier aerial photographs and appears to have been completed by June. Ridgeline erosion can be observed continuing to affect the upper ridgeline area. Additional minor dwellings can be observed within the agricultural terrace area adjacent to the toe of the study catchment.
1977	The lower alluvial toeslope area has now become completely occupied by densely-packed squatter dwellings and small agricultural terraces. No significant changes to the study area are apparent.
1978	No changes of significance can be observed on the January aerial photographs. In the July aerial photograph, works are evident affecting the lower catchment area. These works are likely to be associated with the extension of the East Kowloon Polyclinic platform area and Ping Ting Road. In the excellent quality, low-flight December aerial photographs, a minor road can be observed extending around the spurline presently defining the northern end of the study catchment, with minor deposits of fill clearly evident within the lower catchment hillslope. All the minor dwellings previously located in the valley at the base of the study catchment have been cleared. Emplacement of fill along the southern flank of the East Kowloon Polyclinic platform has also been undertaken, with a minor platform area for car-parking now evident at this location. No significant changes to the study area are apparent.

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YEAR OBSERVATIONS

1979 Emplacement of fill within the valley area at the base of the study catchment has ceased, with the previously emplaced fill now covered by vegetation.

Construction of minor squatter dwellings along the spurline presently defining the southern end of the study catchment can be observed.

1980 No changes of significance can be observed on the April aerial photographs.

In the excellent quality, high-flight November aerial photographs, the lower catchment area appears highly reflective, indicative of works currently being undertaken for the formation of slope No. 11NE-A/C153. Formation of the slope has required the excavation and removal of the lower footslope terrain, with the excavated materials used to form elevated platforms similar to that formed for the East Kowloon Polyclinic.

A highly reflective linear feature can be observed extending down from the ridgeline defining the upper catchment to the top of the slope works. Details of the linear feature and the slope works cannot be ascertained due to the high reflectivity of the site.

In the excellent quality, low-flight December aerial photographs, construction works for the present northern part of slope No. 11NE-A/C153 can be clearly observed. The ridgeline that previously defined the northern end of the study catchment has been removed to form the higher section of slope No. 11NE-A/C153, the upper three berms of which appear to have now been formed. Exposed rock can be observed emerging from the slope face at this location. Construction of the lower slope is currently underway.

The northern part of slope No. 11NE-A/C153 has been partially completed and comprises a series of cut batters with narrow berms.

The linear area of high reflectivity visible extending into the upper slope appears to comprise drainage improvement and/or boulder removal works.

1981 Construction of the northern part of slope No. 11NE-A/C153 and the associated downslope platform areas is continuing and appears to have been completed by November.

1982 Construction of the Buddhist Hung Sean Chau Memorial College is currently underway on the recently constructed platform area. Ping Ting Road has now been extended to the southern end of the Memorial College building.

Slope No. 11NE-A/C153 appears to be chunam-surfaced.

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YEAR	OBSERVATIONS
1983	Construction of the Buddhist Hung Sean Chau Memorial College building has been completed. Construction of the East Kowloon Psychiatric building has commenced. The lower section of the slope in the location of the recent instability comprises an area of exposed rock outcrop, extending upslope for the lower two batter sections. Some areas of dark staining can be observed emanating from the rock outcrop and are likely to correspond to sites of localised seepage. The lower batter section directly to the east of the Buddhist Memorial College building also shows evidence of exposed rock outcrop. Rock outcrop can also be observed within the upper batter sections, although of a more scattered form. The remainder of the slope appears to have been formed within soil, with only scattered corestones visible emerging from the slope face. The slope consists of 6 batter sections near the northern end, decreasing to three batter sections directly opposite from the Buddhist Memorial College building and then increasing once again to 4 batters within its southern end. Drainage provisions can be observed extending across the crest of the slope as well as downslope across the slope face. U-channels are also visible extending across the berm sections. Drainage improvement works are currently underway within Ping Ting Road, immediately to the east of the Buddhist Memorial College building in the January aerial photographs. In the September aerial photographs, Ping Ting Road appears to have been surfaced.
1984	Areas of the alluvial toeslope previously occupied by agricultural terraces and squatter huts, have been completely cleared, together with spurline area presently defining the southern end of the study catchment. Resurfacing works are underway on the lower two batter sections of slope No. 11NE-A/C153 adjacent to the southern end of Ping Ting Road in the January aerial photographs. Resurfacing has been completed by March. A few areas of high reflectivity can be observed within the upper section of the exposed rock outcrop recently affected by instability. The precise nature of these areas of high reflectivity cannot be definitively ascertained. However, their configuration suggests localised block falls. Site formation works for the Hammer Hill Road Sports Ground are currently underway.
1985	No significant changes to the study area are apparent.

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YEAR	OBSERVATIONS
1986	Construction of the present middle part of slope No. 11NE-A/C153 is currently underway in the March aerial photographs and appears to have been completed by August. The spurline that previously defined the southern end of the study catchment has been extensively excavated and the materials deposited within the lower-lying alluvial toeslope terrain. Extension of Ping Ting Road to its presently existent configuration has been undertaken.
1987	No significant changes to the study area are apparent.
1988	The northern part of slope No. 11NE-A/C153 appears to have been recently surfaced. The even character of the surface suggests that the slope has been concrete-covered. (Subsequent review of 1989 colour aerial photographs confirms that the slope has been concrete-covered at this time as the texture of the surface protection appears consistent). In the September aerial photographs, the second and third batters upslope from the area affected by recent instability appear highly reflective, suggesting localised resurfacing has been undertaken. The southern part of the slope was formed by cutting. It was probably formed in association with the formation of Bay View Garden at its toe. It was partially obscured by the buildings of Bay View Garden, and it appears to be covered by sparse vegetation.
1989	Excellent quality, low-flight colour aerial photograph. Single photograph precludes detailed interpretation. Northern part of the slope has been shotcreted-covered. The lowermost batter of the northern part of the slope, directly to the east of the southernmost portion of the Buddhist Memorial College building, has been recently resurfaced in the November aerial photographs.
1990	No significant changes to the study area are apparent.
1991	No significant changes to the study area are apparent.
1992	An area of lighter toned shotcreted surface protection is evident on the uppermost slope batter. This is likely to relate to localised resurfacing.
1993	An area of exposed soil can be observed affecting the upper batter of the northern part of slope in the October aerial photographs. The precise nature of the exposed area cannot be definitively ascertained from these high-flight aerial photographs.

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YEAR	OBSERVATIONS
1993 (Cond')	The area can be more clearly observed on the low-flight October aerial photographs. A linear reflective feature can be observed extending from the crest of the northern part of the slope across the entire slope face to the level of Ping Ting Road. The nature of event that led to the exposure of the underlying materials cannot be definitively determined and may correspond to either localised slope improvement works or slope remediation following failure. However, given the angle of photography, this cannot be more clearly discerned. The area can be very clearly observed on the low-flight November aerial photographs. A recently surfaced section of slope can be observed within the second batter section of the northern part of slope. The lower batter downslope from this recently resurfaced section of slope also appears to have been locally resurfaced but in a more ad hoc manner. Upslope from the recently resurfaced section of slope, an acute area of recently resurfaced slope can be observed within the third batter. The configuration of this area suggests that the location has been recently affected by localised instability. The landslide is likely to correspond to the location of reported incident K93/9/13. Amendment of the recorded incident location should be recommended to more accurately reflect the actual landslide-affected area.
1994	Extensive slope works appear to be currently underway on the northern part area in the April aerial photographs, incorporating the location recently affected by landsliding. These slope works appear to have been completed by May and comprise resurfacing of a substantial part of the slope.
1995	The lower batter of the northern part of the slope (corresponding to the alignment of the previously existent ephemeral streamcourse channel) appears to be dark, possibly due to seepage.
1996	The northern part of slope No. 11NE-A/C153 has been cleared from all vegetation and surface protection in May. Only the section of the third batter recently affected by landsliding remains protected by concrete cover. The areas of rock exposure within the lower and second batters of the northern slope section as well as the scattered areas of rock exposure within the upper batters, is clearly visible. By November, both the northern part of the slope has been resurfaced by concrete.
1997	No significant changes to the study area are apparent.
1998	Unplanned vegetation growth can be observed within the berm drainage provisions. Scattered grass and shrubs are now evident at various locations on the slope face. No seepage can be observed emerging from the slope at any location.

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YEAR	OBSERVATIONS
1999	No significant changes to the study area are apparent.
2000	In the September aerial photographs, a section of recently resurfaced slope can be observed within the lower batter area consistent with the location of the recent slope failure. This area of resurfacing was not evident on the February aerial photographs. However, as the latter aerial photographs were high-flight, the potential presence of such an area cannot be effectively discounted.
2001	In the February aerial photographs, the upper section of the northern part of the slope appears to contain some areas of exposed soil. The cause of the soil exposure cannot be readily determined due to the high-flight of these aerial photographs. In the November aerial photographs, both the northern and middle parts of the slope appear to be currently modified by the construction of additional drainage provisions and resurfacing. The uppermost batter section of the northern slope appears to have been hydroseeded and covered by some form of mesh, as indicated by the difference in colour and texture of the site.
2002	No significant changes to the study area are apparent. No seepage can be observed emanating from any section of the slope on the infrared aerial photographs.
2003	No significant changes to the study area are apparent.

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Table A1 - List of Aerial Photographs (Sheet 1 of 2)

Date Taken	Altitude (ft)	Photograph Number
24 April 1949	8000	Y01748-50
25 January 1963	2700	Y08087-88, Y08127-28
13 December 1964	12500	Y12929-30
16 May 1967	6250	Y13422-23
1969	1800	Y14915-16
23 October 1973	6000	05330-31
28 Aug, 6, 17 Dec 1974	4000	09361-62, 10187, 10446-47
24 December 1975	12500	11992
16, 28, 29 January 1976	3000, 4000, 4000	12232-33, 12936-37, 13087-88
30 June, 4, 7 October 1976	3000, 4000, 6000	14203, 15362-63, 15545-46
4, 24 Nov, 31 Dec 1976	12500, 9000	15963, 16575-77, 17076-78
15 Sep, 21 Dec1977	3000, 4000	19280-82, 20260, 20306
10 January, 5 July 1978	12500, 9000	20749-50, 22370
7 December 1978	4000	24118-19
1 October 1979	4000	27303-04
28 November 1979	10000, 4000	28076-77, 27933
17 April 1980	4000	30125-26
28 Nov, 30 Dec 1980	10000, 3000	33471-72, 35397-99
10 February 1981	5500, 25000	36608-12, 36763
26 October 1981	10000	39073
26 November 1981	4000	39770-71, 39827-28
12 July, 10 October 1982	2000, 10000	42516, 44530-31
24, 25 January 1983	20000, 4000	47142-43, 47392-93
28 Sep, 30 Nov 1983	4000, 10000	49978-79, 51407
1 Dec 1983	20000	51669
7 January, 3 March 1984	3000, 4000	52457-58, 53002-03
5 November 1984	4000	56980-81
7 July, 4 October 1985	10000, 15000	A01763, A02661-62
3, 7 March 1986	3500, 4000	A04229-30, A04462-63
3 Aug, 22 Sep 1986	3500, 4000	A05420-21, A06277-78
7 November 1986	2000	A06880
5 January 1987	20000	A08403-04
14 January 1987	2000, 3500	A08628-29, A08636-37
10, 11 June 1987	2000, 4000	A09044-45, A09529-30
13 July, 9 September 1987	9000, 3500	A09911-12, A10238-39
11 January 1988	10000	A11817-18
2, 3 June 1988	4000, 20000	A12833-34, A13480, A13484
4 June, 8 September 1988	10000, 3500	A13703-04, A14157-59
6 October 1988	4000	A14668-69
21 November 1988	4000	A15698-99

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Table A1 - List of Aerial Photographs (Sheet 2 of 2)

Date Taken	Altitude (ft)	Photograph Number
23 Feb, 29 March 1989	10000, 8000	A16678-79, CN2173
13, 30 November 1989	10000, 20000	A19255-56, A19842-43
13 November 1990	4000	A23628-29
4, 6 December 1990	10000, 4000	A24827-28, A24900-01
20 September 1991	4000	A27477, A27479
29 Oct, 14 Nov 1991	10000	A28854-55, A29280-81
11, 13 December 1991	4000, 20000	A29487, A29491, A29657
16 April, 20 October 1992	4000	A30437-38, A32812-13
11 November 1992	10000	A33041-42
9 July, 19 August 1993	4000, 10000	A35280-81, CN4252
4, 8 October 1993	20000, 4000	CN4393-94, CN4606-07
1, 2 November 1993	4000	CN4810-11, A36109
7, 31 December 1993	10000, 20000	CN5920-21, A37315-16
20 March, 6 April 1994	10000	CN6162, CN6439-40
6 May 1994	5000	A38072-73
20, 21 October 1994	4000, 10000	A39285-86, A39507
12 Feb, 27 Sep 1995	10000, 3500	CN9529-30, CN11333
23, 24 November 1995	10000	CN12273-74, CN12586-87
21 December 1995	20000	CN13199-00
15 May, 21 Nov 1996	4000, 10000	CN13542-43, CN16145-46
16 January 1997	20000	CN16544
26 May 1997	4000	CN17239-40, CN17271-72
1 November 1997	10000	CN19000
14 August, 31 Oct 1998	3500, 4000	CN20739, CN22196-97
10 November 1998	8000	CN21916
3 Feb, 11 June 1999	20000, 2600	CN22254, CN23222-23
11 December 1999	4000	CN25248-49
16 Feb, 26 July 2000	20000, 4000	CN25922-23, CN27549
16 September 2000	4000	CN28204-05
15 February 2001	20000	CN29878
20, 21 November 2001	8000	CW35786-87, CW36436-37
3, 21 January 2002	2000, 16000	CW38110, RW00877-78
7 March 2002	20000	CW38968
9 September 2002	8000	CW45140-41
25 October 2002	4000	RW01656-57
31 May, 25 Sep 2003	4000, 8000	CW47583-84, CW50037
19 October 2003	8000	RW02867-68
25 November 2003	4000	CW53089-90

Note: All aerial photographs are in black and white except for those prefixed with CN, CW or RW.

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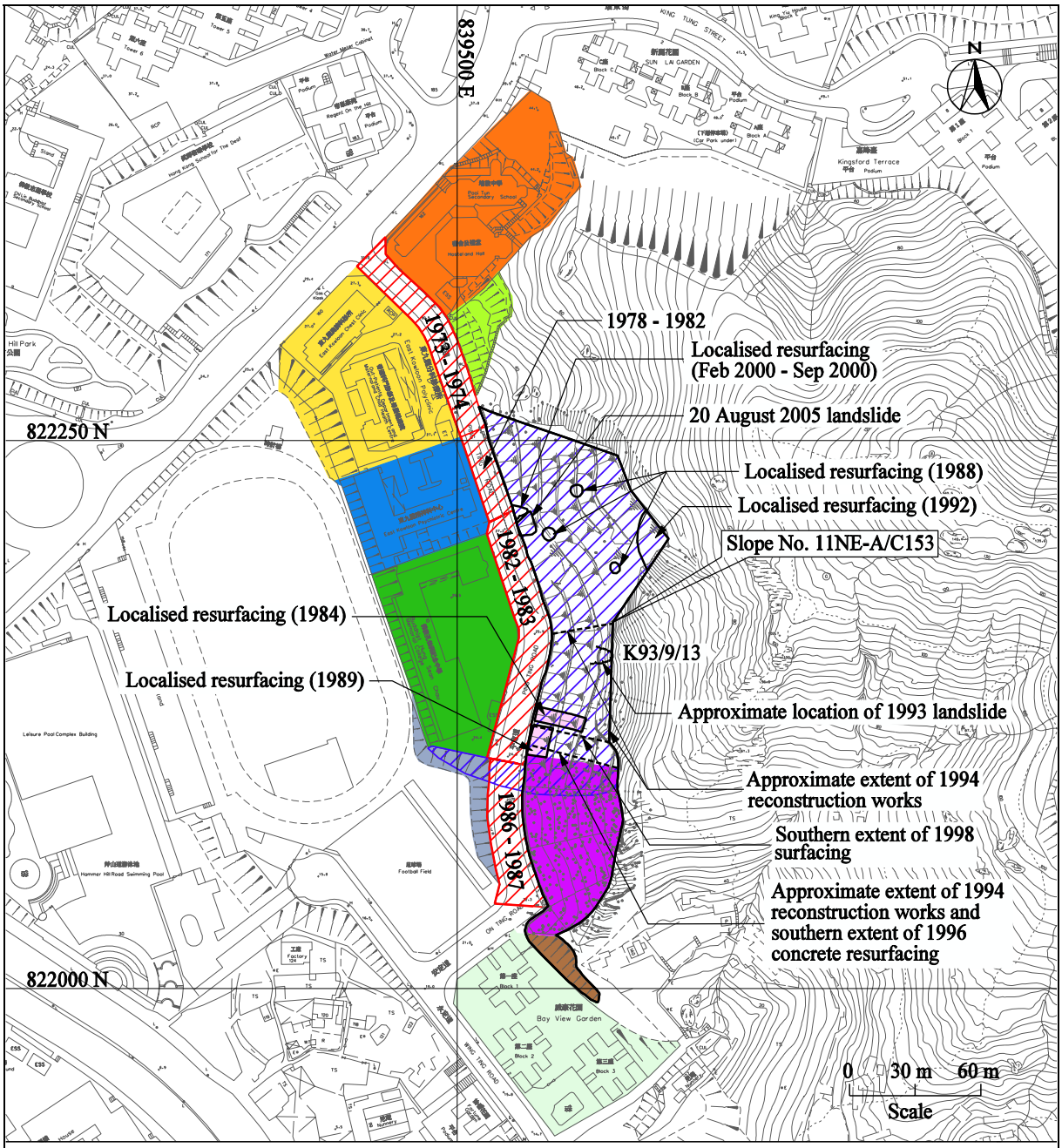

Note: Base plan is extracted from 1:1000 survey sheets Nos. 11NE-7A, 11NE-7B, 11NE-7C and 11NE-7D dated March 2004.

Figure A1 - Site History

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GEO PUBLICATIONS AND ORDERING INFORMATION
土力工程處刊物及訂購資料

A selected list of major GEO publications is given in the next page. An up-to-date full list of GEO publications can be found at the CEDD Website http://www.cedd.gov.hk on the Internet under "Publications". Abstracts for the documents can also be found at the same website. Technical Guidance Notes are published on the CEDD Website from time to time to provide updates to GEO publications prior to their next revision.

部份土力工程處的主要刊物目錄刊載於下頁。而詳盡及最新的土力工程處刊物目錄，則登載於土木工程拓展署的互聯網網頁 http://www.cedd.gov.hk 的"刊物"版面之內。刊物的摘要及更新刊物內容的工程技術指引，亦可在這個網址找到。

Copies of GEO publications (except maps and other publications which are free of charge) can be purchased either by:

writing to
Publications Sales Section,
Information Services Department,
Room 402, 4th Floor, Murray Building,
Garden Road, Central, Hong Kong.
Fax: (852) 2598 7482

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- Placing order with ISD by e-mail at puborder@isd.gov.hk

讀者可採用以下方法購買土力工程處刊物(地質圖及免費刊物除外):

書面訂購
香港中環花園道
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- 致電政府新聞處刊物銷售小組訂購 (電話：(852) 2537 1910)
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- 透過政府新聞處的網站 (http://www.isd.gov.hk) 於網上遞交訂購表格，或將表格傳真至刊物銷售小組 (傳真：(852) 2523 7195)
- 以電郵方式訂購 (電郵地址：puborder@isd.gov.hk)

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Survey & Mapping Office, Lands Department,
23th Floor, North Point Government Offices,
333 Java Road, North Point, Hong Kong.
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