

**REVIEW OF THE
9 JUNE 2006 AND
16 JULY 2006
WASHOUTS ON SLOPE
NO. 11NW-B/FR60 BEHIND
PHOENIX HOUSE,
LUNG CHEUNG ROAD**

GEO REPORT No. 238

Maunsell Geotechnical Services Limited

**GEOTECHNICAL ENGINEERING OFFICE
CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT
THE GOVERNMENT OF THE HONG KONG
SPECIAL ADMINISTRATIVE REGION**

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**This report is largely based on GEO Landslide Study Report
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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
November 2008

FOREWORD

This report presents the findings of a review of two washouts (Incidents Nos. ArchSD/PM2/2006/06/0001 and ArchSD/PM2/2006/07/0001) that occurred in June and July 2006 on slope No. 11NW-B/FR60 behind Phoenix House, Lung Cheung Road. No casualties were reported as a result of either incident.

The first incident, which involved the washout of a fill slope above a mass concrete wall, occurred on 9 June 2006 when a Black Rainstorm Warning was in effect. The landslide debris, which had a volume of about 4 m³, was deposited on a shotcreted slope below the mass concrete wall.

The second incident occurred on 16 July 2006 when a Black Rainstorm Warning was in effect. This involved the washout of the recompacted backfill which was placed in early July 2006 as remedial works to the June 2006 washout, together with erosion at the slope toe. The landslide debris, which had a volume of about 8 m³, was deposited on the shotcreted slope below the mass concrete wall and partly washed down onto a garden to the east of slope No. 11NW-B/FR60.

The key objectives of the review were to document the facts about the washouts, present relevant background information and pertinent site observations made under this review. The scope of the review does not include any ground investigation or detailed diagnosis of the causes of the incidents. Recommendations for follow-up actions are reported separately.

The report was prepared as part of the Landslide Investigation Consultancy for landslides occurring in Kowloon and the New Territories in 2006, for the Geotechnical Engineering Office, Civil Engineering and Development Department, under Agreement No. CE 50/2005 (GE). This is one of a series of reports produced during the consultancy by Maunsell Geotechnical Services Limited.

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Agreement No. CE 50/2005 (GE)
Study of Landslides Occurring in
Kowloon and the New Territories in
2006 - Feasibility Study

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1. INTRODUCTION

Two washout incidents (Nos. ArchSD/PM2/2006/06/0001 and ArchSD/PM2/2006/07/0001) were reported by the Architectural Services Department (Arch SD) to the Geotechnical Engineering Office (GEO) to have occurred on slope No. 11NW-B/FR60 behind Phoenix House, Lung Cheung Road (Figure 1) during the Black Rainstorm Warnings on 9 June and 16 July 2006 respectively. No casualties were reported as a result of either incident.

The first incident involved the washout of the fill material above a mass concrete wall near the northwest corner of slope No. 11NW-B/FR60 (Figure 2 and Plate 1). The landslide debris, with a volume of about 4 m³, was deposited on a shotcreted slope below the mass concrete wall. The second incident involved the washout of the recompacted fill which was placed in early July 2006 as remedial works to the June 2006 washout, together with erosion at the slope toe along the northern boundary of Phoenix House (Figure 2 and Plate 2). The landslide debris, with a volume of about 8 m³, was deposited on the shotcreted slope below the mass concrete wall and partly washed down onto a garden to the east of the slope.

Following the incidents, Maunsell Geotechnical Services Limited (MGSL), the 2006 Landslide Investigation Consultant for Kowloon and the New Territories, carried out a review of the washouts for the GEO under Agreement No. CE 50/2005 (GE).

This report documents the facts about the washouts, findings of the desk study and pertinent site observations made by MGSL. The scope of this review does not include any ground investigation or detailed diagnosis of the causes of the failures.

2. THE SITE

Slope No. 11NW-B/FR60 comprises a south-facing fill slope and retaining wall located to the north of Phoenix House, a halfway house (pre-release centre) for prisoners. The slope is bounded by Lung Yan Road, a 3.5 m wide single lane two-way road, along its crest (Figure 2 and Plate 3). A 6.5 m wide access road, which branches off Lung Yan Road, is situated above the western limb of the slope (Plate 4). A nursery garden with greenhouses and a storeroom is located to the east of the slope (Plate 5).

Slope No. 11NW-B/FR60 comprises a fill slope with a maximum height of about 10 m and a total length of about 100 m. A 1.8 m high, 25 m long L-shaped reinforced concrete retaining wall and a 1.2 m high, 14.5 m long mass concrete retaining wall are situated near the middle and western portions of the slope respectively (Figure 2, Plate 6). The fill slope above the L-shaped retaining wall has a maximum height of about 5.5 m and is inclined at approximately 20°, while the fill slope above the mass concrete wall has a maximum height of about 4 m and is inclined at about 25°. The slope portion and the toe area are hydroseeded. The area below the mass concrete wall and parts of the eastern portion of the fill slope are covered with shotcrete (Figure 2).

The surface drains on slope No. 11NW-B/FR60 comprise a 300 mm wide U-channel along the slope crest at Lung Yan Road and a 225 mm wide U-channel along the crest of the western limb of the slope (Plate 4). An 8 m long section of U-channel near the northwest corner of the slope is offset from the slope crest to mid-slope where some large trees are present (Plate 1). A 300 mm wide U-channel is located along the slope toe while a 225 mm

wide U-channel is present at the top of the L-shaped retaining wall. Stepped channels of sizes varying from 225 mm to 300 mm are located on the slope surface (Figure 2).

The section of Lung Yan Road uphill of slope No. 11NW-B/FR60 has a longitudinal fall of about 1 in 8 towards the northwest corner of the slope (Plate 7). An ephemeral streamcourse (with a catchment area of about 15,000 m²) is intercepted by Lung Yan Road near the east end of slope No. 11NW-B/C506 (Figure 1). The stormwater discharges through a cross-road culvert with an inlet of about 0.7 m deep by 0.6 m wide (Plate 8). Three water pipes (about 200 mm to 300 mm in diameter) traverse the outlet of the culvert, which reduced the effective opening of the outlet to about 0.2 m deep by 0.4 m wide (Plate 9). Downstream of the culvert, the stormwater flows along a short section of 600 mm wide surface channel to the south of Lung Yan Road (Figure 1) and discharges onto an unlined shallow channel, which disperses on the hillside to the west of the access road.

Based on the information provided by the Water Supplies Department (WSD), a 300 mm diameter fresh water main and a 200 mm diameter salt water main are present along Lung Yan Road above slope No. 11NW-B/FR60 (Figure 2). A section of the pipes near the outlet of the cross-road culvert at Lung Yan Road was replaced in 1986. According to the information provided by the Drainage Services Department (DSD), there are no public stormwater drains along the section of Lung Yan Road above the slope.

According to the Slope Maintenance Responsibility Information System (SMRIS) of the Lands Department (Lands D), Correctional Services Department (CSD) is responsible for the maintenance of slope No. NW-B/FR60 and Arch SD is the maintenance agent. The slope and the garden to the east are within government land allocation No. GLA-NK 170 Extension, for which CSD is responsible.

According to the Hong Kong Geological Survey (HKGS) 1:20,000 scale Solid and Superficial Geology Map Sheet No. 11 - Hong Kong and Kowloon (GCO, 1986), the site is underlain by debris flow deposit and medium-grained granite. There is a contact between the coarse-grained and medium-grained granite about 300 m to the north. A northeast-southwest trending fault is located about 300 m to the northwest of slope with a similar trending photolineament located about 400 m to the southwest (Figure 3).

3. SITE DEVELOPMENT HISTORY AND PAST INSTABILITIES

The history of site development has been determined from an interpretation of the available aerial photographs, together with a review of relevant documentary information. Detailed observations from the aerial photograph interpretation (API) are summarised in Appendix A.

The 1963 aerial photographs show that prior to development the study area was located on a south-facing natural hillside at the foot of Beacon Hill with a broad valley in the vicinity of the hillside above the site where clusters of boulders/corestones are present. Natural streamcourses flow down from an adjacent valley and along the toe of the present-day slope No. 11NW-B/FR60 (denoted as S1 in Figure A2).

The section of Lung Yan Road and slope No. 11NW-B/FR60 was constructed around 1964. The extent of the slope was slightly larger than the present layout (Figure 4). The

Architectural Office (AO, re-organised as Arch SD in 1986) was responsible for the construction of Phoenix House at the toe of the slope between 1982 and 1984. The western portion of the slope was removed for the construction of the access road and the slope toe was trimmed back for the formation of the main building of Phoenix House. Illegal dumping of construction waste on the slope has taken place since 1980. The construction waste was partly removed and the slope was formed to an angle of about 30° in 1986 (Section 4.1). Shotcrete was applied on the eastern portion of the slope in 1988, while the remaining area was covered with vegetation. Slope upgrading works comprising a recompacted fill slope, construction of retaining walls and surface drains were carried out between November 2005 and February 2006 (Section 4.3). The hard surface protection at the eastern portion was replaced with hydroseeding.

According to the landslide database, there are no records of any past instability at slope No. 11NW-B/FR60 or in the vicinity of the study area. No signs of landslides on the subject slope can be observed from the API and no natural terrain landslides are recorded on the hillsides above the slope.

4. PREVIOUS ASSESSMENTS AND SLOPE WORKS

Slope No. 11NW-B/FR60 was registered in the Government's Slope Catalogue in May 1976 under the project entitled "Preliminary Studies for the Special Investigation into Fill Slopes". The slope was classified as SIFT Class "B1" in July 1994 under the project entitled "Systematic Inspection of Features in the Territory" (SIFT), i.e. a slope that had "been formed or substantially modified before 30.6.78".

The slope was inspected by Binnie Consultants Limited under the project entitled "Systematic Identification and Registration of Slopes in the Territory" (SIRST) on 4 October 1996. The inspection record shows that there was no sign of seepage and the condition of the slope was assessed as "fair" with "minor crack (1 mm wide)" on the slope cover.

Following an Engineer Inspection in 2000, Arch SD reported to GEO that no retaining wall was observed on slope No. 11NW-B/FR60. The feature registration was subsequently changed to No. 1NW-B/F60 in June 2000. In August 2006, the feature registration was revised to No. 1NW-B/FR60 following the completion of the retaining wall as part of the slope upgrading works in February 2006.

4.1 Geotechnical Design for Phoenix House Development by Fugro in 1980

In October 1980, AO submitted a geotechnical design report prepared by Fugro (HK) Limited (FHK) to the Geotechnical Control Office (GCO, renamed as GEO in 1991) for comments. The report covered the geotechnical design of the site formation within the Phoenix House development and did not cover the assessment of slope No. 11NW-B/FR60.

On 8 December 1980, Scott Wilson Kirkpatrick & Partner (SWKP), acting on behalf of the GCO in checking the submission, pointed out that the design did not consider the stability of slope No. 11NW-B/FR60 and its influence on the proposed development. On 7 January 1981, FHK submitted a cross section to GCO (based on the published survey map with the extent of the slope being only one-half of that observed in the 1964 aerial

photographs) and indicating that the toe of the slope was about 20 m to the north of the development. FHK considered that instability of the fill slope would be unlikely to affect the site. On 24 March 1981, SWKP concurred with FHK's view and reminded AO that construction waste, which had been dumped on the surface of the slope since 1980, should be removed. On 25 September 1981, GCO had no further comments on the design following some amendment of the stormwater drainage details to the east of the slope.

In a memorandum to GCO dated 25 March 1982, AO requested GCO to consider the removal of "illegal dumping" on "Crown Land immediately adjacent to the above site boundary" that would "endanger" the Phoenix House development. On 7 April 1982, Chief Geotechnical Engineer/Public Buildings of the Building Development Department replied that it was unlikely that GCO would be able to carry out any works to slope No. 11NW-B/FR60 before the due date for completion of Phoenix House development in April 1983 and recommended AO to study the slope and carry out any preventive works to the slope if found necessary for the development. On 28 September 1982, SWKP visited the site and noted that additional construction waste was dumped on the slope since their last inspection in October 1980. The distance between the slope toe and the building was reduced to 6 m (Plate 10). In April 1984, AO requested a jurisdiction from Landslips and Rainstorm Damage Committee of the Lands D on the responsibility to remove the construction waste. On 28 May 1984, the Mainland East (ME) Division of GCO, in response to the request by the Director of Lands, reviewed the threat posed by the dumped materials and suggested that partial removal of the illegally dumped materials to an angle of no more than 30°, provision of drains and paving, and installation of a chain-link fence at the slope crest could minimise the threat to Phoenix House. In a memorandum to Lands D dated 28 February 1985, ME Division confirmed that "no further geotechnical assessment is required" as the works are "only partial removal of fill to minimise the threat to existing buildings." A 3 m wide planting area at the slope toe as a buffer zone to further minimise the risk was also recommended by the ME Division of GEO.

On 14 March 1985, in accordance with the recommendations from the ME Division of GEO, AO submitted a slope works proposal (which did not include a detailed geotechnical assessment) to GCO for comments. On 26 April 1985, GCO indicated that they had no adverse geotechnical comments on the proposed works.

The slope works, which included partial removal of construction waste, cutting back the slope to a maximum angle of 30°, application of shotcrete, provision of surface drains and erecting a chain-link fence at slope crest, were completed in June 1986. AO submitted the as-built records to GCO in July 1986.

4.2 Stage 3 Study

A Stage 3 Study on slope No. 11NW-B/FR60 was carried out in 1995 under Agreement No. CE 9/95 of the Landslip Preventive Measures (LPM) Programme. During the course of the study, the slope works carried out by AO in 1986 were noted and as a result the study was terminated in November 1995.

4.3 Engineer Inspections

An Engineer Inspection (EI) was carried out on slope No. 11NW-B/FR60 by Arch SD in June 2000. The EI records noted that some gaps (2 mm to 3 mm wide) were observed along the interface of the U-channel/slope cover at the eastern end of the slope and minor cracks (< 2 mm wide) were observed on the crest pavement. The EI records also noted that the observed distresses appeared to be old and were probably caused by the continuous settlement of the building debris that was left in place after the slope works in 1986 (see Section 4.1). The 2006 washout area was covered with dense vegetation and no particular observation was made in the EI records. There were no signs of seepage or erosion on the slope. The EI recommended sealing the gaps and cracks on the slope as mentioned above, and that slope upgrading works should be carried out.

Another EI of slope No. 1NW-B/F60 was carried out by MGSL for Arch SD in April 2004. The EI records noted that a preliminary stability assessment (using assumed geological profiles and shear strength parameters) was carried out in July 2003, which concluded that the slope did not meet the required safety standards. Detailed design of the slope upgrading works by Arch SD's consultant (Ho Tin & Associates Consulting Engineers Limited (HT)) was in progress at the time of finalising the EI report in April 2004 (see Section 4.4). Apart from some minor cracking on the shotcrete cover near some trees at the northern corner of the slope, the EI did not observe any signs of distress, erosion, or signs of seepage on the slope.

4.4 Geotechnical Design for Slope Upgrading Works by Ho Tin in 2004

Arch SD appointed HT under the "Minor Works Term Consultancy 2002 - 2004 Region 2". On 7 June 2004, Arch SD submitted a geotechnical design report prepared by HT on the proposed upgrading works on slope No. 11NW-B/F60 to the GEO for comments. The proposed works included the replacement of the top 3 m of the loose fill by compacted fill to a maximum angle of 26°, construction of a 1.8 m high L-shaped retaining wall in order to preserve the trees, hydroseeding of the slope surface and provision of surface drainage channels.

The drainage design only considered the catchment within the registered slope boundary and no drainage calculations for the design of the crest channel were provided. It was proposed that an earth bund (about 0.4 m to 1 m high) located along the crest of the western limb of the slope (above the washout location, see Figure 5) should be removed to allow for fill recompaction and that an existing 225 mm wide U-channel along the toe of the earth bund should be re-constructed. The potential impact on the surface drainage provisions as a result of removing this earth bund was not assessed in the design report.

On 18 June 2004, the Mainland West (MW) Division of GEO commented on the design groundwater level, shear strength parameters and the factor of safety in respect of the slope stability assessment. The GEO also suggested the "construction of a dwarf wall and a bigger surface channel along the crest of the slope to prevent overflow of water from Lung Yan Road during heavy rainfall." In response to GEO's comments, HT revised the design to reduce the maximum slope angle to 25° and increase the size of the proposed crest channel along Lung Yan Road from 225 mm to 300 mm wide, without supporting design calculations.

On 11 August 2004, GEO made further comments regarding the shear strength parameters adopted for the fill, the extent of fill recompaction near the slope toe and the retaining wall design. HT provided their responses together with supplementary submissions to the GEO on 6 September 2004. On 22 September 2004, the GEO confirmed that they had no further comments on the proposed slope upgrading works.

On 2 March 2005, HT submitted an amendment design to construct a mass concrete wall near the western limb of the slope in order to reduce the extent of fill recompaction for retaining the existing security fence of Phoenix House as requested by CSD. On 30 March 2005, GEO confirmed that they had no adverse geotechnical comments on the proposed amendment.

Construction works were carried out between November 2005 and February 2006. Based on the *in-situ* dry density test records, the degree of compaction for the filling works achieved a relative compaction higher than 95%. According to the as-built drawing, the crest channel in the vicinity of the 2006 washouts was constructed with a 3 m offset downhill, probably as a result of obstruction by the existing trees.

5. THE 2006 WASHOUTS AND POST-FAILURE OBSERVATIONS

According to the records of the Arch SD and witnesses from CSD, both incidents were observed following the issue of Black Rainstorm Warnings on 9 June 2006 and 16 July 2006 respectively (Plates 1 and 2). The June and July 2006 incidents were reported by Arch SD to LPM Division 1 of the GEO on 24 July 2006 and 23 October 2006 respectively, as part of the quarterly updating of incidents attended to by the slope maintenance departments without the need for input from GEO's District Divisions. The landslide debris from both incidents was deposited on the shotcrete slope cover below the mass concrete wall (Plates 1 and 2) and along the toe channels to the north of the main building of Phoenix House (Plate 11). Debris from the July 2006 washout was also washed down to the garden area east of slope No. 11NW-B/FR60 (Figure 2 and Plate 12).

Following the receipt of the first incident report from Arch SD, MGSL first inspected the site on 18 August 2006 and on several occasions during the course of this study. At the time of the first inspection, MGSL was not aware of the July 2006 washout incident as it had not been reported then.

The landslide debris had been removed at the time of inspection and the landslide scar was backfilled with no-fines concrete in early August 2006 (Plate 13). Based on record photographs from Arch SD, the June 2006 washout scar was about 10 m long by 6 m wide. The depth of scar is estimated to be about 1 m to 1.5 m to the southwest of the stepped channel which was undermined, and less than 0.5 m to the northeast of the stepped channel (Figure 6 and Plate 1).

According to Arch SD's records, remedial works to the June 2006 washout, comprising the removal of landslide debris, backfilling the erosion scars with recompacted fill and placing sandbags (2 layers about 300 mm thick, see Plate 1) along the crest of the scar, were carried out in early July 2006. *In-situ* dry density tests were carried out on the re-compacted backfill by the Public Works Regional Laboratory in early July 2006 and all results indicated a relative compaction greater than 95%.

Based on record photographs from Arch SD and field observations by MGSL, the July 2006 washout has a similar extent as the June 2006 washout (Plates 1 and 2). A 50 m long erosion gully (maximum 0.5 m wide by 0.3 m deep) was noted along the toe of the fence (Figure 2, Plates 6 and 14). According to Arch SD's records, remedial works to the July 2006 washout comprised the removal of debris, backfilling the erosion scars with no-fines concrete (Plate 13) and the construction of an approximately 20 m long and 0.8 m high concrete dwarf wall above the erosion scar (Plate 4). The concrete dwarf wall was constructed between 22 and 24 July 2006. The erosion gully and the landslide scar were backfilled between 24 July 2006 and 8 August 2006.

There were no obvious signs of distress at the crest area above the 2006 washouts or on the L-shaped retaining wall and mass concrete retaining wall. No signs of water seepage were observed at the time of inspections and no blockage of the 225 mm U-channel above the washout was observed.

Apart from a stormwater drainage inlet to the cross-road culvert at the east end of slope No. 11NW-B/C506 (Plate 8), there is no road drainage system along a 200 m long stretch of Lung Yan Road to the west of slope No. 11NE-B/FR60. The road has a longitudinal fall of about 1 in 8 towards the crest of the washout area (Figure 1 and Plate 7). No blockage of the culvert inlet was observed at the time of inspection in August 2006. However, the outlet of the cross-road culvert is substantially blocked by the water pipes and silting was observed at the invert of the outlet (see Section 2 and Plate 9).

6. ANALYSIS OF RAINFALL RECORDS

Rainfall data were obtained from GEO automatic raingauge No. K02, which is the nearest raingauge to the study area and is located about 0.7 km to the southeast at the roof of Block 25, Lung Cheung Court, 15-17 Broadcast Drive, Kowloon Tong (Figure 1). The raingauge records and transmits rainfall data at 5-minute intervals to the Hong Kong Observatory (HKO) and the GEO. The daily rainfall recorded by raingauge No. K02 over the month preceding the washouts in June and July 2007, together with the hourly rainfall readings for the period between 7 and 9 June 2006 and between 14 and 16 July 2006, is presented in Figures 7 and 8 respectively. Black Rainstorm Warnings were issued on 9 June 2006 between 11:15 a.m. and 1:30 p.m. and on 16 July 2006 between 2:50 a.m. and 5:00 a.m.

According to the records of the Arch SD and witnesses from the CSD staff, the first incident was observed on around noon time of 9 June 2006 following the rainstorm, which stopped at about 2:30 p.m. The maximum 1-hour rolling rainfall at raingauge No. K02 was 56 mm between 10:30 a.m. and 11:30 a.m. on 9 June 2006 (Table 1). The second incident was observed on the morning of 16 July 2006 following the rainstorm, which stopped at about 6:10 a.m. The maximum 1-hour rolling rainfall was 111.5 mm between 2:05 a.m. and 3:05 a.m. on 16 July 2006 (Table 2).

Tables 1 and 2 present the estimated return periods for the maximum rolling rainfall for various durations recorded by raingauge No. K02 with reference to historical rainfall data at the HKO in Tsim Sha Tsui (Lam & Leung, 1994). The results show that the 9 June 2006 rainstorm has a return period of less than or equal to 2 years for all rainfall durations. The 1-hour rolling rainfall of the 16 July 2006 rainstorm was the most severe, with a corresponding return period of about 16 years, whilst for other rainfall durations between

5 minutes and 4 hours, the corresponding return periods range from 2 years to about 9 years.

The June and July 2006 rainstorms were also assessed with local rainfall data to evaluate the spatial variability of rainfall. The return periods were assessed based on the statistical parameters derived by Evans & Yu (2001) for rainfall data recorded by raingauge No. K02 between 1984 and 1988 and between 1990 and 1997. The results show that the return periods are comparable to those estimated by the historical rainfall data at Tsim Sha Tsui (Tables 1 and 2).

The maximum rolling rainfall for the 9 June 2006 and 16 July 2006 rainstorms has been compared with the previous major rainfall recorded by raingauge No. K02, which came into operation in September 1978 (Figure 9). The 9 June 2006 rainstorm is less severe than the previous major rainstorms, while the 1-hour rolling rainfall recorded on 16 July 2006 is the most severe rainfall recorded in the past 23 years.

7. DISCUSSION

The June 2006 incident on slope No. 11NW-B/FR60 involved a minor washout failure on an engineered slope (fill recompaction works were completed 3 months before that time) during relatively light rainfall. The repaired section of the slope suffered another minor washout again in July 2006 at the same location during a rainstorm with a return period of 16 years. There are no past instability records on the subject slope before the completion of the upgrading works in 2006. No significant signs of seepage/distress or erosion were observed during the EI records in 2000 and 2004.

During heavy rainfall, significant surface runoff from the streamcourse on the hillsides above (with a fairly substantial catchment area of about 15,000 m²) drains to the culvert inlet at the east end of slope No. 11NW-B/C506 and overtopping from the culvert inlet is likely to occur due to significant blockage of the outlet of the cross-road culvert by the water pipes. The overflow from the culvert inlet probably runs along Lung Yan Road where there is no surface drainage system to intercept the overland flow. As a result, the uncontrolled and concentrated flow of surface water down the road overtopping the crest of slope No. 11NW-B/FR60 probably caused the washout failures.

The 1 m high earth bund that used to be present at the crest of the western limb of the slope, might have served to divert surface water flow from overtopping onto the slope. The bund was removed as part of the slope upgrading works. This has led to an adverse change in the environmental setting of the site. Although a new crest drainage channel was provided, its capacity and adequacy, taking in account the overall site setting, may not have been assessed in detail. The shifting of the crest channel alignment near the 2006 washout area during construction could also have further reduced its effectiveness.

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Table 1 - Maximum Rolling Rainfall at GEO Raingauge No. K02 for Selected Durations Preceding the 9 June 2006 Washout Incident and the Estimated Return Periods

Duration	Maximum ⁽¹⁾ Rolling Rainfall (mm)	End of Period	Estimated Return Period (Year)	
			Lam & Leung ⁽²⁾ (1994)	Data of K02 ⁽²⁾ from Evans & Yu (2001)
5 Minutes	11.0	11:15a.m. on 9 June 2006	< 2	< 2
15 Minutes	27.5	11:20a.m. on 9 June 2006	< 2	2
1 Hour	56.0	11:30a.m. on 9 June 2006	< 2	< 2
2 Hours	91.0	12:45 p.m. on 9 June 2006	< 2	< 2
4 Hours	122.0	1:50 p.m. on 9 June 2006	2	2
12 Hours	138.5	12:50 p.m. on 9 June 2006	< 2	< 2
24 Hours	162.0	2:30 p.m. on 9 June 2006	< 2	< 2
48 Hours	162.0	2:30 p.m. on 9 June 2006	< 2	< 2
4 Days	165.0	2:30 p.m. on 9 June 2006	< 2	< 2
7 Days	234.0	11:20 a.m. on 9 June 2006	< 2	< 2
15 Days	467.0	2:30 p.m. on 9 June 2006	< 2	< 2
31 Days	622.5	2:30 p.m. on 9 June 2006	< 2	< 2
<p>Notes:</p> <ul style="list-style-type: none"> (1) Maximum rolling rainfall was calculated from 5-minute rainfall data. (2) Return periods were derived from the statistical parameters extracted from Table 3 of Lam & Leung (1994). (3) Return periods were also derived from the statistical parameters of raingauge No. K02 extracted from Appendix B of Evans & Yu (2001) to assess the spatial variability of rainfall. (4) According to the eyewitness, the June 2006 washout was observed at around noon time of 9 June 2006. (5) The nearest GEO raingauge to the site is raingauge No. K02, which is situated at about 0.66 km to the east of the site. 				

Table 2 - Maximum Rolling Rainfall at GEO Raingauge No. K02 for Selected Durations Preceding the 16 July 2006 Washout Incident and the Estimated Return Periods

Duration	Maximum ⁽¹⁾ Rolling Rainfall (mm)	End of Period	Estimated Return Period (Year)	
			Lam & Leung ⁽²⁾ (1994)	Data of K02 ⁽²⁾ from Evans & Yu (2001)
5 Minutes	13.0	2:50 a.m. on 16 July 2006	2	3
15 Minutes	37.5	2:55 a.m. on 16 July 2006	9	9
1 Hour	111.5	3:05 a.m. on 16 July 2006	16	15
2 Hours	144.0	4:05 a.m. on 16 July 2006	9	7
4 Hours	159.5	5:40 a.m. on 16 July 2006	5	4
12 Hours	163.5	6:10 a.m. on 16 July 2006	< 2	< 2
24 Hours	175.0	5:50 a.m. on 16 July 2006	< 2	< 2
48 Hours	181.0	6:10 a.m. on 16 July 2006	< 2	< 2
4 Days	181.0	6:10 a.m. on 16 July 2006	< 2	< 2
7 Days	230.0	6:10 a.m. on 16 July 2006	< 2	< 2
15 Days	342.0	6:10 a.m. on 16 July 2006	< 2	< 2
31 Days	515.0	6:10 a.m. on 16 July 2006	< 2	< 2
<p>Notes:</p> <ul style="list-style-type: none"> (1) Maximum rolling rainfall was calculated from 5-minute rainfall data. (2) Return periods were derived from the statistical parameters extracted from Table 3 of Lam & Leung (1994). (3) Return periods were also derived from the statistical parameters of raingauge No. K02 extracted from Appendix B of Evans & Yu (2001) to assess the spatial variability of rainfall. (4) According to the eyewitness, the July 2006 washout was observed in the morning of 16 July 2006. (5) The nearest GEO raingauge to the site is raingauge No. K02, which is situated at about 0.66 km to the east of the site. 				

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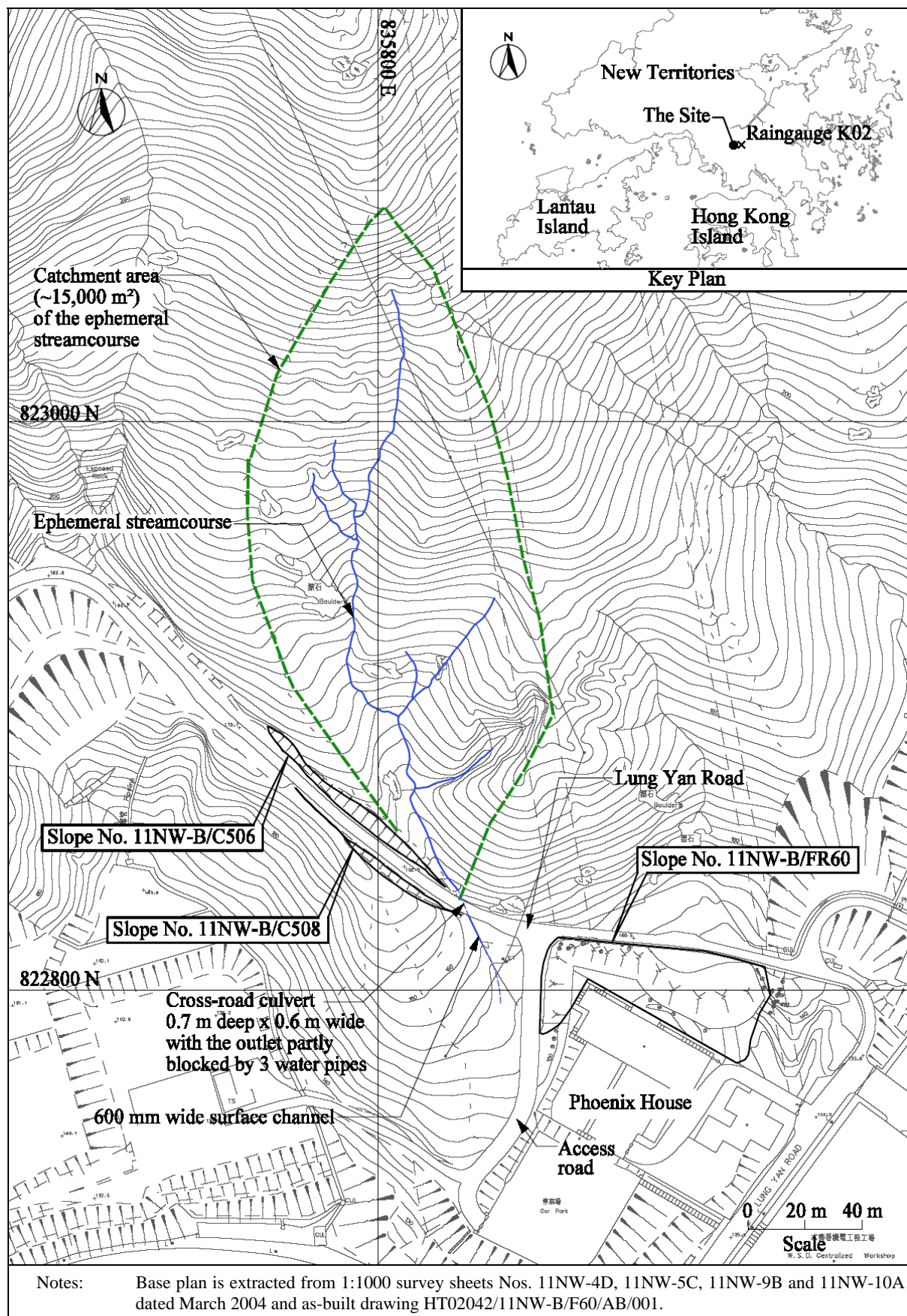


Figure 1 - Location Plan

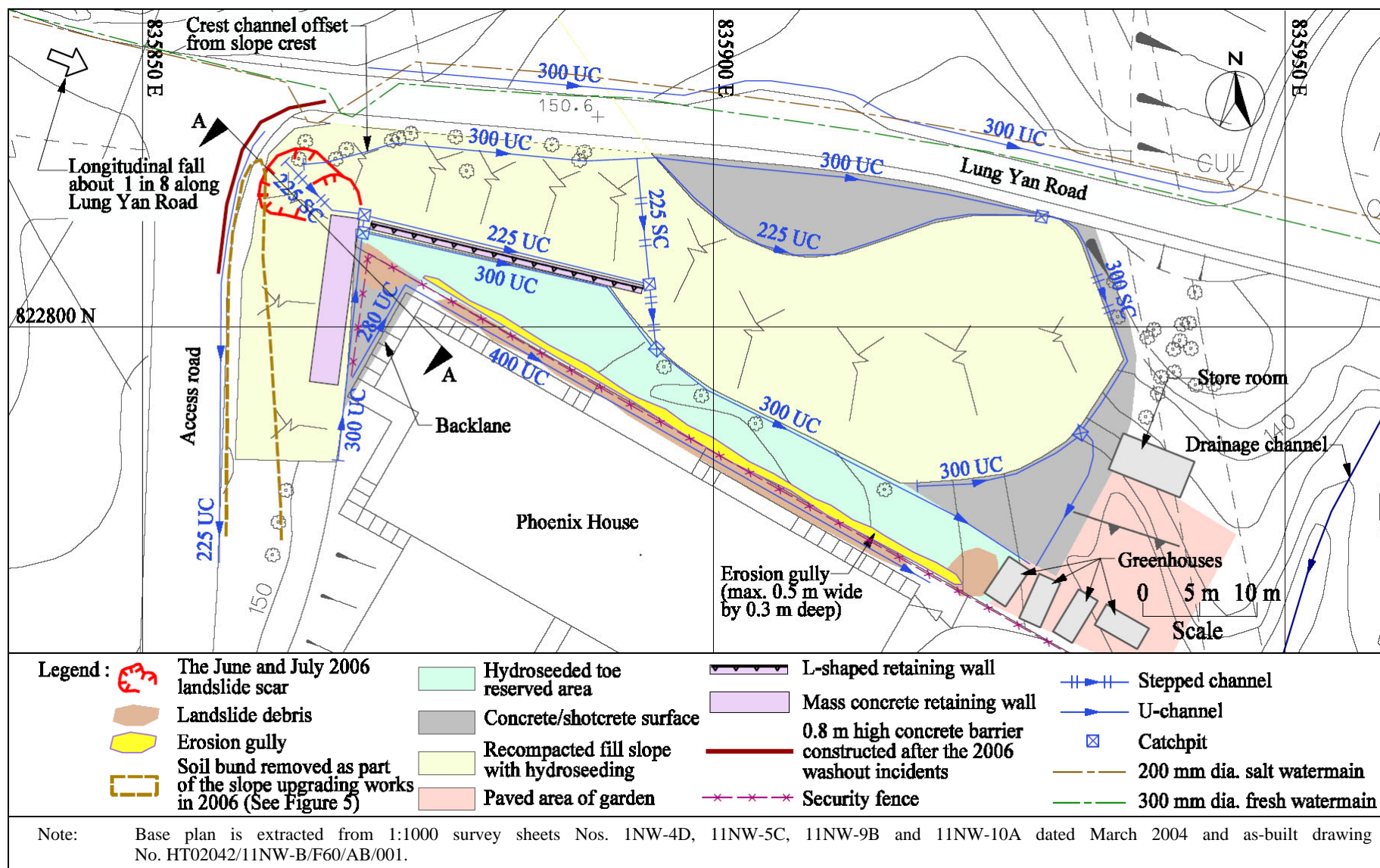


Figure 2 - Site Layout Plan and Field Observations

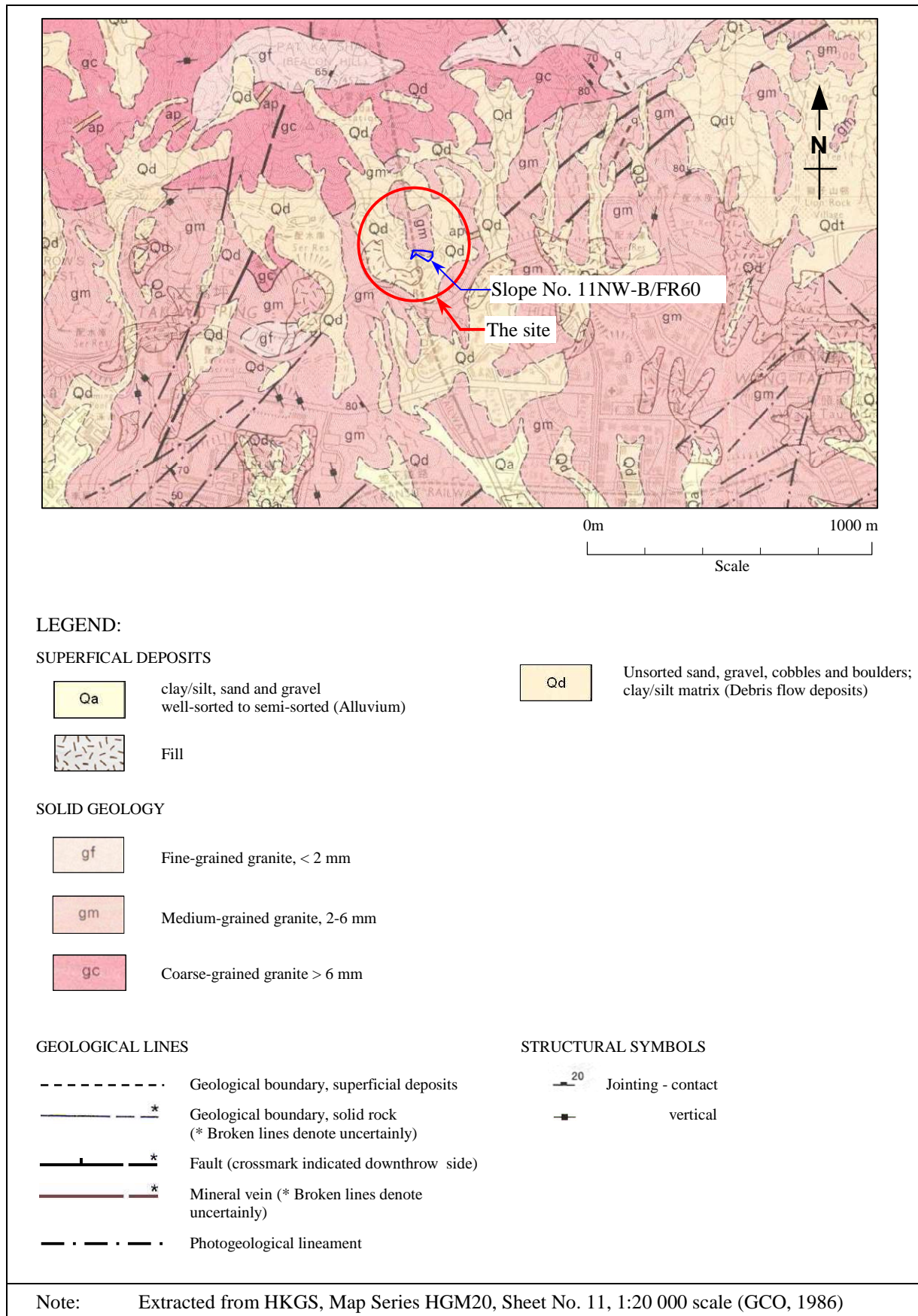


Figure 3 - Regional Geology

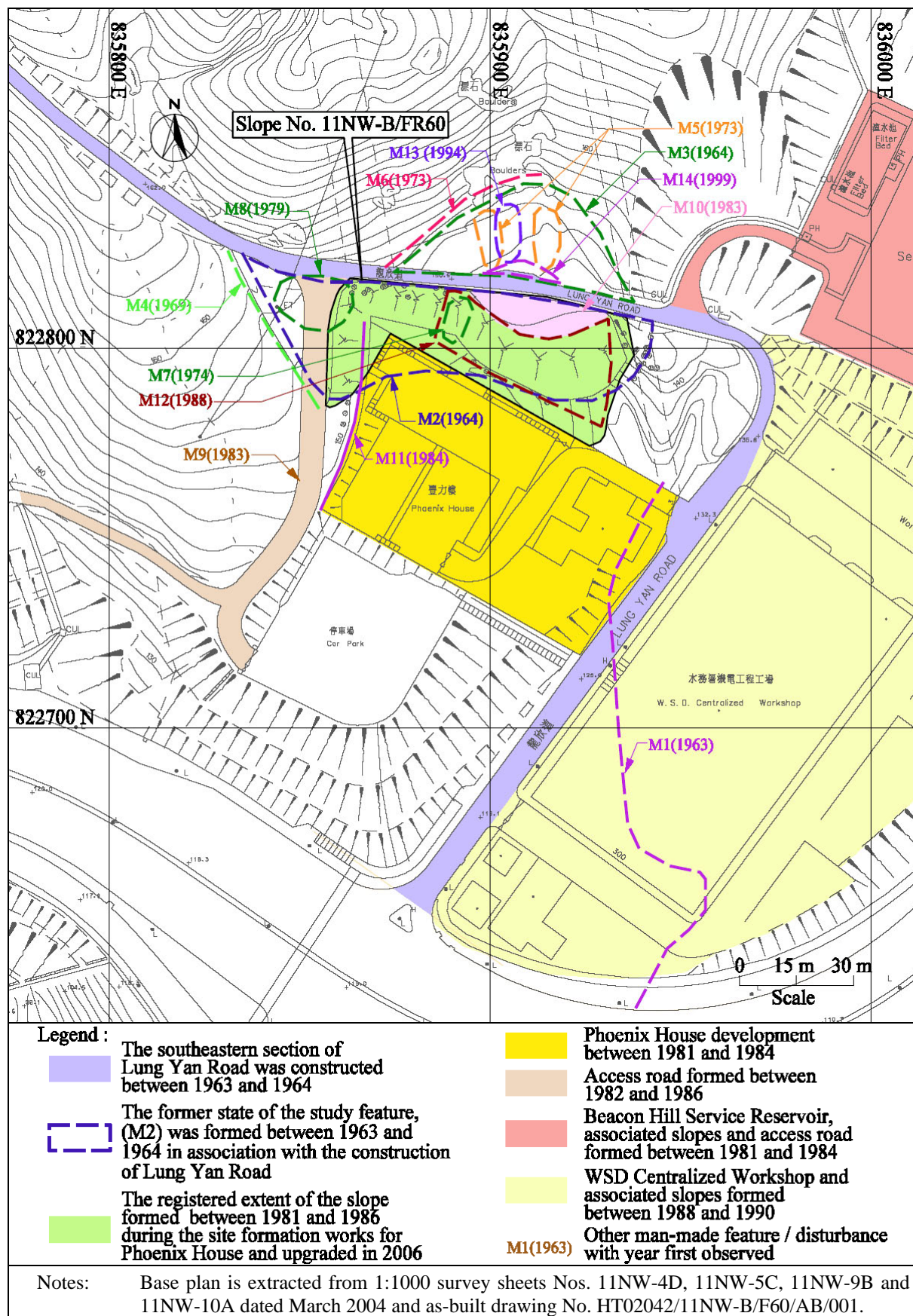
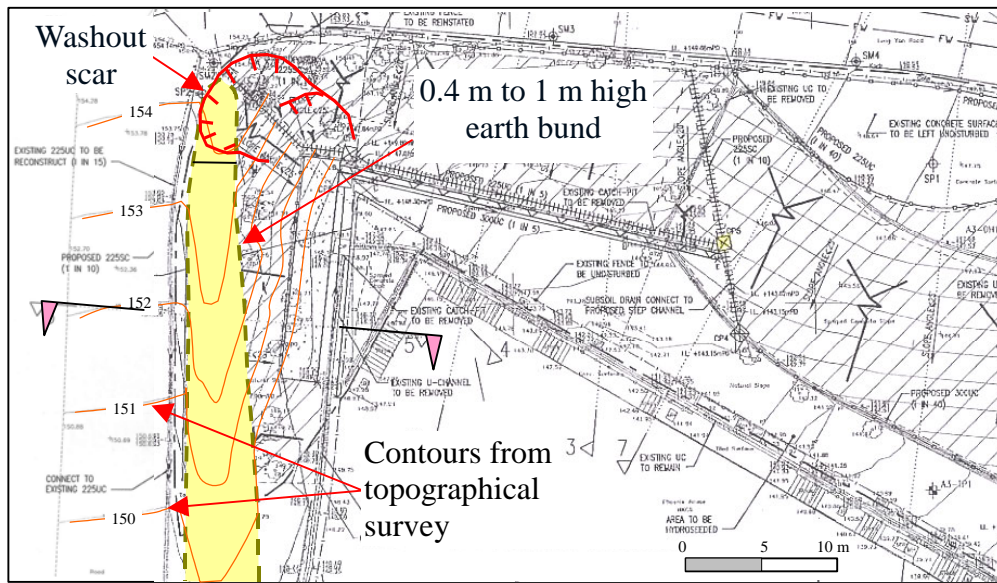
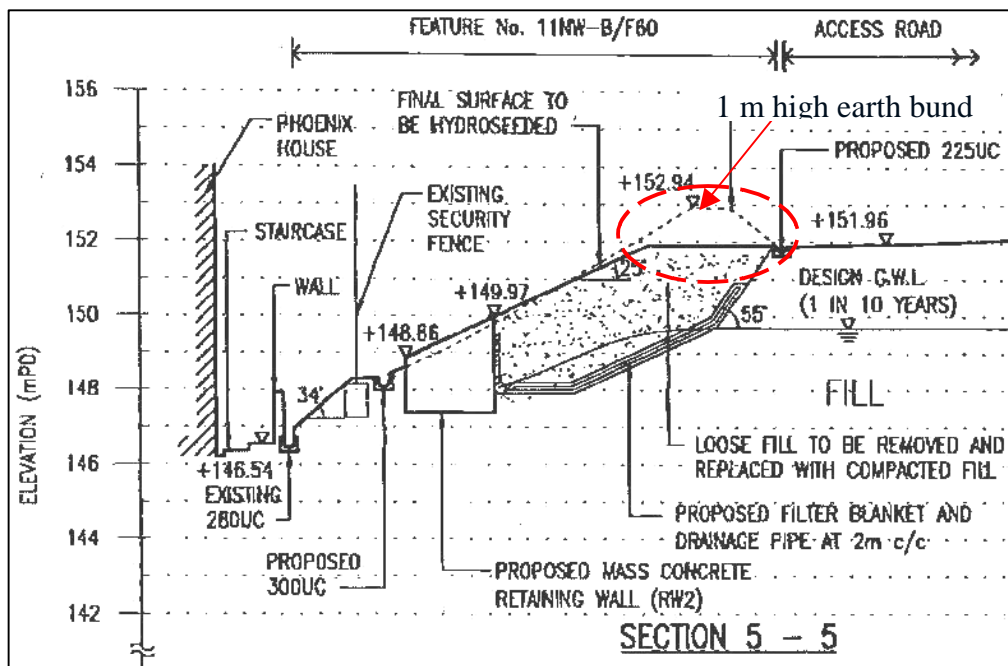


Figure 4 - Site Development History



(a) Plan showing the extent of earth bund prior to slope works



(b) Section showing the earth bund prior to slope works

Note: Information extracted from drawing Nos. HT 2042/11NW-B/F60/001A and HT 2042/11NW-B/F60/002A

Figure 5 - Extent of the Earth Bund Prior to the Slope Upgrading Works in 2005

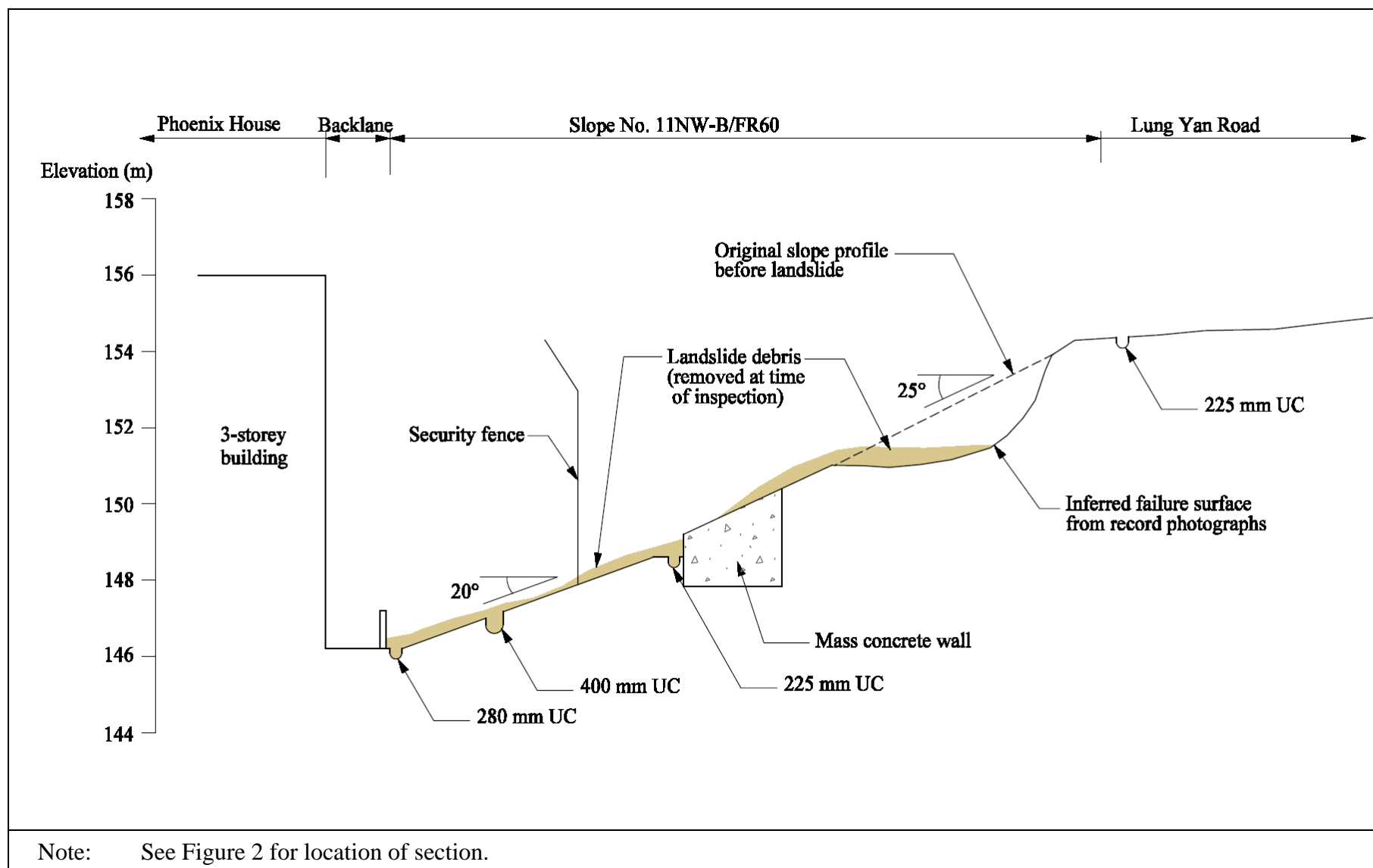
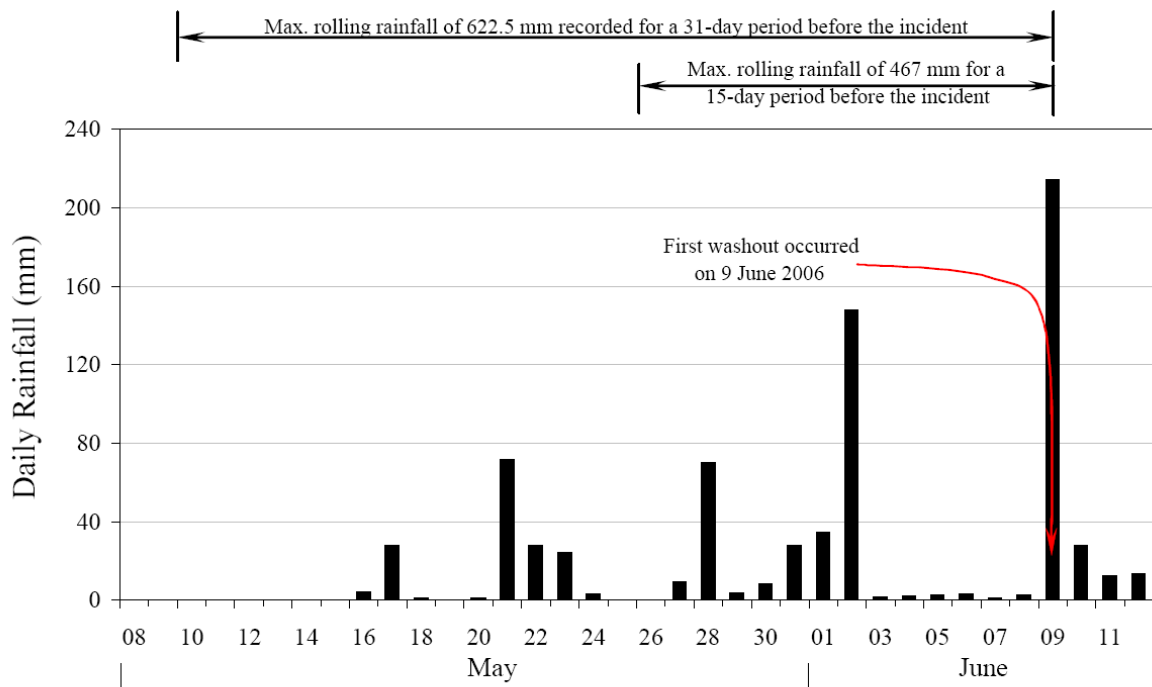
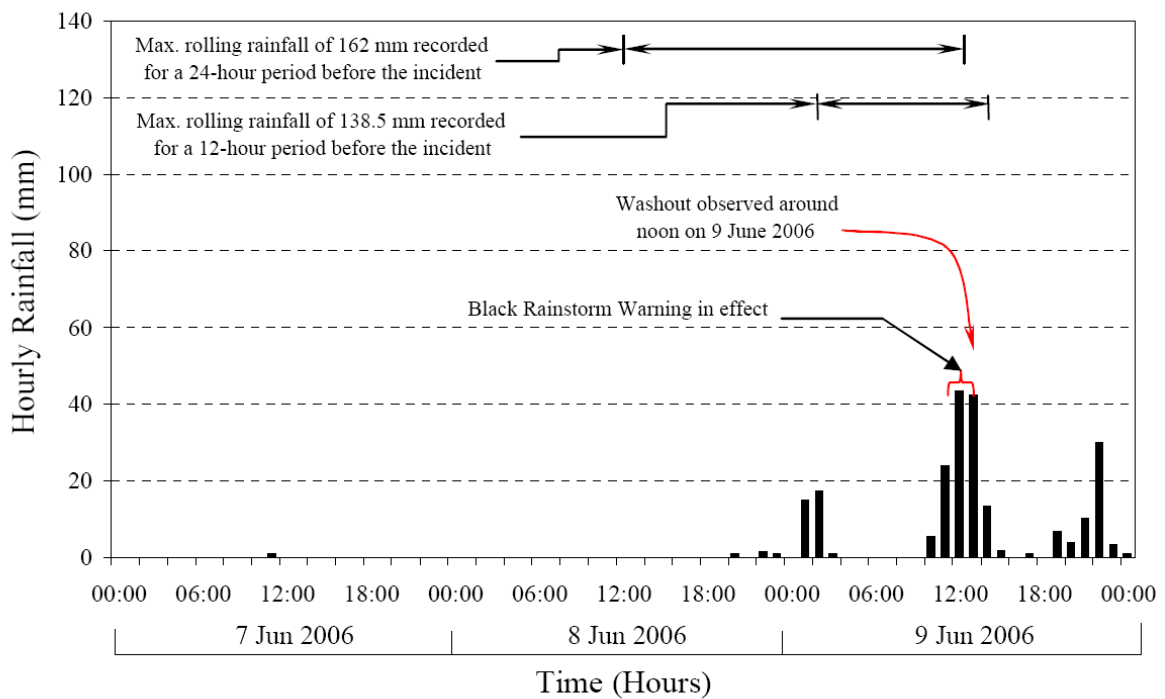


Figure 6 - Cross Section A-A

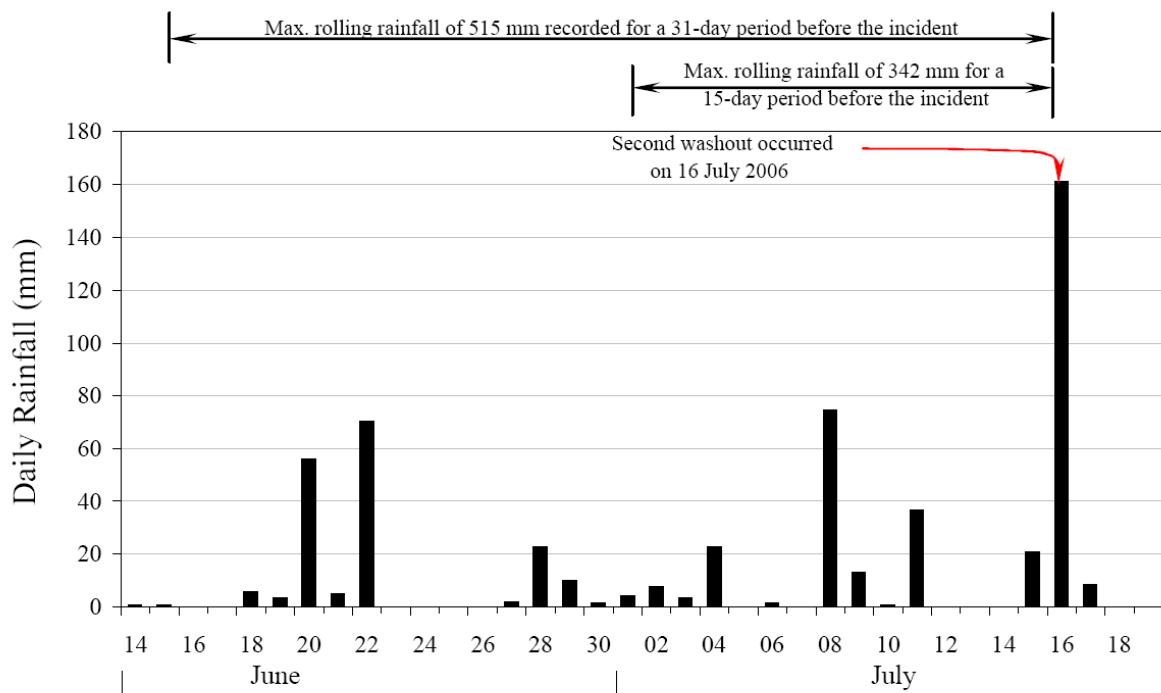


(a) Daily rainfall recorded at GEO Raingauge No. K02 between 8 May 2006 and 12 June 2006

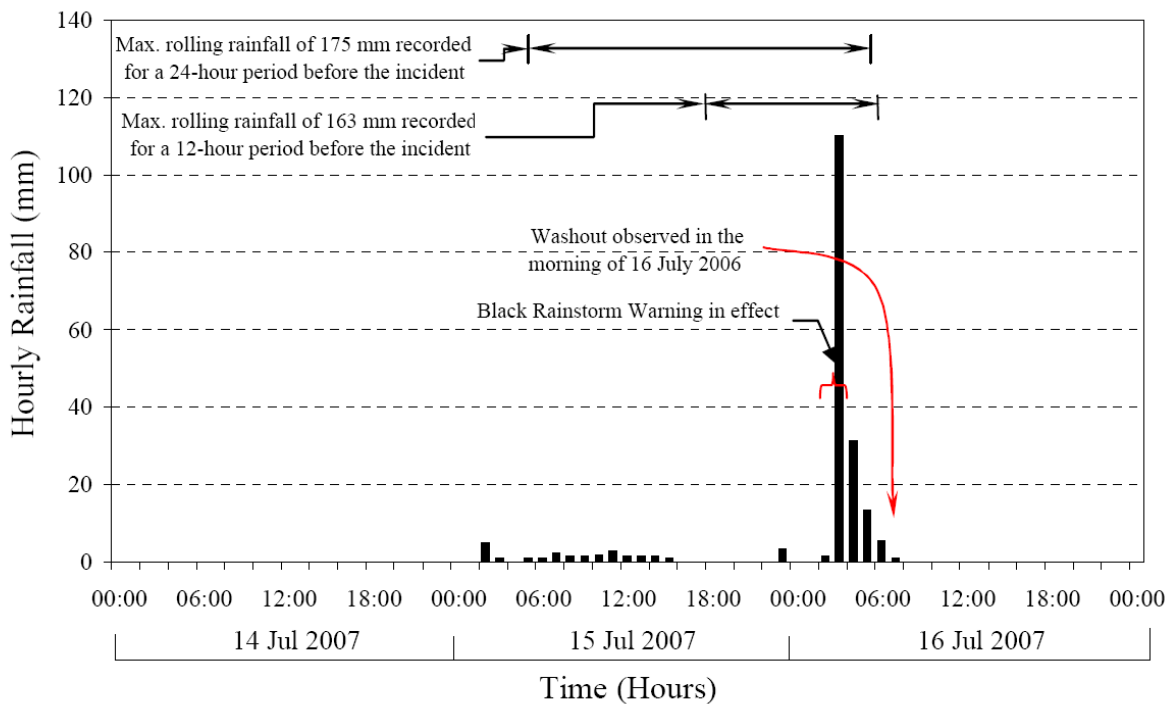


(b) Hourly rainfall recorded at GEO Raingauge No. K02 between 7 June 2006 and 9 June 2006

Figure 7 - Daily and Hourly Rainfall Recorded at GEO Raingauge No. K02 in June 2006



(a) Daily rainfall recorded at GEO Raingauge No. K02 between 14 June 2006 and 19 July 2006



(b) Hourly rainfall recorded at GEO Raingauge No. K02 between 14 July 2006 and 16 July 2006

Figure 8 - Daily and Hourly Rainfall Recorded at GEO Raingauge No. K02 in July 2006

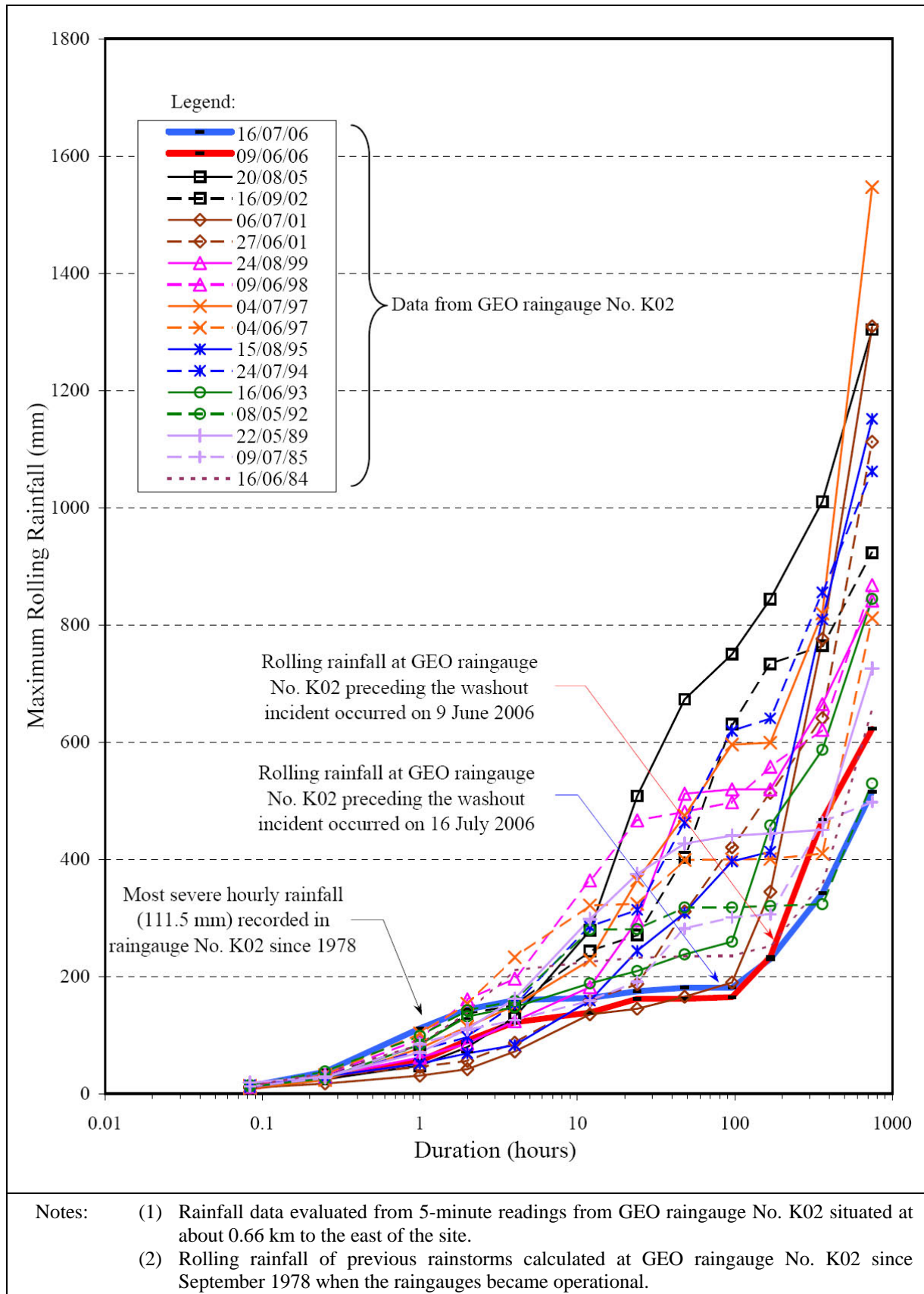


Figure 9 - Maximum Rolling Rainfall for Previous Major Rainstorms at GEO Raingauge No. K02

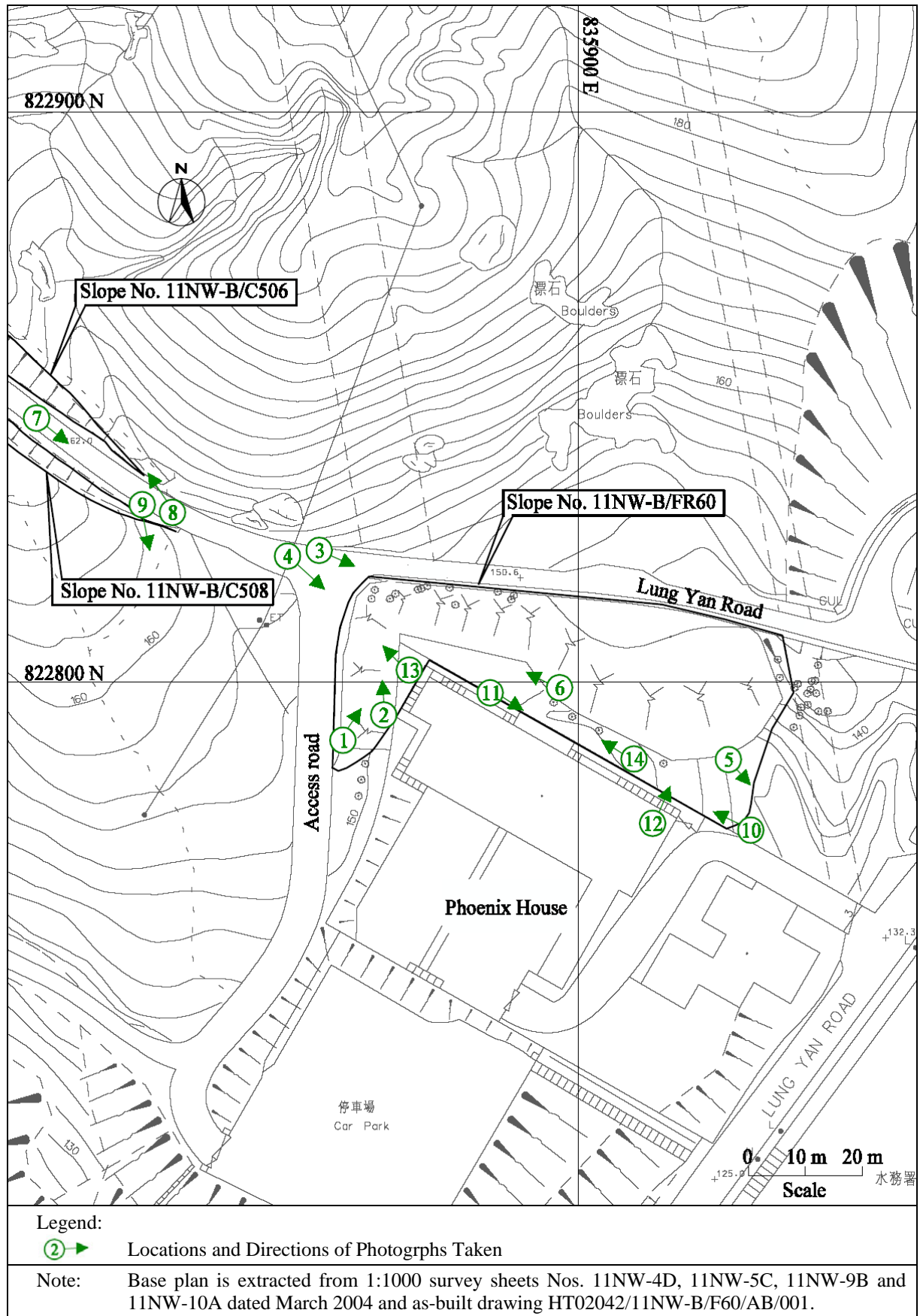


Figure 10 - Locations and Directions of Photographs Taken

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Plate 1 - General View of the 9 June 2006 Washout Incident on Slope No. 11NW-B/FR60
(Photograph taken by Arch SD on 6 July 2006)

Note: See Figure 10 for location and direction of photograph.

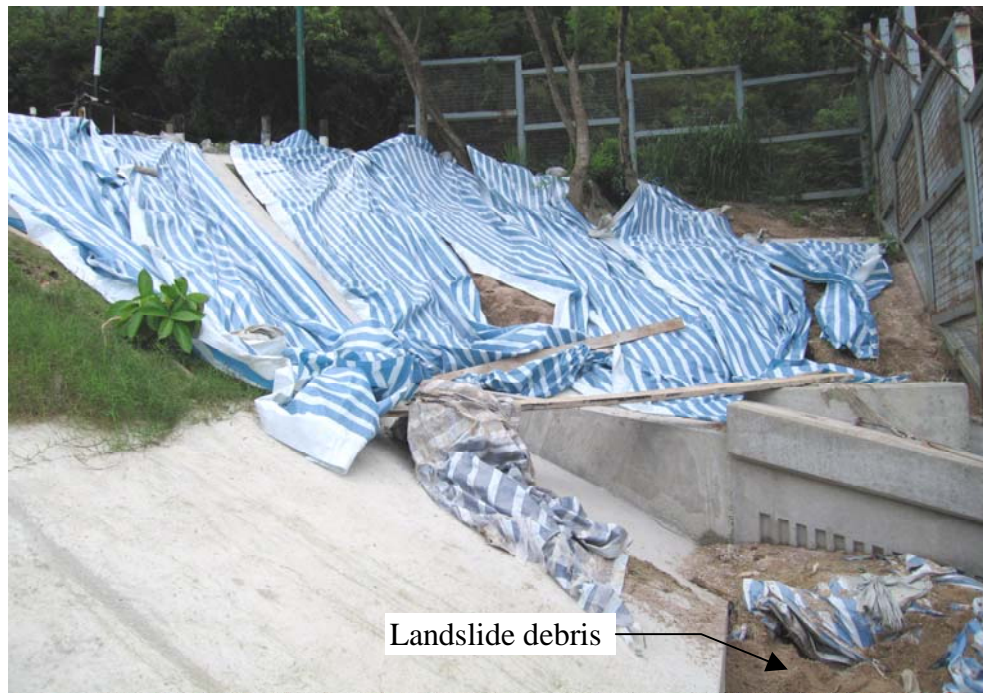


Plate 2 - General View of the 16 July 2006 Washout Incident on Slope No. 11NW-B/FR60
(Photograph taken by Arch SD on 19 July 2006)



Plate 3 - View of Lung Yan Road along Crest of Slope No. 11NW-B/FR60 Looking Downhill
(Photograph taken on 20 September 2006)

Note: See Figure 10 for locations and directions of photographs.

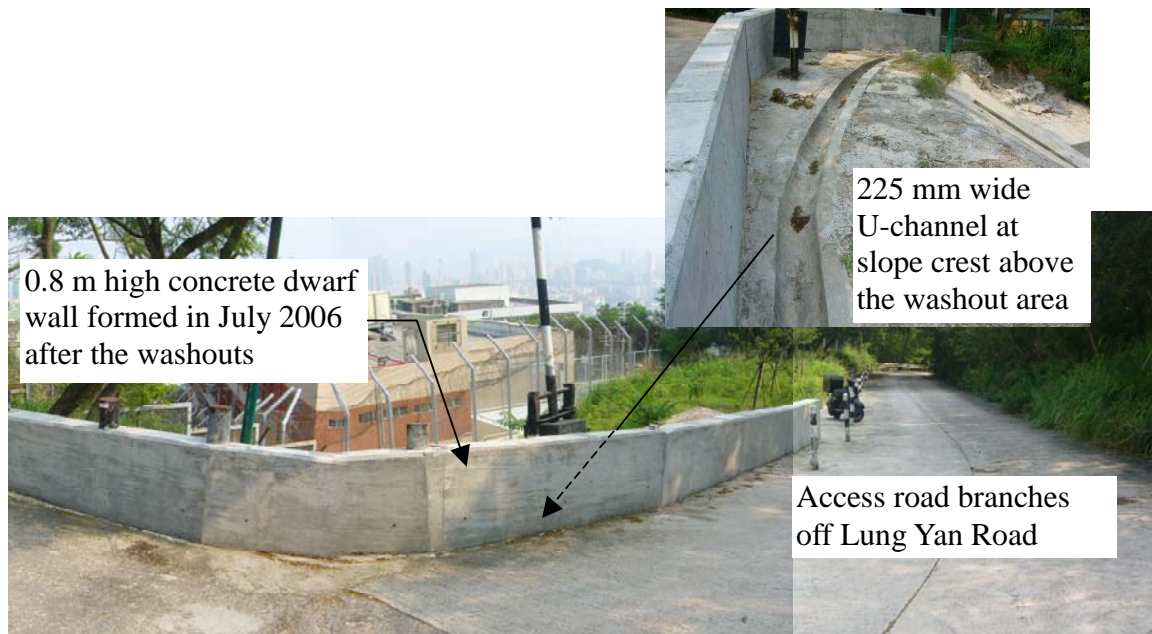


Plate 4 - View of Access Road to the West of Slope No. 11NW-B/FR60 and Concrete Dwarf Wall Constructed after the July 2006 Washout Incident (Photograph taken on 20 September 2006)



Plate 5 - View of Garden to the East of Slope No. 11NW-B/FR60 (Photograph taken by Arch SD on 20 July 2006)

Note: See Figure 10 for locations and directions of photographs.

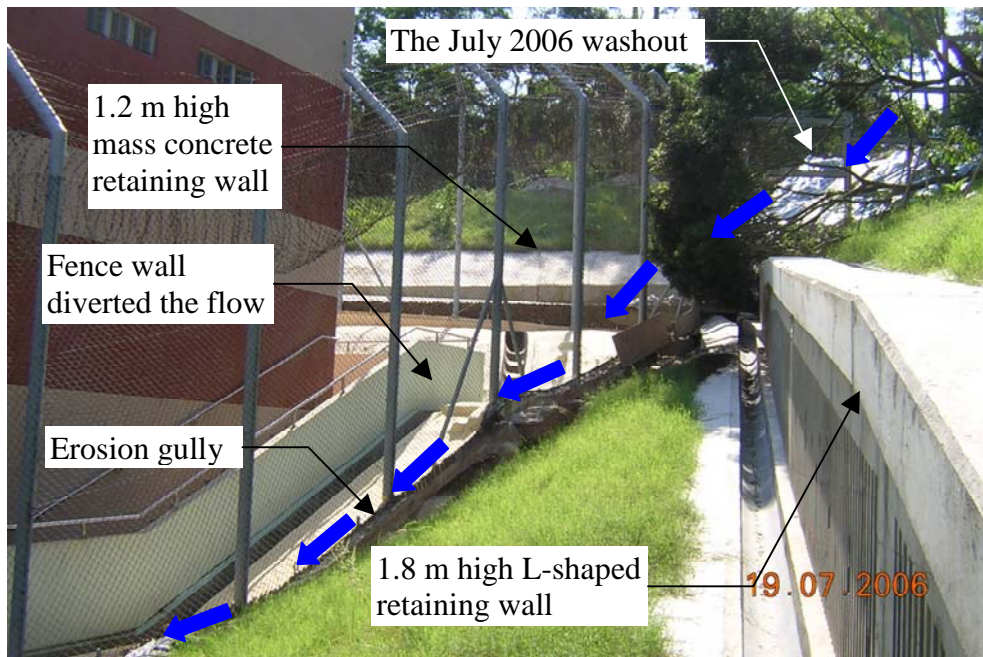


Plate 6 - View of the L-shaped and the Mass Concrete Retaining Walls and Inferred Flow Path of Surface Water during the Washout Incidents (Photograph taken by Arch SD on 19 July 2006)

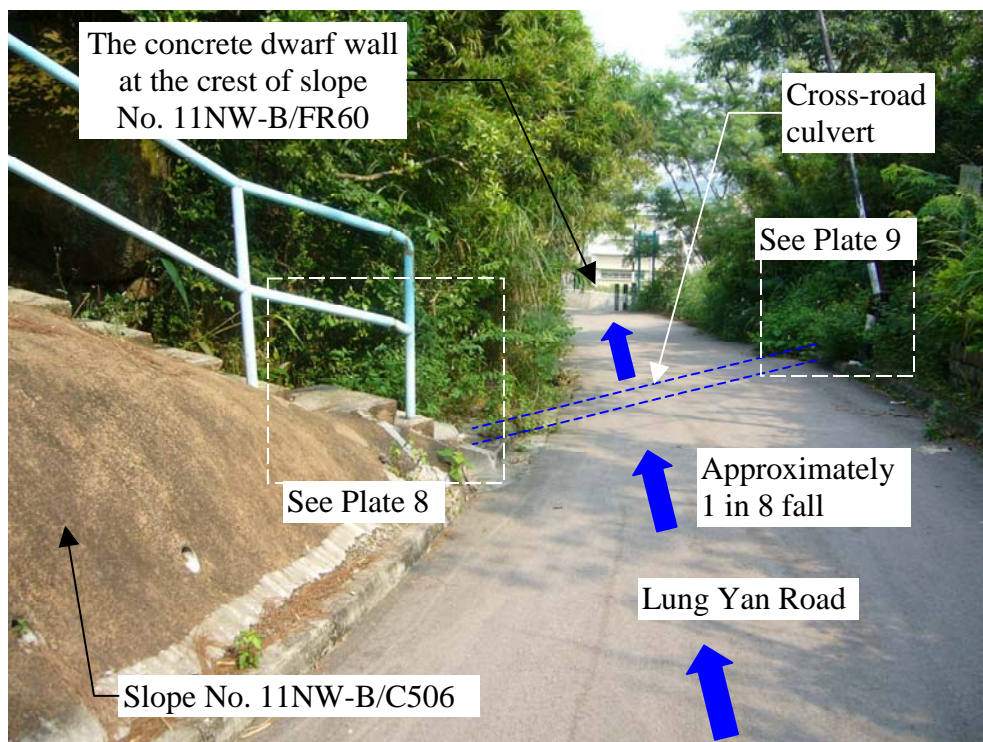


Plate 7 - View of Lung Yan Road Running towards Erosion Scar at the Northwest Corner of Slope No. 11NW-B/FR60 (Photograph taken on 20 September 2006)

Note: See Figure 10 for locations and directions of photographs.



Plate 8 - View of the Ephemeral Streamcourse at East End of Slope No. 11NW-B/C506 and the Drainage Inlet of the Cross-road Culvert (Photograph taken on 20 September 2006)

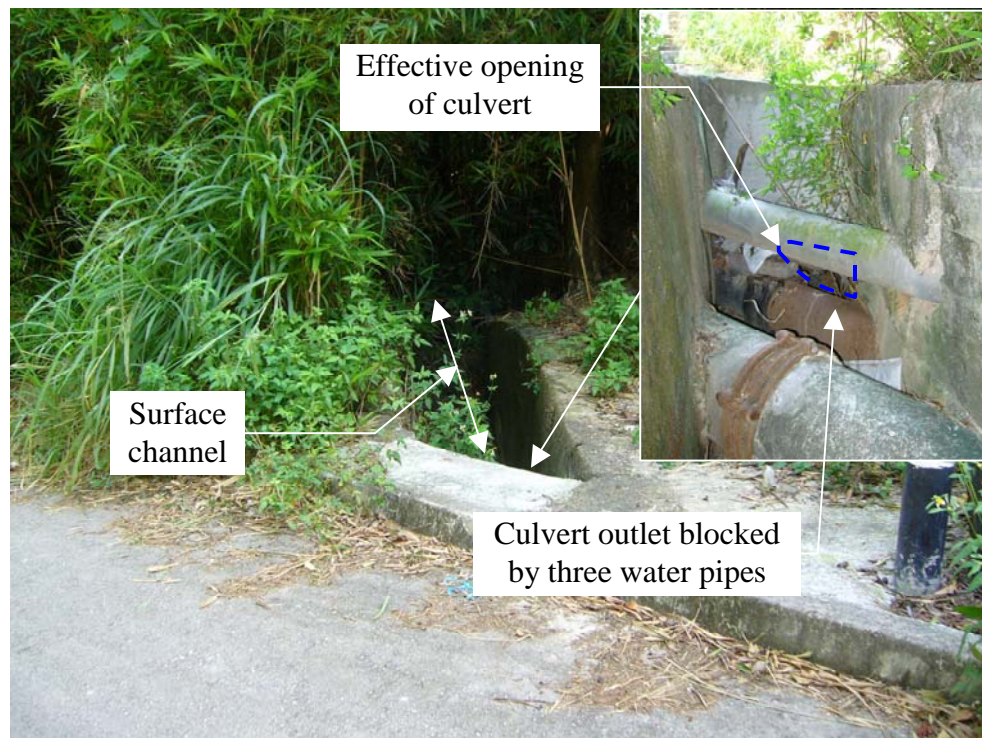


Plate 9 - View of the Surface Channel and the Outlet of the Cross-road Culvert (Photograph taken on 9 October 2007)

Note: See Figure 10 for locations and directions of photographs.

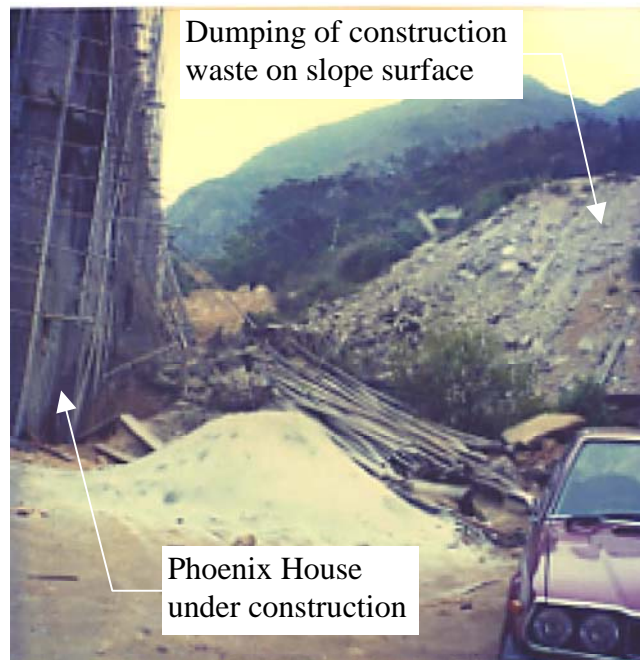


Plate 10 - View of the Illegal Dumping of Construction Waste on Slope No. 11NW-B/FR60 in 1982
(Photograph taken by GCO in 1982)



Plate 11 - Landslide Debris Deposited along the Toe Channels of Slope No. 11NW-B/FR60
(Photograph taken by Arch SD on 19 July 2006)

Note: See Figure 10 for locations and directions of photographs.



Plate 12 - Landslide Debris Deposited near the Garden to the East of Slope No. 11NW-B/FR60
(Photograph taken by Arch SD on 20 July 2006)



Plate 13 - Urgent Repair Works for the July 2006 Washout
(Photograph taken on 18 August 2006)

Note: See Figure 10 for locations and directions of photographs.

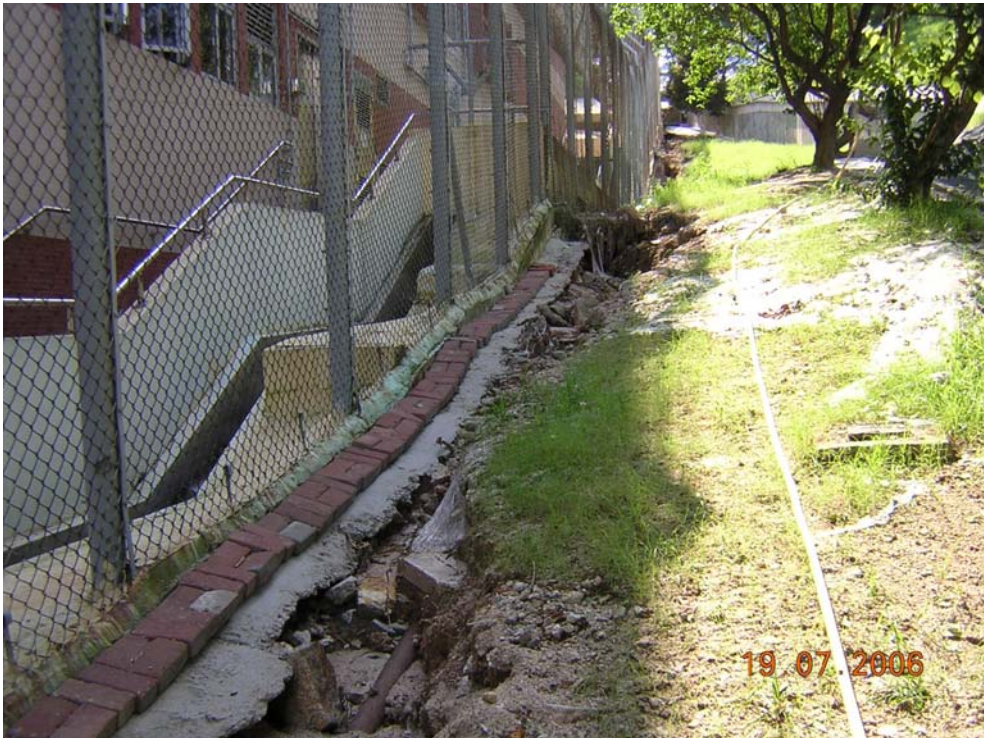


Plate 14 - Erosion Gully along the Toe of Slope No. 11NW-B/FR60
(Photograph taken by Arch SD on 19 July 2006)

Note: See Figure 10 for locations and directions of photographs.

APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

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A1. DETAILED OBSERVATIONS

This appendix sets out the detailed observations made from an interpretation of aerial photographs taken between 1963 and 2006. A list of the aerial photographs reviewed is presented in Table A1. The site development history is shown on Figure A1 and the general geomorphology and hydrology of the site are presented on Figure A2.

YEAR **OBSERVATIONS**

1963 Low flight, excellent resolution aerial photographs.

Slope No. 11NW-B/FR60 and Lung Yan Road has not been formed and the study area consists of a thinly vegetated, approximately south-facing natural hillside at the foot of Beacon Hill. The area, where the subject slope is situated, comprises a broad valley with relatively sharp, southeast trending spurs in the western and eastern flanks (Figure A2). The area forms a natural reception area for the debris emanating from uphill and it is loaded with colluvium with bouldery context in the general vicinity (Figure A2).

The vicinity of the study area is drained by three major southward trending natural streamcourses (denoted S1 to S3, see Figure A2), with two of them (S1 and S2) flowing near the present-day location of slope No. 11NW-B/FR60. These streamcourses merge into an artificial drainage channel (M1) to the east of the present-day location of the slope.

Clusters of boulders/corestones are visible all over the hillside, as well as along the natural streamcourses (Figure A2). Two areas of erosion (E1 and E2, see Figure A2) are identified on the hillsides, to the east and further uphill to the northwest of the study area, which are drained by the streamcourses.

1964 High flight, fair resolution aerial photographs.

The construction of Lung Yan Road is underway and the portion of road in the vicinity of the study area has been formed (Figure A1). Associated cut slopes are evident alongside of the road.

A fill slope (M2), which represents the former state of slope No. 11NW-B/FR60, is evident immediately downhill of Lung Yan Road. An area of disturbance (M3), which is relatively gentle sloping ground formed by filling, is apparent on the other side of the road. This fill material was probably placed during the construction of Lung Yan Road.

1967 No significant changes to the study area are apparent. The uphill section of Lung Yan Road to the northwest of the study area has been constructed.

1969 The hillside of the study area shows an increase in the vegetation density, whereas fill slope M2 and the gently sloping ground M3 are both covered with thin vegetation.

YEAR **OBSERVATIONS**

	A man-made channel (M4) has been formed along the western fringe of the fill slope M2 to divert the flow of natural streamcourse S1, which originally flowed along the toe of fill slope M2.
1972	No significant changes to the study area are apparent. Site formation works and slope works are apparent along the uphill side of Lung Cheung Road.
1973	A surface channel (M6) is visible along the crest of the gently sloping ground M5. Some localised areas of disturbance (M5), probably clearance of vegetation relating to the construction of M6, are evident within the gently sloping ground M3.
1974	No significant changes to the study area are apparent, except that a local area of disturbance (M7) is evident within the mid portion of fill slope M2. The disturbance, which shows a linear alignment, may be related to the construction of some drainage works or dumping of material on the fill slope M2.
1976	No significant changes to the study area are apparent. The local disturbance M5 and M7 are still evident.
1977- 1978	No significant changes to the study area are observed.
1979	The general area is covered with moderate to dense vegetation growth. An area of disturbance (M8) is evident immediately below Lung Yan Road, at the western end of the fill slope M2.
1980	No significant changes to the study area are apparent.
1981	Extensive site formation works, in connection with the construction of Phoenix House and the associated access road, are evident on the hillside immediately below the fill slope M2. The eastern portion of the study feature as well as the gently sloping ground M3 are also being utilised for plant and material storage. Site formation and building construction for the Beacon Hill Service Reservoir have also commenced on the hillside to the northeast of the fill slope M2.
1982	Single aerial photograph. Formation of Phoenix House is underway and a number of building structures have been erected below the fill slope M2. The layout of the fill slope M2 has been altered by the construction of an access road (M9) at the western portion of the slope and the trimming at the toe for the formation of building structures. Formation for the Beacon Hill Service Reservoir and the associated slopes and access road are in progress.

<u>YEAR</u>	<u>OBSERVATIONS</u>
--------------------	----------------------------

1983	Construction works are still evident in the general area of Phoenix House. Slope works are still underway at slope No. 11NW-B/FR60. The associated access road M9, which runs along the western flank of the slope, is being constructed. A small platform (M10) is apparent at the crest of the eastern portion of slope No. 11NW-B/FR60, which is occupied by some construction vehicles.
------	---

Formation for the Beacon Hill Service Reservoir and the associated slope and access road are in progress.

1984	Single aerial photograph.
------	---------------------------

The construction of Phoenix House is complete. The construction plant and material stockpiles, which were previously occupying the small platform M10 as well as the gently sloping ground M3, have both been cleared and the two areas are bare. Slope works appear to be underway within slope No. 11NW-B/FR60. A drainage channel (M11) is evident along the toe of the southwest portion of the slope.

The construction of Beacon Hill Service Reservoir has been completed.

1986	The works at slope No. 11NW-B/FR60 appear to be complete. The current registered slope boundary has been formed. The surface of the slope and the small platform M10 at the crest of its eastern portion are covered with moderately dense vegetation growth.
------	---

Phoenix House complex and the access road M9 to the west of slope No. 11NW-B/FR60 have been completed. The access road is also connected to the large platforms further west.

1988	The eastern portion of slope No. 11NW-B/FR60 (M12) and the small platform M10 directly above have both been cleared of the vegetation growth. The gently sloping ground M3 is covered with moderately dense vegetation.
------	---

Site formation and building works in association with the WSD Centralised Workshop are underway on the hillside to the southeast of slope No. 11NE-B/FR60.

1990	Hard surface protection has been applied to the surface of the eastern portion of slope No. 11NW-B/FR60 (M12), whereas the western portion of the slope remains covered with dense vegetation growth.
------	---

The WSD Centralised Workshop has been formed. In connection with the development, the section of Lung Yan Road along the Workshop has been widened.

1991	No significant changes to the study area are apparent.
------	--

<u>YEAR</u>	<u>OBSERVATIONS</u>
--------------------	----------------------------

1993	The hillsides within the study area and the gently sloping ground M3 are overgrown with dense vegetation, except for the eastern portion of slope No. 11NW-B/FR60 (M12), which is protected by hard surface cover.
1994	No changes of significance are observed except that a local area of disturbance (M13) is evident within the gently sloping ground M3.
1995-1997	No significant changes to the study area are apparent. The western portion of the study feature remains covered with dense vegetation growth.
1999	A small lay-by area (M14) is apparent within the gently sloping ground M3, uphill of slope No. 11NW-B/FR60.
2001-2004	No significant changes to the study area are apparent. The western portion of slope No. 11NW-B/FR60 remains covered with dense vegetation growth.
2006	Slope works were carried out on slope No. 11NW-B/FR60 between 2005 and 2006. The dense vegetation previously observed at the western portion of slope No. 11NW-B/FR60 has been cleared. The hard surface cover on the eastern portion of the slope (M12) has been removed and the upper portion of the slope has been hydroseeded. The toe retaining wall within the mid-height of the slope is evident and the lower part of the slope below the retaining wall is protected by shotcrete.

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Table A1 - List of Aerial Photographs Reviewed

Date taken	Altitude (ft)	Photograph Number
25 January 1963	2700	Y8111-12
13 December 1964	12500	Y12927-28
16 May 1967	6250	Y13458, Y13460
1969	Unknown	Y14888-89
3 October 1972	13000	2283-84
24 October 1973	1800	5379-80
10 August 1974	3000	9334-35
16 August 1976	1900	14703-04
15 September 1977	2000	19252-53
15 June 1978	2000	21973-74
1 October 1979	2000	27351-52
16 April 1980	2000	29722-23
26 November 1981	4000	39784, 39786
21 December 1982	4000	46350
25 January 1983	4000	47421-22
3 March 1984	4000	54009
3 March 1986	4000	A4375-76
6 October 1988	4000	A14714-15
13 November 1990	4000	A23634-35
20 September 1991	4000	A27510-11
4 October 1993	3500	A35860-61
5 May 1994	4000	CN6791-92
27 September 1995	3500	CN11358-59
12 October 1996	5000	CN14733-34
14 November 1997	4000	CN18910-11
11 June 1999	2600	CN23173-74
15 March 2001	4000	CN30136-37
3 January 2002	2000	CW37961-62
5 October 2004	4000	CW60422-23
19 May 2006	4000	CW71968-69
Note: All aerial photographs are in black and white except for those prefixed with CN or CW.		

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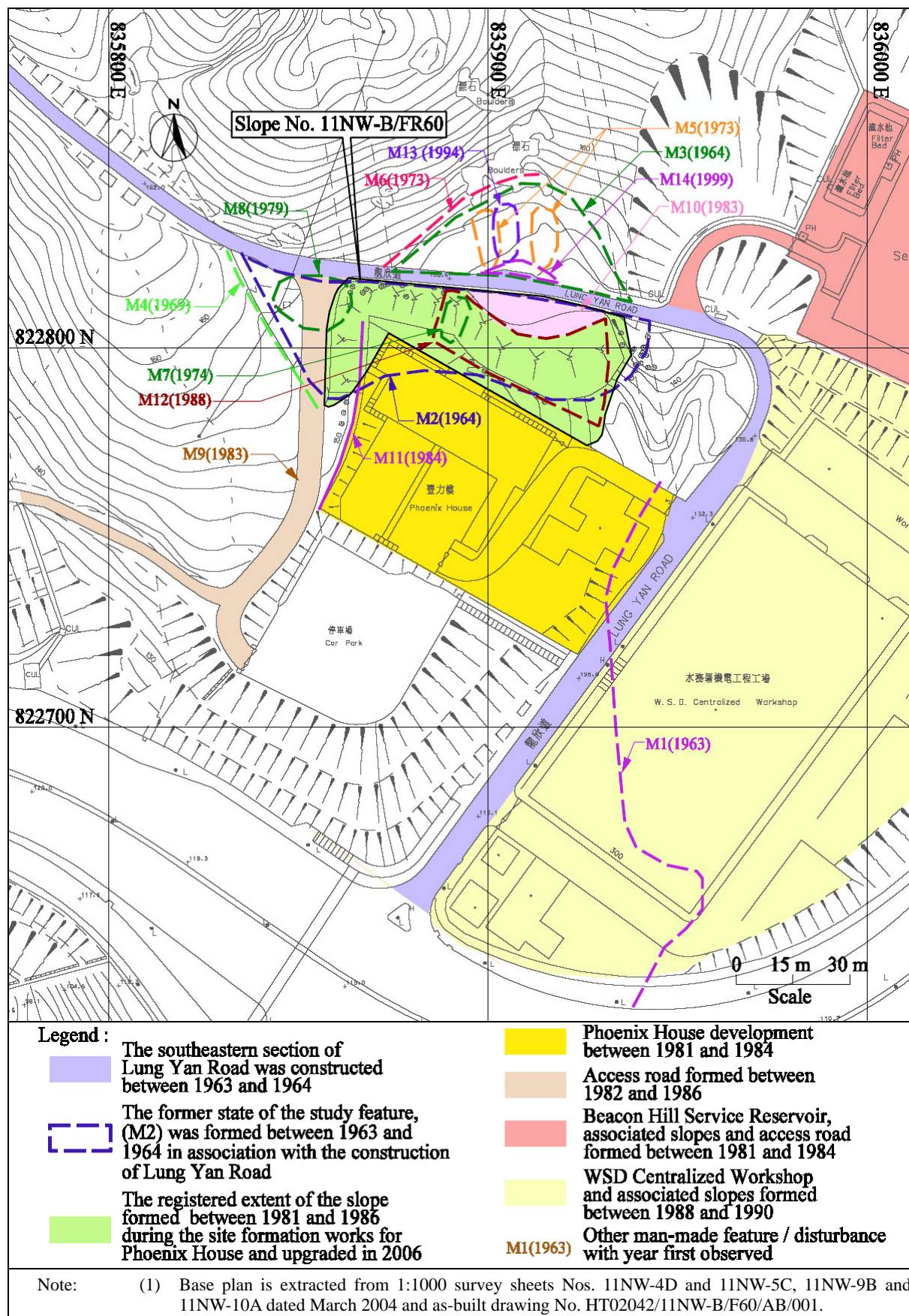


Figure A1 - Site Development History

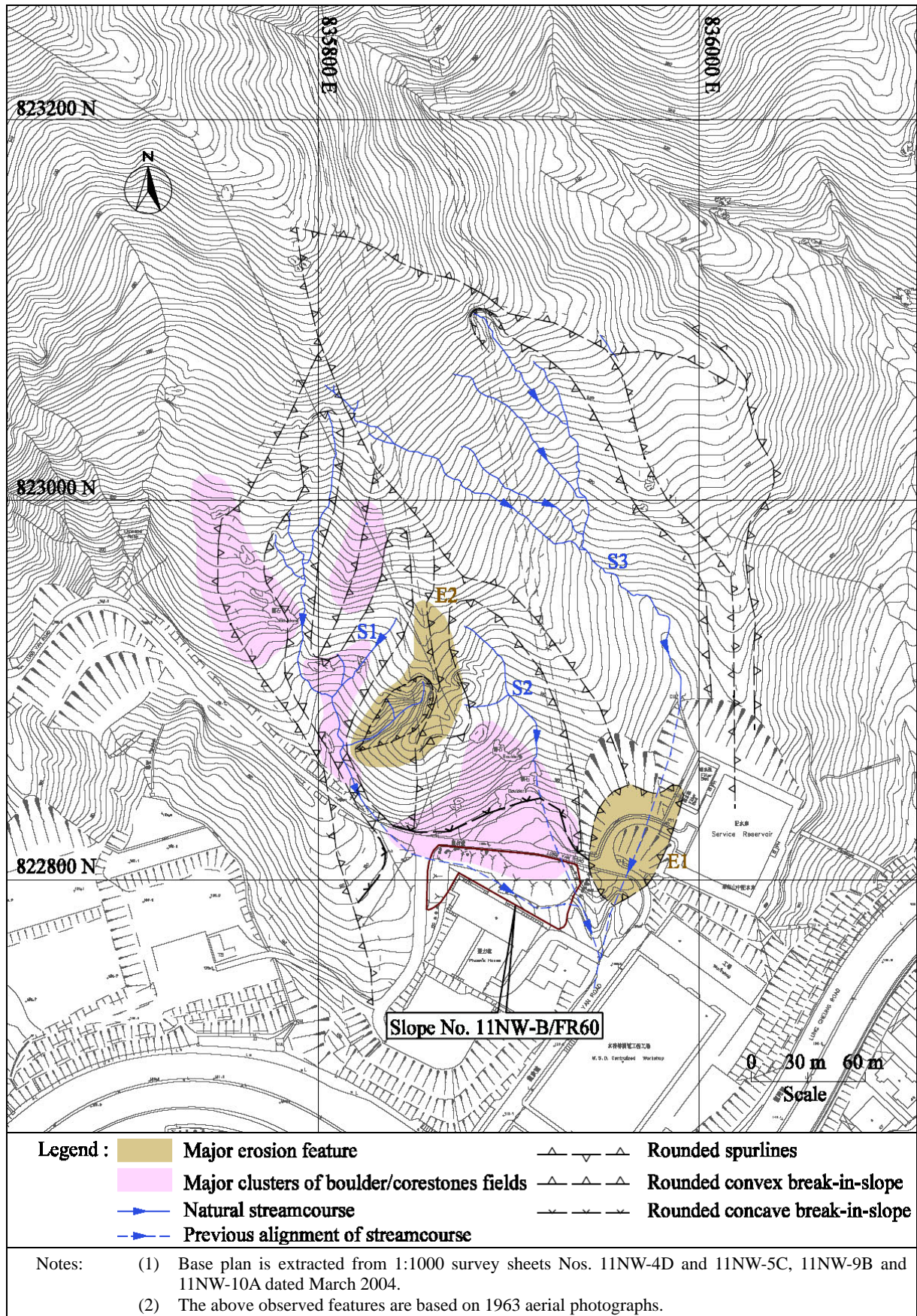


Figure A2 - Site Geomorphology and Hydrology

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.

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

or

- Calling the Publications Sales Section of Information Services Department (ISD) at (852) 2537 1910
- Visiting the online Government Bookstore at <http://www.bookstore.gov.hk>
- Downloading the order form from the ISD website at <http://www.isd.gov.hk> and submit the order online or by fax to (852) 2523 7195
- Placing order with ISD by e-mail at puborder@isd.gov.hk

1:100 000, 1:20 000 and 1:5 000 maps can be purchased from:

Map Publications Centre/HK,
Survey & Mapping Office, Lands Department,
23th Floor, North Point Government Offices,
333 Java Road, North Point, Hong Kong.
Tel: 2231 3187
Fax: (852) 2116 0774

Requests for copies of Geological Survey Sheet Reports, publications and maps which are free of charge should be sent to:

For Geological Survey Sheet Reports and maps which are free of charge:

Chief Geotechnical Engineer/Planning,
(Attn: Hong Kong Geological Survey Section)
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
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Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5346
Fax: (852) 2714 0275
E-mail: wmcheung@cedd.gov.hk

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。

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
美利大廈4樓402室
政府新聞處
刊物銷售組
傳真: (852) 2598 7482

或

- 致電政府新聞處刊物銷售小組訂購 (電話: (852) 2537 1910)
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Geotechnical Manual for Slopes, 2nd Edition (1984), 300 p. (English Version), (Reprinted, 2000).

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

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Geoguide 1 Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2007).

Geoguide 2 Guide to Site Investigation (1987), 359 p. (Reprinted, 2000).

Geoguide 3 Guide to Rock and Soil Descriptions (1988), 186 p. (Reprinted, 2000).

Geoguide 4 Guide to Cavern Engineering (1992), 148 p. (Reprinted, 1998).

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岩土指南第五冊 斜坡維修指南，第三版(2003)，120頁(中文版)。

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