DETAILED STUDY OF THE 16 SEPTEMBER 2002 LANDSLIDE ON SLOPE NO. 11NE-D/C18 AT CHA KWO LING TSUEN, FAN WA STREET, LAM TIN

GEO REPORT No. 160

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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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 last page of this report.

R.K.S. Chan
Head, Geotechnical Engineering Office
January 2005

FOREWORD

This report presents the findings of a detailed study of a landslide incident (GEO incident No. 2002/09/0131) on slope No. 11NE-D/C18, located at Cha Kwo Ling Tsuen, Fan Wa Street, Lam Tin, which occurred at about 11:00 p.m. on 16 September 2002 during heavy rainfall. The landslide involved a failure volume of about 30 m^3 and the debris came to rest against a 2 m-high rockfall fence close to the toe of the slope. A section of the rockfall fence of about 20 m in length was distorted by the impact of the debris. No casualties were reported as a result of the landslide.

The key objectives of the detailed study were to document the facts about the landslide, present relevant background information, review the performance of the rockfall fence, establish the probable causes of the failure and assess the potential for further instability. Recommendations for follow-up actions are presented separately.

The report was prepared as part of the 2001/2002 Landslide Investigation Consultancy for landslides reported within Kowloon and the New Territories between April 2001 and the end of 2002, for the Geotechnical Engineering Office, Civil Engineering Department, under Agreement No. CE 72/2000. This is one of a series of reports produced during the consultancy by Maunsell Geotechnical Services Limited.

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Project Director
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Agreement No. CE 72/2000
Landslide Investigation Consultancy for Landslides Reported within Kowloon and the New Territories between April 2001 and the End of 2002

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1. INTRODUCTION

At about 11:00 p.m. on 16 September 2002, during heavy rainfall, a landslide (GEO incident No. 2002/09/0131) occurred on slope No. 11NE-D/C18, located at Cha Kwo Ling Tsuen, Fan Wa Street, Lam Tin (Figure 1). The landslide (Figure 2 and Plate 1) involved the failure of an estimated 30 m^3 of debris from the upper part of the slope. The landslide debris came to rest against a 2 m-high rockfall fence close to the toe of the slope. A section of the rockfall fence of about 20 m in length was distorted by the impact of the debris. No casualties were reported as a result of the failure.

Following the landslide, Maunsell Geotechnical Services Limited (MGSL), the 2001/2002 Landslide Investigation Consultants for Kowloon and the New Territories, carried out a detailed study of the landslide for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 72/2000.

The key objectives of the detailed study were to document the facts about the landslide, present relevant background information, review the performance of the rockfall fence, establish the probable causes of the failure and assess the potential for further instability. Recommendations for follow-up actions are presented separately.

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

(a) a review of relevant documentary records relating to the development history of the site and the sequence of events leading to the incident,

(b) geological mapping, and detailed inspections and measurements at the landslide site,

(c) aerial photograph interpretation (API),

(d) review of the performance of the rockfall fence,

(e) analysis of rainfall data, and

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

2. THE SITE

2.1 Site Description

Slope No. 11NE-D/C18 is a west-facing cut slope located to the east of Fan Wa Street in Cha Kwo Ling Tsuen, Lam Tin. For ease of reference, a chainage reference line has been established close to the slope toe (Figure 2).

Slope No. 11NE-D/C18 is approximately 220 m long and has a maximum height of about 30 m. The toe of the slope rises from an elevation of approximately 10 mPD at Chainage 0 (the north end) to approximately 22 mPD at Chainage 220 (the south end). The maximum elevation at the slope crest is approximately 54 mPD. The slope typically comprises a lower sub-vertical rock face, approximately 10 m to 15 m high, and an upper soil/rock slope, which has an average angle of about 60°.

Slope No. 11NE-D/C18 has two prominent recesses, one immediately north of the 16 September 2002 landslide location and the other at the south end of the slope (Figure 2).

The slope surface is mostly bare or covered in light vegetation and root growth, with the exception of a 30 m long portion (between Chainages 90 and 120), which was shotcreted following a major landslide in 1995 (Figure 2 and Plate 2), and a 20 m long portion (between Chainages 180 and 200), which is covered with chunam (Figure 2).

The hillside above the crest of the cut slope has a maximum slope angle of about 45° and is covered with dense vegetation. Numerous squatter structures (with squatter control survey numbers assigned by the Housing Department, HD) exist at the north and south ends of the slope toe (Chainages 25 to 45 and Chainages 140 to 220 respectively). Elsewhere, the land at the slope toe is lightly vegetated.

A rockfall fence is situated to the rear of the squatter structures about 5 m in front of the slope toe between Chainages 8.5 and 84 and between Chainages 124 and 154 (Table 1, Figures 2 and 3 and Plate 3). The rockfall fence is 2 m high apart from the section between Chainages 124 and 139, where the rockfall fence comprises a 5 m-high vertical barrier and a 1 m-high inclined portion on top. At Chainage 124, an approximately 2 m-high by 4.5 m long section of the rockfall fence runs normal to the slope.

The rockfall fence has been constructed using steel H-section stanchions of various sizes (101 mm by 101 mm, 76 mm by 156 mm, 156 mm by 88 mm and 160 mm by 80 mm) at 3 m centres (except for the section of the rockfall fence which runs normal to the slope at Chainage 124 where the stanchion spacing is reduced to 2.25 m), connected by three approximately 8 mm diameter tension wires (at the top, middle and bottom of the rockfall fence) with two layers of single-twist wire-mesh, except for the section between Chainages 124 and 139 where the fencing comprises one layer of double-twist wire and one layer of nylon-rope netting. The 5 m-high section of the rockfall fence between Chainages 124 and 139 is also provided with 95 mm by 75 mm I-section walings at heights of about 0.25 m, 2.5 m and 5 m above the ground surface. Full details of the rockfall fence are given in Table 1.

The slope is bounded by slopes Nos. 11NE-D/C499 and 11NE-D/C212 at its north end and by a cut slope No. 11NE-D/C382 at its south end. To the east and southeast are former granite and kaolin quarries respectively (Figure 2 and Plate 4).

No water-carrying services are located at the crest or toe of or on slope No. 11NE-D/C18. A tunnel for the Strategic Sewage Disposal Scheme (SSDS) of the Drainage Services Department runs approximately 90 m north of the slope, at a level of approximately -75 mPD.

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2.2 Maintenance Responsibility and Land Status

According to the Slope Maintenance Responsibility Information System (SMRIS) of the Lands Department (Lands D), the maintenance responsibility of slope No. 11SW-D/C18 rests with the Lands D.

The rockfall fence at the slope toe was constructed by the HD between 1985 and 1987 as part of Squatter Area Improvements (SAI) programme (see Section 2.4). According to the Lands D, following the transfer of squatter control duties in Kowloon from the HD to the Lands D on 1 April 2002, the Squatter Control (Kowloon) Office of the Lands D is responsible for the inspection of the subject rockfall fence as well as issuing repair works orders to the maintenance section of the HD, which is responsible for the maintenance of the rockfall fence.

According to records held by the District Survey Office (DSO) of the Lands D, apart from a government land allocation (No. GLA-TNK 970) located opposite No. 18 Fan Wa Street, there are no land allocations in the form of private land, licences or short-term tenancies in the vicinity of the slope toe. A land status plan reproduced from the DSO's record is presented as Figure 4.

2.3 Subsurface Conditions

2.3.1 Geology

According to the Hong Kong Geological Survey (HKGS) 1:20,000 Solid and Superficial Geology Map Sheet 11 - Hong Kong and Kowloon (GCO, 1986a), the study area is underlain by fine- to medium-grained granite of Mesozoic age. An approximately 50 m wide, east-west trending fine-grained quartz syenite dyke intrusion is shown passing through the southern portion of slope No. 11NE-D/C18 (Figure 5).

The 1:20,000 geological map also indicates that no geological faults pass within 300 m of slope No. 11NE-D/C18. The dominant regional fault directions are north-northwest and north-northeast. The trend of the subject slope face is similar to that of the regional north-northwest trending fault set.

The geological memoir for the area (GCO, 1986b) reports that the Cha Kwo Ling area was quarried for granite aggregate and kaolin and that the kaolin was "derived from a 50 m wide dyke". The memoir also notes that "the surrounding fine- to medium-grained granite is not appreciably kaolinitised".

2.3.2 Previous Ground Investigation

In 1999 and 2000, various contractors carried out ground investigations in the vicinity of the site on behalf of the Hong Kong Housing Authority (HKHA) and the Civil Engineering Department (CED), see Figure 6.

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2.4 Site Development

The history of development of the site has been determined from interpretation of aerial photographs, together with a review of relevant documentary information and site observations. Detailed observations from aerial photograph interpretation (API) are presented in Appendix A. For ease of description in this report, the slope is divided into four areas (Figure 7):

(a) Area 1 (Chainage 0 to 60), at the northern end, where squatter structures and the rockfall fence currently exist at the slope toe,

(b) Area 2 (Chainage 60 to 120), where the September 2002 incident occurred, and below which squatters and almost the entire length of the previous rockfall fence were cleared after a major landslide in 1995 (see Section 2.5.1),

(c) Area 3 (Chainage 120 to 157), where squatter structures and the rockfall fence currently exist at the slope toe, and

(d) Area 4 (Chainage 157 to 226), where squatter structures are present at the slope toe but no rockfall fence has been constructed.

Based on the earliest aerial photographs of the area (taken in 1945), slope No. 11NE-D/C18 appears to have been formed to its present profile by 1945. The area to the east and southeast of the cut slope had been quarried but no structures were present in the immediate vicinity of the slope.

Squatter structures at the toe of the cut slope were first observed in the 1959 aerial photographs and by 1964 the number of structures increased appreciably, particularly below the north and south ends of the slope.

Fan Wa Street was constructed between 1973 and 1974. During the same period, a significant number of squatter structures were constructed between Fan Wa Street and the central portion of slope No. 11NE-D/C18.

Between February and August 1985, HD constructed an approximately 100 m length of a 2 m-high rockfall fence below Areas 1 and 2 between about Chainages 8.5 and 95 (Figure 7) under the SAI programme. Thirty squatter structures located directly below slope No. 11NE-D/C18 were cleared to allow the construction of the rockfall fence (see Section 2.6).

The rockfall fence was extended into Area 3 as part of further SAI works carried out by HD between January and October 1987 (Figure 7). The extended rockfall fence comprised some 30 m to 35 m length of a 5 m-high rockfall fence and about 15 m length of a 2 m-high rockfall fence. A squatter structure was cleared to facilitate the construction of the extension of the rockfall fence (see Section 2.6).

A squatter structure below slope No. 11NE-D/C18 was cleared in 1990 under Non-Development Clearance (NDC) at the recommendation of the GEO (see Section 2.6).

A total of 14 squatter structures below slope No. 11NE-D/C18 was cleared in 1990 and 1992 by HD at the recommendations of the GEO following two landslide incidents (GEO incidents Nos. K90/6/1 and K92/5/9).

Following a major landslide in August 1995 (see Sections 2.5.1 and 2.6), 39 squatter structures below Area 2 were cleared by HD at the recommendation of the GEO. The associated squatter clearance work was completed by 22 October 1996. Repair works, including removal of an approximately 60 m long section of rockfall fence (between Chainages 64 and 124), which was destroyed by the August 1995 landslide (1,000 m^3 in volume), were carried out by the Highways Department (HyD) between November 1996 and January 1997.

2.5 Past Instability

2.5.1 GEO Incident Reports

According to GEO's landslide database, ten landslide incidents were recorded at slope No. 11NE-D/C18 since 1985 (Figure 8).

The location of one of the landslide incidents (GEO incident No. K87/8/3) is not given in the available documentation but MGSL has inferred that it is located within Area 4 by reference to squatter structure (squatter control survey No. RKT/1A/C/C85), which is shown on the GEO incident report. For the nine known locations, a critical review of the GEO Incident Reports, in conjunction with site inspection, suggests that seven of the incidents occurred in different locations to those indicated on the Incident Reports (Figure 8). Relevant details of the incidents, including effects of the landslide debris on the rockfall fence below, are presented in Table 2.

The incidents were mostly landslides or boulder falls/rockfalls and invariably occurred after or during rainfall. The failure volumes did not exceed 20 m^3 with the exception of GEO incident No. K95/8/7, which involved an estimated volume of up to 1,000 m^3 (deduced from the landslide scar dimensions recorded in the incident report as no estimated failure volume was given). For two of the incidents (i.e. GEO incidents Nos. K87/5/1 and K87/5/2), the failure volumes were unknown but they are likely to have been minor (i.e. failure volumes less than 50 m^3) as inferred by the sketches and photographs presented in the respective GEO incident reports.

A review of the GEO incident reports indicates that the debris in four of the ten recorded landslides incidents impacted on the rockfall fence. Of these four cases, impact by the debris of the major landslide in 1995 (GEO incident No. K95/8/7) destroyed a 60 m length of the rockfall fence (Plate 5). The other minor landslide incidents (GEO incidents Nos. K89/5/120, K90/4/2 and K95/8/26), with estimated failure volumes of between 1 m^3 and 20 m^3, did not result in any damage to the rockfall fence. GEO incident No. K92/5/9 is a tree-fall incident and the fallen tree came to rest on the top of the rockfall fence.

Of the other five landslide incidents, GEO incident No. K87/5/2 occurred prior to

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construction of the rockfall fence and in case of GEO Incident No. K85/8/13 the debris came to rest before reaching the rockfall fence. The three remaining landslides, namely, GEO incidents Nos. K87/5/1 (with an unknown failure volume that resulted in the damage of the "steel plate" wall of a squatter structure), K87/8/3 (failure volume about 3 m³ that involved piling up of landslide debris against a squatter structure) and K90/6/1 (failure volume about 1.5 m³ that resulted in the clearance of the affected squatter structures, see Section 2.6) all occurred in Area 4 where no rockfall fence had been constructed.

For those cases where the debris was not contained by the rockfall fence, the estimated travel angles of the debris ranged from about 28° to 53°.

One of the ten recorded landslide incidents (GEO incident No. K92/5/9) occurred a short distance below the site of the 16 September 2002 landslide (Figure 8). A photograph of GEO incident No. K92/5/9, which also delineates the area corresponding to the 16 September 2002 landslide, is presented in Plate 6.

2.5.2 GEO's Database on Landslide Consequence

The Database on Landslide Consequence, which was commissioned by the GEO under Agreement No. GEO 8/95, covers reported landslides involving casualties that occurred between 1948 and 1995. The database was compiled by Mitchell McFarlane Brentnall & Partners International Ltd. (MMBP, 1996) in June 1996 using extracts from archive newspapers and from records available within the GEO. The database provides information on two landslides at slope No. 11NE-D/C18.

The South China Morning Post (SCMP) newspaper reported a landslide that occurred on 3 September 1962 following typhoon 'Wendy'. This incident resulted in four fatalities, eight injuries and 22 people were made homeless (whereas a report in the Wen Wei Po newspaper claimed that over one hundred were made homeless). Whilst no details of the scale of failure were given, it was reported that the landslide occurred on "the hill behind wooden huts Nos. 207, 208, 209 and 209A Main-street" and that "Two of the huts were completely buried and destroyed under tons of earth and rocks, while the others were partially damaged".

The SCMP also reported a landslide that occurred at an unnumbered squatter hut opposite No. 10 Fan Wa Street on 25 August 1976, following tropical storm 'Ellen'. Reporting on the same incident, the Sing Tao Jih Pao stated that "the whole squatter house No. 22x was buried by debris". The landslide caused one fatality.

The locations of these two landslides listed in the Database on Landslide Consequence were not visible on the available aerial photographs but have been inferred by MGSL by reference to the building and squatter structure numbers as reported in the newspapers (Figure 8). No documented plans are available to confirm these locations.

2.5.3 Aerial Photographs

Evidence (in the form of absent vegetation) was observed on aerial photographs for

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four of the recorded landslide incidents (GEO incidents Nos. K85/8/13, K90/4/2, K92/5/9 and K95/8/7), see Figure 8. Vegetation re-established on three of the landslide scars within several years whilst the scar resulting from GEO incident No. K95/8/7 had been covered with hard surfacing by 1997. The remaining recorded GEO incidents, along with the 1962 and 1973 failures listed in the Database on Landslide Consequence, could not be confirmed from the aerial photographs.

In addition, evidence (also based on the absence of vegetation) of two (unrecorded) landslides in Area 4 of slope No. 11NE-D/C18 was observed in the 1967 and 1983 aerial photographs (Figure 8). The 1967 landslide appeared to be minor and by 1972 the scar had been covered with hard surfacing. The 1983 landslide appeared to be relatively localised, although several squatter structures below the scar of the 1983 landslide had been cleared by 1984. New squatter structures had been erected in the cleared area by 1985.

2.6 Squatter Clearance

The history of squatter clearance has been inferred from API and an examination of records in the GEO, Lands D and HD. The layout of the squatter structures, based on information provided by the Squatter Control (Kowloon) Office of the Lands D in April 2003, is given in Figure 9. The locations of the squatter structures are approximate according to Lands D.

On 5 September 1984, upon GEO's recommendation "to create a safety zone" and to allow construction of the rockfall fence at the toe of slope No. 11NE-D/C18, the HD cleared a total of 128 squatter structures under Clearance Order No. KN414. Of these, 30 squatter structures (squatter control survey Nos. RKT/1A/B/38 to 45, 55, 57, 58, 66, 70, 71, 84 to 87, 92, 145, 146, 151, 200, 206 (portion only), 224 and 233 to 237) were located directly below slope No. 11NE-D/C18. The HD confirmed that the squatter structures involved were either demolished or made uninhabitable during the clearance.

In December 1986, the Mainland East Division of the Geotechnical Control Office (GCO, renamed GEO in 1991), made recommendation to the HD to clear the squatter structure assigned with squatter control survey No. RKT/1A/B/224 under NDC although this squatter structure should have been cleared in September 1984 (see preceding paragraph) according to the HD.

A squatter structure (squatter control survey number unknown) below the junction of slope Areas 2 and 3 of slope No. 11NE-D/C18 was cleared in 1987 to facilitate extension of the rockfall fence into Area 3.

An NDC at Cha Kwo Ling Tsuen (clearance No. KN585) was completed in February 1990. According to information provided by the HD, the squatter structures (squatter control survey No. RKT/1A/B/224) below slope No. 11NE-D/C18 was demolished on 16 February 1990.

In June 1990, following a landslide (GEO incident No. K90/6/1), the Mainland East Division of the GCO made the recommendation to the HD to clear squatter structures with squatter control survey Nos. RKT/1A/B/308 and 309, and RKT/1A/C/1, 2, 3, 5 and 6. In

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July 1991, District Lands Office/Kowloon East confirmed that the recommended clearance had been completed.

In May 1992, after a landslide incident (GEO incident No. K92/5/9), the Mainland East Division of the GEO recommended to the HD, clearance of seven squatter structures (squatter control survey Nos. RKT/1A/B/168 to 174). According to records held by the Squatter Control (Kowloon) Office of the Lands D, these squatter structures had been cleared.

In August 1995, as a result of a landslide (GEO incident No. K95/8/7), the Mainland East Division of the GEO made the recommendation to the HD to clear 39 squatter structures (squatter control survey Nos. RKT/1A/B/205, 206, 209 to 211, 215, 218 to 223, 225 to 231, 237 to 248, 250 to 252, 259 to 261 and 310 and also No. YKE/YA3/6). The clearance was carried out by the HD in 1996.

2.7 Previous Studies and Assessments

2.7.1 Phase I Re-Appraisal of Cut and Natural Slopes and Retaining Walls Study

Binnie & Partners (B&P) inspected slope No. 11NE-D/C18 in March 1977, as part of the Phase I Re-appraisal of Cut and Natural Slopes and Retaining Walls Study. B&P (B&P, 1978) considered the slope was a “high” risk-to-life in the event of failure. The slope was subsequently registered in the 1977/78 Slopes Catalogue. The registration report recommended further action to “Warn inhabitants of danger. Provide adequate drainage and rock fall areas. Protect soil slope at north end or evacuate selected squatters”.

2.7.2 Stage 1 Study

In April 1979, the Existing Slopes Division of the GCO undertook a Stage 1 Study of slope No. 11NE-D/C18 (GCO, 1979). The report noted that the slope comprised “mainly zone D and C granite [i.e. Grade II and III granite] with a 1 to 5 m deep layer of zone A [i.e. Grade V granite] layer at the crest”. No observations of seepage or sheeting joints were recorded although the report noted that “Many potential block failures were observed on the rock face as were signs of numerous past rock falls”. The report also noted that two rockfall zones had been fenced off (one below the chunamed area at the southern end of the study feature and the other below slope No. 11NE-D/C499). The report recommended that “If large-scale clearance of the squatters is not scheduled for some time, squatters in immediate danger at the toe should be cleared and a fenced rock fall zone extended where necessary along the toe”.

2.7.3 Cha Kwo Ling Development Investigation - Feasibility Study

In May 1980, B&P provided comments on a Planning Study Layout Plan for the New Works Division of the GCO. B&P noted that the rock slopes in the area “contain large sheeting joints with significant evidence of seepage”. No further relevant records on the Planning Study were found.

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2.7.4 Squatter Area Improvement Studies

Records held by the GEO suggest that the rockfall fence constructed in 1985 was designed by Binnie & Partners (Hong Kong), B&P, for the HD in association with Squatter Area Improvement works and that the "design of rock trap fencing" (i.e. the rockfall fence) was accepted by the Design Division of the GCO. The design drawings or records of design analysis could not be located.

In 1986, B&P made recommendations (B&P, 1986) to the HD to extend the rockfall fence to protect squatter structures from "potentially unstable boulders" on the slope (i.e. close to the junction of Areas 2 and 3). As-constructed drawings indicate that the works were carried out between January and October 1987 and comprised erection of some 20 m of 5 m-high rockfall fence and about 6 m of 2 m-high rockfall fence. These recorded lengths differ from those established from site measurements by MGSL (see Section 2.4). An interview in November 2002 with one of the former B&P engineers responsible for the design of the rockfall fence constructed in 1987 revealed that the rockfall fence was a prescriptive design that was based on walkover surveys and HD's standard drawings and that no slope stability assessment was carried out by B&P.

No records of the stability assessment for slope No. 11NE-D/C18 have been found in the GEO or the HD file records.

2.7.5 SIFT and SIRST Studies

In 1992, the GEO initiated a project entitled "Systematic Inspection of Features in the Territory" (SIFT). This project aimed to search systematically for slopes not included in the 1977/78 Catalogue of Slopes and to update information on previously registered features by studying aerial photographs together with limited site inspections. The SIFT study of slope No. 11NE-D/C18 was carried out in September 1995 and the slope was designated SIFT Class "C1", i.e. a slope that had "been formed or substantially modified before 30.6.78". The SIFT report noted that "Slope cut before earliest available aerial photographs (1959 - F64: 287/288). Failure on part of slope feature can be seen in 1963 aerial photographs" (although no failures could be observed on the 1963 aerial photographs which were reviewed as part of this study).

In July 1994, the GEO commenced a project entitled "Systematic Identification and Registration of Slopes in the Territory" (SIRST), to update the 1977/78 Catalogue of Slopes. An inspection of slope No. 11NE-D/C18 carried out by the SIRST consultant in April 1998 noted slight to moderate seepage "below mid-height or from isolated rock joints" of the slope and observed no signs of distress of the slope. The inspection also recorded that both the crest and toe facilities of slope No. 11NE-D/C18 were undeveloped green belt and the Consequence-to-life Category was taken as '3'. On this basis, the calculated CNPCS score of slope No. 11NE-D/C18 was 3.146.

2.7.6 Feasibility Study for Proposed Development at Cha Kwo Ling Kaolin Mine Site

Fugro (HK) Ltd. (2002) is currently carrying out a study entitled "Feasibility Study for

Development at Cha Kwo Ling Kaolin Mine Site (2001)" on behalf of the Housing Section of the Civil Engineering Department (CED) under Agreement No. CE 81/98. According to the Draft Geotechnical Assessment (GA) Report dated September 2002, the site layout shows that a school is planned at the location of slope No. 11NE-D/C18. The drawings of the proposed site formation show that the subject slope is to be completely removed and that the squatter structures currently located at the slope toe are to be cleared. The tentative programme for commencement of site formation is shown as December 2004.

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2.8 Slope Maintenance Inspections

2.8.1 Engineer Inspections and Routine Maintenance Inspections

On 15 December 1999, Halcrow Asia Partnership (HAP) carried out an Engineer Inspection (EI) of slope No. 11NE-D/C18 on behalf of the Lands D (Plate 7) under Agreement No. CE 48/98. No signs of distress were noted during the EI. The overall state of maintenance of the subject slope was diagnosed as "Poor". The recommendations by HAP are as follows: "Consideration should be given to the removal of squatters (Category 2) at the toe of the feature [identified by HAP] as they are vulnerable to landslips, especially during periods of heavy rain. If the squatters cannot be removed prior to the next raining season, minimal non-structural preventive maintenance work should be undertaken. In the meantime, provision of warning (Dangerous Hillside) Sign - boards erected at the toeline of the slope is recommended. Furthermore, it is recommended to update the SIRST records to reflect the change in consequence-to-life category of feature".

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Following the EI in December 1999, HAP proposed to change the consequence-to-life category of the slope to '1'. This was a subject of discussion between Lands D and the Slope Safety Division of the GEO. At the time of the 16 September 2002 landslide, the consequence-to-life category of slope No. 11NE-D/C18 was '3' according to the Slope Information System.

The December 1999 EI report also recommended routine maintenance works (including unblocking surface channels and removing undesirable vegetation, etc.) and preventive maintenance works (including provisions of surface drainage channels and a slope crest channel).

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Apart from the 1999 EI, no other EIs or routine maintenance inspections of slope No. 11NE-D/C18 were carried out by the Lands D before the 16 September 2002 landslide.

2.8.2 Slope Maintenance and Landslide Repair Works

According to the Lands D, "no maintenance works have been arranged for this feature before the [16 September 2002] landslide due to its low priority as compared with other Cat. 1 and 2 features".

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Following the major landslide on the slope on 12 August 1995 (GEO incident No. K95/8/7), urgent repair works to the failure were carried out by HyD between November 1996 and January 1997. The landslide scar was shotcreted and the destroyed section of the rockfall fence (about 60 m long) was removed, which was not reconstructed as the squatters

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below this slope portion had been cleared.

Subsequent to the 16 September 2002 landslide, urgent repair works comprising shotcreting of the landslide scar and removal of landslide debris, recommended by the Lands D, were completed by the Lands D's contractor on 11 January 2003.

3. THE 16 SEPTEMBER 2002 LANDSLIDE

The landslide, which was reported to the GEO at 4:15 p.m. on 17 September 2002 by The Neighbourhood Advice-Action Council (NAAC), reportedly occurred at 11:00 p.m. on 16 September 2002. No eye-witness accounts of the landslide could be obtained.

The landslide occurred in the central portion of slope No. 11NE-D/C18 (i.e. Area 2) during heavy rainfall and involved the failure of an estimated volume of 30 m^3 of soil and rock material detached from the upper part of the slope, at an elevation of approximately 25 mPD (Figure 2).

The landslide occurred approximately 16 m above the slope toe, and immediately above a near-vertical rock face parallel to the overall slope (Figure 10 and Plate 1). The landslide debris travelled some 5 m beyond the slope toe and came to rest against the 2 m-high rockfall fence. A 20 m long section of the rockfall fence (Chainages 64 to 84) was distorted by the impact of the debris. No casualties were reported as a result of the landslide.

The landslide occurred close to a previous landslide incident (GEO incident No. K92/5/9). A record photograph taken of the previous landslide site (Plate 6) shows that the area of the 16 September 2002 landslide was relatively steep and covered with shrubs. A pre-existing discontinuity, which coincides with the base of the 16 September 2002 landslide scar, is also visible on the photograph.

4. FIELD OBSERVATIONS FOLLOWING THE 16 SEPTEMBER 2002 LANDSLIDE

4.1 Landslide Site at Slope No. 11NE-D/C18

MGSL carried out several inspections of the slope as part of this study in the period between September 2002 and November 2002. The surface of rupture comprised a steep (approximately 80°) main scarp and a relatively planar basal surface dipping adversely out of the slope at an angle of approximately 35° (Figure 10 and Plate 8).

The main scarp was about 3 m high by 10 m wide. The slope-forming materials exposed comprised weak grey and light yellow, highly to moderately decomposed (Grade III to IV) medium-grained granite (PW 30/50 to PW 50/90), see Plate 9.

The scar floor was found to comprise three undulating joints (S1a, S1b, S1c) dipping out of the slope face with a dip angle ranging from 25° to 35° (Figure 10 and Table 3) that extend across the full width of the scar (Plate 10). These joints are inferred to be sheeting joints, primarily due to their rough, undulating nature (typical of defects created by tensile stress-relief forces) and similarity in orientation to the slope of the original hillside. The sheeting joints contain insitu, completely decomposed granite up to 300 mm thick. A

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sheeting joint, S2, similar to joint S1a in orientation but with only slightly decomposed walls and tight aperture, was observed about 6 m below the landslide scar (i.e. about 10 m above the slope toe) at the location of Section A-A, see Figure 10 and Plate 10.

No soil pipes were observed within the surface of rupture and there were no signs of tension cracks above the landslide source area. No natural drainage lines were observed above the landslide crown, and the catchment above the source is generally linear (in plan) and does not lend itself to concentration of surface run-off towards the source area of the landslide.

The landslide source area is underlain by slightly decomposed (Grade II) fine- to medium-grained granite, which exhibits a well-defined geological structure. Three regular joint sets (J1, J2 and J3) are apparent (Figure 11 and Table 3). Sub-vertical joint sets J1 and J2 are normal and parallel to the slope face respectively and act respectively as side and back releases to blocks allowing sliding or toppling on other joints. Joint set J3 is sub-horizontal, dipping into the slope face and is generally not unfavourable to slope stability.

Constant moderate seepage was seen issuing from sheeting joint S1a (Figure 10 and Plate 9) at the time of inspecting the landslide. No seepage was observed from and above sheeting joint S1b (the entire surface of rupture being dry) or from the rock joints below the landslide scar, or within the slope recess to the north.

Due to the steepness of the rock cut face (about 85°) below the source, the failure debris, which was about 30 m^3 in volume, was directed downward onto the relatively flat ground at the slope toe (Plate 1). Further debris travel was constrained by the 2 m-high rockfall fence located approximately 5 m beyond the slope toe (Plate 11). The stanchions and wire-mesh fencing were distorted away from the slope at an angle of approximately 10° to the vertical (Figure 10).

The surface of transportation of the failure debris, which comprised very strong, pinkish grey, slightly decomposed (Grade II) granite, showed signs of mild abrasion but there appeared to be virtually no erosion or entrainment of the surface. Some failure debris had travelled down the recess immediately north of the landslide scar and bifurcated at a tree stump (the tree was probably knocked down by the landslide debris) close to the slope toe (Plate 1). The landslide debris comprised fine to coarse gravelly, slightly silty sand with many cobbles and some boulders of highly to moderately decomposed granite (Grade III to IV).

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4.2 Remainder of Slope No. 11NE-D/C18

Rock joints of similar characteristics to the three undulating sheeting joints (S1a, S1b and S1c) form part of a distinct zone of similarly orientated geological features (designated composite sheeting joint zone S1) that along with sheeting joint S2 at the location of the 16 September 2002 landslide (Figure 10) can also be identified at the location of the 1995 major landslide (which is to the south of the 2002 landslide and now obscured by shotcrete). Based on a critical review of the post-failure photographs of the 1995 landslide, a discontinuity or zone of discontinuities with similar orientation to that of sheeting joint zone S1 outcrops near the crest of the 1995 landslide area whilst the base of the 1995 landslide scar

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is characterised by an outward dipping surface with an orientation similar to that of joint S2 (Plate 12). Owing to limited access and the presence of dense vegetation cover, the persistence of these sheeting joints in areas between the locations of the 1995 and 2002 landslides cannot be assessed in detail. Given the nature and characteristics of sheeting joints, the presence of these sheeting joints between these two locations cannot be ruled out. A joint with similar orientation was also observed in the north, where it extended at least 20 m into the prominent recess and where a joint similar to joint S1a was observed to be ‘open’ in places due to washout of the completely decomposed granite infill. Further sheeting joints could also be seen near the north end of the subject slope, where they occur at lower elevations.

Except for the existing landslide scars, no signs of mass movement or signs of distress associated with sheeting joint controlled failure were observed over the length of slope No. 11NE-D/C18.

The rock joint system J1 to J3 observed at the 2002 landslide was also found over the remainder of slope No. 11NE-D/C18. These main structural controls are consistent throughout the full extent of the slope. Joints of each set, together with random joints, occurred as minor joints (generally tight, closely to medium spaced, not persistent) and also probably as persistent major joints (tight or extremely narrow and medium to widely spaced). Incipient small-scale failures, associated with the interaction of joints J1 and J2, were observed in slope Areas 2 and 3. These failures were particularly prevalent at the junction of slope Areas 2 and 3. There was evidence that vegetation root growth was also contributing to small-scale block failure (Plate 13). In Area 3, the recently detached small rock blocks were contained by the rockfall fence (Plate 14). In Area 2, where the rockfall fence was removed along with squatter structures, some rock blocks had generally come to rest within about 4 m of the slope toe.

Light seepage from the lower rock slope was noted at a number of locations along the length of the study slope. This was not as heavy as the localised seepage observed at the base of the 16 September 2002 landslide source area.

The rock mass in Areas 1 to 3 of the slope appeared to be unaffected by kaolinitisation but owing to difficult access, which was partly caused by dense vegetation, it was not possible to confirm whether the prominent recess at the southern end of the slope (i.e. within the quartz syenite dyke) was also affected by kaolinitisation.

Mature trees were observed at a number of locations along the length of the study slope. A number of trees were growing out of the steep rock face at low angles (typically 20° above the horizontal) with their roots extending into open rock joints.

4.3 Rockfall Fence

The rockfall fence, except for the portion damaged by the 16 September 2002 landslide between Chainages 64 and 84, was generally in a reasonable condition. The stanchions, walings and tension wires were rusted in places, but no significant signs of corrosion or distress were noted. Similarly, no signs of corrosion or distress were noted in the wire fencing.

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The uppermost tension wire was found to be broken between Chainages 22 and 64 and also over the 4.5 m long section at Chainage 124 which runs normal to the slope.

No rockfall fences were found between Chainages 42 and 45 and between Chainages 48 and 52.

5. ANALYSIS OF RAINFALL RECORDS

The nearest GEO automatic raingauge (K08) to the landslide site is located some 800 m northeast of the site at FDBWA Sze To Ho Secondary School (Figure 1). This raingauge records and transmits rainfall data at 5-minute intervals via telephone line to the GEO. The incident occurred at approximately 11:00 p.m. on 16 September 2002.

The daily rainfall recorded by raingauge No. K08 over the month preceding and two days following the landslide incident is presented in Figure 12. The hourly rainfall readings for the period between 15 and 17 September 2002 are also shown on Figure 12. The peak hourly rainfall relevant to the landslide incident (approximately 63 mm) was recorded between midnight and 1.00 a.m. on 17 September 2002.

Analysis of the return periods of the rainfall intensities preceding the landslide incident using the rainfall data recorded by raingauge No. K08 with reference to historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994) is given in Table 4. The results show that the 7-day rolling rainfall of 463 mm before the landslide was the most severe, with a corresponding return period of 4 years. The return periods were also assessed based on statistical parameters derived by Evans & Yu (2001) from data recorded by the local automatic raingauge No. K08 between 1984 and 1997. It is noted that in this case, there is no significant difference between the estimated return periods based on the historical rainfall data at the Hong Kong Observatory and the data from raingauge No. K08.

A comparison of the patterns of nine selected past major rainstorms recorded at raingauge No. K08 between 1986 and 2002 is presented in Figure 13. The rolling rainfall preceding the 16 September 2002 landslide is less severe than the previous rainstorms.

Using the historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994), the return periods of the rainfall intensities for the nine previous recorded landslide incidents have been analysed and are presented in Appendix B. The results show that the most severe rainfall durations vary from 1 hour (with a corresponding return period of about 19 years) to 31 days (with a corresponding return period of about 76 years for the major landslide in August 1995), whist the majority of rainfall durations had return periods of about 2 years.

6. DIAGNOSIS OF THE LANDSLIDE

6.1 Site Setting and Probable Causes and Mechanism of the Landslide

The 16 September 2002 landslide occurred at the crest of cut slope No. 11NE-D/C18, which has a gradient of approximately 85° and the natural hillside above has a maximum gradient of approximately 45°. There is a sharp change in slope morphology immediately north of the landslide scar, where the slope face recedes rapidly to form a prominent recess in the overall slope face.

Post-failure observations at the landslide scar revealed that the upper slope comprised weak, grey and light yellow, highly to moderately decomposed (Grade III to IV) medium-grained granite with some completely decomposed (Grade V) granite infill along rock joints.

The landslide scar is underlain by slightly decomposed (Grade II) granite, which exhibits a well-defined geological structure. Three regular joint sets (J1, J2 and J3) are apparent. Sub-vertical joint sets J1 and J2 are normal and parallel to the slope face respectively (with those at the landslide site forming side and back release planes respectively to the landslide). Joint set J3 is sub-horizontal, dipping into the slope face.

The floor of the landslide is characterised by a composite sheeting joint zone (S1) dipping out of the slope face at approximately 35° and extending the full width of the scar. The lowermost sheeting joint, S1a, forms a boundary between an upper partially weathered rock mass and a lower, relatively impermeable rock mass.

The natural terrain above the landslide does not lend itself to concentration of surface run-off toward the landslide source area. However, in the recess to the north, seepage was observed from sheeting joint S1a. Completely decomposed (Grade V) granite infill had been washed out in places, suggesting that the seepage had been continuing for some time.

The primary failure mechanism was translational sliding along adversely dipping sheeting joints in the source area, at an elevation of about 25 mPD. The following factors are considered to have contributed to the failure:

(a) an oversteep soil/rock cut slope with weak rock mass,

(b) presence of an adversely orientated composite sheeting joint zone (S1) which formed the floor of the rupture surface,

(c) presence of sub-vertical joint sets J1 and J2 which formed side and back release surfaces respectively, and facilitated sliding on sheeting joint S1, and

(d) presence of a prominent recess immediately north of the source area which might have reduced the confining pressure to the rock mass in the locality, allowing joint sets J1 and J2 to gradually open up with time in a northward and westward direction respectively.

The landslide was probably triggered by infiltration and it is likely that transient water ingress into the near-surface sheeting joints acted to increase the pore water pressure and reduce the shearing resistance along the joint infill.

The rainstorm preceding the landslide had a return period of about 4 years and was not particularly severe. Progressive deterioration may therefore also have contributed to the landslide. In particular, the adjacent slope recess could have acted to reduce confining

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pressures, allowing joint sets J1 and J2 to open with progressive downslope movements and hence reducing their shearing resistance. Marginal stability may have been maintained for many years until the effects of progressive deterioration of the slope condition meant that infiltration during a comparatively unexceptional rainstorm was sufficient to cause failure. Persistent, moderate seepage was observed close to the base of the surface of rupture after the landslide.

The cause of the 16 September 2002 landslide is therefore considered to be due to the build-up of transient water pressure within the adversely orientated sheeting joint.

6.2 Mobility of the Landslide Debris

The landslide debris comprised fine to coarse gravelly, slightly silty sand with many cobbles and some boulders of highly to moderately decomposed (Grade III to IV) granite.

Due to the steepness of the rock face below the source, the failed mass fell directly downwards onto the relatively flat ground at the slope toe. The landslide debris came to rest at the slope toe and the reach of the debris was constrained by the 2 m-high rockfall fence located about 5 m beyond the slope toe. The landslide debris piled up to about the top of the rockfall fence, which was distorted away from the slope at an angle of approximately 10° from the vertical.

No field evidence of any fast movement of the landslide debris was identified in post-failure observations. The comparatively minor damage to the rockfall fence indicates that the velocity of the landslide debris had substantially reduced after impacting the floor at the toe of the slope. Only a small volume (< 0.5 m^3) of debris had travelled over the rockfall fence. Post-failure observations indicated that the landslide debris was dry, which is consistent with the observation of no seepage above sheeting joint S1a at the base of the landslide scar.

6.3 Performance of the Rockfall Fence

Review of the various GEO incident reports indicates that the rockfall fence was struck by the landslide debris in five of the eleven recorded landslide incidents (including the September 2002 landslide, see Section 2.5.1 and Table 2). One of the other six incidents occurred prior to the construction of the rockfall fence. In another case, the landslide debris came to rest before reaching the rockfall fence and three other incidents occurred in Area 4 where no rockfall fence had been constructed. Another landslide incident is a tree-fall incident and the fallen tree came to rest on the top of the rockfall fence.

The rockfall fence was prescribed by a geotechnical consultant in 1986 and no detailed design assessment was carried out. The rockfall fence appeared to be effective in intercepting some minor landslide incidents (volumes ranging from 1 m^3 to 30 m^3). However, a 60 m length of rockfall fence was destroyed by the August 1995 major landslide (a failure volume of about 1,000 m^3).

7. DISCUSSION

The joint system defines approximately rectangular blocks dipping slightly into the slope face, which does not give rise to potential failure on a uniform west-facing slope. However, due to the steepness of the slope face and the presence of slope recesses and local changes in the orientation of the slope face, possible failure modes exist over certain parts of the slope. These modes include toppling and wedge failures, which are likely to give rise to relatively small-scale detachments. In addition, the presence of sheeting joints dipping out of the slope face, if persistent over a large area, combined with seepage and/or the structural joint control, could provide the potential for large-scale sliding failures, such as that illustrated by the 12 August 1995 major landslide with a failure volume of about 1,000 m^3.

Several of the past landslides at the subject slope have been small in volume (< 30 m^3) and form spatial clusters that appear to identify zones susceptible to instability (Figure 14). To date, the large-scale, sheeting joint-controlled failure on 12 August 1995 (1,000 m^3) and the sheeting joint-controlled failure on 16 September 2002 (30 m^3) have been confined to Area 2. In Areas 1, 3 and 4, previous failures are characterised by small-scale rockfalls, which appear to have been controlled by the geological structure of joint sets J1 and J2 in conjunction with local variations in orientation of the slope face.

Area 2 is associated with all the contributory factors listed in Section 6.1 above, most notably the sheeting joints and associated seepage. The sheeting joints are adversely orientated, dipping out of the slope face at about 25° to 35° and may be laterally extensive (possibly tens of metres to the south and about 20 m to the north of the 16 September 2002 landslide). Owing to the limited access and the dense unplanned vegetation in parts of the slope (see Plate 12), the persistence of these discontinuities could not be assessed in detail. However, the possibility that they may continue for a substantial distance cannot be ruled out. The joints are typically very widely spaced and infilled with Grade V granite with an aperture width of up to 300 mm. Depending on factors such as shear strength of the joints and their persistence within the slope, permeability and potential for build-up of water pressure, together with the presence of sub-vertical release joints, there is potential for future large-scale landsliding on sheeting joints as well as small-scale toppling and sliding in Area 2. No obvious signs of distress or mass movement were observed during the present study. Open space currently exists at the slope toe of Area 2 and the consequence-to-life in the event of minor failures in this locality is unlikely to be high.

Areas 1, 3 and 4 (where there are squatter structures fairly close to the slope toe) are associated with most of the factors listed in Section 6.1 except that no seepage was observed and no adversely orientated sheeting joints were identified. Potential instability appear to be confined to toppling and wedge failures, which are likely to be relatively small-scale failures. This was confirmed in Area 3, where incipient toppling failures and recent rock block detachments were observed. These localised failures are likely to continue, although no immediate and obvious danger to the squatter structures below Areas 1, 3 or 4 was apparent at the time of inspection by MGSL in September 2002.

It is anticipated that the adversely orientated sheeting joints will continue to promote instability in the long term. At the time of inspection by MGSL, no obvious signs of major distress which might be a precursor to large-scale incipient failure were observed and hence there was no immediate and obvious danger to the squatter structures below. However, the

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possible influence of the adversely orientated sheeting joints in the development of potential large-scale slope instability is uncertain but cannot be discounted.

8. CONCLUSIONS

The September 2002 landslide on slope No. 11NE-D/C18 occurred at about 11:00 p.m. during heavy rainfall. The estimated volume of the landslide was 30 m³, which was deposited at the toe of the steep soil/rock slope immediately below the landslide source. The debris was contained by a rockfall fence close to the slope toe. No casualties were reported as a result of the landslide.

The landslide was probably triggered by infiltration and the build-up of transient water pressure within the near-surface sheeting joints during the rainfall preceding the failure.

The failure mode involved translational sliding along adversely dipping sheeting joints and was also controlled by sub-vertical joint sets J1 and J2 (which formed side and back release surfaces respectively). Persistent seepage at the base of the surface of rupture and the presence of a prominent recess immediately north of the source of the landslide are also contributory factors to the failure.

Slope No. 11NE-D/C18 has a history of instability, which has mostly involved small-scale (< 30 m³) toppling/sliding failures probably associated with unfavourably orientated steeply dipping joint sets forming back and side release surfaces. Large-scale failure has also occurred (i.e. in 1995) probably due to an unfavourable combination of the steeply dipping joint sets and adversely orientated sheeting joints.

Given the geological setting, the potential for localised small-scale failures is present in all four areas of slope No. 11NE-D/C18. Adversely orientated sheeting joints were identified over certain parts of the slope (i.e. at the locations of the August 1995 and September 2002 landslides). Owing to the limited access and the dense unplanned vegetation cover in parts of the slope, the actual persistence of these features could not be assessed in detail. However, the possible influence of the adversely orientated sheeting joints in the development of potential large-scale slope instability is uncertain but cannot be discounted.

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Table 1 - Details of the Existing Rockfall Fence at Slope No. 11NE-D/C18 (Sheet 1 of 2)

Chainage (m)		Details of the Rockfall Fence	Remarks
From	To		
8.5	23.5	• 2.0 m high • 101 × 101 stanchions at approximately 3 m centres • Two layers of single-twist wire fencing • 3 Nos. approximately 8 mm diameter tension wires at top, middle and base of fence	• Minimum distance to slope toe: 6 m • Distance to nearest squatter structure: N/A
22	64	• 2.0 m high • 101 × 101 stanchions at approximately 3 m centres • Two layers of single-twist wire fencing • 3 Nos. approximately 8 mm diameter tension wires at top, middle and base of fence	• Uppermost tension wire broken. • Section of fence missing from CH42 to CH45 and from CH48 to CH52 • Minimum distance to slope toe: 6 m • Distance to nearest squatter structure: 1 m
64	84	• 2.0 m high	• Other details not known as the rockfall fence was covered by debris of the September 2002 landslide
124	124	• 2.0 m high • 76 × 156 stanchions at approximately 2.25 m centres (fence over this section is 4.5 m long comprising 3 Nos. stanchions) • Concrete footing 0.5 m × 0.5 m • Two layers of single-twist wire fencing • 3 Nos. approximately 8 mm diameter tension wires at top, middle and base of fence	• Uppermost tension wire broken. • Minimum distance to slope toe: 4 m • Distance to nearest squatter structure: N /A

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Table 1 - Details of the Existing Rockfall Fence at Slope No. 11NE-D/C18 (Sheet 2 of 2)

Chainage (m)		Details of the Rockfall Fence	Remarks
From	To		
124	139	• 5 m vertical barrier + 1.4 m high inclined (45°) portion • 156 × 88 stanchion sections at approximately 3 m centres • 95 × 75 I section waling at 0.25 m, 2.5 m and 5.0 m height • Between CH134 and CH139, stanchions embedded in concrete wall. Wall height varies from 0 m to 2 m. Wall thickness 0.24 m increased to 0.6 m at stanchions locations • Concrete footing 0.6 m × 0.6 m • One layer of double-twist wire + one layer of nylon-rope netting. • 3 Nos. approximately 8 mm diameter tension wires at top, middle and base of fence	• Minimum distance to slope toe: 4 m • Distance to nearest squatter structure: N/A
139	154	• 2.0 m high fence • 160 × 80 stanchions at approximately 3 m centres • Concrete footing 0.6 m × 0.6 m • Two layers of single-twist wire fencing • 3 Nos. approximately 8 mm diameter tension wires at top, middle and base of fence	• Minimum distance to slope toe: 3 m • Distance to nearest squatter structure: 15 m

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Table 2 - Summary of Recorded Landslide Incidents at Slope No. 11NE-D/C18 and Mitigating Effects of the Rockfall Fence (Sheet 1 of 4)

GEO Incident No. and Date	Key Details of Landslide and Comments Based on Site Observations and Review of GEO Incident Report	Mitigating Effects of the Rockfall Fence
2002/09/131 on 16 Sept 2002	• Landslide comprising 30 m³ of soil/rock • Area location 2 • Possible cause of failure attributed to "Infiltration, seepage and failure along an adverse joint plane" • Estimated pre-failure slope gradient: 45° • Estimated travel angle of debris: 71° (contained by fence)	• Landslide debris contained by rockfall fence • Rockfall fence distorted and damaged • No consequence as a result of the landslide
K95/8/26 on 31 Aug 1995	• Boulder fall (< 1 m³) behind squatter structure with squatter control survey No. RKT/1A/B/151 • Area location 1 • Possible cause of failure attributed to "infiltration" • Estimated pre-failure slope gradient: 80° • Estimated travel angle of debris: 60° (contained by fence)	• Boulder contained by rockfall fence • No damage to the rockfall fence • Squatter structure with squatter control survey No. RKT/1A/B/151 temporarily evacuated
K95/8/7 on 12 Aug 1995	• Landslide in soil/rock cut slope • Sketch indicates landslide scar maximum 20 m wide × 25 m to 30 m long × 2 m to 3 m deep (i.e. up to 1,000 m³ estimated by MGSL) • Area location 2 • Possible cause of failure not given • Photographs suggest the failure was by translational sliding of the insitu rock mass, with possible sheeting joint close to base of landslide source • Estimated travel angle of debris: 60° (contained by fence)	• Landslide debris contained by rockfall fence • Rockfall fence (60 m length) destroyed by the failure debris • 39 squatter structures (with squatter control survey Nos. RKT/1A/B/205, 206, 209 to 211, 215, 218 to 223, 225 to 231, 237 to 248, 250 to 252, 259 to 261 and 310) permanently evacuated and 152 residents affected

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Table 2 - Summary of Recorded Landslide Incidents at Slope No. 11NE-D/C18 and Mitigating Effects of the Rockfall Fence (Sheet 2 of 4)

GEO Incident No. and Date	Key Details of Landslide and Comments Based on Site Observations and Review of GEO Incident Report	Mitigating Effects of the Rockfall Fence
K92/5/9 on 8 May 1992	• Fallen tree • Area location 2 (directly below the 16 September 2002 landslide) • Possible cause of failure not given • Estimated pre-failure slope gradient: 80°	• Tree came to rest on top of the rockfall fence (just above roof of squatter structures) • No damage to the rockfall fence • 7 squatter structures (with squatter control survey Nos. RKT/1A/B/168-174) permanently evacuated
K90/6/1 on 2 June 1990	• 1.5 m³ of highly/moderately decomposed rock • Area location 4 • Possible cause of failure attributed to "infiltration" • Estimated pre-failure slope gradient: 85° • Estimated travel angle of debris: 53°	• Incident outside of rockfall fence location • 7 squatter structures (with squatter control survey Nos. RKT/1A/C1-7, Nos. RKT/1A/B308-9) and 3 "illegal" structures (between squatter with squatter control survey Nos. RKT/1A/C1-7 and the toe of slope) affected • Squatter structures with squatter control survey Nos. RKT/1A/C/3, 5, 6 & Nos. RKT/1A/B/308-9 demolished on 20 December 1990 • Squatter structures with squatter control survey Nos. RKT/1A/C/1 & 2 cleared on 24 January 1991 (brick walls allowed to remain as barrier) • Squatter structures with squatter control survey Nos. RKT/1A/C/4 & 7 temporarily evacuated
K90/4/2 on 12 April 1990	• 10 m³ of highly/moderately decomposed rock • Area location 3 • Possible cause of failure attributed to "infiltration/rock joints widened by tree roots" • Estimated pre-failure slope gradient: 60° • Estimated travel angle of debris: 34° (contained by fence)	• Landslide debris contained by rockfall fence • No damage to the rockfall fence • No consequence as a result of the landslide

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Table 2 - Summary of Recorded Landslide Incidents at Slope No. 11NE-D/C18 and Mitigating Effects of the Rockfall Fence (Sheet 3 of 4)

GEO Incident No. and Date	Key Details of Landslide and Comments Based on Site Observations and Review of GEO Incident Report	Mitigating Effects of the Rockfall Fence
K89/5/120 on 20 May 1989	• Rockfall involving 5 m³ of rock and boulders • Area location 3, behind squatter structure with squatter control survey No. RKT/1A/B/238 • Possible cause of failure attributed to "erosion" • Photographs show large, unshotcreted, scar which appears to include the 1985 landslide (Incident No. K85/8/13) • Estimated pre-failure slope gradient: 60° • Estimated travel angle of debris: 34° (contained by fence)	• Landslide debris contained by rockfall fence • No damage to the rockfall fence • No consequence as a result of the landslide
K87/8/3 on 30 August 1987	• 3 m³ of fill material • Location unknown • The referred squatter control survey number (No. RKT/1A/C/85) suggests incident occurred in Area 4 • Possible cause of failure not given	• Outside of rockfall fence location • Squatter structure with squatter control survey No. RKT/1A/C/C85 affected
K87/5/2 on 8 May 1987	• Boulder fall • Area location 3 • Possible cause of failure given as "unknown" • Estimated pre-failure slope gradient: 70° • Estimated travel angle of debris: 30°	• Occurred just prior to construction of the rockfall fence in Area 3 • Squatter structure with squatter control survey No. RKT/1A/B/238 affected

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Table 2 - Summary of Recorded Landslide Incidents at Slope No. 11NE-D/C18 and Mitigating Effects of the Rockfall Fence (Sheet 4 of 4)

GEO Incident No. and Date	Key Details of Landslide and Comments Based on Site Observations and Review of GEO Incident Report	Mitigating Effects of the Rockfall Fence
K87/5/1 on 29 April 1987	• Debris load - no details of volume provided • Area location 4 • Possible cause of failure attributed to "debris surcharge" • Estimated pre-failure slope gradient: 80° • Estimated travel angle of debris: 28°	• Outside of rockfall fence location • Squatter structure with squatter control survey No. RKT/1A/C/103 affected with its illegal portion subsequently demolished as a result of the landslide
K85/8/13 on 28 August 1985	• 20 m^3 of soil/rock and a tree • Area location 2, adjacent to squatter structures with squatter control survey Nos. RKT/1A/B/206, 209, 218 & 220 • Occurred one week after the rockfall fence was constructed at the slope toe • Possible cause of failure attributed to "infiltration" • Photographs suggest the failure was by translational sliding of the in situ rock mass • The scar floor, covered by soil, dips out of the slope face at 30° to 40°, above a cliff about 4 m to 5 m high • Estimated pre-failure slope gradient: 50° • Estimated travel angle of debris: 45°	• The failed debris came to rest before reaching the (then) newly completed rockfall fence • No consequence as a result of the landslide
Note: Locations of the incidents are shown in Figures 8 and 14.		

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Table 3 - Details of Sheeting Joints and Rock Joints at the September 2002 Landslide

Details of Sheeting Joints

Joint Set Ref.	Dip/Dip Direction	Persistence	Aperture	Roughness
S1a	30°/277°	> 5 m	200 mm	Rough undulating
S1b	30°/283°	> 5 m	300 mm	Rough undulating
S1c	38°/291°	> 5 m	200 mm	Rough undulating

Details of Rock Joints

Joint Set Ref.	Dip/Dip Direction	Observations
J1	76°/168°	sub-vertical and normal to the slope face - act as side releases to blocks sliding
J2	64°/247°	sub-vertical and near-parallel to the slope face - form back releases to blocks toppling or sliding
J3	11°/104°	sub-horizontal and dipping slightly into the overall slope face - favourable to slope stability

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Table 4 - Maximum Rolling Rainfall at GEO Raingauge No. K08 for Selected Durations Preceding the Landslide on 16 September 2002 and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years) (See Note 2)
5 Minutes	9.0	04:30 hours on 15 September 2002	< 2
15 Minutes	23.5	04:35 hours on 15 September 2002	< 2
1 Hour	64.5	04:55 hours on 15 September 2002	< 2
2 Hours	93.5	05:10 hours on 15 September 2002	< 2
4 Hours	117.0	05:10 hours on 15 September 2002	2
12 Hours	175.5	09:10 hours on 15 September 2002	2
24 Hours	198.5	06:45 hours on 15 September 2002	< 2
48 Hours	302.5	20:45 hours on 16 September 2002	3
4 Days	362.5	23:00 hours on 16 September 2002	3
7 Days	463.0	23:00 hours on 16 September 2002	4
15 Days	469.0	23:00 hours on 16 September 2002	< 2
31 Days	574.5	23:00 hours on 16 September 2002	< 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). The return periods obtained by the two methods do not show a significant difference.
(3) The use of 5-minute data for return period of rainfall durations between 2 hours and 31 days results in better data resolution, but may slightly over-estimate the return periods using data by Lam & Leung (1994), which are based on hourly rainfall for these durations.
(4) According to an eyewitness, the landslide occurred at about 11:00 p.m. on 16 September 2002.
(5) The nearest GEO raingauge to the landslide site is raingauge No. K08 situated at about 800 m to the east of the site.

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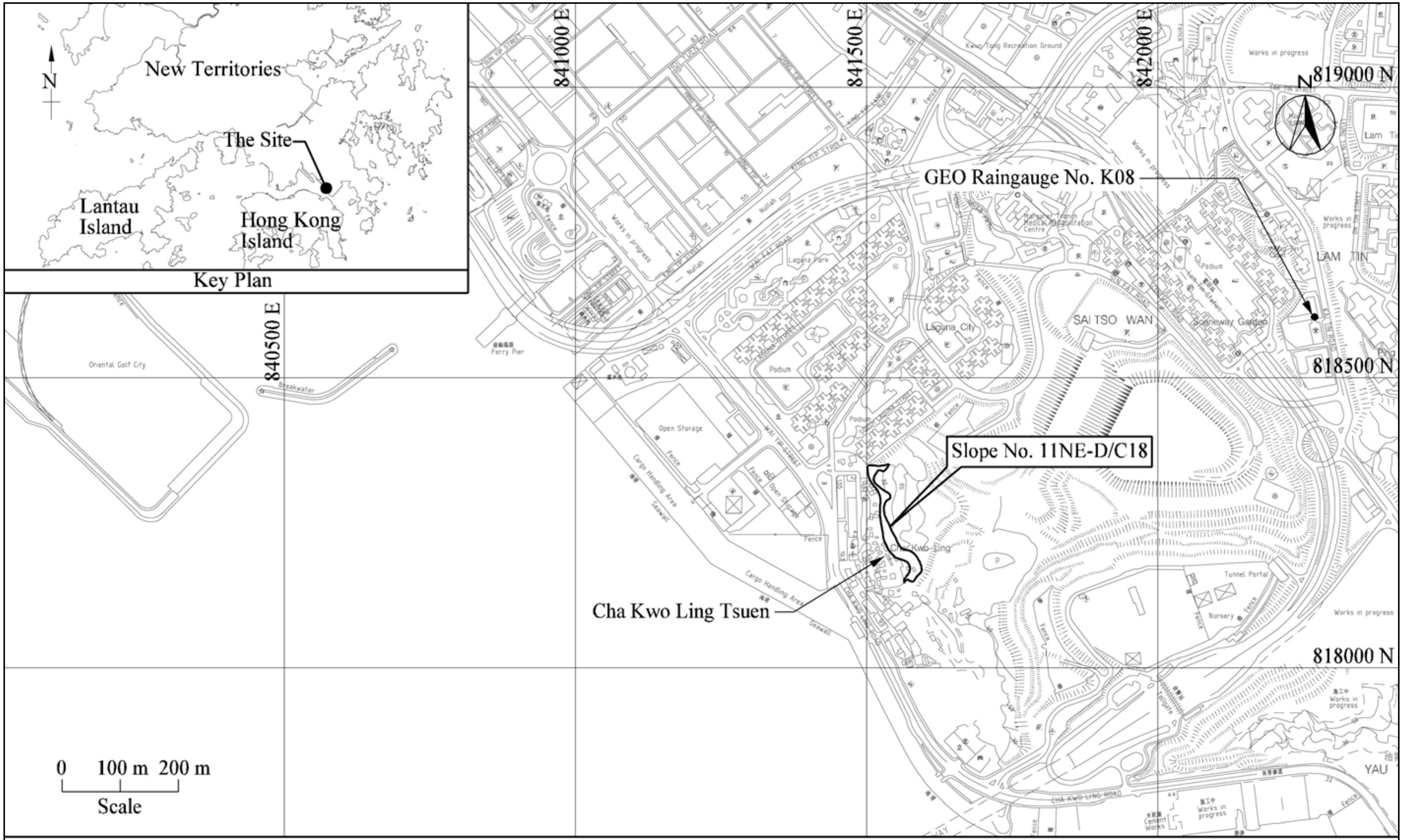
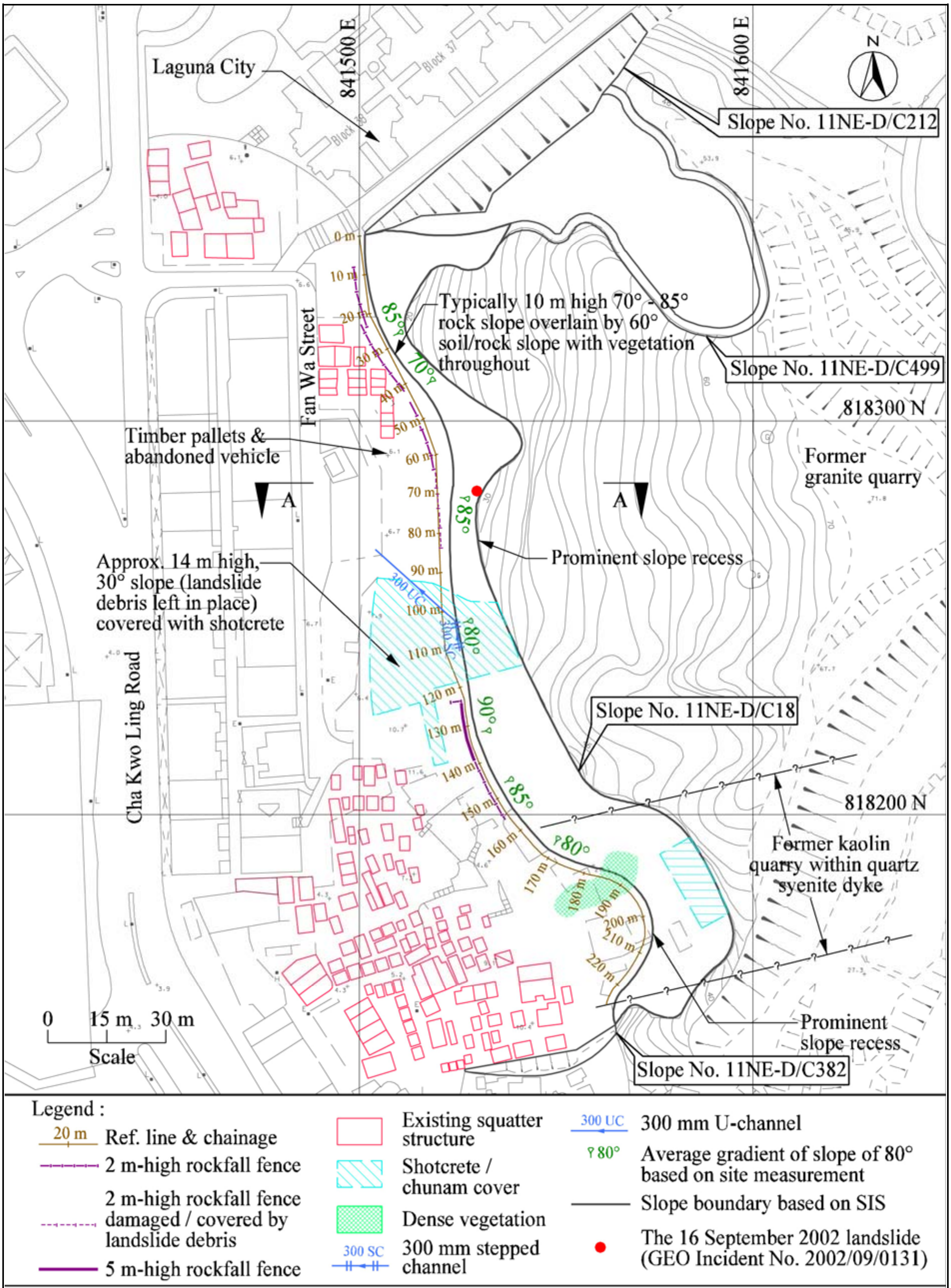


Note : Base plan is extracted from 1 : 5000 survey sheets Nos. 11NE-C, 11NE-D and 11SE-B.

Figure 1 - Site Location Plan



Notes : (1) Base plan is extracted from 1 : 1000 survey sheet No. 11NE-23D dated March 2001.
(2) The site observations presented were made during inspections carried out between September and November 2002.

Figure 2 - Site Observations

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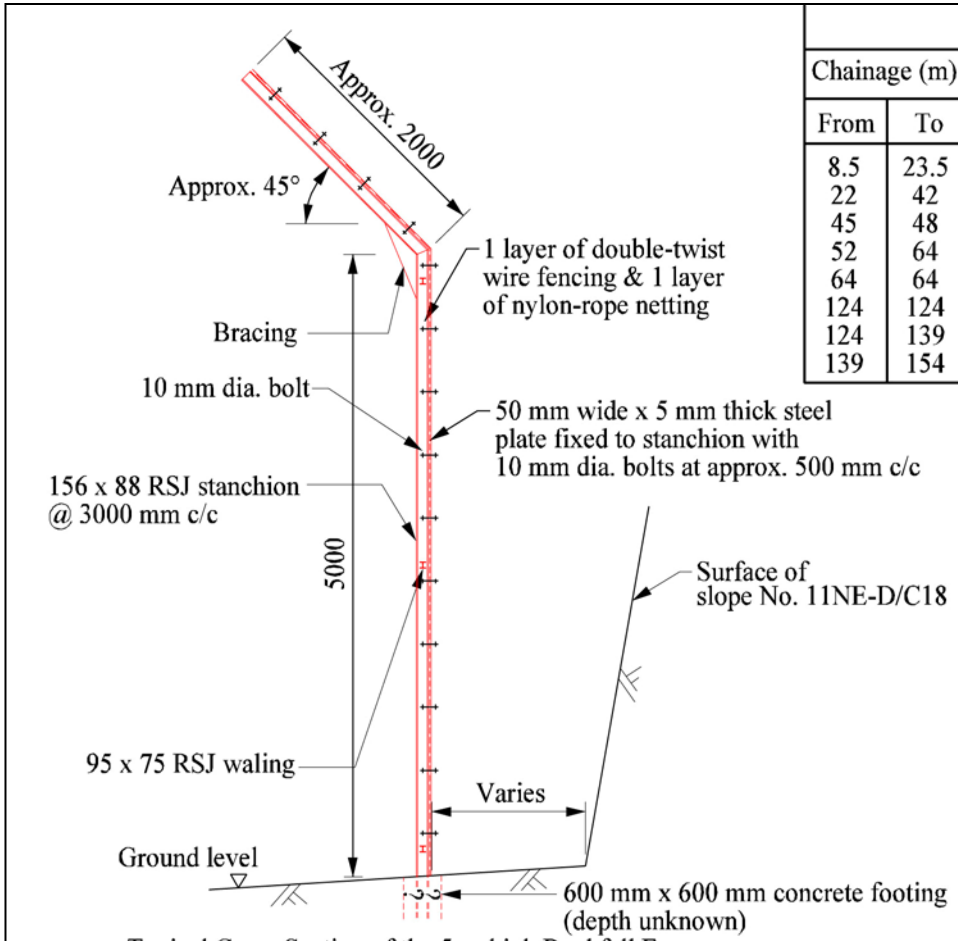
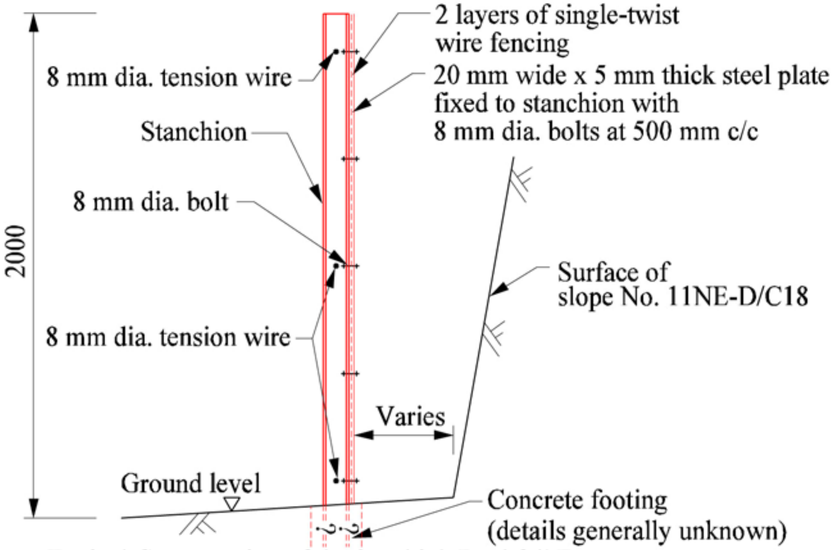


Typical Cross-Section of the 5 m-high Rockfall Fence
(Not to scale)

		Summary of the Rockfall Fence Details				
Chainage (m)		Height of rockfall fence (m)	Stanchion size (mm)	Stanchion spacing (mm)	Minimum distance to slope toe (m)	Footing size (mm)
From	To					
8.5	23.5	2	101 x 101	3000	6	Unknown
22	42	2	101 x 101	3000	6	Unknown
45	48	2	101 x 101	3000	6	Unknown
52	64	2	101 x 101	3000	6	Unknown
64	64	2	Unknown	Unknown	Unknown	Unknown
124	124	2	76 x 156	2250	4	500 x 500
124	139	5	156 x 88	3000	4	600 x 600
139	154	2	160 x 80	3000	3	600 x 600



Typical Cross-section of the 2 m-high Rockfall Fence
(Not to scale)

Notes :
(1) All dimenions are approximate and are given in mm unless otherwise stated.
(2) Details of the rockfall fence are based on site observations and measurement.
(3) See Table 1 for more specific details of the 2 m-high rockfall fence.
(4) Rockfall fence between Ch. 64 and Ch. 84 was covered by landslide debris and hence details are not known.

Figure 3 - Typical Details of the Rockfall Fence

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Legend:

———	New grant lots, G.L.A., MOD etc.	320	Old schedule lots
- - - -	Deposit plans	321	Old schedule lots (Survey data available)
— — — —	G.L.A. without formal allocation or Temp G.L.A.	KIL 1233	Old new grant lots, New grant lots
┅┅┅┅	CLL/GLL/LA/STT/TA/LOA/MODI/MOT/STW, Adv. Possession Licence/(Proposed) Walkway, Right of Temp Occupation of Land	KIL 1234	Old new grant lots, New grant lots (Survey data available)

Notes:
(1) This figure on the land status within the study site is reproduced from District Survey Office Lot Index Plan - 1 : 1000 map sheet No. 11NE-23D dated November 2002.
(2) The latest information on the layout of the squatter structures is provided by the Squatter Control (Kowloon) Office of the Lands D and is given in Figure 9.

Figure 4 - Land Status Plan

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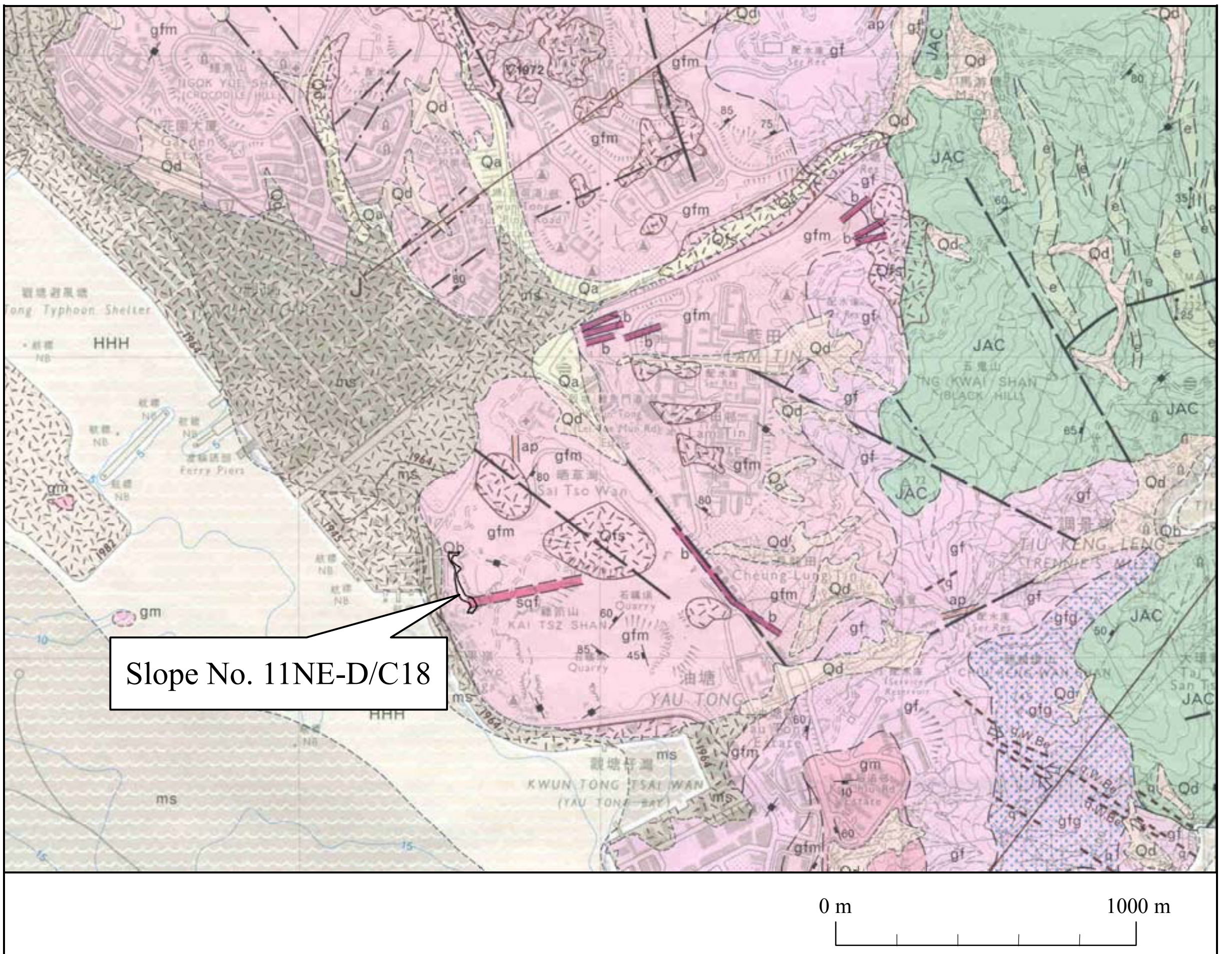

Legend:

▨	Fill	ap	Aplite
Qb	Beach deposits	ms	Marine sand
gfm	Fine- to medium-grained granite	—■—	Inclined jointing
sqf	Fine-grained quartz syenite	—■—	Vertical jointing
HHH	Marine mud	- - - - - -	Fault
gm	Medium-grained granite	----------------	Geological boundary, superficial deposit

Note: Figure is extracted from Hong Kong Geological Survey, Map Series HGM20, Sheet No. 11, 1 : 20 000 scale (GEO, 1986).

Figure 5 - Regional Geology

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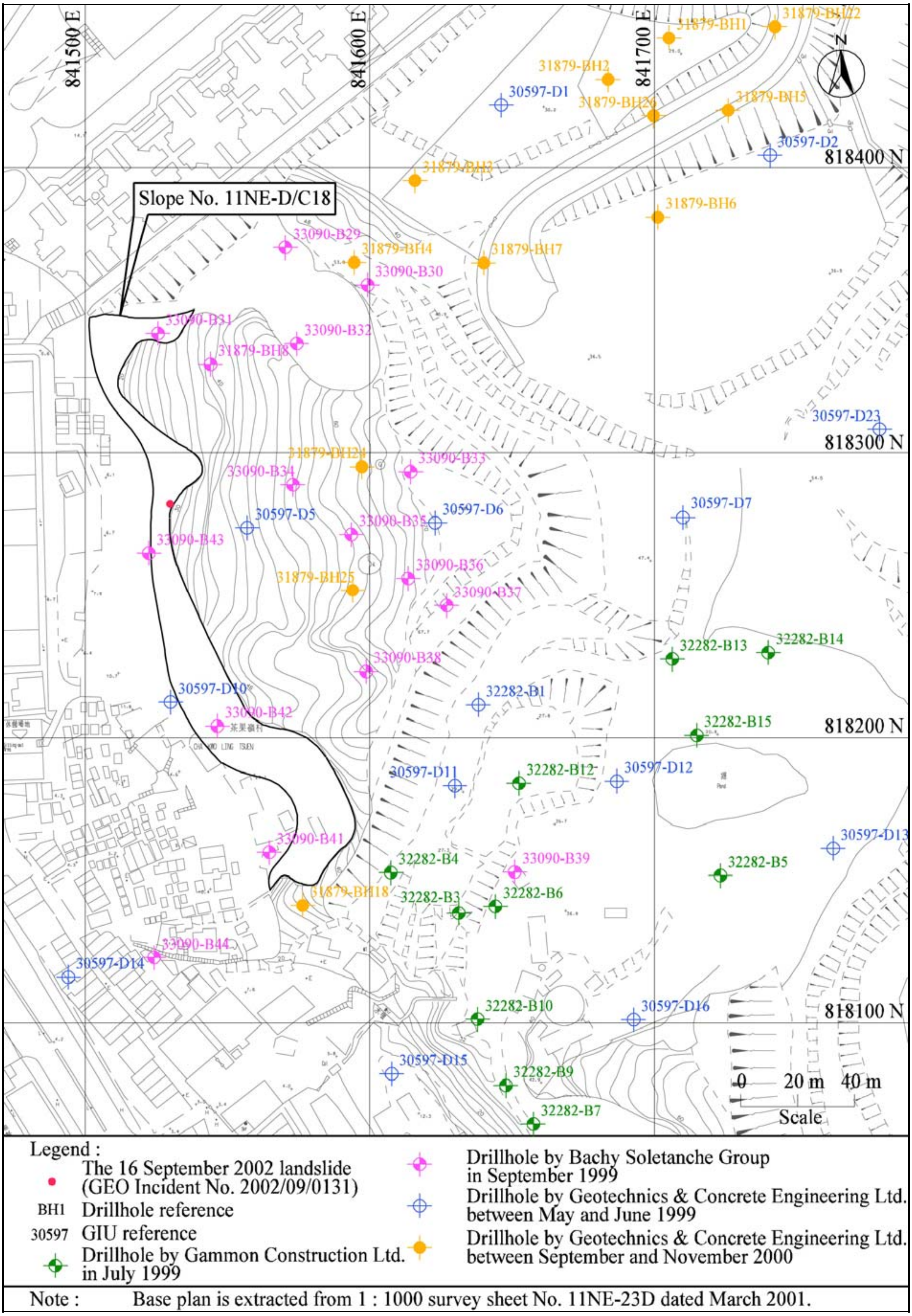

Figure 6 - Plan of Previous Ground Investigation

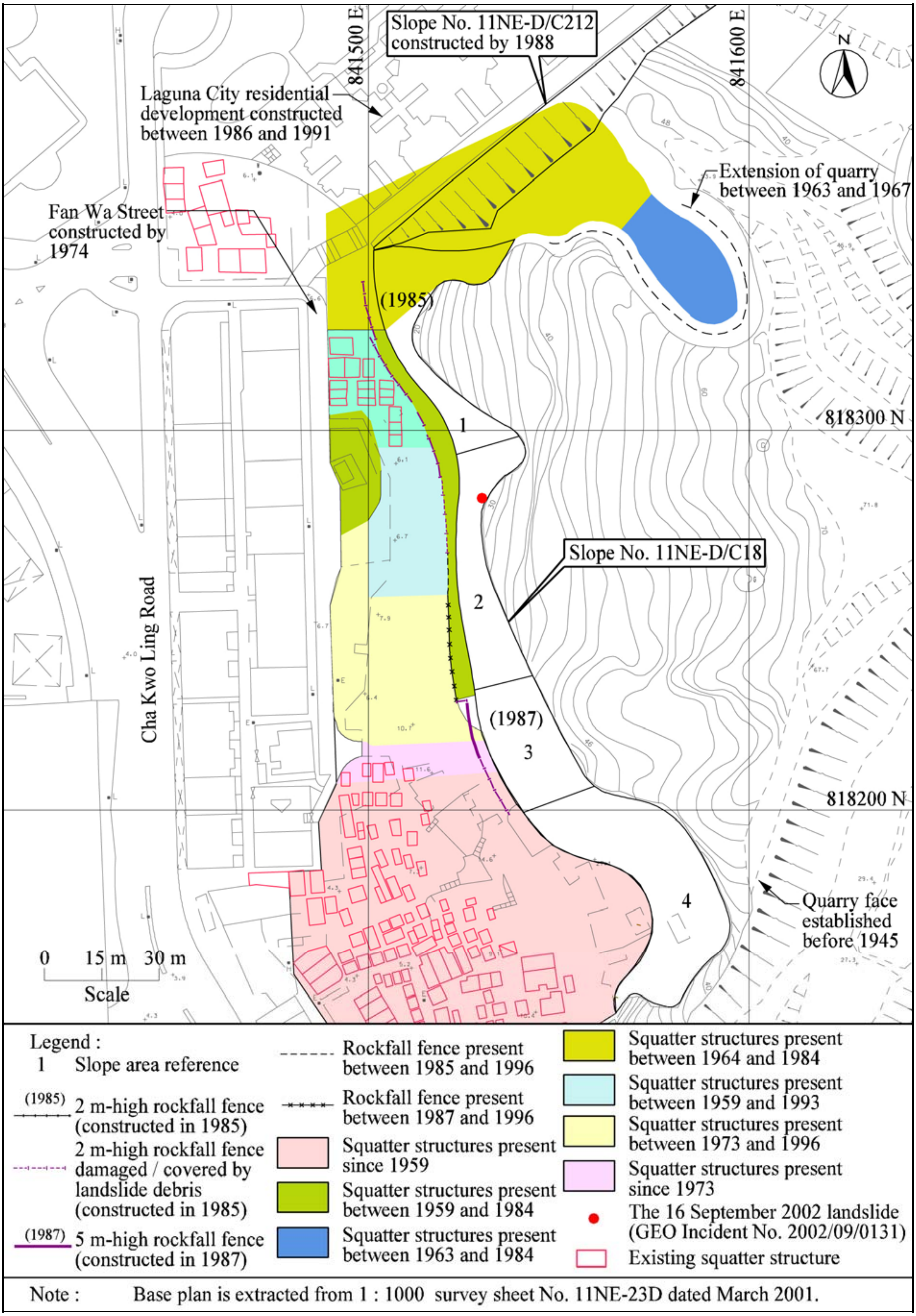

Figure 7 - Site Development History

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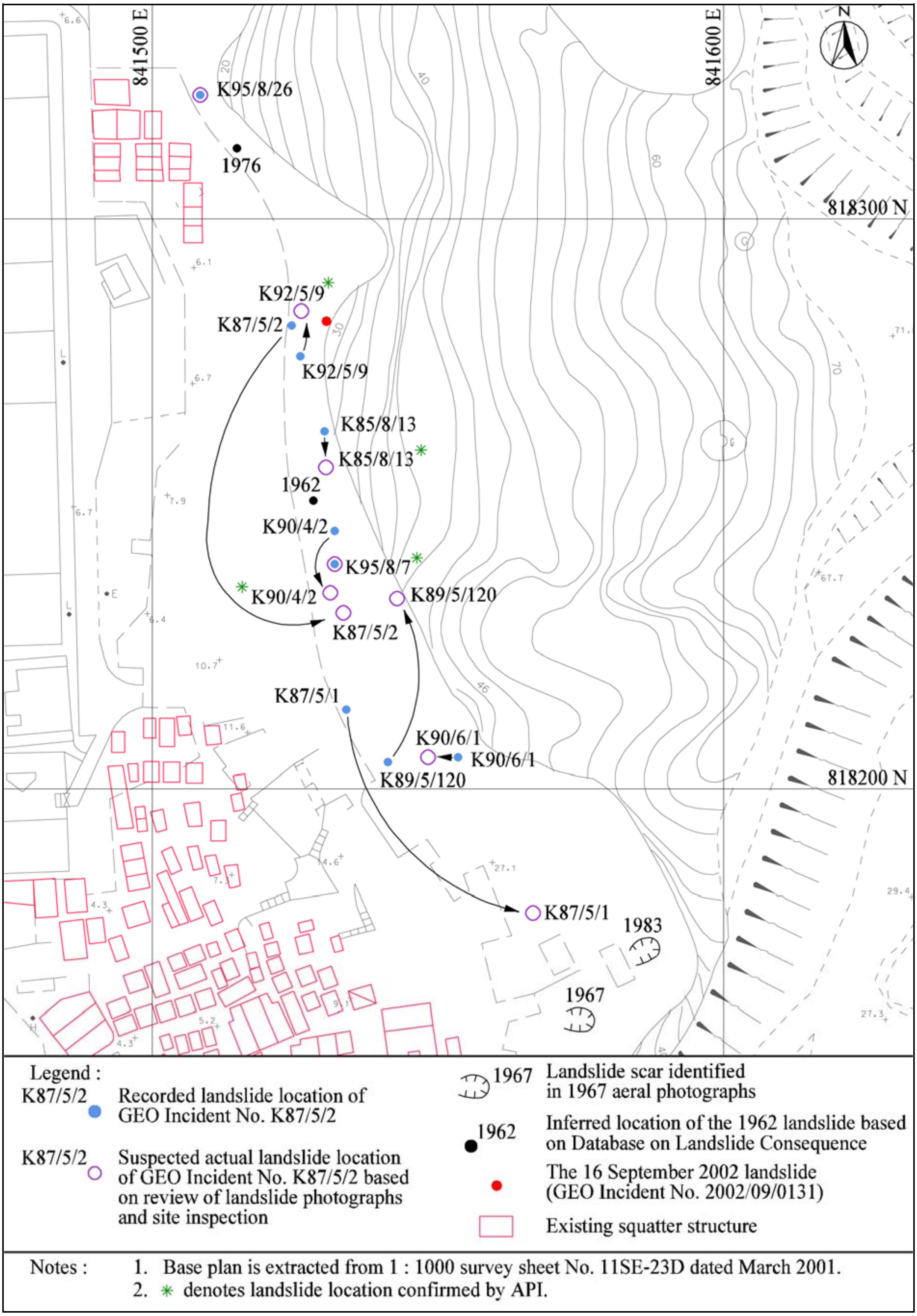

Legend :

K87/5/2 ● Recorded landslide location of GEO Incident No. K87/5/2

K87/5/2 ○ Suspected actual landslide location of GEO Incident No. K87/5/2 based on review of landslide photographs and site inspection

1967 Landslide scar identified in 1967 aeral photographs

● 1962 Inferred location of the 1962 landslide based on Database on Landslide Consequence

● The 16 September 2002 landslide (GEO Incident No. 2002/09/0131)

▭ Existing squatter structure

Notes :

1. Base plan is extracted from 1 : 1000 survey sheet No. 11SE-23D dated March 2001.
2. ✳ denotes landslide location confirmed by API.

Figure 8 - Past Instability

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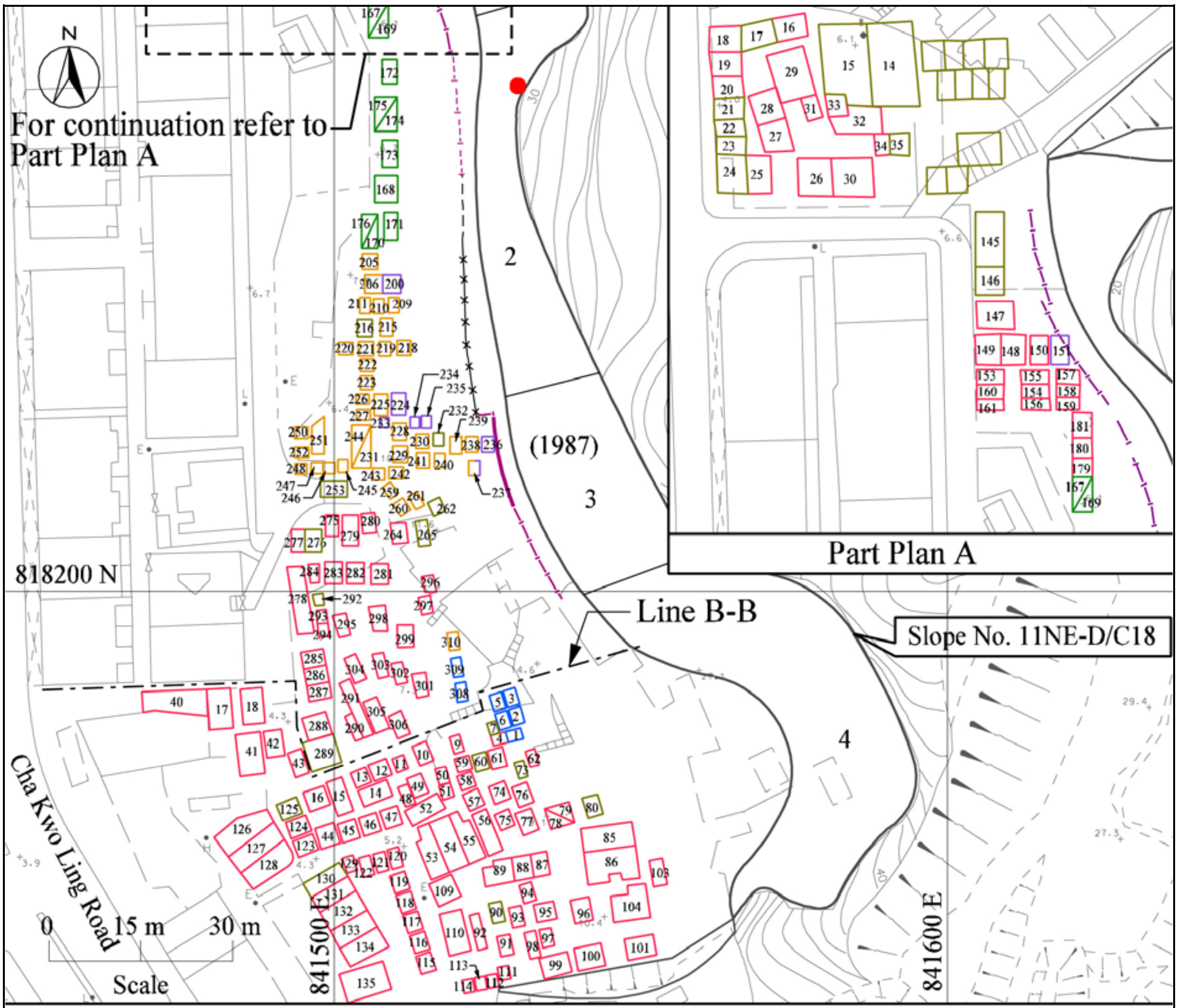

Legend :

● The 16 September 2002 landslide

🟥 Existing squatter structure

🟪 Squatter structure cleared in 1984 under SAI programme

🟫 Cleared squatter structure (year of clearance unknown)

🟦 Squatter structure cleared in 1991 as a result of GEO Incident No. K90/6/1

🟩 Squatter structure cleared in 1992 as a result of GEO Incident No. K92/5/9

🟧 Squatter structure cleared in 1996 as a result of GEO Incident No. K95/8/7

1 Slope area reference

(1985) 2 m-high rockfall fence (constructed in 1985)

(1985) 2 m-high rockfall fence damaged / covered by landslide debris (constructed in 1985)

(1987) 5 m-high rockfall fence (constructed in 1987)

– – – – – Rockfall fence present between 1985 and 1996

×–×–×–× Rockfall fence present between 1987 and 1996

Notes :

(1) Base plan is extracted from 1 : 1000 survey sheet No. 11NE-23D dated March 2001.

(2) The information on the locations of the squatter structures is provided by the Squatter Control (Kowloon) Office of the Lands D in April 2003. According to the Lands D, the locations of the squatter structures are approximate only.

(3) For clarity, common prefixes to squatter control survey numbers (being RKT/1A/B/ and RKT/1A/C/ for squatter structures to the north and south of Line B-B respectively) are not shown.

(4) Squatter control survey numbers for existing squatter structures are provided by the Lands D whereas those for the cleared structures are assessed by MGSL based on records held by the GEO, HD & Lands D.

(5) Further to the clearance of 30 squatter structures in 1984 by HD, squatter structure with squatter control survey No. RKT/1A/B/224 was recommended for NDC by the GCO in December 1986.

Figure 9 - Squatter Layout Plan

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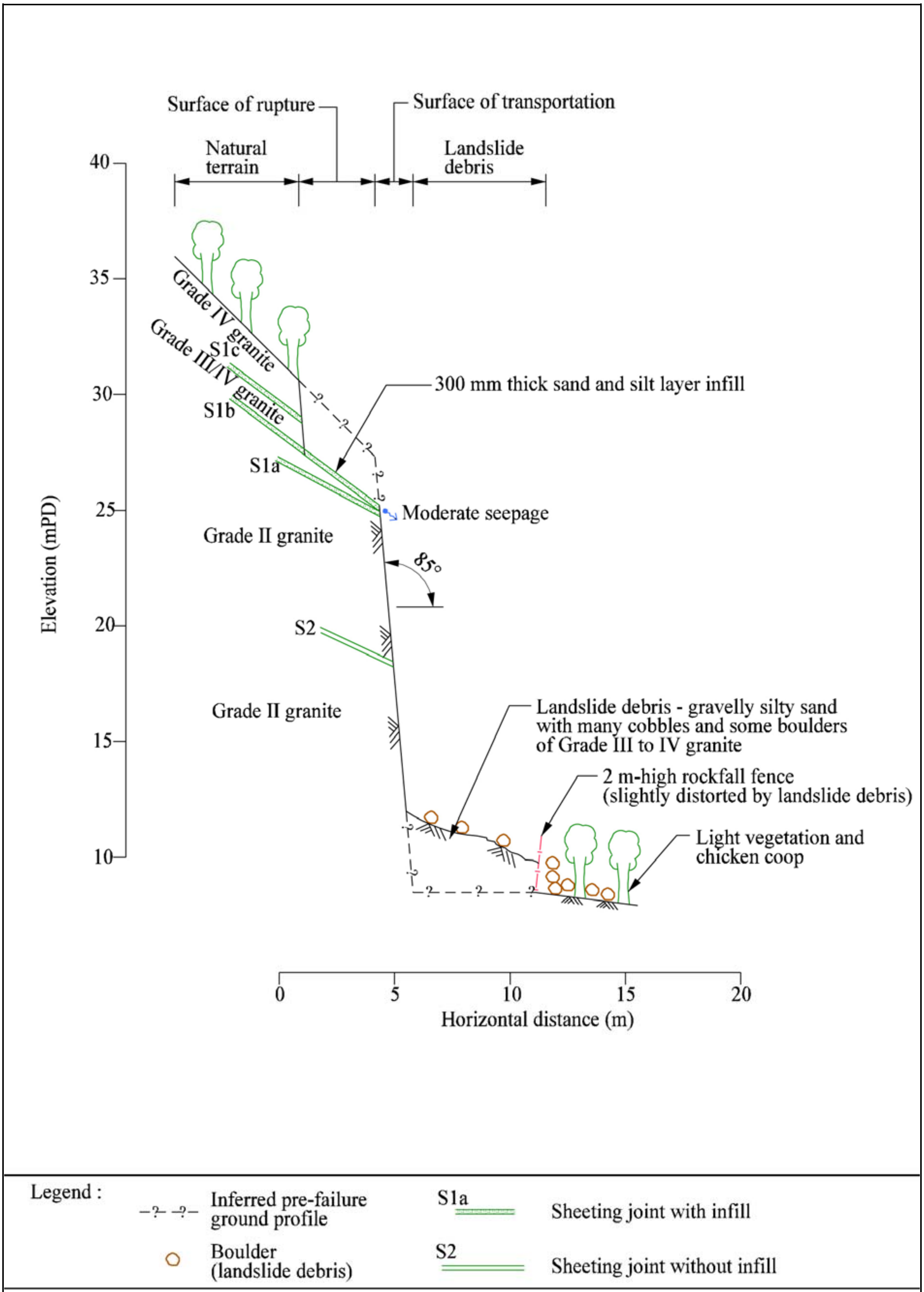

Note : See Figure 2 for location of cross-section.

Figure 10 - Cross-Section A-A through the Landslide Site

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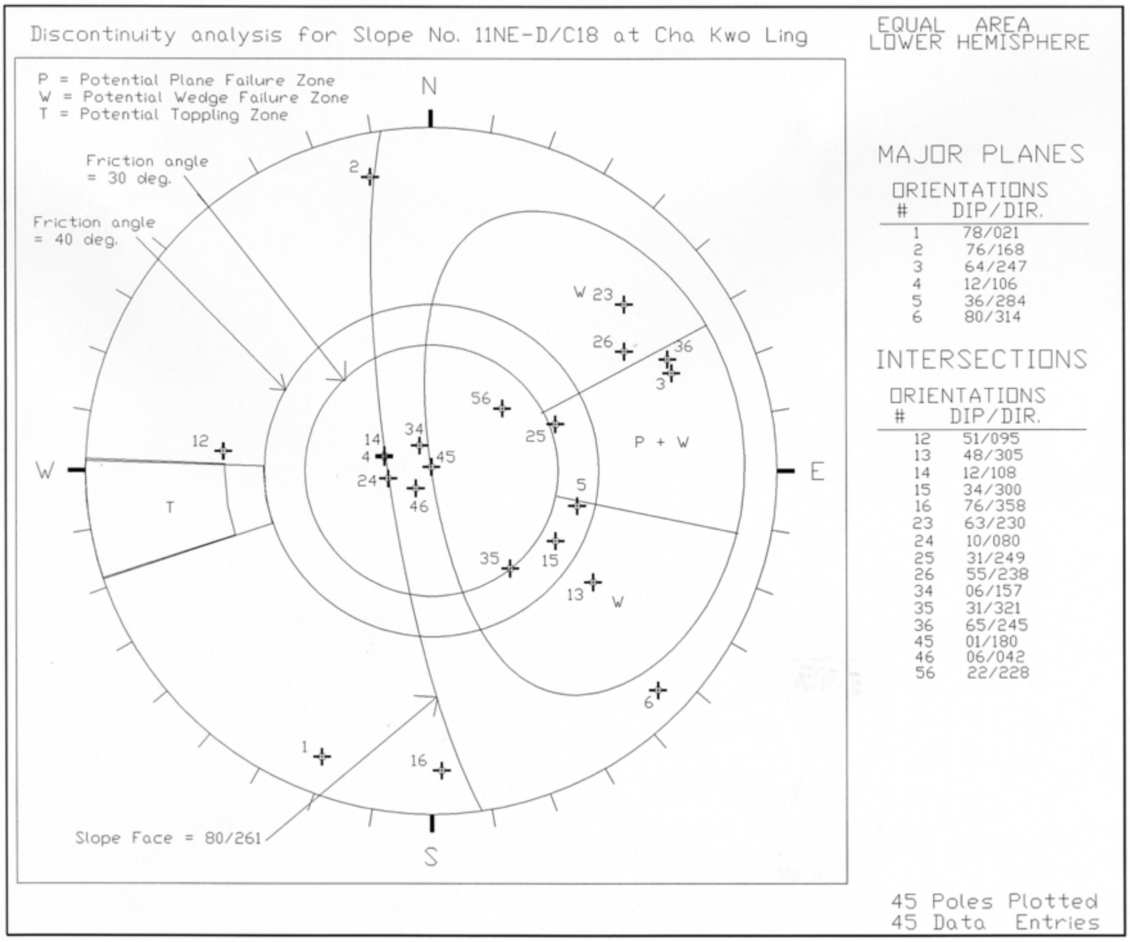


MAJOR PLANES

ORIENTATIONS

#	DIP/DIR.
1	78/021
2	76/168
3	64/247
4	12/106
5	36/284
6	80/314

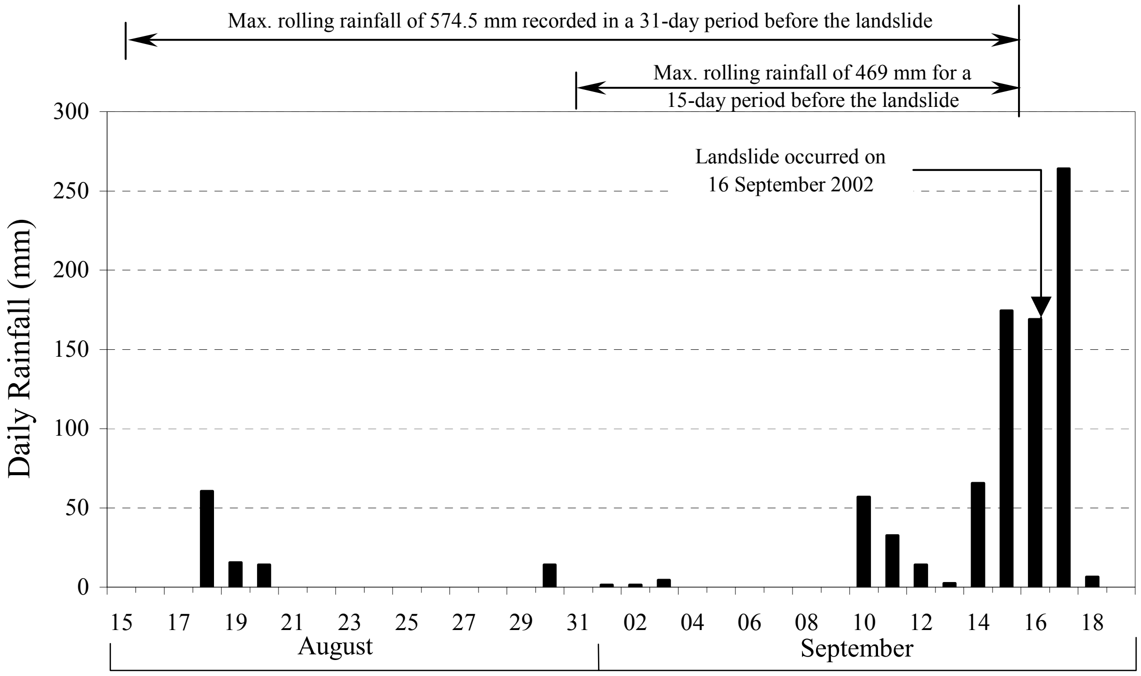
INTERSECTIONS

ORIENTATIONS

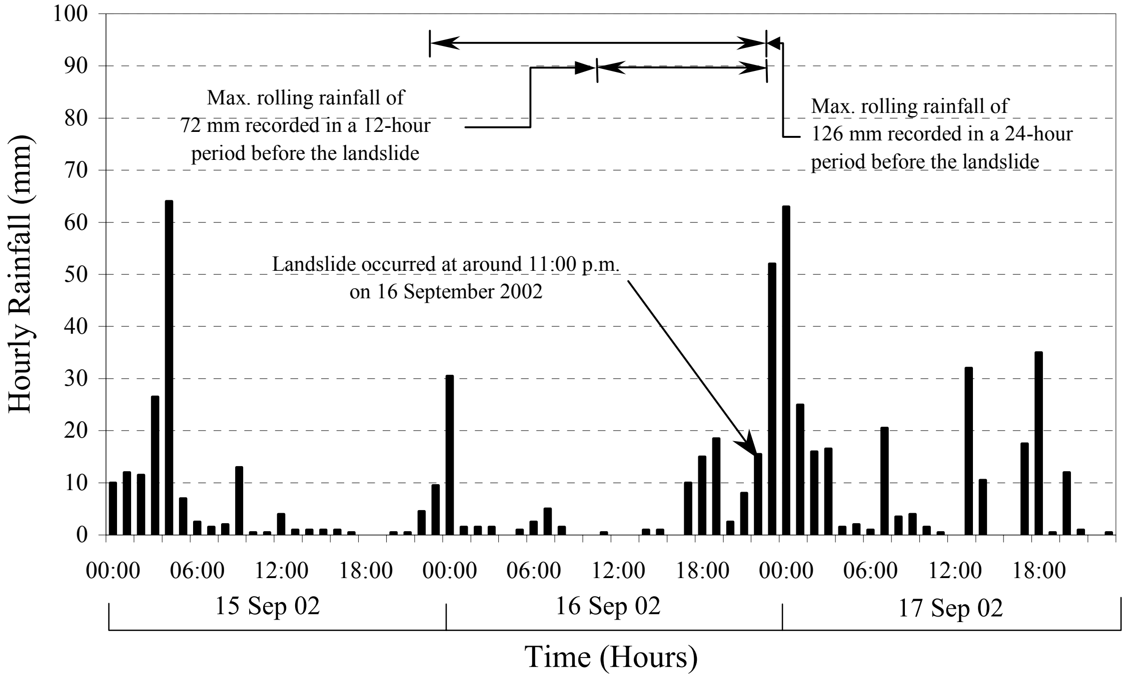
#	DIP/DIR.
12	51/095
13	48/305
14	12/108
15	34/300
16	76/358
23	63/230
24	10/080
25	31/249
26	55/238
34	06/157
35	31/321
36	65/245
45	01/180
46	06/042
56	22/228

Notes:
(1) # 1 and # 2 represent Joint Set J1 (Steeply dipping, side release surfaces)
(2) # 3 represents Joint Set J2 (steeply dipping, back release surfaces)
(3) # 4 represents Joint Set J3 (shallow dipping, favourable orientation)
(4) # 5 represents Sheeting Joints (moderately dipping, unfavourable orientation)

Figure 11 - Major Joint Planes at the Landslide Location



(a) Daily Rainfall Recorded at GEO Raingauge No. K08 between 16 August and 20 September 2002



(b) Hourly Rainfall Recorded at GEO Raingauge No. K08 between 15 and 17 September 2002

Figure 12 - Daily and Hourly Rainfall Recorded at GEO Raingauge No. K08

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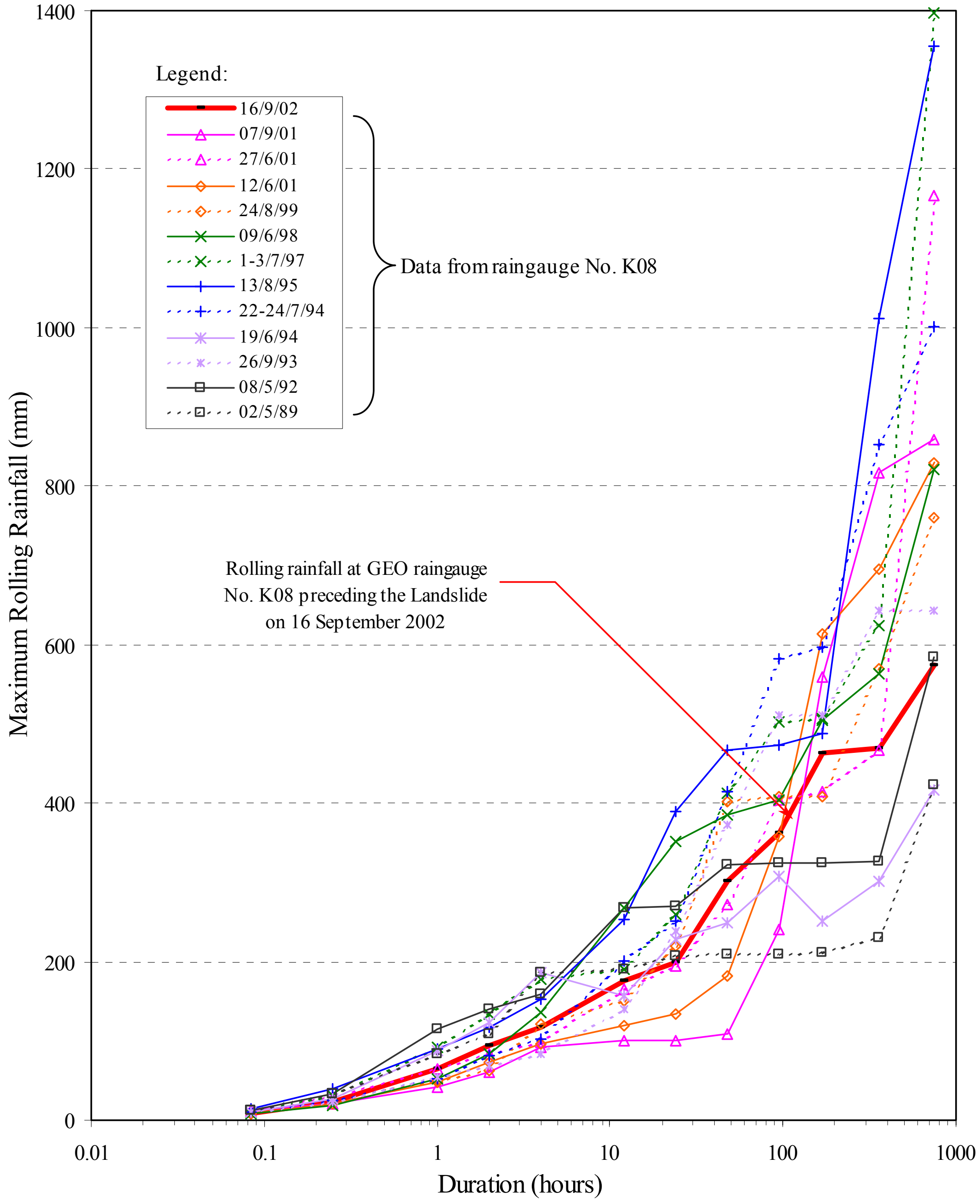

Notes:	(1)	Previous rainstorms data obtained from GEO Report No. 62 - "Areal Extent of Intense Rainfall in Hong Kong 1975 to 1995" (Malone, 1997) and selected rainstorms from 1996 to 2000.
	(2)	Rainfall data evaluated from 5-minute readings from GEO raingauge No. K08 (about 800 m east of the site).
	(3)	Rolling rainfall of previous rainstorms calculated at GEO raingauge No. K08 since March 1983 when the raingauge became operational.

Figure 13 - Maximum Rolling Rainfall for Previous Major Rainstorms at GEO Raingauge No. K08

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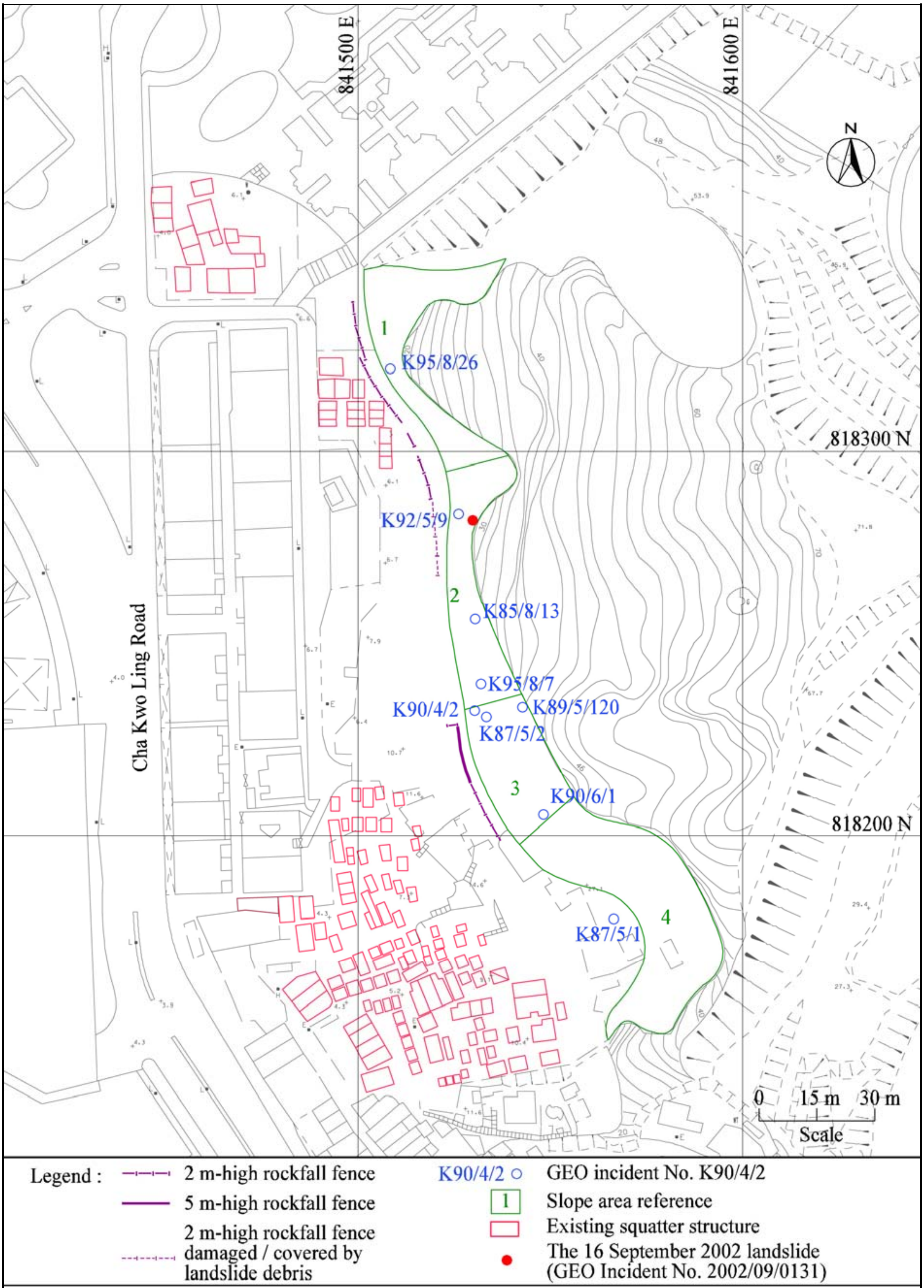
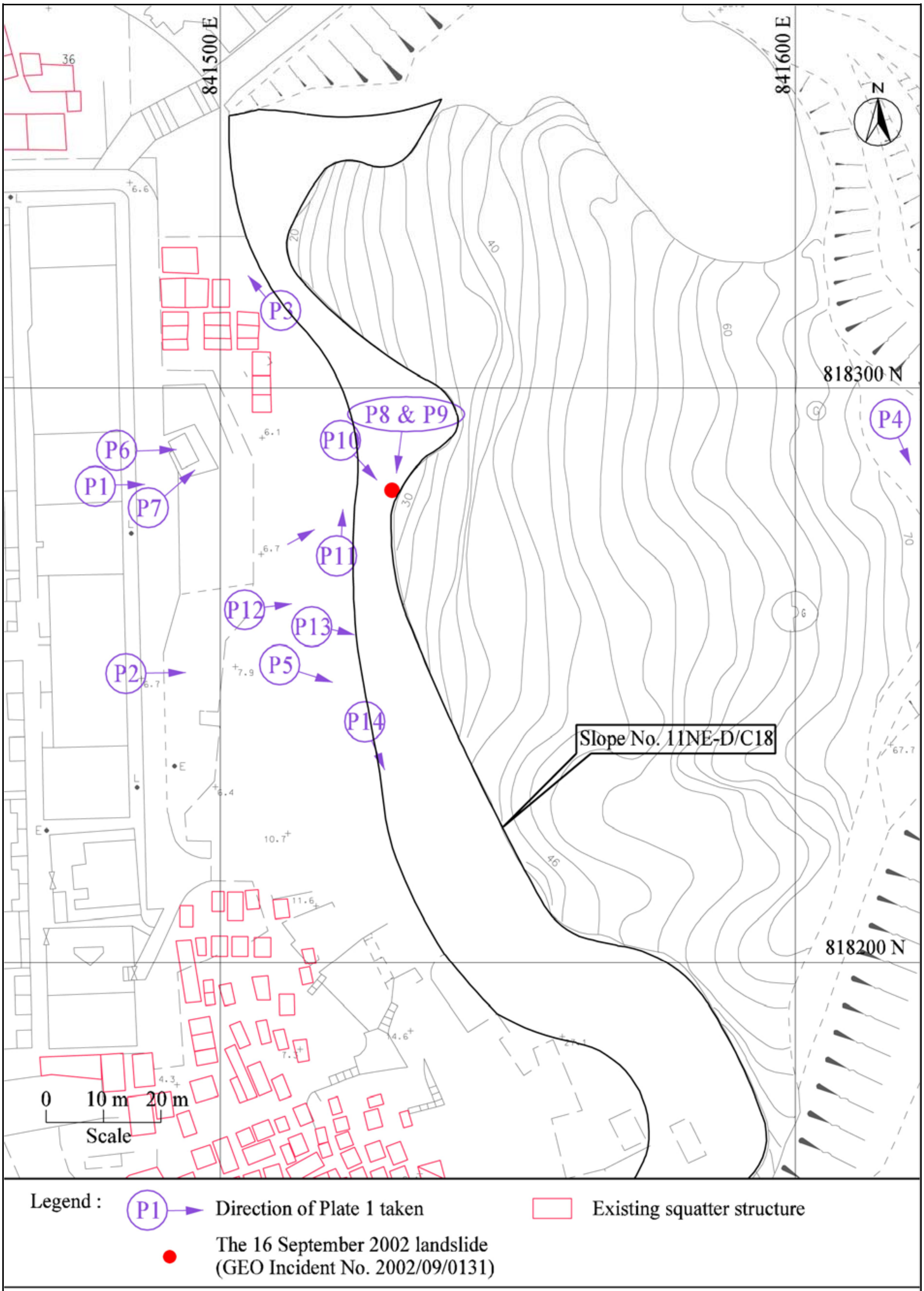


Note : Base plan is extracted from 1 : 1000 survey sheet No. 11NE-23D dated March 2001.

Figure 14 - Slope Areas and Previous Landslide Incidents



Note : Base plan is extracted from 1 : 1000 survey sheets No. 11NE-23D dated March 2001.

Figure 15 - Locations and Directions of Photographs Taken

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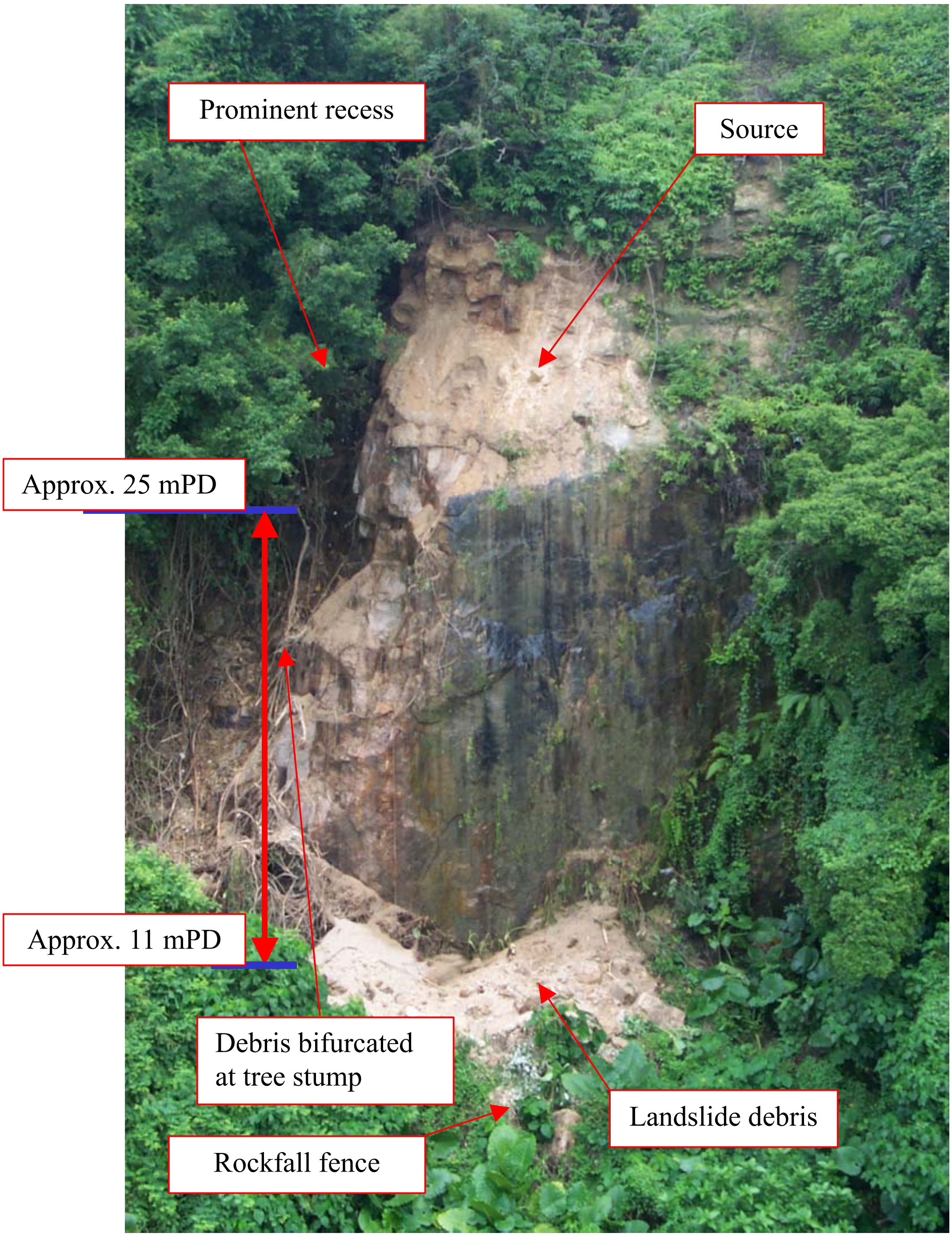

Plate 1 - Front View of the 16 September 2002 Landslide
(Photograph taken on 19 September 2002)

Note: See Figure 15 for location and direction of photograph.

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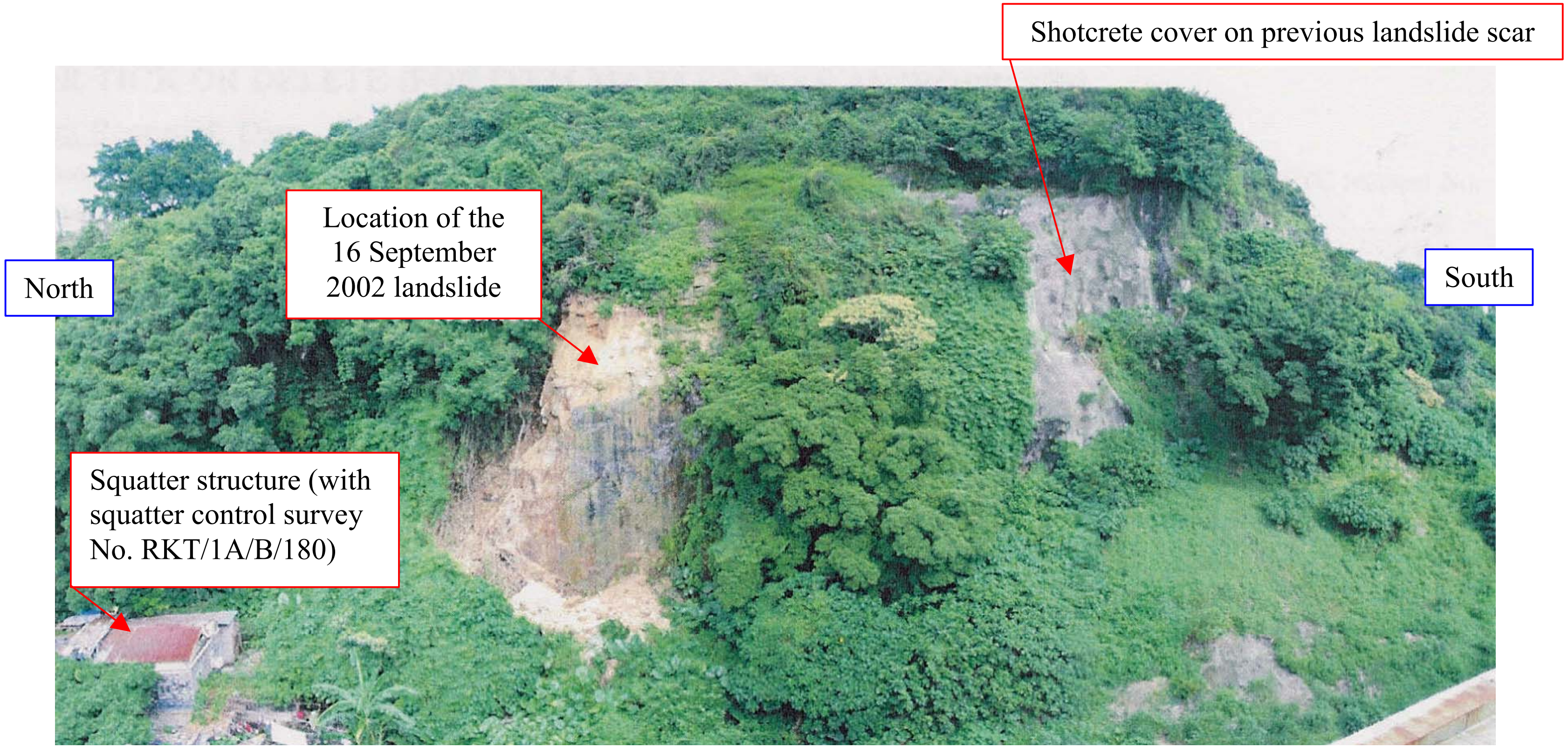

Plate 2 - General View of Slope No. 11NE-D/C18 (Photograph taken by GEO on 17 September 2002)

Note: See Figure 15 for location and direction of photograph.

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Plate 3 - View of the Rockfall Fence at the Slope Toe
(Photograph taken on 27 November 2002)

Note: See Figure 15 for location and direction of photograph.

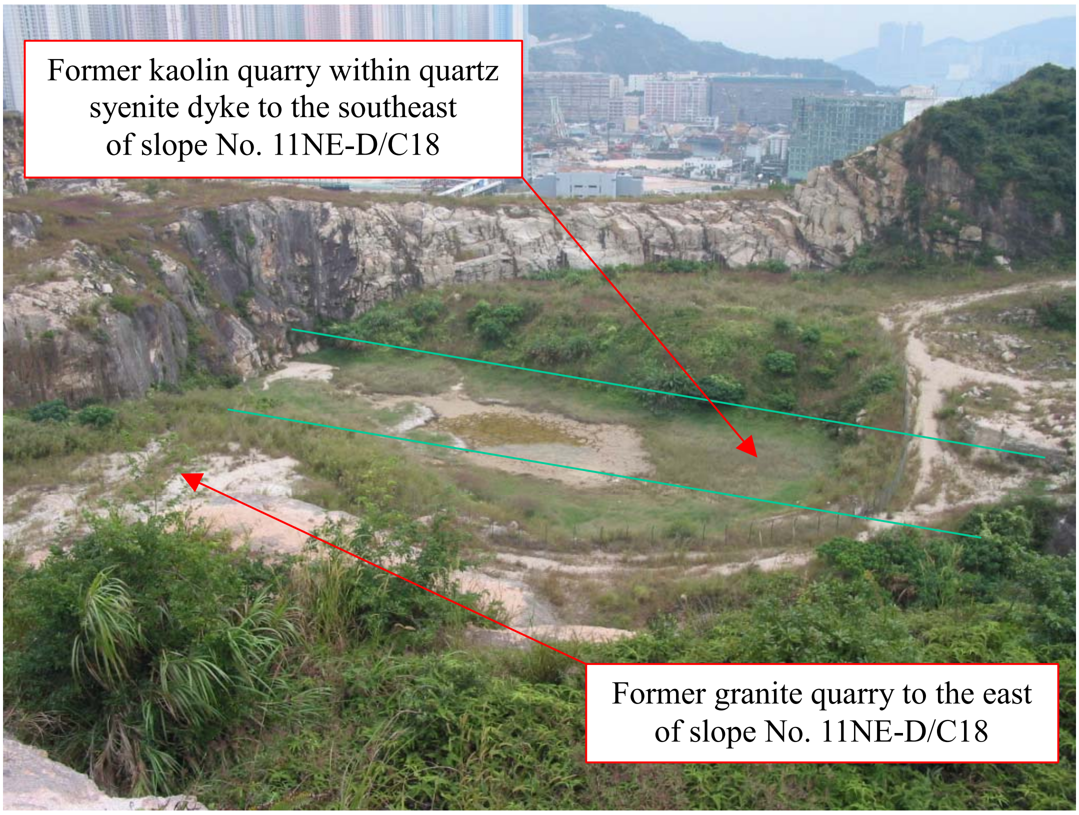

Plate 4 - View of Former Quarries to the East of Slope No. 11NE-D/C18
(Photograph taken on 27 November 2002)

Note: See Figure 15 for location and direction of photograph.

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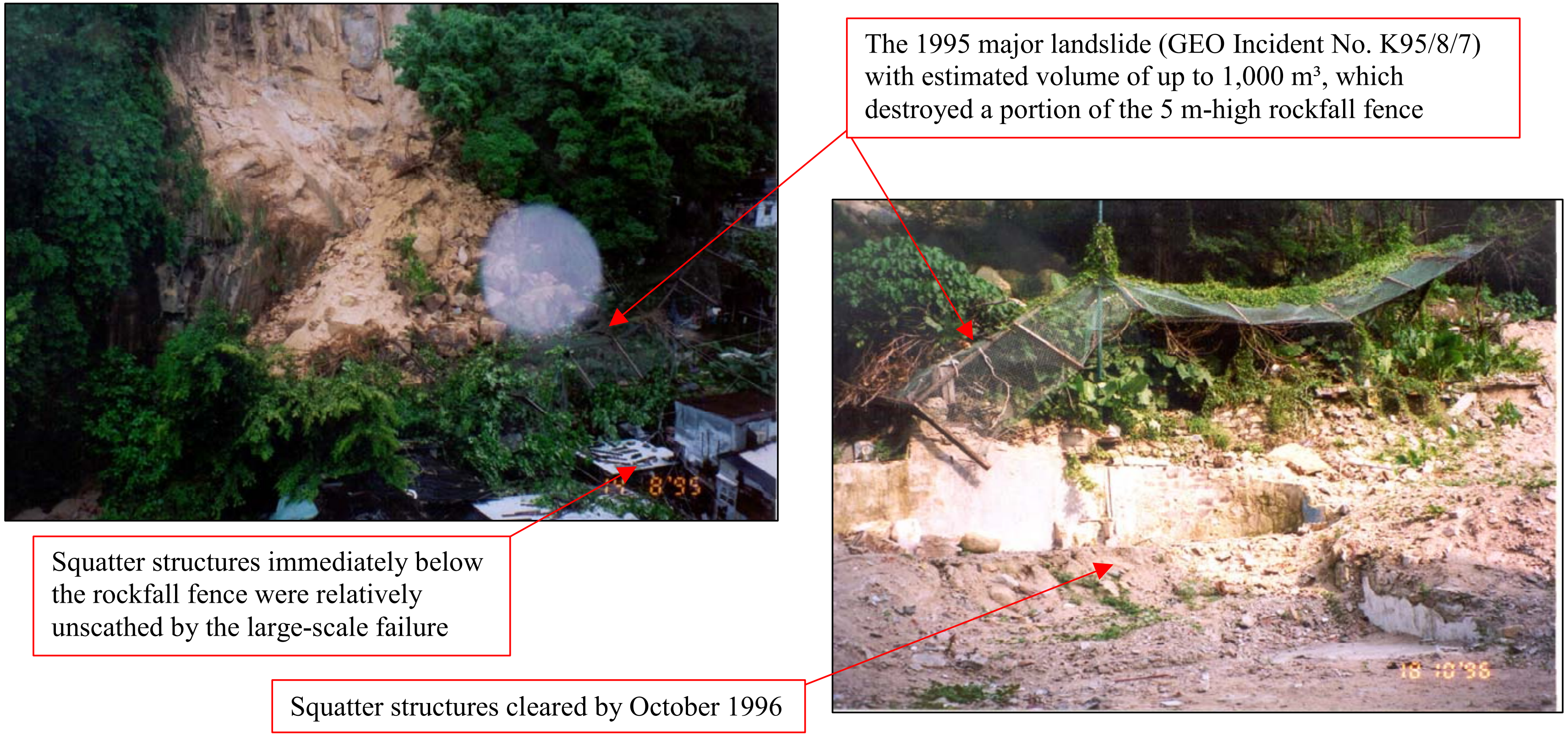

The 1995 major landslide (GEO Incident No. K95/8/7) with estimated volume of up to 1,000 m^3, which destroyed a portion of the 5 m-high rockfall fence

Squatter structures immediately below the rockfall fence were relatively unscathed by the large-scale failure

Squatter structures cleared by October 1996

Plate 5 - View Showing the Mitigating Effects of the Rockfall Fence During a Previous Landslide
(Photographs taken by GEO on 14 August 1995 and 18 October 1996)

Note: See Figure 15 for location and direction of photograph.

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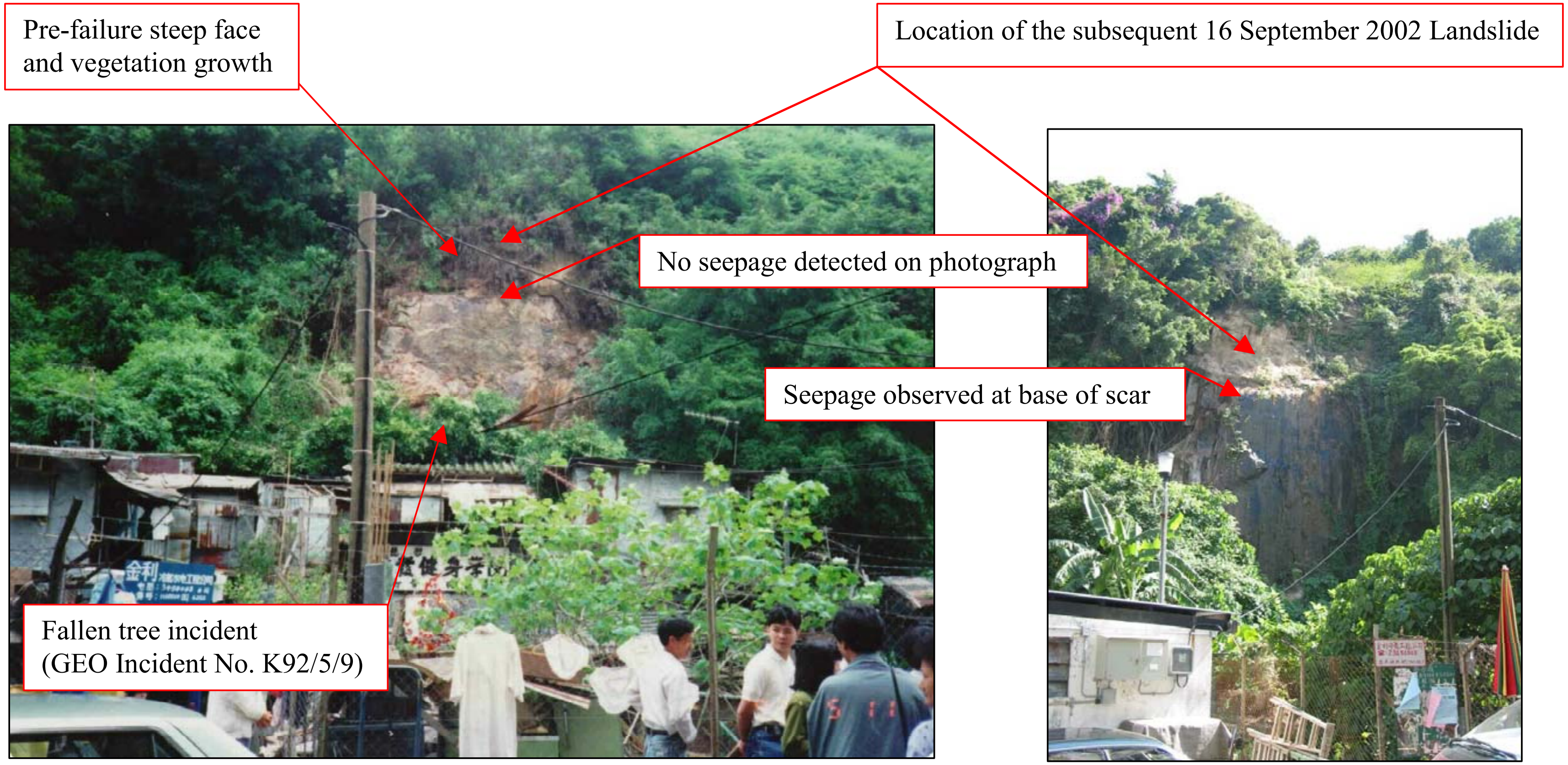

(a) Photograph taken by GEO in May 1992 showing the pre-failure view of the landslide site

(b) Photograph taken by MGSL in November 2002 showing the post-failure view of the landslide site

Plate 6 - Pre-Failure and Post-Failure Terrain at the Landslide Location
(Photographs taken by GEO in May 1992 and by MGSL in November 2002)

Note: See Figure 15 for location and direction of photograph.

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Plate 7 - View of Slope No. 11NE-D/C18 (Photograph taken by the Lands D on 19 December 1999)

Note: See Figure 15 for location and direction of photograph.

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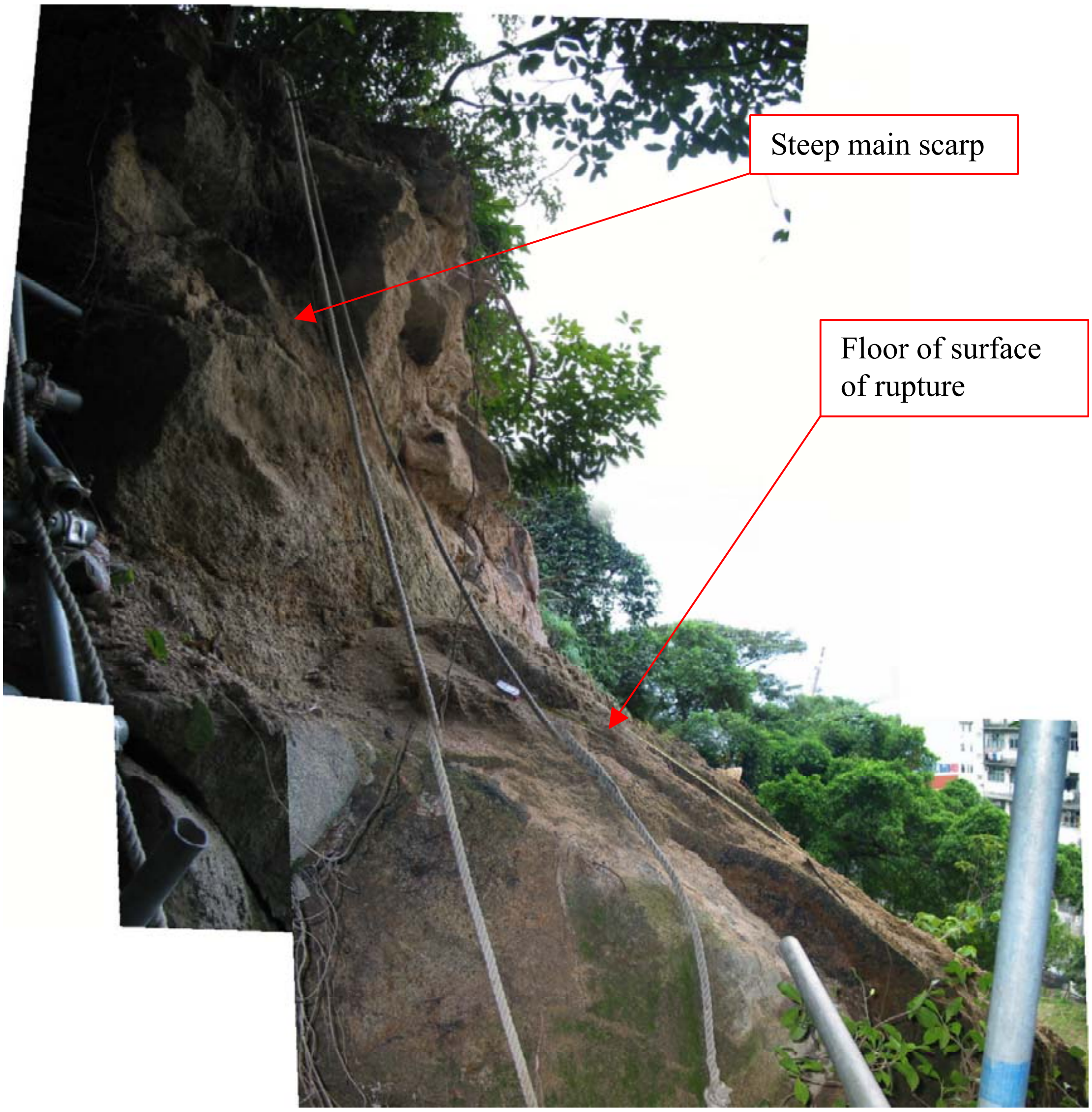

Plate 8 - Sideview of the Landslide Scar (Photograph taken on 27 November 2002)

Note: See Figure 15 for location and direction of photograph.

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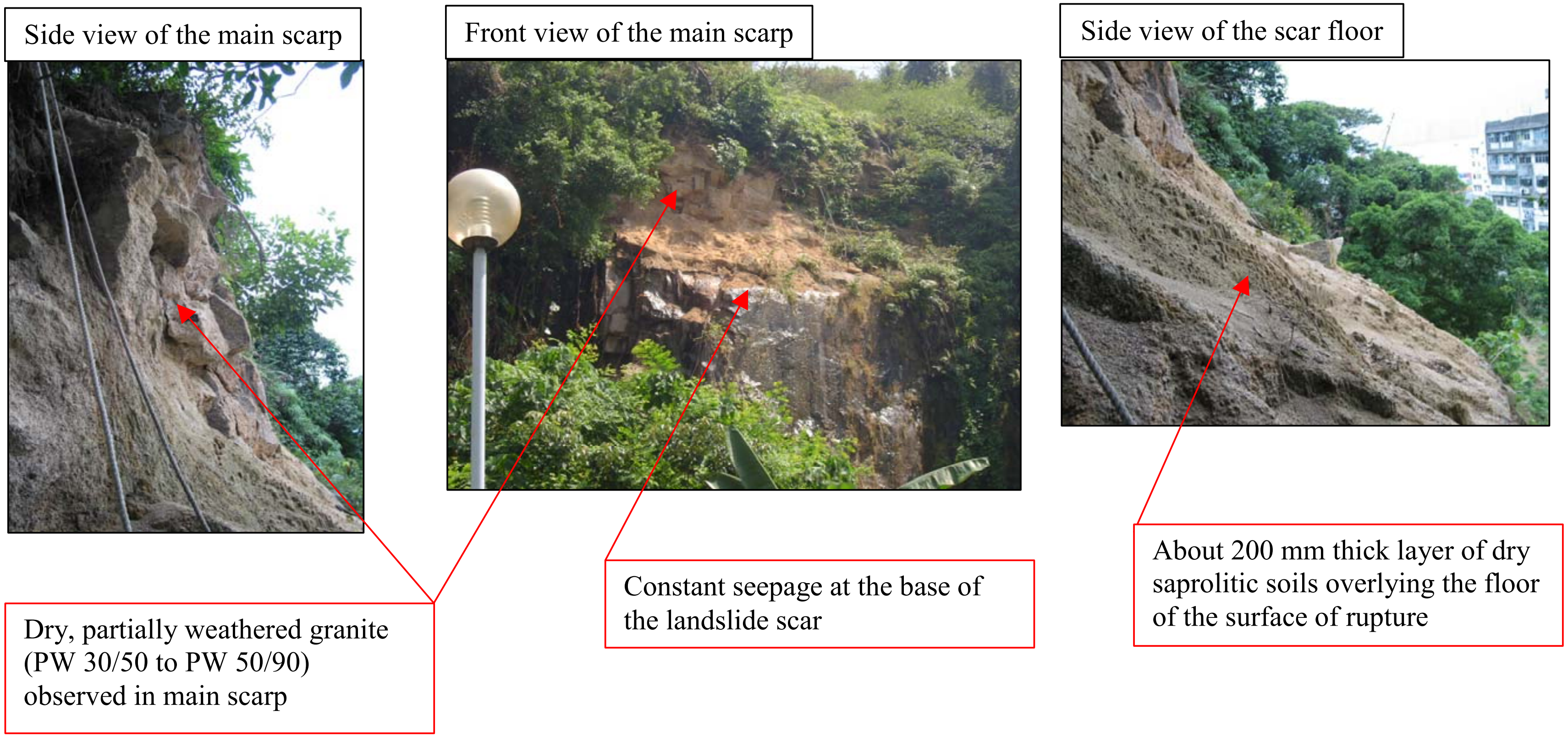

Side view of the main scarp

Front view of the main scarp

Side view of the scar floor

Dry, partially weathered granite (PW 30/50 to PW 50/90) observed in main scarp

Constant seepage at the base of the landslide scar

About 200 mm thick layer of dry saprolitic soils overlying the floor of the surface of rupture

Plate 9 - View of the Surface of Rupture (Photograph taken on 27 November 2002)

Note: See Figure 15 for location and direction of photograph.

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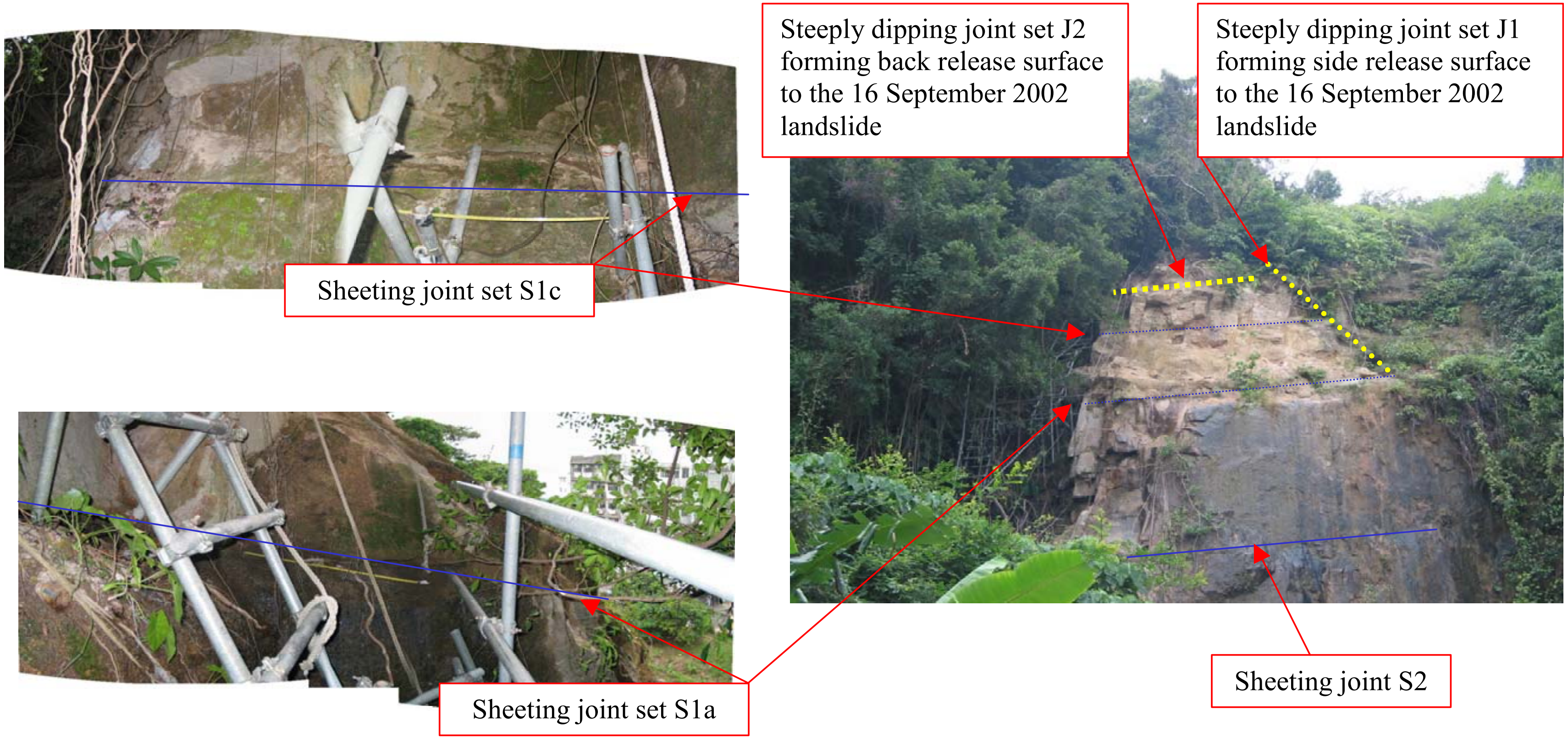

Plate 10 - View Showing the Main Structural Controls at the Landslide Source
(Photographs taken on 27 November 2002)

Note: See Figure 15 for location and direction of photograph.

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Landslide debris contained by the existing rockfall fence

Landslide debris comprising Grade IV granite with cobbles and some boulders of Grade III granite

Plate 11 - View of the Landslide Debris (Photographs taken on 27 November 2002)

Note: See Figure 15 for location and direction of photograph.

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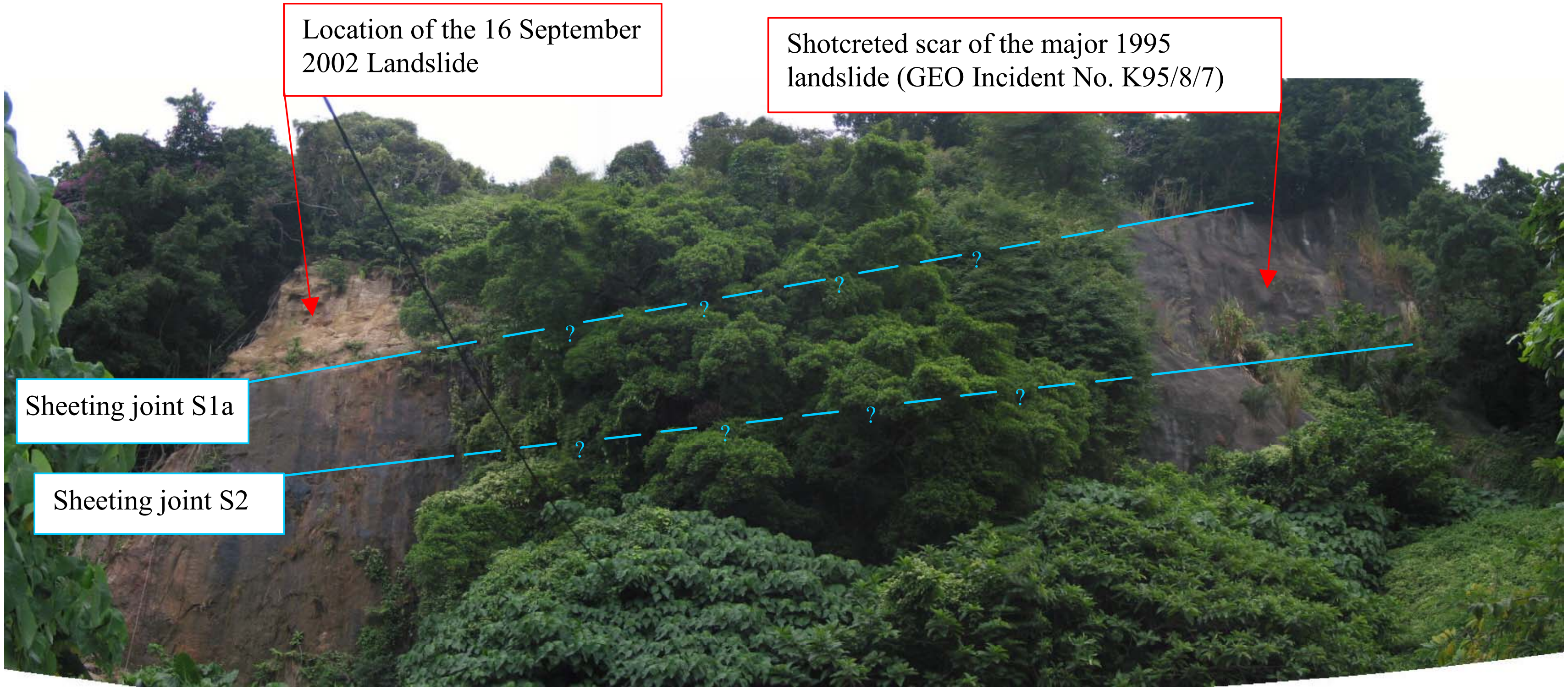

Plate 12 - View of the Sheeting Joints in Area 2 (Photograph taken on 27 November 2002)

Note: See Figure 15 for location and direction of photograph.

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Plate 13 - View of Incipient Failure Exacerbated by Vegetation Growth
(Photograph taken on 10 October 2002)

Note: See Figure 15 for location and direction of photograph.

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Recent block detachments contained by the 5 m high rockfall fence in Area 3. Similar failures (due to toppling and wedge sliding) observed at various locations along the slope toe.

Plate 14 - View Showing Typical Small-scale Failures Contained by the Rockfall Fence (Photograph taken on 10 October 2002)

Note: See Figure 15 for location and direction of photograph.

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APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

CONTENTS

A.1 DETAILED OBSERVATIONS

The following report comprises the detailed observations made from a review of aerial photographs taken between 1945 and 2002. A list of the aerial photographs studied and a location plan (Figure A1) are also attached.

YEAR	**OBSERVATIONS**
1945	Slope No. 11NE-D/C18 appears to have been formed to its present-day profile. The quality and scale of the photographs do not allow a detailed assessment of the study slope and its immediate vicinity. Between the toe of slope No. 11NE-D/C18 and the coast, the land is uneven, rough in areas or under small scale cultivation or being utilised for salt production or for local mining (possibly exploitation of china clay (kaolin)). Slope No. 11NE-D/C18 is covered with sparse vegetation with areas of erosion within the crest areas. Scattered dwellings are present close to the alignment of the Cha Kwo Ling Road which is yet to be constructed and appears on the photograph as a drainage line or track. To the west of the future Cha Kwo Ling Road primary reclamation is evident (formation of the future fuel tank farm) on which mature cultivated fields have been established. To the southeast and east of slope No. 11NE-D/C18 it is evident that mine workings are in operation.
1954	The quality of the photographs are poor with only major opencast mining activities being able to be discerned to the east and south of slope No. 11NE-D/C18, and minor reclamations constructed to the west.
1959	The quality of the photographs are poor, however bare ground is present on the crest area of the study slope and scattered squatter structures are present between the toe of slope No. 11NE-D/C18 and Cha Kwo Ling Road which is under construction following the line of the original coast. Extensive mine operations are evident to the south and east of slope No. 11SW-D/C18.
1961	Evidence of bare ground in the crest area within the central portion of slope No. 11NE-D/C18 is observed. Extensive establishment of squatter structures is evident between the toe of slope No. 11NE-D/C18 and Cha Kwo Ling Road (under construction) adjacent to the southern section of the study slope. In the central section of the study area, establishment of squatter structures is less dense with areas of rough ground present. Dense establishment of squatter structures can be seen adjacent to the toe of the northern section of slope No. 11NE-D/C18. Extension of the mine workings to the northeast of the crest of slope No. 11NE-D/C18 (opposite the present-day Tower 37 of the Laguna City development) is observed.

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YEAR	OBSERVATIONS
1963	Only areas adjacent to the northern extremity of slope No. 11NE-D/C18 can be seen in the photograph. Dense establishment of squatter structures is evident between the toe of slope No. 11NE-D/C18 and Cha Kwo Ling Road, although those squatter structures directly adjacent to the road have been cleared presumably for tower block construction. The northeastern extension (opposite the present-day Tower 37 of Laguna City) of the mine workings continues with the deepening of operations. In this area of the workings, scattered squatter structures are present in its northernmost area.
1964	No significant changes are apparent within slope No. 11NE-D/C18. Squatter structures are now present along the northern toe of slope No. 11NE-D/C18 (parallel to the present-day Laguna City Tower Blocks 34 to 38). The tower block at Nos. 189-193 Cha Kwo Ling Road is under construction, and cleared land is evident in other areas directly adjacent to Cha Kwo Ling Road.
1967	A steep rock face forming the lower southern section of slope No. 11NE-D/C18 can be seen. Directly adjacent to this location, bare ground is evident which may provide possible evidence of a minor basal slide. Bare ground/erosion is also present at the crest. Construction of the tower block at Nos. 189-193 Cha Kwo Ling Road has been completed, with cleared land still evident in other areas directly adjacent to the road. The construction of new seawall sections and partial infilling provide evidence of further reclamation being commenced to the west of Cha Kwo Ling Road. Final excavation level of the opencast operations east of the southern extremity of slope No. 11NE-D/C18 may have been reached, with the presence of a high and near vertical hanging wall (in the known kaolin mine). Mining operations to the northeast of slope No. 11NE-D/C18 (opposite the present-day Tower 37 of Laguna City) may have been completed with a dense squatter development present throughout this worked area.

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YEAR	OBSERVATIONS
1972	Areas of bare ground are present mostly within the crest area of the study slope. An extensive surface covering (possibly chunam) is visible in the upper and middle slope sections of slope No. 11NE-D/C18 above the dense squatter structures in the southern part of the slope. The northern toe of slope No. 11NE-D/C18 (parallel to the present-day Laguna City Tower Blocks 34 to 38) has a decreased number of squatter structures with the former northwestern extension of the opencast workings (opposite from the to be constructed Tower 37 of Laguna City) devoid of squatter dwellings. Cha Kwo Ling Building, Cheung Lee Building, Yau Fook Building, Kam See Building and Kar Hing Building have all been constructed, and the Wing Tak Building under construction. Fan Wa Street is not yet present. Reclamation to the west of Cha Kwo Ling Road is complete. Northeastern opencast mining section (opposite the to be constructed Tower 37 of Laguna City) is now re-vegetated and the mine workings appear to have ceased.
1973	Vegetation cover over slope No. 11NE-D/C18 is denser with establishment of small trees or large shrubs over the whole slope surface. Large trees are evident along the entire toe of the study slope but concentrated in the southern and northern extremity zones. Limited squatter clearance thought to be for the construction of Yuen Cheong Building is visible. Dense establishment of squatter structures now present between the central section of the toe of the study slope and the track/Fan Wa Street. The northern toe of the study slope (parallel to the present-day Laguna City Tower Blocks 34 to 38) has only a small number of scattered squatter structures. Wing Tak Building and the Church are completed. Obvious track or preliminary works for Fan Wa Street is evident. Most of the mining operations appear to have been ceased, with the only opencast workings with associated processing plant limited to areas directly to the southeast of slope No. 11NE-D/C18 (i.e. the known kaolin mine).
1974	Cleared bare or eroded ground is evident within the abandoned northeastern opencast workings extension area (opposite the then proposed Tower 37 of Laguna City and downslope of the crest of the present-day slope No. 11NE-D/C499). Squatter structures re-established along northern toe of slope No. 11NE-D/C18 (parallel to the present-day Laguna City Tower Blocks 34 to 38), as well as the previously abandoned northeastern opencast workings extension area. High density squatter structures visible between the toe of the slope and the entire length of the now completed Fan Wa Street. Yuen Cheong, Luen Hing & Wing Wah Buildings have been constructed.

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YEAR	OBSERVATIONS
1975	Cleared area (observed in the 1974 aerial photographs) within the abandoned northeastern opencast workings extension area is being used for establishment of squatter structures (two structures have been built). Kar Wah Building had been constructed.
1976	No significant changes to slope No. 11NE-D/C18 or to the adjacent squatter structures are apparent.
1977	Only the northern section of slope No. 11NE-D/C18 and the adjacent establishment of squatter structures at the toe are covered by the photographs. No significant changes to slope No. 11NE-D/C18 or to the adjacent squatter structures are apparent.
1979	No significant changes to slope No. 11NE-D/C18 or to the adjacent squatter structures are apparent. Filling of the former opencast mine pit (now Sai Tso Wan Landfill) to the east of slope No. 11NE-D/C18 is on-going.
1980	Evidence of localised areas of surface erosion below the crest of the present-day slope No. 11NE-D/C499. Large trees are evident along the entire toe of the central section of slope No. 11NE-D/C18. Filling completed and restoration site formation benching has commenced for the Sai Tso Wan Landfill to the east of slope No. 11NE-D/C18. Formation of cut slope benches has commenced to the east of the central and northern sections of the study slope for future basal warehouse/factory development.
1981	No significant changes to slope No. 11NE-D/C18 or to the adjacent squatter structures are apparent. Further restoration bench development of Sai Tso Wan Landfill site east of slope No. 11NE-D/C18 is visible.
1982	No significant changes to slope No. 11SW-D/C18 or to the adjacent squatter structures are apparent. Further restoration bench development of Sai Tso Wan Landfill site east of slope No. 11NE-D/C18 with vegetation established on lower benches.
1983	Over the chunam section surface within the southern portion of slope No. 11NE-D/C18 evidence of extensive surface erosion down slope, and beyond the toe into squatter structures, is apparent. This may have been a landslide event as a comparison with the 1982 aerial photographs indicates that mature trees are absent and approximately 5 squatter structures have disappeared. Site formation for Sai Tso Wan Landfill site east of the study slope is nearing completion with all the benches being vegetated. Warehouse/factory construction is also apparent to the east of the study slope in the original mine working area.

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YEAR	OBSERVATIONS
1984	Vegetation cover has densified with nearly the entire surface of slope No. 11NE-D/C18 covered by a canopy of either trees or large bushes. This canopy has masked the previous identified bare/eroded crest areas of the study slope. Vegetation is re-establishing in the previous year indicated surface erosion/landslide area below the chunam slope in the southern extremity of slope No. 11NE-D/C18. Re-establishment of squatter structures is also occurring in this area. Squatter clearance between the toe of the study slope and Fan Wa Street, opposite the Yuen Cheong and Wing Tak Buildings, has taken place, with the area being used as a car park/container storage yard. Local deepening of the opencast pit (presumably for kaolin exploitation) to the east of the southern extremity of slope No. 11NE-D/C18 has also taken place. Warehouse/factory construction continuing to east of slope No. 11NE-D/C18 in the original mine working area with the benching of the cut slope nearing completion.
1985	Vegetation and squatter structures have been totally re-established in the 1983 surface erosion/landslide area below the chunam slope in the southern extremity of slope No. 11NE-D/C18. Squatter structures have been cleared within the abandoned northeastern opencast workings extension area to the northeast of slope No. 11NE-D/C18 (opposite the to be constructed Tower 37 of Laguna City). This area appears to be extensively eroded which perhaps provides supporting evidence for the documented landslide (GEO incident No. K84/5/10) in the area. In addition, squatter clearance is also apparent along the northern toe of the study slope (parallel to the present-day Laguna City Tower Blocks 34 to 38) and on the slope directly south and below the crest forming the western edge of the afore-mentioned northeastern opencast working extension area.
1986	Crest areas of slope No. 11NE-D/C18 show evidence of a decrease in vegetation density with only grassland prevalent. Site formation works (cutting and filling) for Laguna City have commenced to the north of slope No. 11NE-D/C18 beyond the toe of the slope. Squatter structures have been re-established in the abandoned northeastern opencast workings extension area (opposite the to be constructed Tower 37 of Laguna City). Continued deepening of opencast pit for kaolin exploitation to the east of the southern extremity of slope No. 11NE-D/C18.

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YEAR	OBSERVATIONS
1987	The clear scar of the documented landslide incident (GEO incident No. K85/8/13) can be seen with the associated debris trail extending close to the base of slope No. 11NE-D/C18. Site formation works continue to the north of slope No. 11NE-D/C18 beyond the toe of the slope and the squatter structures with the major cut slope bordering the study slope (for the Laguna City development) nearing completion. Commencement of construction of small temporary buildings at the crest of the Sai Tso Wan Landfill site.
1988	Photographs show the area immediately northeast of slope No. 11NE-D/C18. Construction of the major cut slope adjoining slope No. 11NE-D/C18 (for the Laguna City development) is complete. Further construction and placement of containers on the crest of the Sai Tso Wan Landfill.
1989	Construction, and possibly localised squatter clearance, is taking place around the Latrine adjacent to Fan Wa Street and opposite the Wing Tak Building. Site formation works for Laguna City have extended close to the northern toe of the study slope. As a result all former squatter structures from this area have been cleared. Temporary structures and containers on the crest of the Sai Tso Wan Landfill absent. Lagoonal lake formed within locally deepened (kaolin) workings to the east of the southern extremity of slope No. 11NE-D/C18.
1990	Work continues around the Latrine between the toe of slope No. 11NE-D/C18 and Fan Wa Street opposite the Wing Tak Building. Two graves are evident on study slope crest. The major cut slope adjoining slope No. 11NE-D/C18 (for the Laguna City development) is partly vegetated and the foundations for Laguna City Tower Blocks 34 to 38 have been completed.
1991	No significant changes to slope No. 11NE-D/C18 or to the adjacent squatter structures are apparent. Laguna City Blocks 34 to 38 completed. Sai Tso Wan Landfill full surface drainage established and all areas have a vegetation covering. Redevelopment of the area immediately to the northwest of Sai Tso Wan Landfill is in progress.

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YEAR	OBSERVATIONS
1992	Indications of surface erosion and bare ground near the base of the slope No. 11NE-D/C18 may provide evidence of the recorded minor landslide (GEO incident No. K90/4/2). Redevelopment of area immediately to the northwest of Sai Tso Wan Landfill completed.
1993	Squatter clearance observed in the central portion of slope No. 11NE-D/C18, between the Latrine and the toe of the slope. Lower slopes of Sai Tso Wan Landfill covered by bush vegetation with installation of gas/leachate monitoring wells through the top of landfill cap.
1994	No significant changes to slope No. 11NE-D/C18 or to the adjacent squatter structures are apparent.
1995	Possible evidence of documented landslide incident (GEO incident No. K92/5/9) is apparent, indicated by a steep scar and a break in the dense vegetation cover. Clear evidence of documented landslide (GEO incident No. K95/8/7) with fresh scar and debris trail reaching the toe of the slope.
1996	Shotcreting of the scarp of documented landslide (GEO incident No. K95/8/7) is ongoing. Extensive squatter clearance between the toe of slope No. 11NE-D/C18 and Fan Wa Street between the Wing Wah Building and the Church. Kaolin mine workings, directly adjacent to the southern extremity of slope No. 11NE-D/C18 appear to have been abandoned.
1997	Shotcreting of the scarp of the documented landslide (GEO incident No. K95/8/7) is completed with the slope toe area to the edge of Fan Wa Street being bare.
1998	Re-vegetation of the 1996 cleared squatter area which was bare in the previous year.
1999	Bare ground may provide possible evidence of the documented landslide (GEO incident No. K97/7/5) at the southwestern-most lip of the abandoned northeastern opencast workings extension area (opposite Tower 37 of Laguna City). Drilling rigs are evident above the documented landslide (GEO incident No. K95/8/7) and directly above this location at the crest of slope No. 11NE-D/C18, as well as adjacent to the now demolished warehouse/factory and within the abandoned kaolin mine workings area to the east of the slope.

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YEAR	OBSERVATIONS
2000	Bare ground at the southeastern corner of slope No. 11NE-D/C499 provides further evidence of the documented landslide (GEO incident No. K97/7/5). Isolated re-establishment of trees within the shotcreted extent of the documented landslide (GEO incident No. K95/8/7).
2001	No significant changes to slope No. 11NE-D/C18 or to the adjacent squatter structures are apparent.
2002	Further vegetation growth is evident within the landslide scar and shotcreted extent of the documented landslide (GEO incident No. K95/8/7), as well as the upslope areas above this landslide site. Previously cleared squatter area (1996) has a well-established vegetation cover.

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Table A1 - List of Aerial Photographs

Date Taken	Altitude (feet)	Aerial Photograph
11 November 1945	20,000	3030-3131
2 November 1954	28,300	Y02647-48
5 October 1959	40,000	Y04608-09
17 January 1961	30,000	Y04835-36
25 January 1963	2,700	Y07868-69
13 December 1964	12,500	Y12904-05
16 May 1967	6,250	Y13336-37
14 July 1972	2,700	1941-42
12 October 1973	2,500	4971-72
6 December 1974	4,000	10167-68
2 December 1975	4,500	11600-01
4 October 1976	4,000	15320-21
21 December 1977	4,000	20364-65
28 November 1979	10,000	28031-32
17 April 1980	4,000	30046-47
26 October 1981	10,000	39039-40
10 October 1982	10,000	44510-11
30 November 1983	10,000	51382-83
7 January 1984	2,000	52443-44
7 July 1985	10,000	A01727-28
22 September 1986	4,000	A06409-10
11 June 1987	4,000	A09559-60
15 June 1988	2,200	70013-14
7 July 1989	2,500	A17340-41
13 November 1990	4,000	A23695-96
20 September 1991	4,000	A27372-73
16 April 1992	4,000	A30356-57
26 July 1993	4,000	A35528-33529
8 October 1993	4,000	CN4598-99*
6 May 1994	4,000	A38052-53
27 September 1995	3,500	CN11236-37*
18 November 1996	5,000	CN15656-57*
26 May 1997	4,000	CN17149-50*
31 October 1998	4,000	CN22162-63*
11 June 1999	2,600	CN23076-77*
16 February 2000	20,000	CN25916-17*
26 July 2000	4,000	CN27455-56*
15 February 2001	20,000	CN29879-80*
16 August 2001	8,000	CW32196-97*
2 April 2002	3,000	CW39294-95*

Note: All aerial photographs are in black and white except those denoted with an asterisk.

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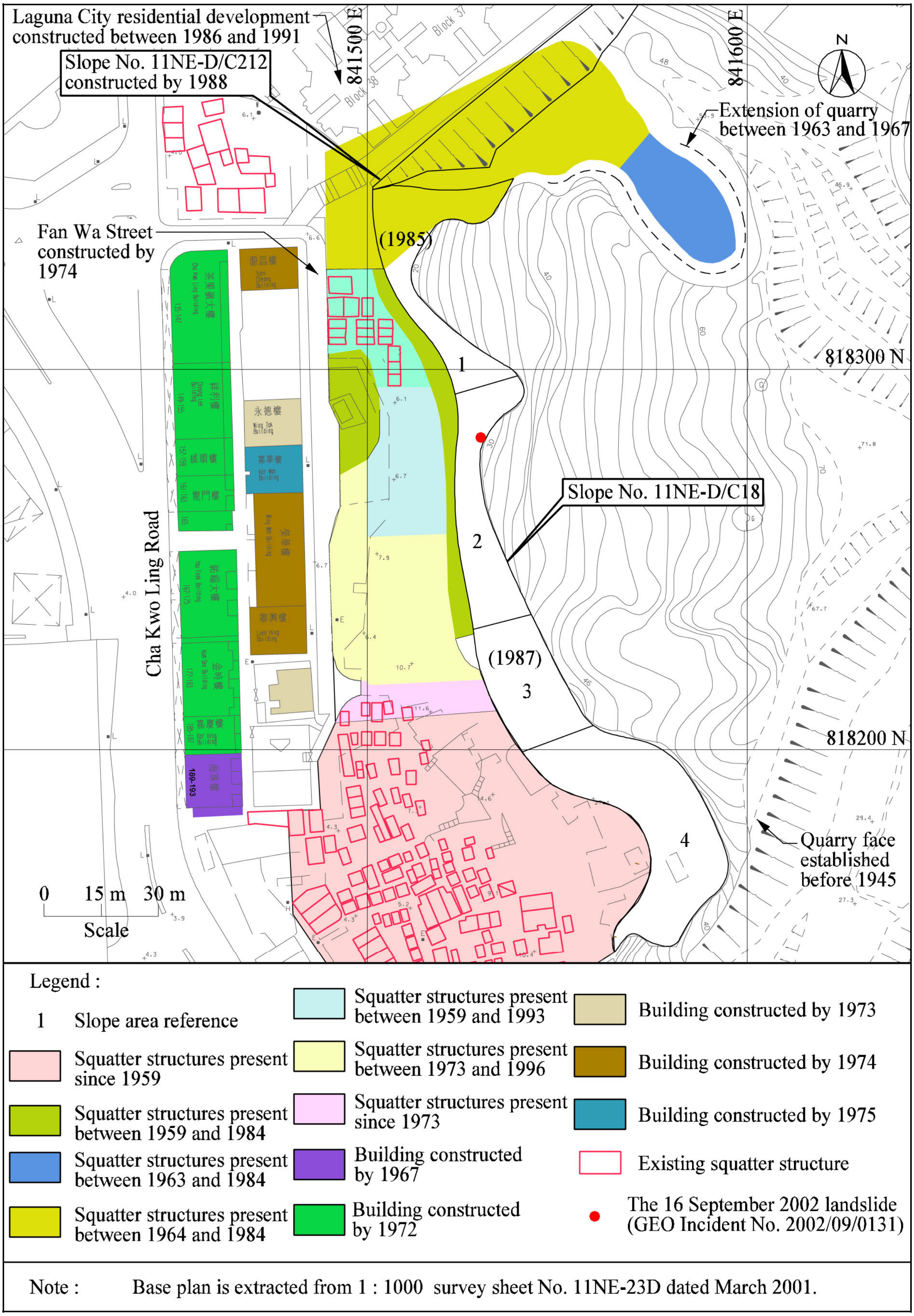

Note : Base plan is extracted from 1 : 1000 survey sheet No. 11NE-23D dated March 2001.

Figure A1 - Aerial Photograph Interpretation

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APPENDIX B

ANALYSES OF RAINFALL RECORDS FOR PREVIOUS RECORDED LANDSLIDES

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Table B1 - Maximum Rolling Rainfall at GEO Raingauge No. K08 for Selected Durations Preceding the Landslide on 31 August 1995 and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years) (See Note 2)
5 Minutes	0.5	13:30 hours on 31 August 1995	< 2
15 Minutes	0.5	13:30 hours on 31 August 1995	< 2
1 Hour	1.0	13:50 hours on 31 August 1995	< 2
2 Hours	1.0	14:00 hours on 31 August 1995	< 2
4 Hours	1.0	13:50 hours on 31 August 1995	< 2
12 Hours	1.0	13:50 hours on 31 August 1995	< 2
24 Hours	1.0	13:50 hours on 31 August 1995	< 2
48 Hours	12.0	14:00 hours on 30 August 1995	< 2
4 Days	129.0	14:00 hours on 30 August 1995	< 2
7 Days	134.5	14:00 hours on 30 August 1995	< 2
15 Days	136.5	13:50 hours on 31 August 1995	< 2
31 Days	1260.0	13:50 hours on 31 August 1995	76

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). The return periods obtained by the two methods do not show a significant difference.
(3) The use of 5-minute data for return period of rainfall durations between 2 hours and 31 days results in better data resolution, but may slightly over-estimate the return periods using data by Lam & Leung (1994), which are based on hourly rainfall for these durations.
(4) According to GEO Incident Report No. K95/8/26, the landslide occurred at about 2:00 p.m. on 31 August 1995.
(5) The nearest GEO raingauge to the landslide site is raingauge No. K08 situated at about 800 m to the east of the site.

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Table B2 - Maximum Rolling Rainfall at GEO Raingauge No. K08 for Selected Durations Preceding the Landslide on 12 August 1995 and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years) (See Note 2)
5 Minutes	5.0	16:40 hours on 12 August 1995	< 2
15 Minutes	14.5	16:50 hours on 12 August 1995	< 2
1 Hour	35.5	17:00 hours on 12 August 1995	< 2
2 Hours	42.0	17:00 hours on 12 August 1995	< 2
4 Hours	68.5	07:00 hours on 12 August 1995	< 2
12 Hours	151.0	17:00 hours on 12 August 1995	< 2
24 Hours	211.5	17:00 hours on 12 August 1995	< 2
48 Hours	250.0	17:00 hours on 12 August 1995	< 2
4 Days	250.0	17:00 hours on 12 August 1995	< 2
7 Days	291.0	07:15 hours on 12 August 1995	< 2
15 Days	789.0	17:00 hours on 12 August 1995	15
31 Days	1169.5	17:00 hours on 12 August 1995	43

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). The return periods obtained by the two methods do not show a significant difference.
(3) The use of 5-minute data for return period of rainfall durations between 2 hours and 31 days results in better data resolution, but may slightly over-estimate the return periods using data by Lam & Leung (1994), which are based on hourly rainfall for these durations.
(4) According to GEO Incident No. K95/8/7, the landslide occurred at about 5:00 p.m. on 12 August 1995.
(5) The nearest GEO raingauge to the landslide site is raingauge No. K08 situated at about 800 m to the east of the site.

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Table B3 - Maximum Rolling Rainfall at GEO Raingauge No. K08 for Selected Durations Preceding the Landslide on 08 May 1992 and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years) (See Note 2)
5 Minutes	12.5	06:55 hours on 08 May 1992	< 2
15 Minutes	34.5	06:55 hours on 08 May 1992	5
1 Hour	114.5	07:25 hours on 08 May 1992	19
2 Hours	139.5	08:15 hours on 08 May 1992	8
4 Hours	160.0	09:05 hours on 08 May 1992	5
12 Hours	228.0	14:30 hours on 08 May 1992	4
24 Hours	236.0	12:30 hours on 08 May 1992	3
48 Hours	282.0	14:30 hours on 08 May 1992	3
4 Days	283.0	14:30 hours on 08 May 1992	< 2
7 Days	284.0	14:30 hours on 08 May 1992	< 2
15 Days	284.5	14:30 hours on 08 May 1992	< 2
31 Days	523.0	14:30 hours on 08 May 1992	< 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). The return periods obtained by the two methods do not show a significant difference.

(3) The use of 5-minute data for return period of rainfall durations between 2 hours and 31 days results in better data resolution, but may slightly over-estimate the return periods using data by Lam & Leung (1994), which are based on hourly rainfall for these durations.

(4) According to GEO Incident Report No. K92/5/9, the landslide occurred at about 02:30 p.m. on 8 May 1992.

(5) The nearest GEO raingauge to the landslide site is raingauge No. K08 situated at about 800 m to the east of the site.

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Table B4 - Maximum Rolling Rainfall at GEO Raingauge No. K08 for Selected Durations Preceding the Landslide on 2 June 1990 and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years) (See Note 2)
5 Minutes	5.0	11:40 hours on 1 June 1990	< 2
15 Minutes	12.5	11:50 hours on 1 June 1990	< 2
1 Hour	40.0	12:10 hours on 1 June 1990	< 2
2 Hours	48.0	12:40 hours on 1 June 1990	< 2
4 Hours	56.0	05:00 hours on 2 June 1990	< 2
12 Hours	85.5	19:15 hours on 1 June 1990	< 2
24 Hours	87.0	22:00 hours on 1 June 1990	< 2
48 Hours	87.0	22:00 hours on 1 June 1990	< 2
4 Days	90.5	22:00 hours on 1 June 1990	< 2
7 Days	119.5	19:15 hours on 1 June 1990	< 2
15 Days	129.0	18:50 hours on 1 June 1990	< 2
31 Days	211.0	22:00 hours on 1 June 1990	< 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). The return periods obtained by the two methods do not show a significant difference.
(3) The use of 5-minute data for return period of rainfall durations between 2 hours and 31 days results in better data resolution, but may slightly over-estimate the return periods using data by Lam & Leung (1994), which are based on hourly rainfall for these durations.
(4) According to GEO Incident Report No. K90/6/1, the landslide occurred at about 5:00 a.m. on 2 June 1990.
(5) The nearest GEO raingauge to the landslide site is raingauge No. K08 situated at about 800 m to the east of the site.

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Table B5 - Maximum Rolling Rainfall at GEO Raingauge No. K08 for Selected Durations Preceding the Landslide on 12 April 1990 and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years) (See Note 2)
5 Minutes	5.0	09:40 hours on 11 April 1990	< 2
15 Minutes	10.5	09:50 hours on 11 April 1990	< 2
1 Hour	19.5	09:55 hours on 11 April 1990	< 2
2 Hours	21.5	10:10 hours on 11 April 1990	< 2
4 Hours	23.0	12:30 hours on 11 April 1990	< 2
12 Hours	41.5	20:15 hours on 11 April 1990	< 2
24 Hours	56.5	16:00 hours on 11 April 1990	< 2
48 Hours	90.0	16:00 hours on 11 April 1990	< 2
4 Days	98.5	21:25 hours on 11 April 1990	< 2
7 Days	104.0	18:50 hours on 10 April 1990	< 2
15 Days	183.0	21:25 hours on 11 April 1990	< 2
31 Days	185.0	21:25 hours on 11 April 1990	< 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). The return periods obtained by the two methods do not show a significant difference.

(3) The use of 5-minute data for return period of rainfall durations between 2 hours and 31 days results in better data resolution, but may slightly over-estimate the return periods using data by Lam & Leung (1994), which are based on hourly rainfall for these durations.(4)According to GEO Incident Report No. K90/4/2, the landslide occurred at about 2:30 a.m. on 12 April 1990.

(5) The nearest GEO raingauge to the landslide site is raingauge No. K08 situated at about 800 m to the east of the site.

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Table B6 - Maximum Rolling Rainfall at GEO Raingauge No. K08 for Selected Durations Preceding the Landslide on 20 May 1989 and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years) (See Note 2)
5 Minutes	0.0	N/A	< 2
15 Minutes	0.0	N/A	< 2
1 Hour	0.0	N/A	< 2
2 Hours	0.0	N/A	< 2
4 Hours	0.0	N/A	< 2
12 Hours	0.0	N/A	< 2
24 Hours	0.0	N/A	< 2
48 Hours	0.0	N/A	< 2
4 Days	0.0	N/A	< 2
7 Days	0.0	N/A	< 2
15 Days	0.0	N/A	< 2
31 Days	59.5	00:00 hours on 16 May 1989	< 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). The return periods obtained by the two methods do not show a significant difference.
(3) The use of 5-minute data for return period of rainfall durations between 2 hours and 31 days results in better data resolution, but may slightly over-estimate the return periods using data by Lam & Leung (1994), which are based on hourly rainfall for these durations.
(4) According to GEO Incident Report No. K89/5/120, the landslide occurred on 20 May 1989.
(5) The nearest GEO raingauge to the landslide site is raingauge No. K08 situated at about 800 m to the east of the site.

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Table B7 - Maximum Rolling Rainfall at GEO Raingauge No. K08 for Selected Durations Preceding the Landslide on 8 May 1987 and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years) (See Note 2)
5 Minutes	3.0	18:15 hours on 7 May 1987	< 2
15 Minutes	4.5	19:50 hours on 7 May 1987	< 2
1 Hour	9.0	19:00 hours on 7 May 1987	< 2
2 Hours	16.0	20:00 hours on 7 May 1987	< 2
4 Hours	21.5	21:45 hours on 7 May 1987	< 2
12 Hours	24.5	04:45 hours on 8 May 1987	< 2
24 Hours	32.5	13:20 hours on 8 May 1987	< 2
48 Hours	32.5	13:20 hours on 8 May 1987	< 2
4 Days	36.0	13:20 hours on 8 May 1987	< 2
7 Days	47.5	13:20 hours on 8 May 1987	< 2
15 Days	47.5	13:20 hours on 8 May 1987	< 2
31 Days	311.0	01:00 hours on 6 May 1987	< 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). The return periods obtained by the two methods do not show a significant difference.

(3) The use of 5-minute data for return period of rainfall durations between 2 hours and 31 days results in better data resolution, but may slightly over-estimate the return periods using data by Lam & Leung (1994), which are based on hourly rainfall for these durations.

(4) According to GEO Incident Report No. K87/5/2, the landslide occurred on 8 May 1987.

(5) The nearest GEO raingauge to the landslide site is raingauge No. K08 situated at about 800 m to the east of the site.

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Table B8 - Maximum Rolling Rainfall at GEO Raingauge No. K08 for Selected Durations Preceding the Landslide on 29 April 1987 and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years) (See Note 2)
5 Minutes	0.0	N/A	< 2
15 Minutes	0.0	N/A	< 2
1 Hour	0.0	N/A	< 2
2 Hours	0.0	N/A	< 2
4 Hours	0.0	N/A	< 2
12 Hours	0.0	N/A	< 2
24 Hours	0.0	N/A	< 2
48 Hours	0.0	N/A	< 2
4 Days	0.0	N/A	< 2
7 Days	0.0	N/A	< 2
15 Days	8.5	00:00 hours on 29 April 1987	< 2
31 Days	298.0	01:00 hours on 29 April 1987	< 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). The return periods obtained by the two methods do not show a significant difference.
(3) The use of 5-minute data for return period of rainfall durations between 2 hours and 31 days results in better data resolution, but may slightly over-estimate the return periods using data by Lam & Leung (1994), which are based on hourly rainfall for these durations.
(4) According to GEO Incident Report No. K87/5/1, the landslide occurred on 29 April 1987.
(5) The nearest GEO raingauge to the landslide site is raingauge No. K08 situated at about 800 m to the east of the site.

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Table B9 - Maximum Rolling Rainfall at GEO Raingauge No. K08 for Selected Durations Preceding the Landslide on 28 August 1985 and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years) (See Note 2)
5 Minutes	5.0	08:45 hours on 27 August 1985	< 2
15 Minutes	10.5	08:50 hours on 27 August 1985	< 2
1 Hour	24.5	08:55 hours on 27 August 1985	< 2
2 Hours	33.0	09:00 hours on 27 August 1985	< 2
4 Hours	47.0	09:10 hours on 27 August 1985	< 2
12 Hours	72.5	12:00 hours on 27 August 1985	< 2
24 Hours	115.0	00:20 hours on 27 August 1985	< 2
48 Hours	207.0	21:10 hours on 27 August 1985	< 2
4 Days	226.0	09:10 hours on 28 August 1985	< 2
7 Days	264.0	21:10 hours on 27 August 1985	< 2
15 Days	425.5	16:35 hours on 27 August 1985	< 2
31 Days	479.0	09:10 hours on 28 August 1985	< 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). The return periods obtained by the two methods do not show a significant difference.

(3) The use of 5-minute data for return period of rainfall durations between 2 hours and 31 days results in better data resolution, but may slightly over-estimate the return periods using data by Lam & Leung (1994), which are based on hourly rainfall for these durations.

(4) According to GEO Incident Report No. K85/8/13, the landslide occurred on 28 August 1985.

(5) The nearest GEO raingauge to the landslide site is raingauge No. K08 situated at about 800 m to the east of the site.

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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.

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://bookstore.esdlife.com
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- 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,
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Civil Engineering and Development Building,
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Civil Engineering and Development Building,
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Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5345
Fax: (852) 2714 0275
E-mail: ykhui@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
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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)
- 進入網上「政府書店」選購，網址爲 http://bookstore.esdlife.com
- 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)
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地政總署測繪處
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傳真: (852) 2116 0774

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土木工程拓展署
土力工程處
規劃部總土力工程師
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傳真: (852) 2714 0247
電子郵件: sdcampbell@cedd.gov.hk

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傳真: (852) 2714 0275
電子郵件: ykhui@cedd.gov.hk

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MAJOR GEOTECHNICAL ENGINEERING OFFICE PUBLICATIONS
土力工程處之主要刊物

GEOTECHNICAL MANUALS

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.

GEOGUIDES

Geoguide 1	Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2000).
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).
Geoguide 5	Guide to Slope Maintenance, 3rd Edition (2003), 132 p. (English Version).
岩土指南第五冊	斜坡維修指南，第三版(2003)，120頁(中文版)。
Geoguide 6	Guide to Reinforced Fill Structure and Slope Design (2002), 236 p.

GEOSPECS

Geospec 1	Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997).
Geospec 2	Model Specification for Reinforced Fill Structures (1989), 135 p. (Reprinted, 1997).
Geospec 3	Model Specification for Soil Testing (2001), 340 p.

GEO PUBLICATIONS

GCO Publication No. 1/90	Review of Design Methods for Excavations (1990), 187 p. (Reprinted, 2002).
GEO Publication No. 1/93	Review of Granular and Geotextile Filters (1993), 141 p.
GEO Publication No. 1/96	Pile Design and Construction (1996), 348 p. (Reprinted, 2003).
GEO Publication No. 1/2000	Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (2000), 146 p.

GEOLOGICAL PUBLICATIONS

The Quaternary Geology of Hong Kong, by J.A. Fyfe, R. Shaw, S.D.G. Campbell, K.W. Lai & P.A. Kirk (2000), 210 p. plus 6 maps.

The Pre-Quaternary Geology of Hong Kong, by R.J. Sewell, S.D.G. Campbell, C.J.N. Fletcher, K.W. Lai & P.A. Kirk (2000), 181 p. plus 4 maps.

TECHNICAL GUIDANCE NOTES

TGN 1	Technical Guidance Documents

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