DETAILED STUDY OF THE SEPTEMBER 2001 LANDSLIDE ON THE HILLSIDE BELOW KWUN PING ROAD, NORTH OF TSZ WAN SHAN

GEO REPORT No. 153

Maunsell Geotechnical Services Ltd.

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

DETAILED STUDY OF THE SEPTEMBER 2001 LANDSLIDE ON THE HILLSIDE BELOW KWUN PING ROAD, NORTH OF TSZ WAN SHAN

GEO REPORT No. 153

Maunsell Geotechnical Services Ltd.

This report was originally produced in December 2002 as GEO Landslide Study Report No. LSR 10/2002

First published, December 2004

Prepared by:

Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon,
Hong Kong.

Table of Contents

Table of Contents

Table of Contents

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
December 2004

FOREWORD

This report presents the findings of a detailed study of a landslide incident (GEO Incident No. 2001/09/0091), which was reported to GEO on 2 September 2001, on a fill slope and the hillside immediately below Kwun Ping Road about 600 m north of its junction with Shatin Pass Road, north of Tsz Wan Shan. The landslide involved a failure volume of about 20 m^3. A section of the road verge collapsed with the landslide undermining a narrow portion of the road pavement. No casualties were reported as a result of the failure and no road closure was required.

The key objectives of the detailed study were to document the facts about the landslide, present relevant background information and establish the probable causes of the incident. Recommendations for follow-up actions are reported 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. CE72/2000. This is one of a series of reports produced during the consultancy by Maunsell Geotechnical Services Limited.

L.J. Endicott

Dr. L.J. Endicott
Project Director
Maunsell Geotechnical Services Limited

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

CONTENTS

1. INTRODUCTION

On 2 September 2001, a landslide (GEO Incident No. 2001/09/0091) was reported to have occurred on a fill slope and the hillside immediately below Kwun Ping Road about 600 m north of its junction with Shatin Pass Road, north of Tsz Wan Shan (Figure 1 and Plate 1). The landslide involved a failure volume of about 20 m^3. A section of the road verge collapsed with the landslide undermining a narrow portion of the road pavement. No casualties were reported as a result of the failure and no road closure was required.

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 and establish the probable causes of the failure. One of the main aims of the study was to assess whether the backfilled trench for the installation of an 80 mm diameter ductile iron fresh watermain in 1996/1997, played a role in the landslide or not. Recommendations for follow up actions are reported 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) topographic survey, geological mapping, and detailed inspections and measurements at the landslide site,

(c) limited ground investigation and laboratory testing,

(d) aerial photograph interpretation (API),

(e) analysis of rainfall data,

(f) engineering analysis of the failure, and

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

2. THE SITE

2.1 Site Description

The landslide occurred on a fill slope and the hillside below, which are located on the west (downhill) side of Kwun Ping Road, about 600 m north of its junction with Shatin Pass Road (Figures 1 and 2 and Plate 1). The fill slope was about 3 m high with a maximum fill thickness of about 1 m and inclined at approximately 40° to the horizontal. This fill slope was not registered in the Government's Slope Catalogue as it was not eligible for registration

because of its geometry and Consequence Category. A thin veneer of fill (less than 0.1 m in thickness, see Section 5.2) extends about 3 m from the toe of this fill slope into the natural hillside below. The angle of inclination of the hillside below the fill slope is approximately 40° for a distance of 30 m and gradually reduces to about 20°. The fill slope and the hillside below were covered with dense vegetation, comprising shrubs and trees.

Kwun Ping Road at the landslide site is a 3 m to 4 m wide, one lane, two way carriageway with passing bays, at an elevation of about 330 mPD. According to the limited ground investigation carried out following the landslide under this detailed study (see Section 5.4), the road surface is composed of an approximately 30 mm thick layer of bitumen overlying a 170 mm thick slab of concrete. The section of the road in the vicinity of the landslide site falls at about 1 in 10 towards the north. A topographic survey carried out under this detailed study established that the section of the road immediately above the landslide site has no cross fall, although there is a bend in the road at this particular location. The concrete road kerb (approximately 100 mm in height) on the west (downhill) side of the road is supported by a 600 mm wide by 150 mm deep no fines concrete edge strip (Figure 3).

There is a cut slope (No. 7SE-C/C352) on the uphill side of the section of Kwun Ping Road above the landslide site. It is about 35 m long, 4 m high and is inclined at approximately 62°. The slope surface is partly vegetated and partly shotcreted. The shotcrete cover is provided with 50 mm nominal diameter weepholes spaced at between 1.4 m and 1.8 m centres along the slope toe. A natural hillside inclined at 38° and covered with dense vegetation extends to an elevation of about 425 mPD above the crest of this slope.

A 300 mm U-channel (Figure 2) runs along the east side of Kwun Ping Road and directs upslope surface runoff into a series of catchpits located along the same side of the road in the vicinity of the landslide site. Surface runoff collected in each catchpit is then discharged onto the natural hillside on the west (downhill) side of the road via a 400 mm diameter cross-road drain. Road drainage gullies are also provided along both sides of Kwun Ping Road. Drainage gullies located on the east side of the road discharge surface runoff directly into the cross-road drain described above. Some manhole covers for telephone cable joint box were observed near the east side of the road.

Below the landslide site, there are remains of squatter units at the foot of the natural hillside about 45 m downhill of Kwun Ping Road. These squatter units were previously registered by the Housing Department (HD) in its 1982 Squatter Structure Survey with squatter control survey Nos. RKYS/A/51, 52 and 54 (Figure 3).

2.2 Water-carrying Services and Utilities

According to information provided by the utilities undertakers, an 80 mm diameter ductile iron fresh watermain and a telephone cable (with a 100 mm cable duct and joint boxes) have been installed beneath Kwun Ping Road at the landslide site (Figure 4). Based on field observations and documentary records, a telephone cable duct with joint boxes appears to have been laid near the east side of Kwun Ping Road.

2.3 Maintenance Responsibility

According to the Lands Department (Lands D), the September 2001 landslide occurred within unallocated Government land. Based on the Slope Maintenance Responsibility Information System (SMRIS) of the Lands D, Highways Department (HyD) is responsible for the maintenance of slope No. 7SE-C/C352. According to Home Affairs Department (HAD) the responsibility for the maintenance of Kwun Ping Road rests with them.

2.4 Site History

The site development history (Figure 3) has been established from aerial photographs taken between 1945 and 2000, and a review of documentary records in GEO and information provided by the Water Supplies Department (WSD). Details of the Aerial Photograph Interpretation (API) carried out as part of this detailed study are presented in Appendix A.

The earliest aerial photographs available (taken in 1945) show that Kwun Ping Road was a one lane road with approximately the same alignment as that of the present day. In the vicinity of the landslide site, a small fill slope on the west side of the road is visible in the 1967 aerial photograph and it was probably formed in association with the road widening works carried out between 1964 and 1967 (Figure 3).

Cultivation terraces were formed in 1963 on the hillside to the west of Kwun Ping Road below the landslide site and appeared to have been abandoned by 1977 (Figure 3). By 1982, the abandoned cultivation terraces were covered with dense vegetation. A squatter unit (designated as Squatter Unit A in this report and previously assigned a squatter control survey No. RKYS/A/54 by HD under their 1982 Squatter Structure Survey) is visible in the 1963 aerial photographs at the foot of the hillside below Kwun Ping Road, about 45 m downhill of the 2001 landslide site. Two other squatter units (designated as Squatters Units B and C respectively in this report and previously assigned squatter control survey Nos. RKYS/A/51 and 52 respectively by HD) are visible on the 1967 aerial photographs immediately adjacent to the Squatter Unit A. All three of these squatter units were located within unallocated Government land. Squatter Units A, B and C had not been inspected by the GEO under the Non Development Clearance (NDC) Programme before the September 2001 landslide since this area was not covered by the priority classification previously adopted for the selection of squatter areas for inspections under the NDC Programme. Based on API, the three squatter units were substantially demolished by 1986.

An access road connecting Kwun Ping Road and the area now strewn with the remains of Squatters Units A, B and C at the foot of the hillside is first visible on the 1972 aerial photographs (Figure 3). According to HAD, a no-fines concrete edge strip was constructed alongside the road kerb on the west edge of Kwun Ping Road by HAD in 1996. The no-fines concrete edge strip and concrete road kerb construction details extracted from HAD's drawing No. ST/96/13, are shown in Figure 3. No records of road maintenance works were available from the HAD.

Between 1996 and 1997, an 80 mm diameter ductile iron fresh watermain was laid on the west side of the road at a depth of about 1.2 m by Union Contractors Limited for WSD as part of the 'Water Supply to Remote Villages under Scheme 18' project, Contract

No. 44/WSD/94. The works were supervised by WSD. According to WSD, the works were carried out in accordance with the "General Specification for Civil Engineering Works, 1992 Edition". Accordingly, the top 200 mm of the backfill was compacted to a relative compaction not less than 98% and the backfill between the top 200 mm layer and the 300 mm layer directly above the watermain was compacted to 95% relative compaction. The material up to 300 mm above the watermain was compacted to 85%.

According to WSD's file records available for MGSL's inspection, three in-situ density tests at a depth of 150 mm below road formation level were carried out in February 1997 by WSD within the backfilled trench in the vicinity of the landslide site (i.e. along Kwun Ping Road within about 40 m of the landslide site). Also, in October 1996, one standard compaction test was carried out by the Public Works Central Laboratory on a soil sample taken from a location about 50 m to the north of the landslide site. The dry densities of the backfill material obtained from these three tests ranged from 1.58 Mg/m^3 to 1.62 Mg/m^3 and the maximum dry density of the soil sample determined from the standard compaction test was 1.61 Mg/m^3. Based on these tests results, the relative compaction of the backfilled material shown in WSD's records ranged between 98.1% and 100.6%. No in-situ density test results for the backfill material at deeper levels in the vicinity of the landslide site could be found from the records available for MGSL's inspection.

The profiles of the cut slopes along the east side of the road have not been changed significantly since the road was first constructed (i.e. pre-1945).

2.5 Past Instability

Prior to the 2001 incident, there are no records of previous landslides in the vicinity of the September 2001 landslide site in the GEO landslide database or the Natural Terrain Landslide Inventory.

Under the API carried out by MGSL, an old landslide scar on the natural hillside above slope No. 7SE-C/C352 was observed in the 1961 aerial photographs. The scar had become re-vegetated some time before 1963. Several relict landslides were also identified upslope of Kwun Ping Road (Figure 3 and Appendix A).

Based on API, no signs of instability were observed on the small fill slope that was involved in the September 2001 landslide. Furthermore no signs of instability of the other small fill slopes and the natural hillside in the vicinity of the September 2001 landslide along the downhill side of Kwun Ping Road could be observed from the API.

3. THE SEPTEMBER 2001 LANDSLIDE INCIDENT

At about 0:05 a.m. on 2 September 2001, the GEO received a Police report of a landslide (GEO Incident No. 2001/09/0058), which had occurred on slope No. 7SE-C/C352 (Section 2.1). This landslide at cut slope No. 7SE-C/C352, which is located on the east side of Kwun Ping Road above the subject landslide site, was inspected by GEO at about 2:00 p.m. on the same day. According to the GEO Incident Report, the landslide on cut slope No. 7SE-C/C352 involved a failure of about 8 m^3 of highly decomposed granite. The

landslide debris blocked about a quarter of the width of the road including the 300 mm U-channel at the toe of the slope (Figure 2).

During the inspection of the above landslide by GEO, another landslide (GEO Incident No. 2001/09/0091), which is the subject of this study, was observed on the small fill slope and the hillside below (i.e. to the west of) Kwun Ping Road approximately 10 m to the northwest of the landslide site of GEO Incident No. 2001/09/0058. The main landslide scar, which extended across the roadside verge and up to about 500 mm beneath the road pavement, was about 10 m long by 15 m wide with a maximum depth of about 1 m (Figures 2 and 5 and Plate 1). The landslide debris, with a volume of about 20 m^3, was deposited on the natural hillside below Kwun Ping Road. There is no direct information or witness account to indicate which of these landslides occurred first.

4. FIELD OBSERVATIONS BY MGSL

4.1 Observations from Field Inspections Following the Landslide

Following the landslide incident, MGSL inspected the site on 10 September 2001. At the time of inspection, the landslide scar had not been covered by shotcrete, which was subsequently applied to the scar as part of the urgent repair works recommended by GEO.

The subject landslide (GEO Incident No. 2001/09/0091) involved the failure of an approximately 3 m high fill slope and the hillside on the downhill side of the road and a thin veneer of fill (about 0.5 m thick) on the natural hillside located to the west of and immediately below Kwun Ping Road. The hillside was covered with dense vegetation including trees and shrubs. The landslide scar was about 10 m long by 15 m wide with a maximum depth of about 1 m (Figures 2 and 5 and Plate 1). The main scarp is inclined at about 65° to the horizontal. The materials exposed in the main scarp of the landslide comprised yellowish brown to dark brown fine to coarse sand with gravel- and occasional cobble-sized fragments of rock (probably comprising an upper 1 m layer of fill placed during the backfilling of the trench excavated in conjunction with the laying of the 80 mm diameter fresh watermain and a lower layer of fill, probably deposited in association with the widening of Kwun Ping Road) underlain by a thin layer of topsoil (less than 100 mm in thickness) and yellowish brown to dark brown, sandy silt/clay with gravel- and cobble-sized fragments of rock (colluvium) (Plate 2). Within the source of the landslide, the rupture surface appears to have been very close to the interface between the fill and the underlying colluvium.

The landslide debris was deposited on the natural hillside below Kwun Ping Road. The landslide debris comprised yellowish brown, gravelly, silt/sand, and orangish brown, gravelly, silt/sand with cobble- and boulder-sized rock fragments as well as sections of concrete kerbstone and fragments of no-fines concrete edge strip. At the time of inspection carried out by MGSL on 10 September 2001, the landslide debris was observed to be loose and still wet.

The west side of an approximately 10 m long section of Kwun Ping Road behind the main scarp of the landslide site was undermined up to a depth of approximately 500 mm, with the road pavement overhanging up to about 300 mm (Plate 2). Sections of the no-fines concrete edge strip and the concrete road kerb had collapsed over a length of about 15 m at the crest of the landslide scar (Plates 3 and 4). A 15 m long by 1 m wide strip of the road

pavement above the landslide main scarp had settled about 30 mm (Plate 3). It appears that the east edge of this settled strip was delineated by an old crack (being part of a crack designated as crack No. 1 in this report, see Section 4.2), which was sealed with cement mortar for an extent of about 23 m, along the west edge of the road (Plate 3). During the inspection on 10 September 2001, MGSL observed that the crack had re-opened.

Landslide debris, mainly sandy material with a few boulders up to about 1 m^3, was deposited downhill as far as the area with remains of Squatters Units A, B and C, some 45 m from the road (Figure 2 and Plates 5 and 6). An old, 2.2 m high, concrete wall at the end of the debris trail and located behind the area with the remains of Squatters Units A, B and C might have obstructed the movements of the landslide debris. The concrete wall was apparently damaged by the landslide debris, which included boulders and possibly the broken segments of kerbstone and strips of no-fines concrete (Figure 2 and Plate 5). The travel angle of the landslide debris was calculated to be 30° (based on field measurement from the crest of the main scarp to the portion of the segment of kerbstone and strips of no-fines concrete deposited on the hillside at an elevation of about 307 mPD, i.e. excluding the outwash of the debris).

Erosion gullies with a maximum depth of 0.5 m were observed along the debris trail, where vegetation and fallen trees were aligned in the direction of flow of the landslide debris (Plate 7). Broken segments of the concrete kerbstone and no-fines concrete edge strip (up to between 2 m and 3 m long) were deposited about 45 m from the roadside. No signs of past instability or signs of significant deterioration of the other small fill slopes and the hillside in the close vicinity of the landslide were observed during MGSL's inspections. The landslide debris did not appear to be channelised as there are no natural drainage lines in the vicinity of the landslide site.

Another landslide (GEO Incident No. 2001/09/0058) occurred on slope No. 7SE-C/C352 on the east side of Kwun Ping Road. At the time of MGSL's inspection on 10 September 2001, the landslide debris had been removed and the landslide scar had been covered with shotcrete as part of the urgent repair works and a detailed examination of the material exposed at the landslide scar could not be made. The landslide scar was about 5 m wide by 6 m high with a maximum depth of about 300 mm. The estimated volume of the landslide was about 8 m^3 (Figure 2).

Two utilities services have been laid along Kwun Ping Road in the vicinity of the landslide site which comprise a telephone cable duct and an 80 mm diameter fresh watermain of WSD. Based on site observations of the locations of the telephone cable duct joint boxes, it has been confirmed that the duct for the telephone cables is running along the east (uphill) side of Kwun Ping Road. Although there was no direct information to indicate the exact horizontal alignment of the 80 mm diameter fresh watermain, it is apparently that the watermain had been laid at the west side of Kwun Ping Road as a 900 mm wide strip of bitumen surfacing with distinct colour along the west side of Kwun Ping Road was observed.

4.2 Cracks on Kwun Ping Road

The pavement construction of Kwun Ping Road consists of a 170 mm thick concrete slab with a 30 mm thick bituminous surface, as revealed in the trial pits which were excavated

as part of the ground investigation under this detailed study following the landslide incident (see Section 5.4). During the site inspection on 10 September 2001, MGSL identified numerous cracks with differential movement (both horizontal and vertical), on the road surface along Kwun Ping Road. Theses are aligned in both longitudinal and traverse directions with respect to the road. On 4 January 2002, the cracks were mapped between about 60 m to the south of the landslide site and the junction with the access road to the area with the remains of Squatter Units A, B and C, some 80 m to the north of the landslide site. Details of the crack mapping are shown in Figure 6 and the salient points concerning the cracks are summarised below. For the purpose of this study, a chainage system along Kwun Ping Road has been established from a lamp post, which is located about 56 m to the south of the subject landslide site. The location of the lamp post is designated as Chainage 0, with increasing chainage to the north.

Crack No. 1, which is the most conspicuous and persistent (Figure 6 and Plate 8), was observed on the west side of the Kwun Ping Road about 0.7 m from the kerb. The alignment of this crack was observed to coincide approximately with the east edge of the trench excavated for the laying of the 80 mm diameter fresh watermain as confirmed by MGSL's ground investigation (see Section 5.4). The crack was continuous and could be traced back as far as the junction with Shatin Pass Road, which is approximately 600 m to the south of the landslide site. Downward and outward displacement had occurred on the west side of the crack. The crack width at the landslide location was about 5 mm and the differential settlement ranged from 15 mm to 30 mm. The maximum crack width recorded was about 25 mm, approximately 23 m to the south of the landslide site at about Chainage 8. The maximum differential settlement of the road pavement across the crack was approximately 40 mm at about Chainage 80 (Plates 8 and 9), some 20 m to the north of the subject landslide site. The crack was found to have extended through the pavement of Kwun Ping Road (about 200 mm in depth) and terminating at the top of the subgrade (see Section 5.4).

A section of Crack No. 1 (between Chainages 47 and 70 which is immediately above the September 2001 landslide site) was sealed with cement mortar. This sealed section of Crack No. 1 was found by MGSL to have re-opened (Figure 6 and Plate 3).

Crack No. 2 was discontinuous and occurred between the no-fines concrete edge strip and the concrete road kerb (Plate 10). About 10 m to the south of the subject landslide site, the width of the opening and the downhill differential movement were consistently about 30 mm (Plates 11 and 12). Approximately 10 m to 15 m to the north of the subject landslide site, the width ranged from 10 mm to 25 mm and the settlement was up to some 40 mm on the west side of the crack. Crack No. 3 was located along the inner edge of a passing bay and exhibited minor settlement, whereas Cracks Nos. 4 to 8, were aligned across the road.

All cracks were infilled with silt and some were covered with vegetation indicating that they were not recent. With the exception of a section of Crack No. 1 as mentioned above, none of the cracks had been repaired.

5. POST-LANDSLIDE GROUND INVESTIGATIONS

5.1 General

As part of this detailed study, a ground investigation (Figure 7) comprising trial pits,

slope surface stripping, GCO probes tests, in-situ density tests and laboratory tests were carried out by Gammon-Skanska Limited under the supervision of MGSL. The objectives of the ground investigation were to explore the subsurface condition at the landslide site and the cracks along Kwun Ping Road. The condition of the fill material was also investigated. The near-surface materials revealed within and adjacent to the landslide scar by the ground investigation are shown in Figures 2 and 5.

5.2 Slope Surface Stripping

Between December 2001 and February 2002, three 500 mm wide slope surface strips (Nos. S1 to S3) were formed to a maximum depth of 100 mm. Slope surface strips Nos. S1 and S2 were excavated through the landslide scar immediately below Kwun Ping Road and were both about 12 m long (measured along the slope surface) while slope surface strip No. S3, which was about 11 m long (measured along the slope surface), was located about 15 m to the north of the scar through the small unregisterable fill slope below Kwun Ping Road and along the thin veneer of fill on the natural hillside.

Fill, which was probably deposited during the widening of Kwun Ping Road, was encountered in the upper 1 m to 1.5 m of the slope surface strips Nos. S1 and S2 (i.e. at the 65° steep main scarp of the landslide scar). The fill generally comprised yellowish brown silty sand (slope surface strip No. S1) and sandy silt (slope surface strip No. S2), with some angular to sub-angular fine to coarse gravel- and cobble-sized fragments of rock. Between 1.5 m and 12 m from the tops of the slope surface strips, yellowish brown silty sand and sandy silt with some angular to sub-angular gravel- and cobble-sized fragments of rock of colluvium and rootlets were encountered below a thin veneer of fill.

Along the upper 5.5 m of slope strip No. S3 (measured along the slope surface), fill was encountered throughout the 100 mm deep surface stripping. The fill generally comprised yellowish brown to dark brown, sandy to very sandy silt with gravel- and cobble-sized fragments of rock. The material exposed on the slope strip No. S3 from 5.5 m to 11 m was topsoil with a thin layer of fill (less than 0.1 m in thickness) comprising yellowish brown to dark brown, silty fine to coarse sand with angular to sub-angular fine to coarse gravel.

5.3 GCO Probes

On 7 June 2002, 15 GCO probes tests (Nos. P1 to P15) were carried out to depths of between 1.2 m and 5.5 m on the hillside below Kwun Ping Road within the area of fill on the hillside (Figure 7). The probe values were recorded as the number of blows for every 100 mm depth of penetration of the probe. The tests were terminated when three consecutive readings with more than 30 blows for 100 mm penetration were achieved. More than 70% of the test results recorded probe values below 10 and about 47% of the results were below 5. The GCO probe tests generally indicated the presence of loose materials (probably fill and colluvium), which extended to a maximum depth of almost 4 m within the area of the small unregisterable fill slopes.

5.4 Trial Pits

In January and February 2002, seven trial pits (Nos. TP1 to TP7) were excavated (Figure 7). Five of the trials pits (Nos. TP1 to TP5) were excavated to investigate the ground conditions at several locations to the west of Crack No. 1 along the edge of Kwun Ping Road. Trial pit No. TP6 was excavated across Crack No. 1 and trial pit No. TP7 was located on the hillside at the north edge of the landslide scar. Details of in-situ density tests carried out in the trial pits are discussed in Section 5.5.

Trial pits Nos. TP1 to TP6 were excavated through the portion of the road pavement (which probably had been reinstated after installation of the 80 mm diameter ductile iron fresh watermain). The reinstated road pavement was found to comprise an approximately 170 mm thick concrete slab with a 30 mm thick bituminous cover (Plate 13). The trial pits were terminated at a depth of approximately 0.9 m where a concrete obstruction (probably the protective cover to the 80 mm diameter ductile iron fresh watermain) was encountered. In trial pits Nos. TP1 to TP5, two layers of fill were encountered beneath the concrete road slab. The upper layer, which was between about 100 mm and 250 mm thick, generally comprised light grey to brown, silty sand with angular to sub-angular fine to coarse gravel-sized fragments of rock. The lower layer of fill, which was between about 500 mm and 700 mm thick, comprised firm yellowish brown slightly sandy silt/clay with some angular to sub-angular, fine to coarse gravel and cobble-sized fragments of rock. In trial pit No. TP6, an upper layer of fill with a maximum thickness of about 200 mm was encountered on the west (downhill) face of the trial pit and colluvium, which was proved to a depth of 1.0 m, was noted on the east side of the trial pit. The colluvium consisted of yellowish brown, mottled light grey, silty fine to coarse sand with some angular to sub-angular fine to coarse gravel- and cobble-sized fragments of rock. In-situ density tests were carried out on the fill encountered in the trial pits (see Section 5.5).

A discontinuous void (up to about 20 mm wide) between the underside of the concrete road pavement and the underlying fill was observed at the location of trial pit No. TP2 (Plate 14). In trial pit No. TP6, Crack No. 1 was found to extend through the bitumen and concrete pavement of Kwun Ping Road (about 200 mm depth), terminating at the top of the subgrade (Plate 15).

Trial Pit No. TP7 was located within the landslide scar, adjacent to the north flank of the main scarp, within the area of the small unregisterable fill slope approximately 3 m below the edge of Kwun Ping Road. The trial pit, which was excavated to a maximum depth of about 1.2 m, encountered a discontinuous layer of fill overlying colluvium of variable composition. The fill layer, up to 150 mm thick and only present in the east face of the trial pit, consisted of yellowish brown, fine to coarse sand with angular to sub-angular fine to coarse gravel- and occasional cobble-sized fragments of rock. The colluvium varied both laterally and vertically and generally comprised an upper and lower layer. The upper layer consisted of about 0.5 m of firm to stiff yellowish brown to dark brown, sandy silt/clay with angular to sub-rounded gravel- and cobble-sized fragments of rock. Below this layer was approximately 300 mm of orangish brown, silty, fine to medium sand, with sub-angular cobbles and occasional boulder-sized fragments of rock.

5.5 In-situ Density and Laboratory Tests

In January 2002, 17 in-situ density tests were carried out in the trial pits between 0.3 m and 1.0 m below ground surface and 15 standard compaction tests were carried out on soil samples recovered from the trial pits. Of these tests, 13 in-situ density tests were carried out within the backfilled trench (probably for the 80 mm diameter fresh watermain). Corresponding laboratory standard compaction tests of the backfill were also carried out for the determination of the relative compaction of the backfill. The test results are summarised in Table 1. All of the five results of the in-situ density tests carried out at about 0.3 m below ground surface (corresponding to the top 200 mm of the fill within the backfilled trench, see Section 2.4) indicated relative compaction ranging from 68.6% to 97.1%, with an average value of 89.8% (i.e. less than 98% as stipulated in the General Specification). The results of the five in-situ density tests carried out at 0.6 m below ground surface (corresponding to the middle layer of the backfill within the backfilled trench referred to by the General Specification, see Section 2.4), indicated relative compaction ranging from 79.8% to 107.2% with an average value of 88.8%. Four out of five test results of the relative compaction of fill material at the middle layer are less than 95%. A total of three in-situ density tests were carried out at about 0.9 m below the road surface (corresponding to the bottom layer of the backfill within the backfilled trench referred to by the General Specification, see Section 2.4) and the results indicated relative compaction ranging from 64.6% to 68.6% with an average value of 67% (i.e. less than 85% as stipulated in the General Specification). The test results also indicate that the relative compaction of the fill material decreased with depth over the test zone.

6. ANALYSIS OF RAINFALL RECORDS

The nearest GEO automatic raingauge (No. K07 which has been in service since March 1983) to the landslide site is located at Ching Tak House, Tsz Wan Shan, approximately 1.4 km to the southwest of the landslide site (Figure 1). A Red Rainstorm Warning was hoisted between 10:05 p.m. and 10:45 p.m. on 1 September 2001 and a Black Rainstorm Warning was in force between 10:45 p.m. on 1 September 2001 and 3:15 a.m. on 2 September 2001. The exact time of the landslide incident is unknown but it probably occurred between 10:00 p.m. on 1 September 2001 (when the hourly rainfall exceeded 20 mm) and 3:00 a.m. on 2 September 2001 (just before the hourly rainfall dropped below 5 mm).

The daily rainfall recorded by raingauge No. K07 over the preceding month and three days following the incident is presented in Figure 8. The hourly rainfall readings for the period between 31 August and 2 September 2001 are also shown in Figure 8. The peak hourly rainfall of approximately 72 mm, was recorded in the 24-hour period preceding the September 2001 landslide. For the purpose of rainfall analysis, the landslide was assumed to have occurred before 3:00 a.m. of 2 September 2001 when the rain had almost ceased and the hourly rainfall dropped below 5 mm.

Table 2 presents the estimated return periods for the maximum rolling rainfall for various durations based on historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994). The result shows that the 5-minute, 4-day and 7-day rolling rainfalls of 14 mm, 390 mm and 467 mm respectively were the most severe, with a corresponding return period of about 3 to 4 years. The return periods based on the data recorded by raingauge

No. K07 between 1984 and 1997 were also assessed based on the statistical parameters derived by Evans & Yu (2001). 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 those from the local raingauge No. K07.

A comparison of the patterns of selected past major rainstorms recorded at raingauge No. K07 between 1992 and 2001 is presented in Figure 9. The rolling rainfall indicates that the rainstorm on 2 September 2001 was not exceptionally heavy compared with previous rainstorms.

7. THEORETICAL STABILITY ANALYSES

Theoretical stability analyses using the rigorous solution of Morgenstern & Price (1965) were carried out to assist in the diagnosis of the probable causes of the landslide. The analyses examined the likely operative range of shear strength parameters along the surface of rupture for different groundwater conditions at the time of failure. The cross-section through the landslide included in the stability analyses was based on Section A-A presented in Figure 5.

The pre-failure slope profile was interpreted from topographic survey plans, photographic records and post-failure observations. The geometry of the surface of rupture and ground profile is based on site measurements by MGSL, post-failure topographic survey and ground investigation.

The stability analyses were carried out using a range of shear strength parameters which cover the typical range of values of shear strength parameters given for fill and colluvium in Table 8 of Geoguide 1 (GEO, 1993). Various levels of elevated groundwater pressure above the surface of rupture together with the development of full hydrostatic pressure within the backfilled trench immediately behind the main scarp were assumed for the purpose of the stability analyses.

The results of the analyses are presented in Figure 10. These indicate that the development of a transient groundwater pressure corresponding to a piezometric level of about 0.5 m above the surface of rupture would be sufficient to initiate failure in the slope.

8. DIAGNOSIS OF THE PROBABLE CAUSES OF THE LANDSLIDE

8.1 Site Setting and Probable Sequence of the Landslide

The September 2001 landslide occurred on a small fill slope and the hillside immediately below Kwun Ping Road. Based on the results of the ground investigation carried out under this study, the slope forming materials of the small fill slope with a fill thickness of about 1 m was loose (see Section 5.3). The fill was probably deposited onto the hillside when Kwun Ping Road was widened in the late 1960s. Although there is no available information on previous engineering input to the formation of this fill slope (i.e. no records of previous stability assessment and checking to demonstrate the compliance with the required safety standards), there are no records of any past failures on this slope and on the hillside below Kwun Ping Road, prior to the September 2001 landslide.

According to WSD's record, an 80 mm diameter fresh watermain was installed beneath Kwun Ping Road between 1996 and 1997. The construction of the watermain and the associated trench excavation and backfilling works were carried out in accordance with the General Specifications for Civil Engineering Works (Hong Kong Government, 1992) and the works were supervised by WSD. Accordingly, the top 200 mm of the backfill was compacted to a relative compaction not less than 98% and the backfill between the top 200 mm layer and the 300 mm layer directly above the watermain was compacted to 95% relative compaction. The material up to 300 mm above the watermain was compacted to 85%. MGSL inspected the available WSD construction records and noted that three in-situ density tests carried out in the top 150 mm of the backfill to the trench for the installation of the watermain, had relative compaction values higher than 95%. No information was found in the WSD records to indicate the degree of compaction of the backfill at deeper levels.

The results of in-situ density tests carried out in this backfill material, probably the backfill to the trench for the installation of the 80 mm diameter fresh watermain, under this study indicated that the three layers of backfill (each about 300 mm in thickness) in downward sequence have average relative compaction of 89.8%, 88.8% and 67% respectively.

Extensive surface cracking and ground settlement of the pavement of the west side of Kwun Ping Road were observed by MGSL following the September 2001 landslide. Cracks extended to the bottom of the pavement and voids between the underside of the road pavement slab and the subgrade at the main scarp of the September 2001 landslide were exposed during trial pit excavation carried out under this investigation. An old crack (a 23 m long section of crack No. 1 just behind the landslide scar) to the east of the backfill trench, which was previously sealed with cement mortar was found to have re-opened. This old crack was found to be infilled with silt and covered with vegetation (see section 4.2), which suggests that it had been opened for some time before the September 2001 landslide. Cracks along the both sides of the trench were probably caused by settlement of the backfill to the trench (probably for the installation of the 80 mm diameter watermain), which in turn allowed direct ingress of surface water and wetting of the loose backfill. With time, the wetted loose backfill probably induced progressive settlement and led to the development of new cracks and/or widening of old cracks. Eventually, extensive surface cracking and ground settlement would have developed, thus increasing the vulnerability to water ingress.

Two landslides (GEO Incident No. 2001/09/0058 on slope No. 7SE-C/C352 on the uphill side of the road and the subject incident, GEO Incident No. 2001/09/0091, on the downhill side of the road) happened in the vicinity. There is no direct information to confirm the order of these two landslides along Kwun Ping Road. Based on the field observations and the site setting as discussed above, it was probable that the minor incident on cut slope No. 7SE-C/C352 on the uphill side of Kwun Ping Road occurred first, and then the landslide debris which blocked about a quarter of the width of the road and the 300 mm U-channel at the toe of the slope could have diverted surface runoff from the hillside above the cut slope towards the site of the subject landslide. The presence of the extensive cracks on the road above the landslide site would then have allowed surface infiltration into the fill slope below and causing its failure.

8.2 Probable Causes of the Landslide

The September 2001 landslide was probably triggered by the development of transient elevated water pressures within the loose fill slope and the hillside as a result of concentrated water ingress. On top of the surface runoff on the road surface, additional surface water from the upper hillside above Kwun Ping Road was probably directed to the section of the road immediately above the September 2001 landslide site by the debris from the landslide on the nearby uphill cut slope (GEO Incident No. 2001/09/0058). Concentrated direct water ingress through the extensive system of cracks on the road surface could have led to the development of elevated water pressure within the small loose fill slope and the hillside and triggered the sliding failure of the small fill slope and the hillside.

The September 2001 landslide (GEO Incident No. 2001/09/0091) below Kwun Ping Road was probably caused by the build-up of transient groundwater pressure. As demonstrated in the theoretical stability analysis (Section 7), assuming that the backfill to the trench behind the main scarp was fully saturated, with a full hydrostatic pressure, the development of a transient groundwater pressure corresponding to a piezometric level of about 0.5 m above the surface of rupture would be sufficient to initiate the failure of the slope. Direct surface infiltration into the small loose fill slope and the thin veneer of fill below Kwun Ping Road, would also have provided a source of water ingress. Since the rainfall preceding the failure was not particularly severe (with estimated return periods of 3 to 4 years, see Section 6), direct infiltration alone was unlikely to have triggered the September 2001 landslide below Kwun Ping Road, since the small fill slope and the thin veneer of fill below Kwun Ping Road would have been subjected to direct infiltration during more serve rainstorms in the past. MGSL found no records or indications of past instability and observed no signs of deterioration of the fill slopes and the hillside in the immediate vicinity of the landslide.

The travel angle of the landslide debris (approximately 30°) and the damage of the old concrete wall near the squatter units, at the toe of the debris, would at first appear to suggest that the landslide debris was quite mobile, particularly in view of the fact that the fill was loose and the hillside is steep (about 40°). If the old concrete wall had not obstructed the movement of the landslide debris, the travel angle would probably have been lower than 30°. Wong & Ho (1996) suggested that landslides involving liquefaction of loose fill typically have travel angles ranging from 15° to 30° and it is therefore possible that the subject failure could have involved liquefaction of the loose fill. However since the fill was only about 1 m thick, the relatively low stress levels near the ground surface, suggests that the fill probably dilated rather than collapsing, a prerequisite to liquefaction. Alternatively, the geometry of the landslide source and the location of the surface of rupture at the interface between the fill and the colluvium could have triggered a simple sliding failure once the pore pressures within the fill had risen sufficiently.

The collapse of the road kerb, which would otherwise have prevented surface runoff on Kwun Ping Road from spilling onto the failure scar, would have allowed surface runoff to flow directly onto the landslide scar at the bend in the road. The surface runoff would have quickly saturated the landslide debris and washed it downhill, thus increasing its apparent mobility. Concentrated surface runoff as a result of the collapse of the road kerb would have probably led to further erosion and entrainment of the thin veneer of fill on the hillside below Kwun Ping Road.

9. CONCLUSIONS

The September 2001 landslide (GEO Incident No. 2001/09/0091) below Kwun Ping Road involved a sliding failure (total volume of failure of about 20 m^3) of a small unregisterable (approximately 3 m high) loose fill slope, the adjoining hillside and a thin veneer (about 1 m thick) of fill on the hillside during moderate rainfall with a maximum return period of about four years. The failure was probably triggered by the saturation of the backfill to the trench immediately behind the main scarp and the build-up of transient groundwater pressure within the relatively thin layer of loose fill. As a result of the landslide, Kwun Ping Road was partly undermined. The landslide debris travelled down a 40° steep natural hillside, which was covered with dense vegetation. No casualties were reported and road closure was required as a result of the landslide incident.

A 1.2 m deep backfilled trench, which was formed for the installation of an 80 mm diameter fresh watermain between 1996 and 1997, runs along the crest of the fill slope beneath Kwun Ping Road. The backfill material within the trench was found to be loose at depths within 0.9 m of the ground surface. Extensive cracks and ground settlement of the pavement of Kwun Ping Road had developed on the surface of Kwun Ping Road probably as a result of the settlement of the loose backfill to the trench for the installation of the watermain.

The blockage of the 300 mm U-channel by the debris from the 8 m^3 failure (GEO Incident No. 2001/09/0058) on a nearby cut slope No. 7SE-C/C352 on the uphill side of Kwun Ping Road could have caused the diversion of surface runoff from the hillside above the cut slope towards the subject landslide site. The extensive system of cracks on the surface of Kwun Ping Road are aligned in both longitudinal and traverse directions with respect to the road and evidence suggests that they were old and mostly un-repaired. The cracks probably provided a direct pathway for ingress of additional surface water into the underlying trench backfill. The concentrated ingress of surface water through the cracks on the road would have wetted up the loose fill slope below the road and this together with the direct infiltration of rainfall probably triggered the failure. The trench with inadequately compacted backfill probably played a notable role in the failure.

10. REFERENCES

Evans, N.C. & Yu, Y.F. (2001). Regional Variation in Extreme Rainfall Values. Geotechnical Engineering Office, Hong Kong, 81 p. (GEO Report No. 115).

Gammon Skanska Limited (2002). Ground Investigation Term Contract: Agreement No. CE 72/2000, W.O. No. 53201/207M/GI-1 & GI-2 - Natural Hillside adjacent to Kwun Ping Road, Shatin Pass. Field Work and Laboratory Test Report. Report prepared for Geotechnical Engineering Office, Hong Kong.

Geotechnical Engineering Office (1993). Guide to Retaining Wall Design (Geoguide 1), (Second edition). Geotechnical Engineering Office, Hong Kong, 268 p.

Hong Kong Government (1992). General Specification for Civil Engineering Works - Volume 1. Hong Kong Government, 280 p.

Lam, C.C. & Leung, Y.K. (1994). Extreme Rainfall Statistics and Design Rainstorm Profiles at Selected Locations in Hong Kong. Royal Observatory, Hong Kong, Technical Note No. 86, 89 p.

Malone, A.W. (1997). Areal Extent of Intense Rainfall in Hong Kong 1979 to 1995. Geotechnical Engineering Office, Hong Kong, 85 p. (GEO Report No. 62)

Morgenstern, N.R. & Price, V.E. (1965). The analysis of the stability of general slip surfaces. Geotechnique, vol. 15, pp 79-93.

Wong, H.N. & Ho, K.K.S. (1996). Travel distance of landslide debris. Proceedings of the Seventh International Symposium on Landslides, Trondheim, Norway, vol. 1, pp 417-422.

LIST OF TABLES

Table 1 - Summary of In-situ Density and Laboratory Compaction Test Results

Trial Pit No.	Sample Depth (m)	Material Description[2]	Moisture Content (%)	Dry Density (Mg/m³)	Laboratory Compaction Test			Relative Compaction of Fill (%)
					Sample Type[3]	Maximum Dry Density (Mg/m³)	Optimum Moisture Content (%)	
TP1	0.3	Brown, silty, gravelly, clayed SAND (FILL)	23	1.16	L	1.69	18	68.6
	0.6		22	1.78	L	1.66	20	107.2
	0.9	Dark brown, slightly gravelly, sandy SILT/CLAY (FILL)	-	-	L	1.67	19	-
TP2	0.3	Dark brown, gravelly, silty, clayed SAND (FILL)	20	1.68	L	1.73	17	97.1
	0.6	Brown, silty, clayed SAND (FILL)	18	1.56	L	1.74	17	89.7
	0.9	Dark brown, slightly gravelly, sandy SILT/CLAY (FILL)	-	-	L	1.74	17	-
TP3	0.3	Brown, silty, gravelly, clayed SAND (FILL)	20	1.65	L	1.78	16	92.7
	0.6		20	1.40	L	1.73	17	80.9
	0.9		21	1.18	L	1.74	17	67.8
TP4	0.3	Dark brown, slightly gravelly, sandy SILT/CLAY (FILL)	22	1.60	L	1.70	19	94.1
	0.6		26	1.42	L	1.64	21	86.6
	0.9		28	1.16	L	1.69	18	68.6
TP5	0.3	Brown, silty, clayed, very gravelly SAND (FILL)	14	1.66	L	1.72	18	96.5
	0.6		18	1.38	L	1.73	18	79.8
	0.9	Brown, slightly sandy, silty, clayed GRAVEL (FILL)	16	1.13	L	1.75	17	64.6
TP6	0.3	Brown, silty, clayed, very gravelly SAND (COLL)	21	1.46	L	1.53	25	95.4
	0.5		22	1.51	L	1.59	23	95.0
	0.7	Brown, slightly sandy, gravelly SILT/CLAY (COLL)	23	1.40	L	1.56	24	89.7
	0.9		23	1.18	-	-	-	-
TP7	0.2	Yellowish brown, clayed, gravelly, very silty SAND (FILL)	24	1.15	-	-	-	-
	0.4		16	1.45	-	-	-	-
	0.6		22	1.28	-	-	-	-
	0.8		15	1.34	-	-	-	-

Notes: (1) The in-situ density and laboratory compaction tests were carried out by Gammon Skanska Limited in 2002.
(2) COLL denotes colluvium.
(3) L denotes large disturbed sample.

Table of Contents
Table of Contents
Table of Contents

Table 2 - Maximum Rolling Rainfall at GEO Raingauge No. K07 for Selected Durations Preceding the Landslide on 2 September 2001 and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years) (See Note 2)
5 Minutes	14.0	22:05 hours on 1 September 2001	3
15 Minutes	27.5	22:10 hours on 1 September 2001	< 2
1 Hour	72.0	23:00 hours on 1 September 2001	2
2 Hours	105.0	23:25 hours on 1 September 2001	3
4 Hours	139.0	00:45 hours on 2 September 2001	3
12 Hours	164.0	03:00 hours on 2 September 2001	< 2
24 Hours	198.5	03:00 hours on 2 September 2001	< 2
48 Hours	204.0	03:00 hours on 2 September 2001	< 2
4 Days	390.0	02:55 hours on 2 September 2001	4
7 Days	467.0	03:00 hours on 2 September 2001	4
15 Days	467.0	03:00 hours on 2 September 2001	< 2
31 Days	580.5	03:00 hours on 2 September 2001	< 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 (2000). 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) The landslide occurred sometime between 10:00 p.m. on 1 September 2001 and 6:00 a.m. on 2 September 2001. For the purpose of rainfall analysis, the landslide was assumed to be occurred before 3:00 a.m. of 2 September 2001 when the rain was substantially cease and hourly rainfall dropped below 5 mm per hour.
(5) The nearest GEO raingauge to the landslide site is raingauge No. K07 situated at about 1.4 km to the southwest of the site.

LIST OF FIGURES

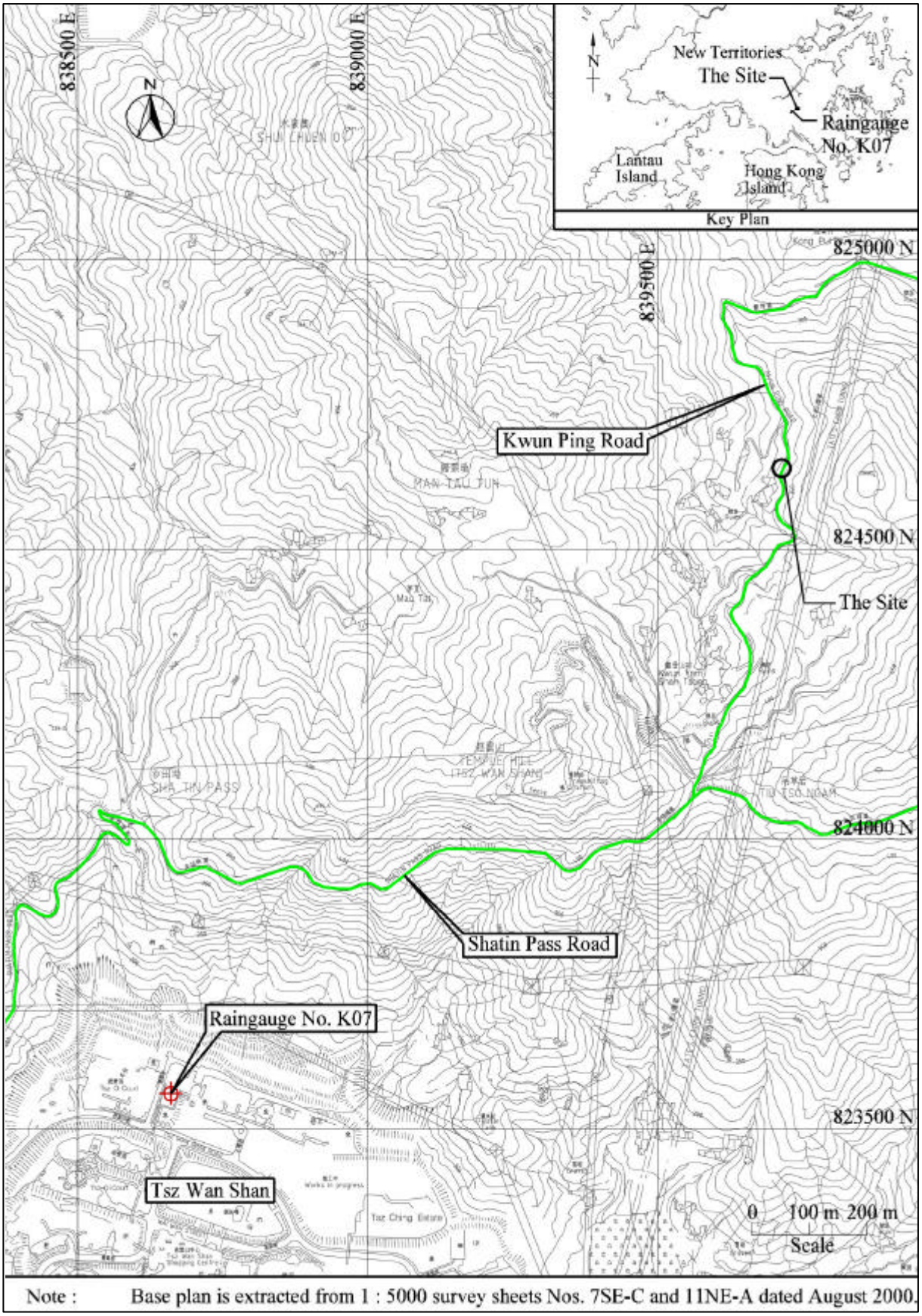


Figure 1 - Site Location Plan

Table of Contents
Table of Contents
Table of Contents
Table of Contents

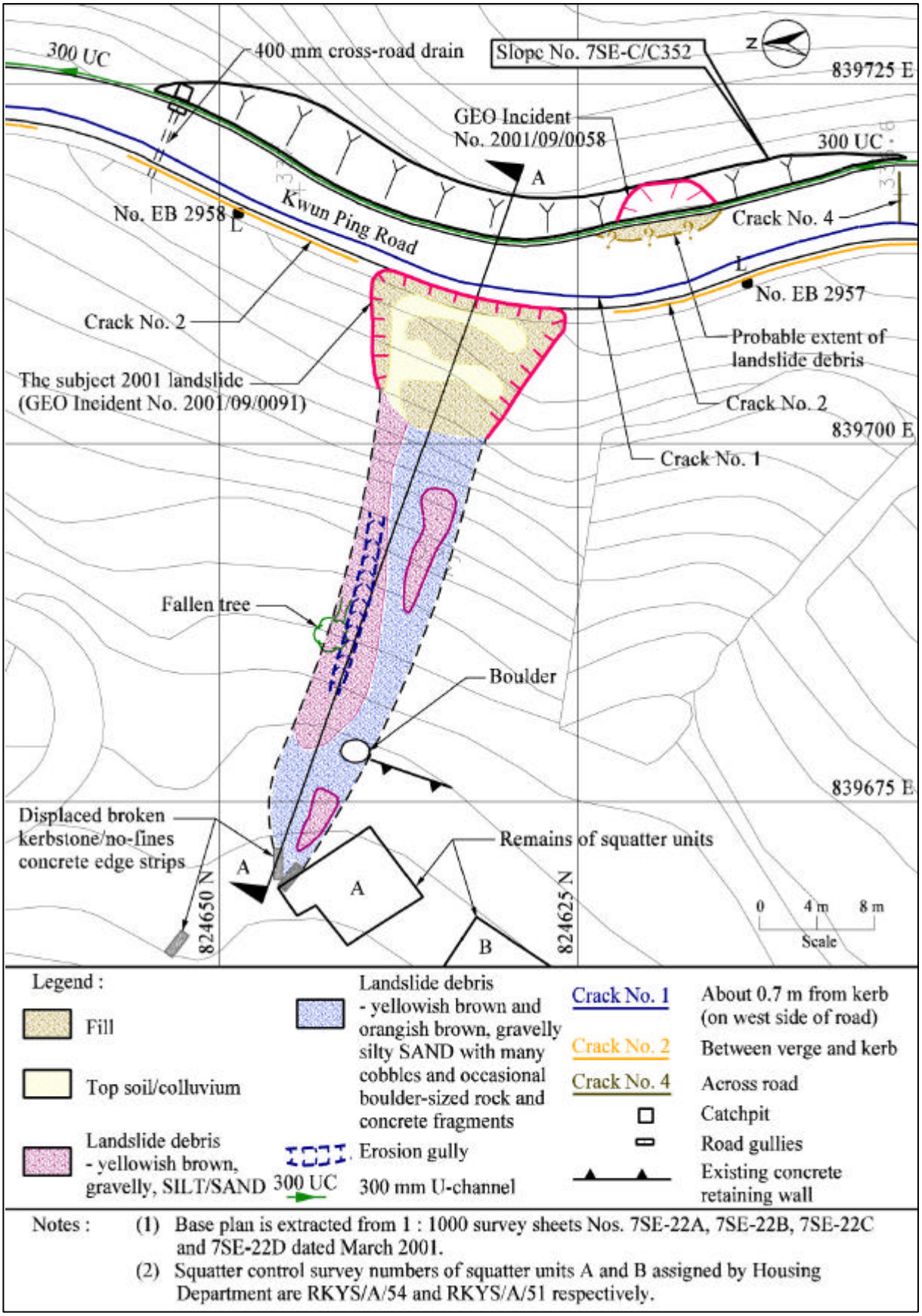


Figure 2 - Site Observations

Table of Contents
Table of Contents
Table of Contents
Table of Contents

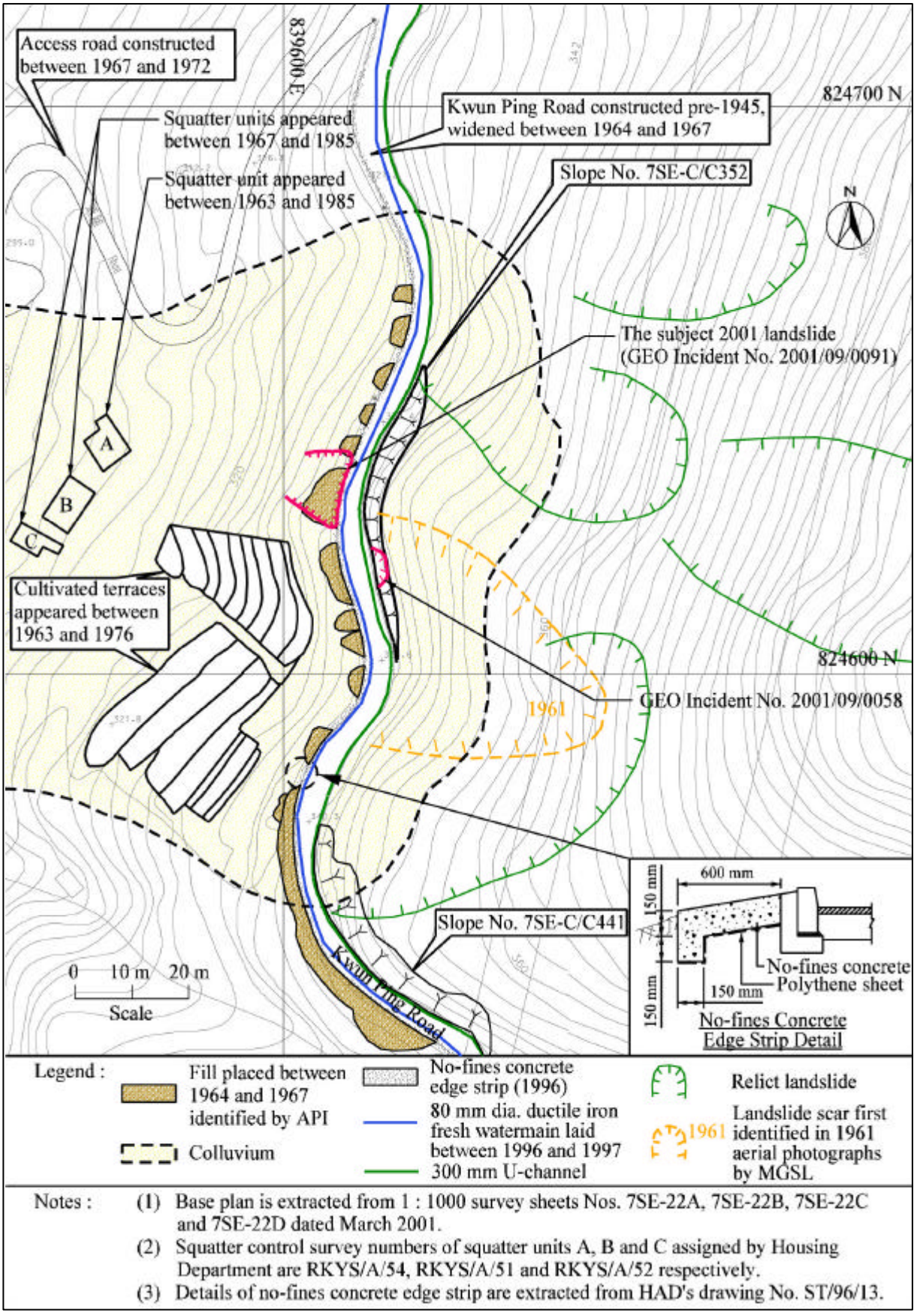


Figure 3 - Site History and Past Instability

Table of Contents
Table of Contents
Table of Contents
Table of Contents

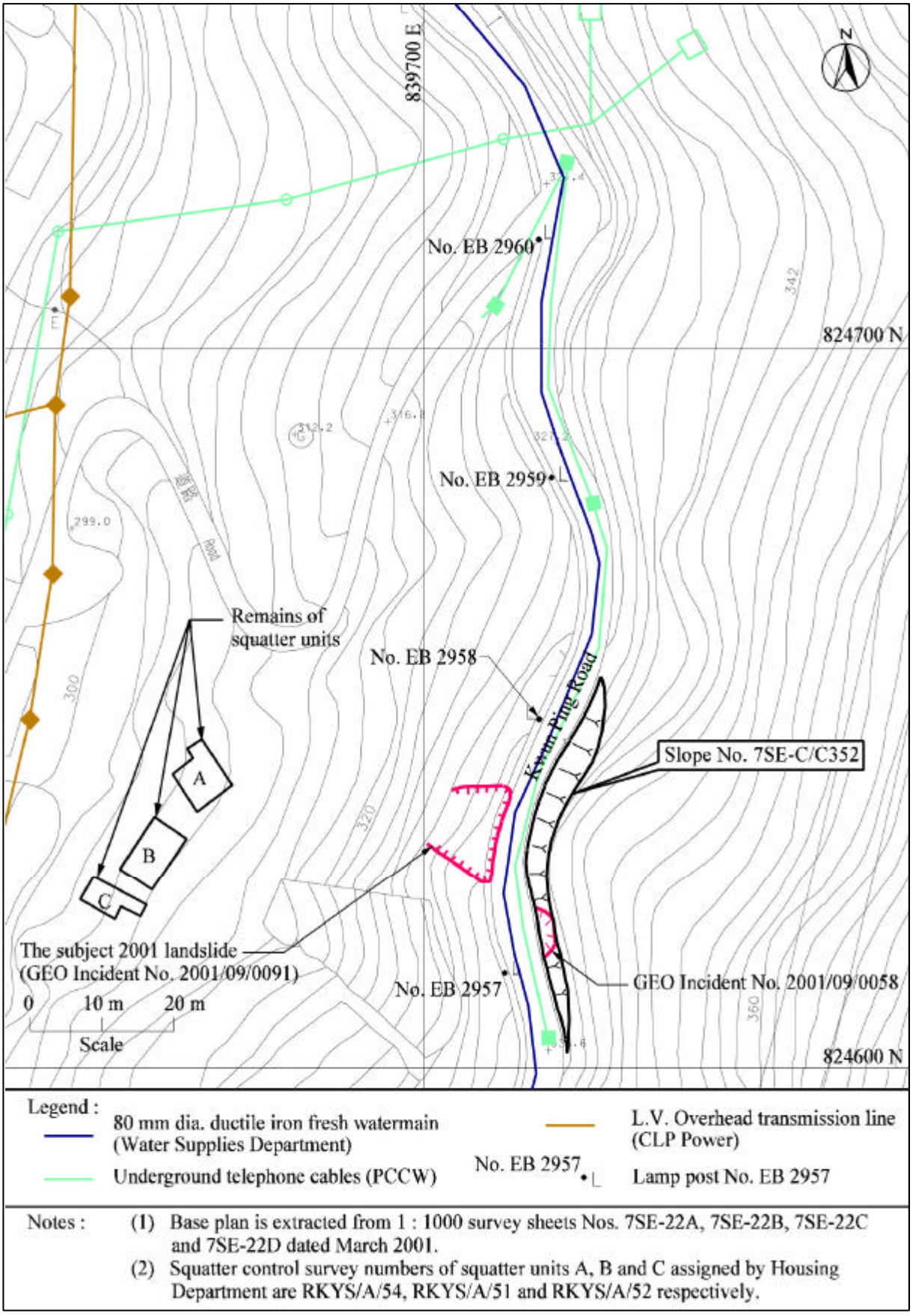


Figure 4 - Utilities Plan

Table of Contents
Table of Contents
Table of Contents
Table of Contents

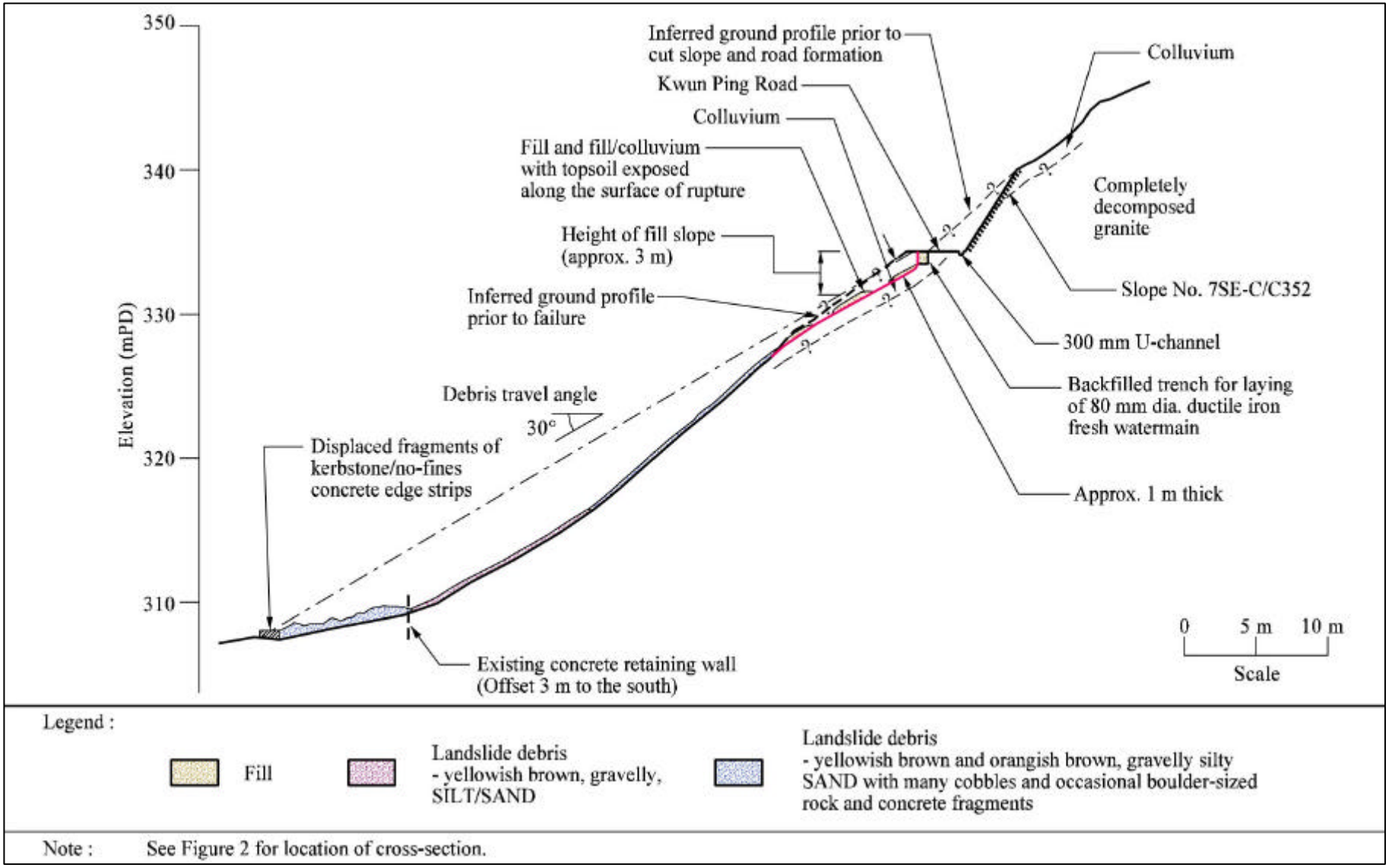


Figure 5 - Section A-A through the Landslide Scar

Table of Contents
Table of Contents
Table of Contents
Table of Contents

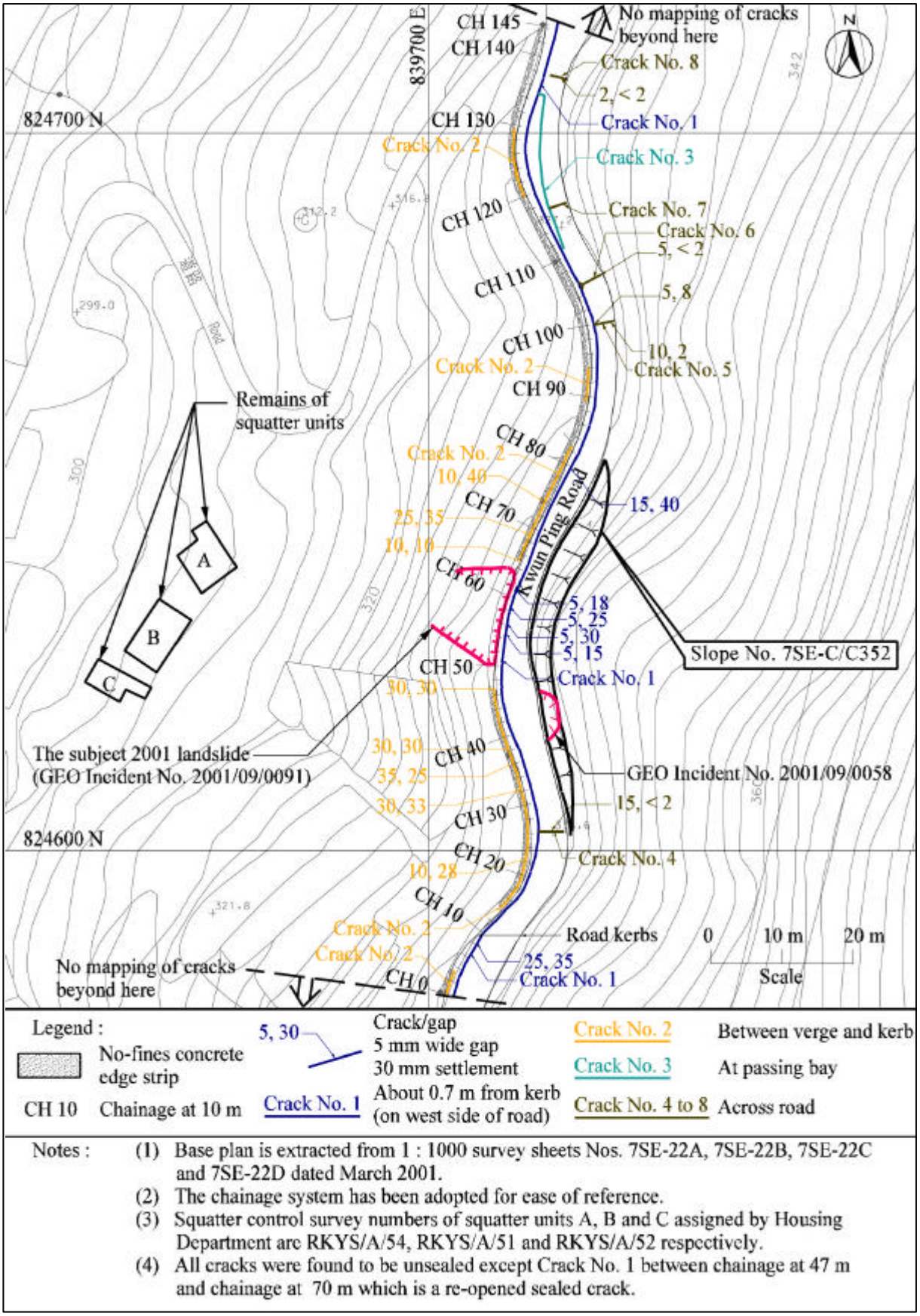


Figure 6 - Mapping of Cracks

Table of Contents
Table of Contents
Table of Contents
Table of Contents

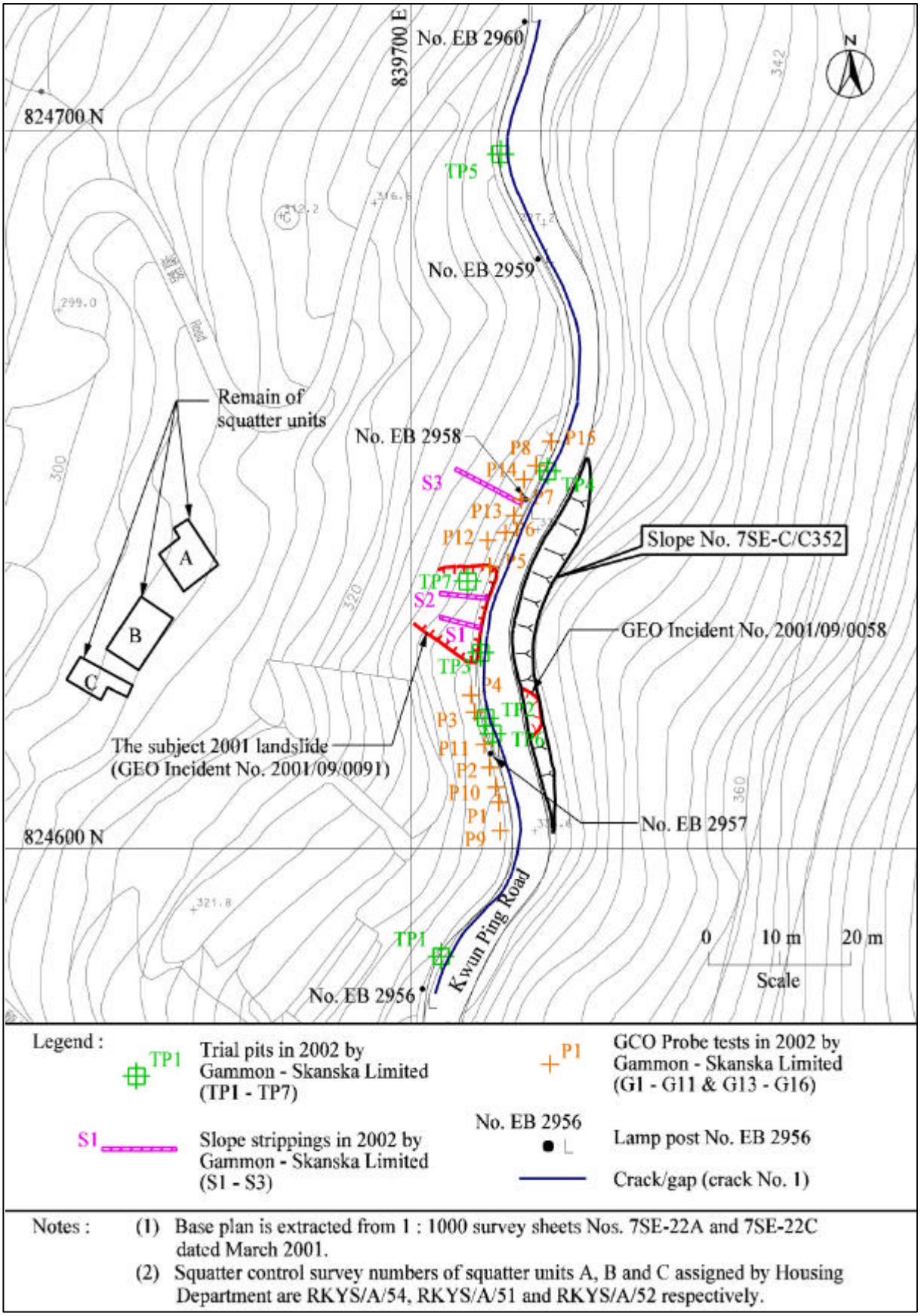
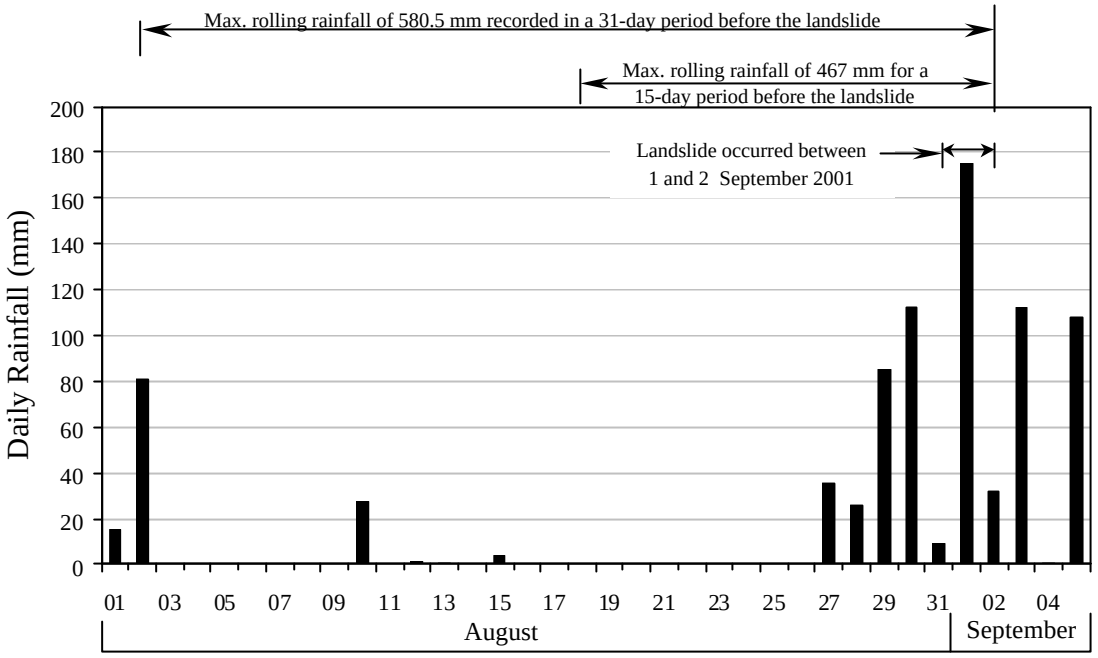
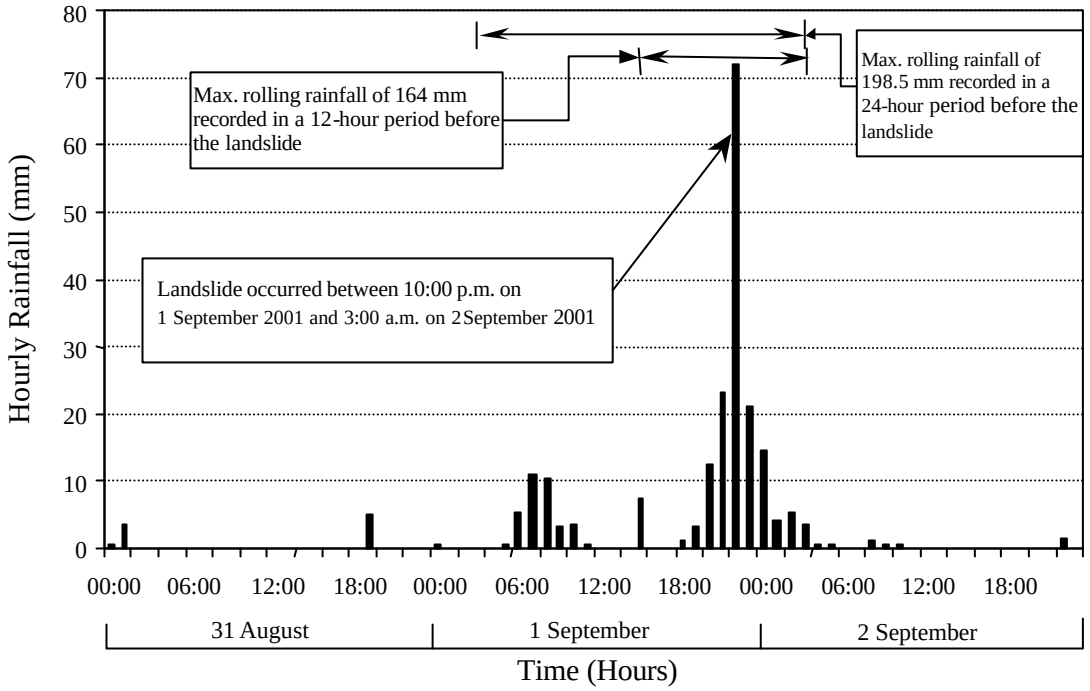


Figure 7 - Ground Investigation Plan

Table of Contents
Table of Contents
Table of Contents
Table of Contents

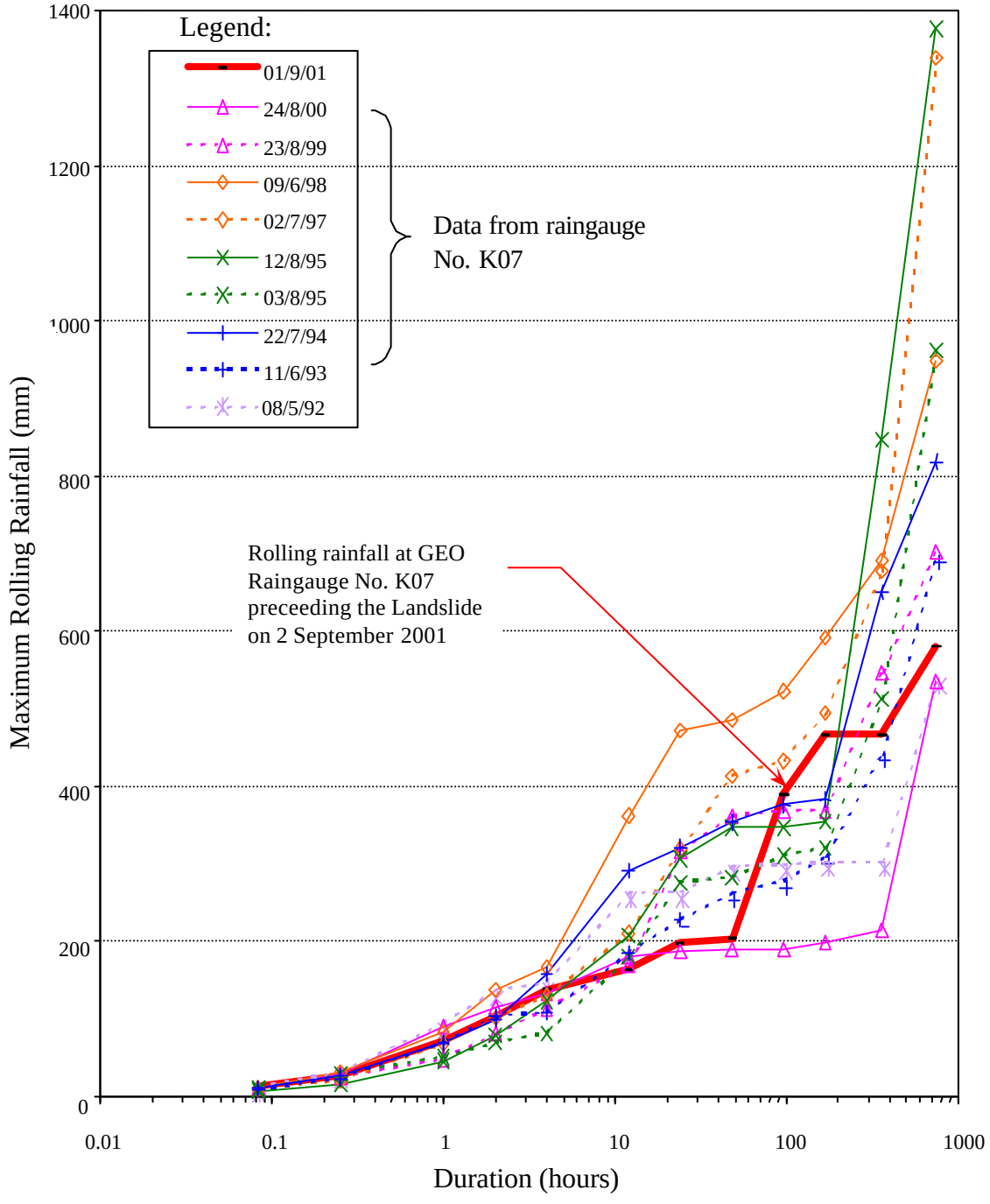


(a) Daily Rainfall Recorded at GEO Raingauge No. K07 between 1 August and 5 September 2001



(b) Hourly Rainfall Recorded at GEO Raingauge No. K07 between 31 August and 2 September 2001

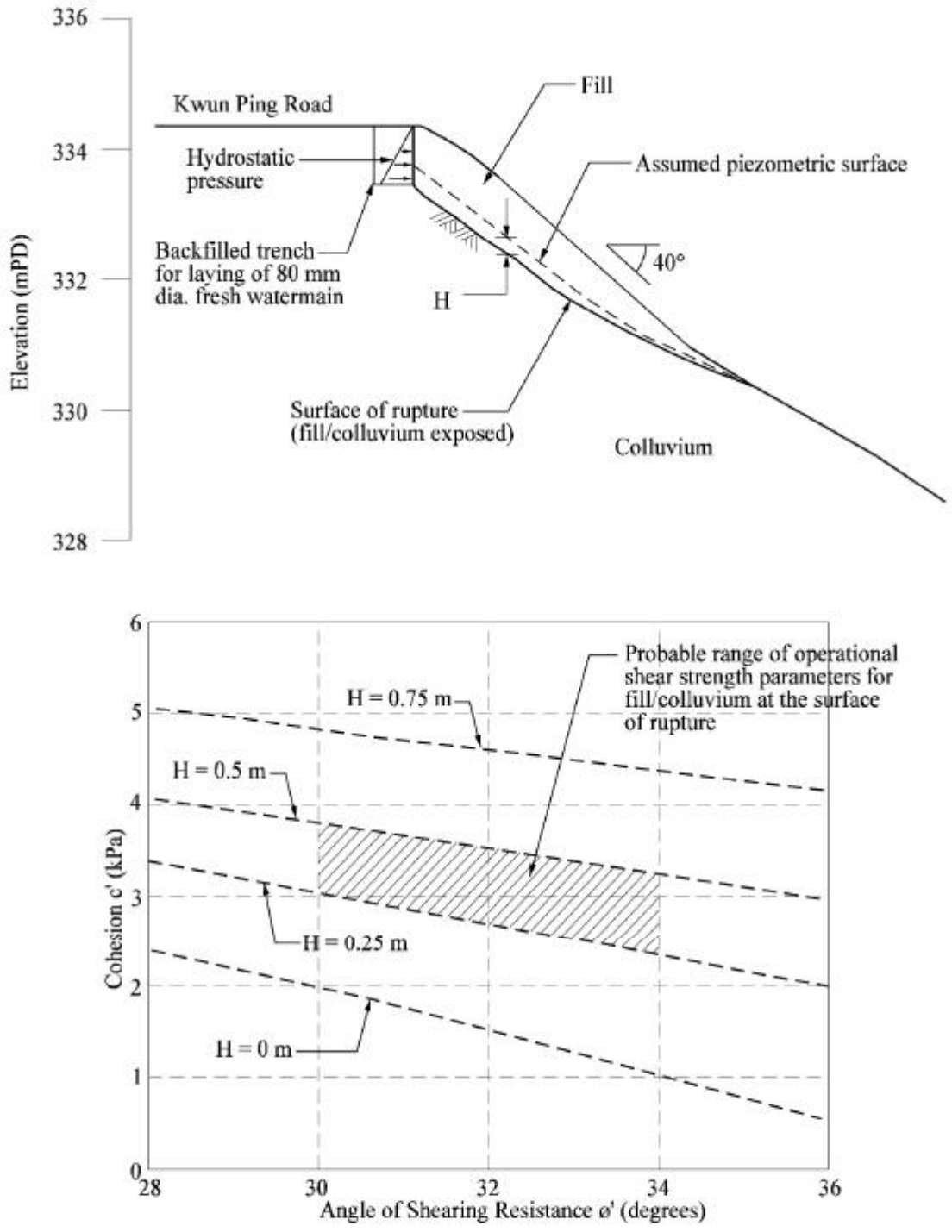
Figure 8 - Daily and Hourly Rainfall Recorded at GEO Raingauge No. K07



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. K07 (about 1.4 km southwest of the site).
(3) Rolling rainfall of previous rainstorms calculated at GEO raingauge No. K07 since March 1983 when the raingauge became operational.

Figure 9 - Maximum Rolling Rainfall for Previous Major Rainstorms at GEO Raingauge No. K07

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Legend : – – – – Factor of safety equal to unity (i.e. limiting equilibrium)

Note : The pre-failure slope profile and the surface of the rupture area are based on topographic survey plans, photographic records and post-failure observations.

Figure 10 - Summary of Sensitivities Analyses

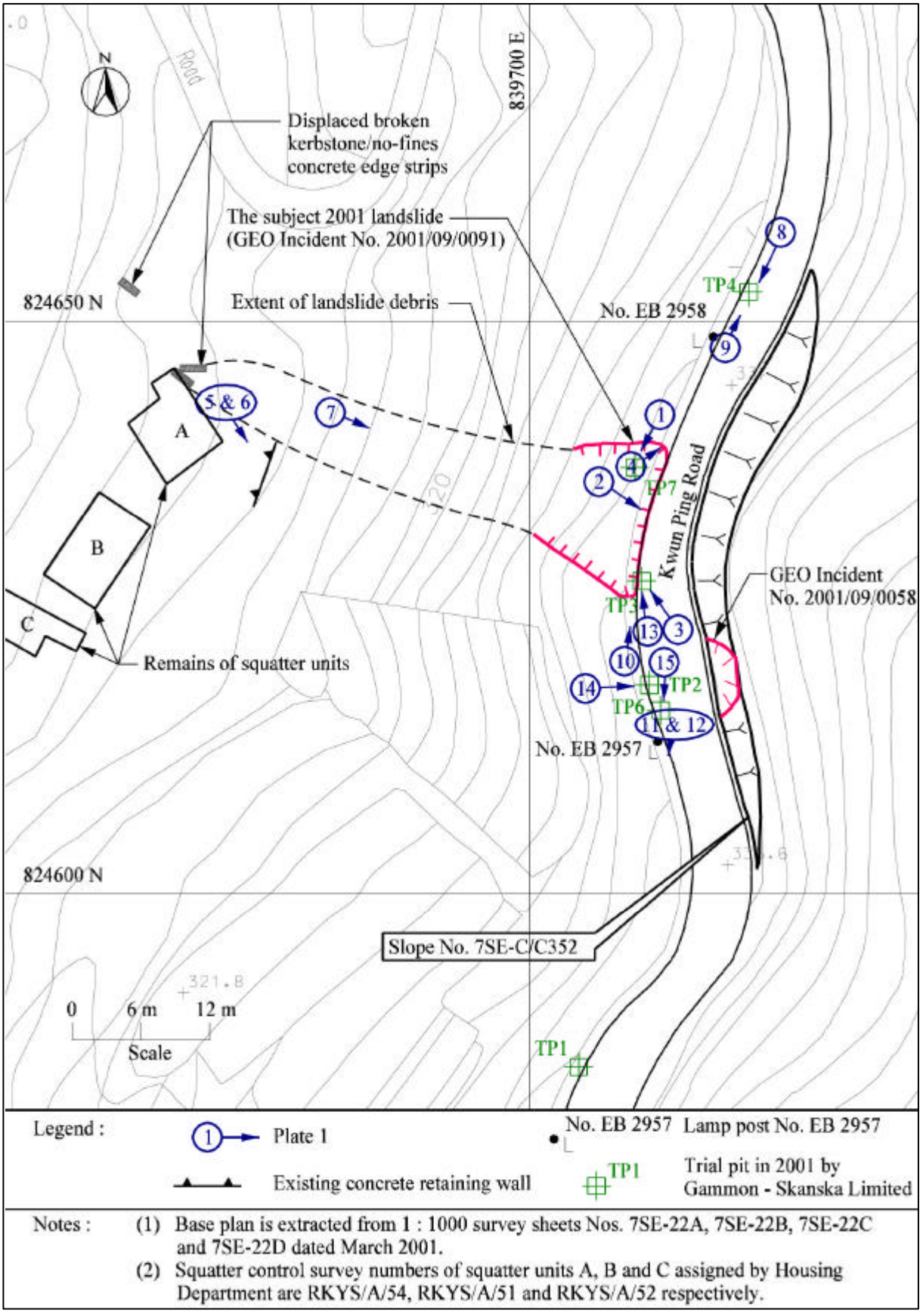


Figure 11 - Locations and Directions of Photographs

Table of Contents
Table of Contents
Table of Contents
Table of Contents

LIST OF PLATES

Plate 1 - General View of the Landslide Site
(Photograph taken on 2 September 2001 by GEO)

Plate 2 - Collapse of Sub-grade below Kwun Ping Road
(Photograph taken on 10 September 2001)

Note: See Figure 11 for locations and directions of photographs.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

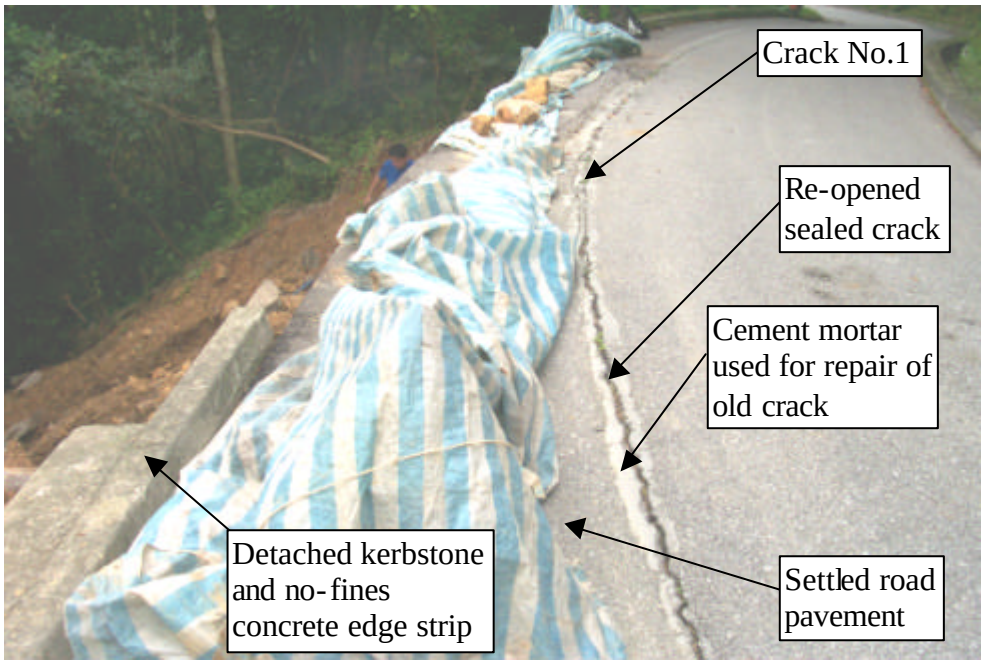


Plate 3 - View from Road Showing Re-opened Sealed Crack No.1, Settled Road Pavement, Detached Kerbstone and No-fines Concrete Edge Strip
(Photograph taken on 10 September 2001)

Plate 4 - View of a Section of Collapsed No-fines Concrete Edge Strip and Kerbstone
(Photograph taken on 10 September 2001)

Note: See Figure 11 for locations and directions of photographs.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 5 - View Showing Damaged Concrete Retaining Wall behind Area with Remains of Squatter Units
(Photograph taken on 21 January 2002)

Plate 6 - View Showing Fragments of Displaced No-fines Concrete Edge Strips
(Photograph taken on 21 January 2002)

Note: See Figure 11 for locations and directions of photographs.

Plate 7 - View of the Landslide Site from Below Showing Disturbed Vegetation on the Debris Trail
(Photograph taken on 22 January 2002)

Plate 8 - View of Crack No. 1 Observed above Landslide Scar on Western Side of Kwun Ping Road
(Photograph taken on 13 December 2001)

Note: See Figure 11 for locations and directions of photographs.

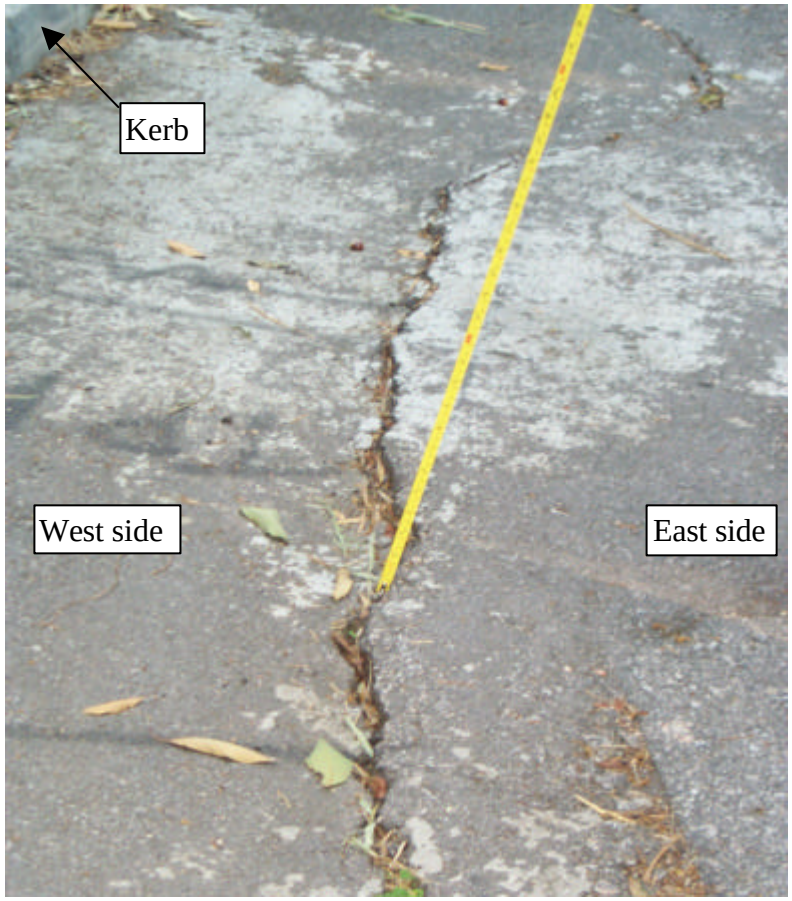


Plate 9 - Differential Settlement of Road Pavement across Crack No. 1
(Photograph taken on 4 January 2002)

Plate 10 - Differential Settlement along Kerb/No-fines Concrete Edge Strip
(Photograph taken on 4 January 2002)

Note: See Figure 11 for locations and directions of photographs.

Plate 11 - Differential Settlement about 30 mm across Crack No. 2
(Photograph taken on 4 January 2002)

Plate 12 - Width of Gap about 35 mm across Crack No. 2
(Photograph taken on 4 January 2002)

Note: See Figure 11 for locations and directions of photographs.

Plate 13 - View Showing a Typical Section through the Road Pavement in Trial Pit No. TP3
(Photograph taken on 21 January 2002)

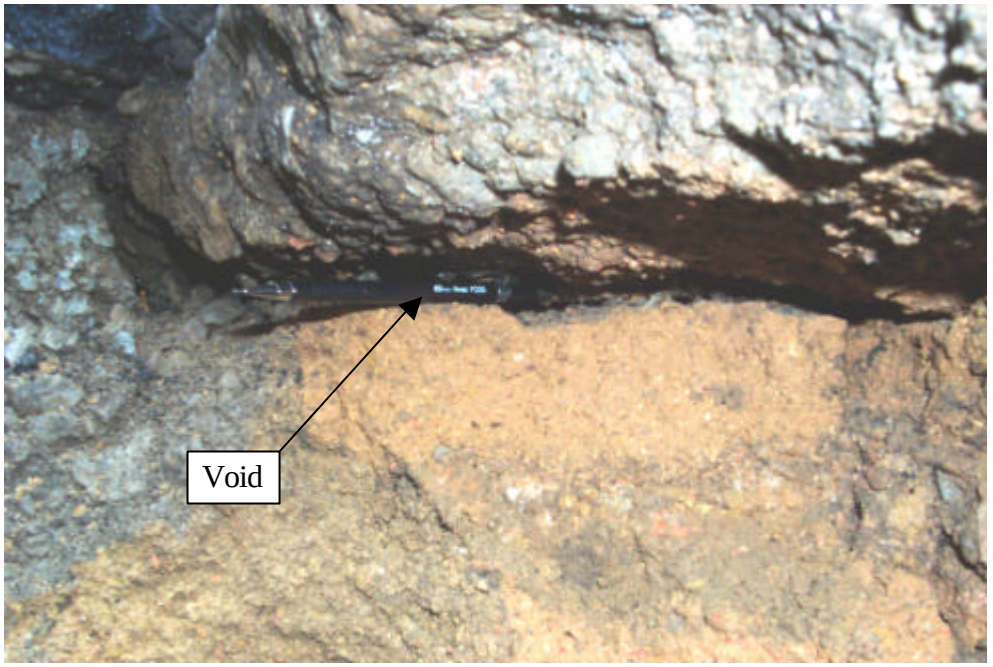


Plate 14 - View of Void between Sub-grade and Underside of Concrete Road Pavement in Trial Pit No. TP2
(Photograph taken on 21 January 2002)

Note: See Figure 11 for locations and directions of photographs.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

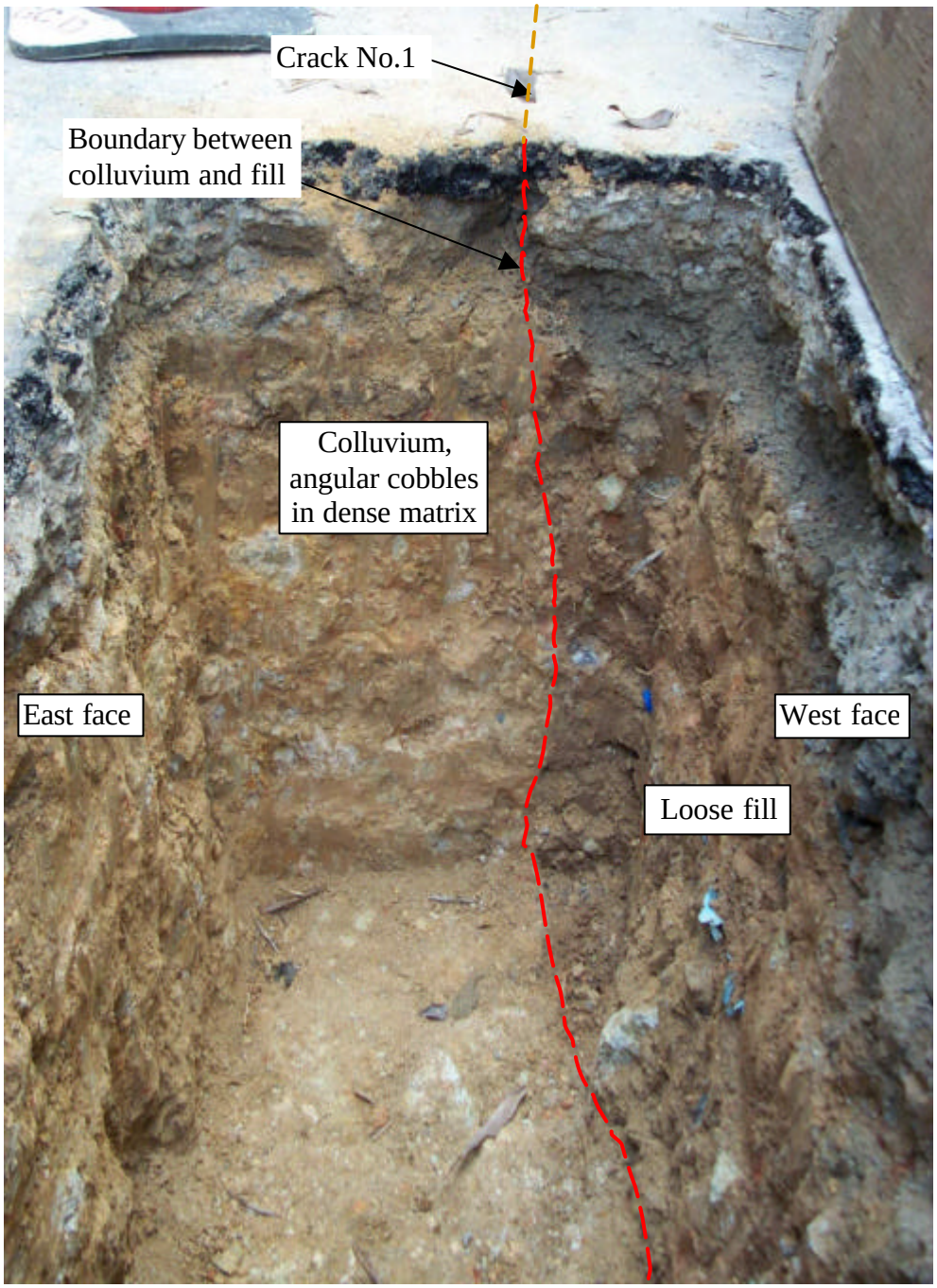


Plate 15 - General View of Trial Pit No. TP6
(Photograph taken on 10 January 2002)

Note: See Figure 11 for location and direction of photograph.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

CONTENTS

A1. DETAILED OBSERVATIONS

The study area comprises the terrain immediately above and below Kwun Ping Road in the vicinity of cut slope No. 7SE-C/C352 from 1945 to 2000. A list of the aerial photographs studied and a location plan (Figure A1) are also attached.

YEAR	OBSERVATIONS
November 1945	Altitude and quality of the photographs make detailed feature identification difficult. The study area is comprised of fully vegetated natural hillside with a westerly aspect. Kwun Ping Road has already been constructed.
November 1954	No observable changes.
December 1956	No observable changes.
October 1959	The study area is not very clear on the photographs.
January 1961	A patch of bare slope surface is visible upslope of cut slope No. 7SE-C/C352. This is considered to be a landslide scar.
January 1963	The study area can be seen to contain numerous relict landslide features. These features are constrained by well-defined convex breaks in slope. These landslide features appear to have initiated immediately upslope from Kwun Ping Road and to have extended further downslope below the road and along the drainage lines to the terrain below Kwun Yam Shan Tsuen. Colluvium from these relict landslide features appears to have accumulated around the lower extent of the drainage lines. Minor areas of rock outcrop are visible within natural terrain upslope from Kwun Ping Road. Well-developed cultivation terraces are visible immediately downslope from the road opposite slope No. 7SE-C/C352. A squatter unit (A) is built in the vicinity of the terraces.
December 1964	No observable changes.

YEAR	OBSERVATIONS
1967	Kwun Ping Road is widened.
	Fill materials appears to have been deposited, probably in association with the road widening works, on the downslope side of Kwun Ping Road.
	Two squatter units (B and C) are built next to squatter unit A.
October 1972	An access road connecting Kwun Yam Shan and Kwun Ping Road is built.
	Some agricultural fields adjacent to Kwun Ping Road are abandoned.
	A bare patch of land is noted immediately upslope from the agricultural terracing in the southern part of the study area.
October 1973	Some re-vegetation of the bare patch noted in the 1972 photographs has taken place.
December 1975	No observable changes.
November 1976	The vegetation in the study area becomes denser.
December 1977	All cultivation terraces along Kwun Ping Road has been abandoned.
	Vegetation is growing on the bare patch noted in the 1976 photographs.
January 1978	No observable changes.
November 1979	No observable changes.
February 1981	No observable changes.
October 1982	The abandoned cultivation terraces are completely covered by dense vegetation.
December 1983	No observable changes.
October 1984	No observable changes.
October 1985	No observable changes.
December 1986	Squatter units A, B and C have been demolished.
June 1988	No observable changes.
November 1989	The study area has been completely covered by dense vegetation.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

YEAR	OBSERVATIONS
December 1990	No observable changes.
October 1991	No observable changes.
November 1992	No observable changes.
December 1993	No observable changes.
September 1995	No observable changes.
November 1997	No observable changes.
November 1998	No observable changes.
October 1999	No observable changes.
February 2000	No observable changes.

LIST OF TABLES

Table A1 - List of Aerial Photographs Used in API

Date	Altitude (ft)	Photograph Number
10 November 1945	20000	Y00610-11
18 November 1954	29200	Y02708-09
27 December 1956	16700	Y03440-1
5 October 1959	40000	Y04631-3
17 January 1961	30000	Y04961-2
26 January 1963	4100	Y08650-1
13 December 1964	12500	Y12974-5
1967	Unknown	Y13464-5
3 October 1972	13000	2269-70
23 October 1973	6000	5358
19 December 1975	12500	11789-90
23November 1976	12500	16547-8
21 December 1977	4000	20213-4
10 January 1978	4000	20726-7
28 November 1979	10000	28100-1
10 February 1981	5500	36603-4
10 October 1982	10000	44565-6
13 December 1983	5000	51964-5
20 October 1984	11000	56478-9
4 October 1985	15000	A02685-6
21 December 1986	10000	A08163-4
4 June 1988	10000	A13746-7
20 November 1989	10000	A19363-4
3 December 1990	10000	A24375-6
29 October 1991	10000	A28819-20
11 November 1992	10000	A33264-5
5 December 1993	10000	CN5415-6
5 September 1995	2500	CN10954-5
1 November 1997	10000	CN19022-3
10 November 1998	8000	CN21873-4
27 October 1999	4000	A50480-1
16 February 2000	20000	CN26069-71

Note: All aerial photographs are in black and white except those denoted with a CN prefix besides the photograph number.

LIST OF FIGURES

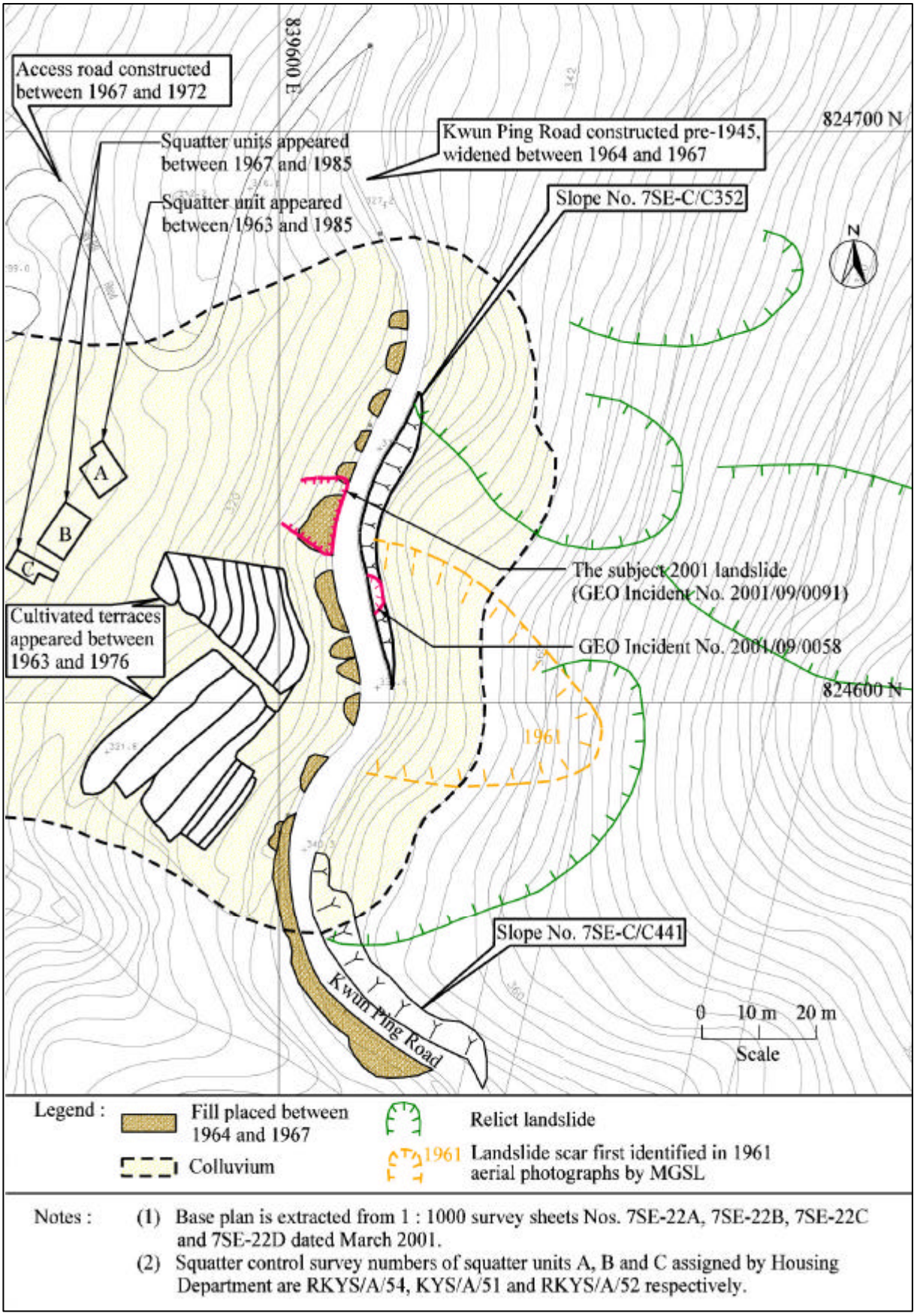


Figure A1 - API Observations

Table of Contents
Table of Contents
Table of Contents
Table of Contents

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

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

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

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

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

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
- Downloading the order form from the ISD website at http://www.isd.gov.hk and submit the order online or by fax to (852) 2523 7195
- Placing order with ISD by e-mail at puborder@isd.gov.hk

讀者可採用以下方法購買土力工程處刊物(地質圖及免費刊物除外):

書面訂購
香港中環花園道
美利大廈4樓402室
政府新聞處
刊物銷售組
傳真: (852) 2598 7482

或

- 致電政府新聞處刊物銷售小組訂購 (電話：(852) 2537 1910)
- 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)
- 以電郵方式訂購 (電郵地址：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

讀者可於下列地點購買1:100 000，1:20 000及1:5 000地質圖：

香港北角渣華道333號
北角政府合署23樓
地政總署測繪處
電話: 2231 3187
傳真: (852) 2116 0774

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

For Geological Survey Sheet Reports and maps which are free of charge:
Chief Geotechnical Engineer/Planning,
(Attn: Hong Kong Geological Survey Section)
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5380
Fax: (852) 2714 0247
E-mail: sdcampbell@cedd.gov.hk

For other publications which are free of charge:
Chief Geotechnical Engineer/Standards and Testing,
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5345
Fax: (852) 2714 0275
E-mail: ykhui@cedd.gov.hk

如欲索取地質調查報告、其他免費刊物及地質圖，請致函：

地質調查報告及地質圖:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
規劃部總土力工程師
(請交:香港地質調查組)
電話: (852) 2762 5380
傳真: (852) 2714 0247
電子郵件: sdcampbell@cedd.gov.hk

其他免費刊物:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
標準及測試部總土力工程師
電話: (852) 2762 5345
傳真: (852) 2714 0275
電子郵件: ykhui@cedd.gov.hk

Table of Contents
Table of Contents
Table of Contents

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

Table of Contents

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.

Table of Contents

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.

Table of Contents

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

Table of Contents