Geotechnical Area Studies Programme-

GASP Report I

Hong Kong and Kowloon

Geotechnical Control Office
Civil Engineering Services Department
Hong Kong

First published, May 1987

This Report was prepared in the Planning Division of the Geotechnical Control Office by A. D. Burnett, D. C. Cox, M. J. Dale, K. A. Emery J. N. Fowler, A. Hansen, N. E. Johnson, R. J. Purser and K. A. Styles.

Address:

Geotechnical Control Office
Empire Centre, 6th Floor
Tsim Sha Tsui East, Kowloon
Hong Kong.

This publication is available from:

Government Publications Centre
General Post Office Building, Ground Floor
Connaught Place
Hong Kong.

Overseas orders should be placed with:

Publications (Sales) Office
Information Services Department
Baskerville House, 2nd Floor
13 Duddell Street
Hong Kong.

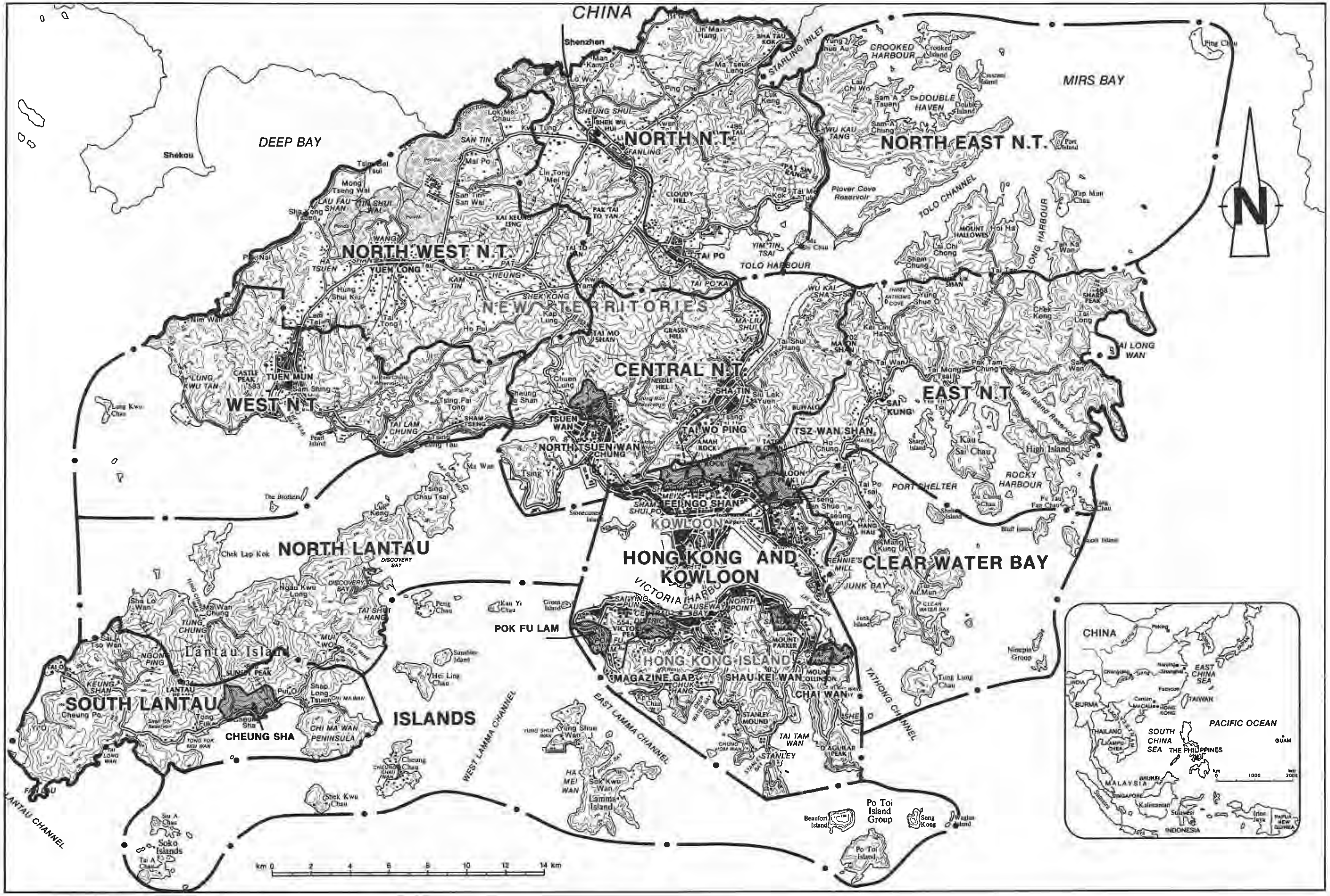
Price in Hong Kong: HK$240.

GASP Report I

Geotechnical Area Studies Programme-

Hong Kong and Kowloon

Geotechnical Control Office
Civil Engineering Services Department
Hong Kong
May 1987



Map of the Territory of Hong Kong Showing the Locations of the Geotechnical Area Studies.
(Boundaries of the Regional Studies are shown by dashed lines and locations of District Studies are indicated by dark screens)

FOREWORD

This Report aims to provide an adequate geotechnical basis for the planning and land use management of Hong Kong Island and Kowloon, mainly by way of information presented on a series of maps at a scale of 1:20 000. It is the first of twelve reports to be published as a result of the Territory-wide Geotechnical Area Studies Programme (GASP) carried out by the Geotechnical Control Office between 1979 and 1985.

GASP is based largely on terrain classification techniques using aerial photographs, together with field reconnaissance and the evaluation of a large number of existing site investigation records. It employs a unique system of terrain evaluation developed especially for Hong Kong conditions for the analysis and interpretation of the available data.

The GASP Reports were originally conceived as providing information almost solely for territorial land use planning, for which purpose the mapping scale of 1:20 000 is considered to be suitable. However, the information they contain also provides a good basis for engineering feasibility studies of large sites. The overall geotechnical assessment of a study area is presented on a series of seven user-oriented maps. Four of these are supplied with this published Report—the Engineering Geology Map (EGM), Geotechnical Land Use Map (GLUM), Physical Constraints Map (PCM), and Generalised Limitations and Engineering Appraisal Map (GLEAM). The GLUM classifies the terrain into four classes according to the level of geotechnical limitations, the PCM presents the major physical constraints that are likely to influence development, and the GLEAM delineates broad areas with potential for development from the geotechnical and planning points of view. In addition to the four maps accompanying this Report, the Terrain Classification Map, Landform Map and Erosion Map can be consulted in the Geotechnical Information Unit of the Geotechnical Control Office.

Users of GASP Reports should make reference to the new 1:20 000 scale Hong Kong Geological Survey Maps and Memoirs which are being prepared by the Geotechnical Control Office. These will provide more up to date geological information than is available in this Report. The Geological Map which covers Hong Kong and Kowloon, together with the accompanying Memoir, has recently been published (Geotechnical Control Office, 1986).

This Report was originally produced in July 1984, for use within the Hong Kong Government on the basis of information assembled during the period January 1982 to July 1984. This fact should be borne in mind by users, who should also note that the contents of the Report have for the most part not been updated. Further, although every effort has been made to ensure the accuracy of the information contained in the Report, this cannot be guaranteed. The Geotechnical Control Office cannot therefore accept any liability for errors in the data or for misinterpretations made during the study.

It must be emphasized that this document was prepared for general planning and resource evaluation purposes. As a general rule, 1:20 000 scale maps, particularly the GLUM, should not be used to evaluate parcels of land smaller than 3 hectares in size, and should never be interpreted, reproduced or enlarged to a scale greater than 1:20 000. Failure to heed this warning could result in serious misinterpretation of the information they contain.

The GASP study was undertaken by a team of specialist Geotechnical Engineers in the Planning & Terrain Evaluation Section of the Planning Division of the GCO, which included Messrs D. C. Cox, M. J. Dale, K. A. Emery, A. Hansen, N. F. Johnson, R. J. Purser and the late Mr J. N. Fowler. The Planning & Terrain Evaluation Section is led by Mr K. A. Styles, and the Planning Division is under the direction of Dr A. D. Burnett.

The Geotechnical Control Office acknowledges the co-operation and assistance given by the Commissioner of the Soil Conservation Service of New South Wales, Australia, who made available Mr K. A. Emery, a specialist Aerial Photograph Interpreter, to participate in the study. Acknowledgements are also due to the Buildings & Lands Department of the Hong Kong Government, who provided most of the aerial photographs used in the study, a few of which are reproduced in this Report.

E. W. Brand
Principal Government Geotechnical Engineer
May 1987

CONTENTS

List of Figures

List of Maps

List of Plates

List of Tables

1. INTRODUCTION

1.1 The Hong Kong and Kowloon Geotechnical Area Study

This Report presents the results of a 1:20 000 scale Regional Geotechnical Area Study of Hong Kong Island and Kowloon which was carried out in the Geotechnical Control Office between January 1982 and July 1984. The area covered by the study, which is designated as GASP I, is shown in Figures 1 to 3.

The study is based primarily on:

(*a*) Terrain classification using aerial photograph interpretation (API).

(*b*) Examination of geotechnical data collected from existing site investigation records and available literature.

(*c*) Field reconnaissance.

Subsurface investigations were not carried out specifically for this study.

This Geotechnical Area Study was based on the bedrock geology given on the 1:50 000 scale geological map produced by Allen & Stephens (1971). The mapping of the superficial deposits was carried out independently during the study.

It should be noted that the Geotechnical Control Office is at present remapping the whole Territory geologically to produce a new series of maps at a scale of 1:20 000, together with accompanying Memoirs. These will supersede both the bedrock geology and the mapping of superficial deposits presented in this Report. The two new maps which cover the area dealt with in this GASP Report will be available in early 1987 (Geotechnical Control Office, 1986, 1987), together with the accompanying Memoir (Strange & Shaw, 1986).

1.2 The Geotechnical Area Studies Programme

The Geotechnical Area Studies Programme (GASP) was initiated by the Geotechnical Control Office in September 1979 with the aim of providing systematic geotechnical input for land management and development planning of the Territory of Hong Kong. The Programme encompasses the entire land area of the Territory at a scale of 1:20 000 and a number of selected areas at 1:2 500.

The GASP areas were selected so that the results of each Study can be used for the planning and engineering feasibility of future development. For this purpose, the study results are summarised on a series of maps and overlays.

The Geotechnical Area Studies were planned to be carried out in the following three phases:

(*a*) *Regional Study*—Initial geotechnical assessment (at a scale of 1:20 000) based entirely upon aerial photograph interpretation, site reconnaissance and existing geotechnical information.

(*b*) *District Study: Stage 1*—Initial geotechnical assessment (at a scale of 1:2 500), based entirely upon aerial photograph interpretation, site reconnaissance and existing geotechnical information, to provide a more detailed assessment of specific areas identified in the Regional Studies.

(*c*) *District Study: Stage 2*—Expanded geotechnical assessment, based upon the results of a Stage 1 Study together with data obtained from a planned programme of site investigation.

Twelve Regional Studies have been completed, which cover the Territory of Hong Kong. This is the first of the Reports to be published; eleven others will follow in due course. A number of District Studies: Stage 1 have been carried out, whilst these Reports are only for use within Government, some information in map form is available on request (see Section 1.7 and 1.8).

1.3 Aims of the Geotechnical Area Studies Programme

The Geotechnical Area Studies Programme (GASP) Reports produced for regional appraisal are designed for development planning and engineering feasibility at a scale of 1:20 000. They provide relatively specific physical resource information for the assessment of geotechnical limitations and the engineering geological characteristics of the terrain for outline and strategic planning purposes.

Nine terrain-related land resource factors are assessed in this study: slope angle, geological materials, terrain component, erosion and instability, slope aspect, relief, vegetation, existing land use and rainfall. All these factors are important for assessing the nature, degree and intensity of geotechnical constraint associated with the terrain. They are discussed in detail in Appendices A and C.

In this Report, the maps are presented in both a technical and a non-technical format to make the geotechnical information they contain usable by a wide readership. The non-technical aspects are designed for planners, landscape architects, estate surveyors and land agents, while the more technical discussion is designed for civil and geotechnical engineers and engineering geologists.

It should be noted that the need for appropriate site investigation is not obviated by the results of a Geotechnical Area Study.

1.4 Organisation of the Report

The main text, contained in Sections 1 to 4, provides a summary of the study and its findings. The figures are located after the references.

Section 2 describes the topography, geology, geomorphology, hydrology, vegetation, erosion and land use of the Hong Kong and Kowloon study area. A detailed description of the geological units is provided in Appendix C.

Section 3 provides an assessment of the material characteristics and summarises the technical findings of the study. Section 4 provides a geotechnical assessment for development planning and discusses the suitability for development of various parts of the study area from an engineering point of view.

The conclusions are presented in Section 5, and Section 6 contains the cited references.

The figures are designed to explain and demonstrate the system used for compiling the maps and transparent overlays from the data. Figure 21 illustrates the system, and Figures 23 to 29 are extracts from the set of maps. The full size originals of these overlays are held by the Geotechnical Control Office. A fold-out base map for use with the transparent overlays is given at Figure 30, and fold-out legends are inserted before Figure 23.

A selection of maps, plans, stereopairs and photographs follow the example figures in the report, and these are presented as Plates 1 to 20. These plates, together with Figure 2, provide a visual impression of the study area.

Appendix A provides details of the techniques used in the terrain evaluation system. Appendix B tabulates the terrain-related data from the study. Appendix C contains supplementary information on geology along with information on site investigations, aerial photographs and rainfall relevant to the Hong Kong and Kowloon study area. Appendix D discusses landform evolution and its relationship to engineering. A glossary of terms used in the Programme is presented in Appendix E.

A copy of the Geotechnical Land Use Map (GLUM), the Physical Constraints Map (PCM), the Engineering Geology Map (EGM) and the Generalised Limitations and Engineering Appraisal Map (GLEAM) of the study area are contained in the accompanying Map Folder. Information relating to the preparation and limitations of these maps is presented in Section 1.5 and in Appendix A.

1.5 Maps Produced within the Regional Study

1.5.1 *General*

Maps are available in two forms for a Regional GASP Report. They are prepared in conventional line form, and the information they contain is also summarised within a computer data bank for the production of computer-generated plots.

The conventional line maps are produced by standard cartographic processes, whereas the computer plots are totally machine generated. The conventional line maps are either completely or partially derived from the information stored on the Terrain Classification Map. Figure A1 in Appendix A shows the relationship between map type and the method of production.

The computer-generated plots are referenced to the Hong Kong Metric Grid, and information is stored within a grid cell framework. Computer-generated plots can be produced at various scales from 1:20 000 to 1:100 000.

Currently, there are seven conventional line maps produced at a scale of 1:20 000 for each regional study area. The broad characteristics and purpose of each map is listed below. There are a number of general rules for the use of these maps, and these are discussed at Appendix A.10.

1.5.2 *Terrain Classification Map (TCM)*

This map records the general nature of the geological material (insitu, colluvial, alluvial, etc), slope angle, terrain component, erosion and instability. It forms the basis of the mapping system and is not designed for general distribution. The map is produced by aerial photograph interpretation and field work. An example is provided in Figure 29.

1.5.3 *Landform Map (LM)*

This map is totally derived from the Terrain Classification Map, and it summarises the broad terrain pattern; slope angle and terrain component are delineated at a scale of 1:20 000. It is designed for the use of technical and non-technical users who require general landform data for planning purposes. An example is presented in Figure 27.

1.5.4 *Erosion Map (EM)*

This map is totally derived from the Terrain Classification Map, and it delineates the broad pattern of erosion and instability at a scale of 1:20 000. It is designed for technical or non-technical users who require information regarding the general nature, degree and intensity of erosion and instability for planning and/or engineering purposes. An example is presented in Figure 28.

1.5.5 *Geotechnical Land Use Map (GLUM)*

This map is totally derived from the Terrain Classification Map, and it delineates the general level of geotechnical limitation associated with the terrain at a scale of 1:20 000. It is designed for non-technical users who require general information relating to geotechnical difficulty of the terrain for development planning. A copy of the GLUM Classification System is presented at Table 1.1, and a detailed discussion is provided in Appendix A.7. An example of the map is provided in Figure 23, and a copy of the map sheet is located in the Map Folder.

Table 1.1 GLUM Classification System

Characteristics of GLUM Classes	Class I	Class II	Subclass IIS	Class III	Class IV
Geotechnical Limitations	Low	Moderate		High	Extreme
Suitability for Development	High	Moderate	Moderate – Low	Low	Probably Unsuitable
Engineering Costs for Development	Low	Normal	Normal – High	High	Very High
Intensity of Site Investigation Required	Normal	Normal		Intensive	Very Intensive
Typical Terrain Characteristics (Some, but not necessarily all of the stated characteristics will occur in the respective Class)	Gentle slopes and insitu soils. Minor erosion on flatter slopes. Undisturbed terrain (minor cut and fill only).	Flat to moderate slopes. Colluvial soils showing evidence of minor erosion. Insitu soils which may be eroded. Reclamation. Rock outcrops. Poor drainage. Cut and fill slopes of low height.	Floodplain subject to periodic flooding and inundation.	Steep slopes. Colluvial and insitu soils showing evidence of severe erosion. Poor drainage. Cut and fill slopes of moderate height.	Combination of characteristics such as steep to very steep slopes, general instability on colluvium, severe erosion, poor drainage, high cut and fill slopes.

Note: This classification system is intended as a guide to planners and is not to be used for a detailed geotechnical appraisal of individual sites.

1.5.6 *Physical Constraints Map (PCM)*

This map is totally derived from the Terrain Classification Map, and it presents the major physical land resource constraints at a scale of 1:20 000. It is designed for technical or non-technical users who require information relating to the types of physical constraints which affect the terrain. It should be used in conjunction with the GLUM but is designed to stand alone as an assessment of the physical resources for general planning and engineering purposes. An example of this map is presented in Figure 24 and is discussed in detail in Appendix A.6. A copy of the map sheet is located in the Map Folder.

1.5.7 *Engineering Geology Map (EGM)*

Some of the information in this map is derived from the Terrain Classification Map, and some is compiled from other geological sources. This map displays the broad pattern of geological materials at a scale of 1:20 000. It is designed for technical users who require engineering geological information for strategic planning and engineering purposes. An example is presented in Figure 25 and is discussed in detail in Appendix A.8. A copy of the map is located in the Map Folder.

1.5.8 *Generalised Limitations and Engineering Appraisal Map (GLEAM)*

This map is prepared by an assessment of the terrain information recorded in the Terrain Classification Map, GLUM, PCM, EGM and current land management. This map evaluates the engineering-related factors which influence the potential of the terrain for future development. Areas with potential are identified at a scale of 1:20 000. The GLEAM is designed for technical and non-technical users who require information relating to the engineering suitability of the terrain for development. An example of the map is presented in Figure 26, and a detailed discussion is provided in Section 4.2 and in Appendix A.9. A copy of the map is located in the Map Folder.

1.5.9 *Computer-generated Maps*

Information from the Terrain Classification Map and other sources is summarised within the Geotechnical Terrain Classification System (GEOTECS). Land resource information is stored in a data bank management system which is referenced to the Hong Kong Metric Grid.

GEOTECS enables the rapid production of computer-generated plots which assist in the correlation of terrain attributes and other data on a Territory-wide basis. GEOTECS enables the interaction between land resources to be investigated, and permits the development of planning and engineering strategies. Computer-generated plots or tables can be based on any attribute or combination of attributes stored within the system. GEOTECS records data on a two-hectare grid cell basis and is recommended for use at a scale of approximately 1:50 000 for strategic planning and resource inventory purposes.

A number of computer-generated plots are presented within this Report which demonstrate the flexibility and multifunctional application of GEOTECS as a tool for resource evaluation.

1.6 Suitability of the Maps for Technical and Non-Technical Use

The maps accompanying this Report are designed for a range of users with quite different professional backgrounds. In Table 1.2, each map is assessed in relation to its expected value to a variety of potential users. A number of professional groups which require geotechnical information (technical or non-technical) are highlighted. The list of five disciplines given in the table is by no means exhaustive, but it illustrates the potential of the maps for different requirements. A three-class user recommendation (Fundamental, Useful and Background) indicates the relative value of each map to users.

Table 1.2 Value of the Maps Produced in a Regional GASP Report

Type of Map	Value of the Maps Produced at 1:20 000 Scale for Regional Assessment (of sites generally greater than 10 ha in size)				
	—Strategic Planner —Town Planner	—Landscape Architect	—Estate Surveyor —Land Agent	—Civil Engineer	—Geotechnical Engineer —Engineering Geologist
GLUM*	Fundamental	Fundamental	Fundamental	Fundamental	Useful
PCM*	Fundamental	Fundamental	Background	Fundamental	Fundamental
EGM*	Background	Background	Background	Fundamental	Fundamental
GLEAM*	Fundamental	Fundamental	Fundamental	Fundamental	Fundamental
LM	Useful	Useful	Background	Background	Background
EM	Useful	Useful	Background	Useful	Useful
TCM	Background	Background	Background	Background	Background
GEOTECS	Fundamental	Useful	Fundamental	Useful	Fundamental

* Located in the Map Folder accompanying this Report.

1.7 GASP District Studies Relevant to the Study Area

Seven GASP District Studies: Stage 1 have been undertaken within the study area at a scale of 1:2 500. The areas covered by these are shown in Figure 3. Approximately 1 650 ha of the geotechnically problematical terrain within the Hong Kong and Kowloon area have been assessed, and the results are summarised in a general form in Table 1.3. Some 70% of the terrain evaluated is subject to high to extreme geotechnical limitations. As an indication of the magnitude of the slope stability problem associated with this terrain, a total of over 800 landslips were recorded during the District studies.

Although the District GASP Reports are not available to the public, some of the maps produced at 1:2 500 scale are available through the Geotechnical Information Unit of the Geotechnical Control Office.

Table 1.3 GLUM Classes and Landslips within the GASP District Studies Located in the Hong Kong and Kowloon Regional Study Area

Study Area	District Stage 1 GASP Report No.	Geotechnical Limitation (GLUM Class—ha)				No. of Landslips	Total Area (ha)
		Low I	Moderate II	High III	Extreme IV		
Pok Fu Lam	1	14.0	84.0	70.0	50.0	102	218.0
Tsz Wan Shan	2	8.0	76.0	261.0	117.0	255	462.0
Fei Ngo Shan	5	7.0	24.5	99.3	115.2	167	246.0
Shau Kei Wan	6	23.7	29.8	64.9	13.3	64	131.7
Chai Wan	8	17.2	81.3	83.0	8.4	36	189.9
Tai Wo Ping	9	33.0	44.8	76.9	28.7	29	183.4
Magazine Gap	12	7.8	36.8	155.9	10.9	163	211.4
Total		110.7	377.2	811.0	343.5	818	1 642.4

1.8 Access to GASP Data

Much of the data used in preparation of this Report and the maps not included in the accompanying Folder are available through the Geotechnical Information Unit (GIU) of the Geotechnical Control Office.

A number of large scale (1:2 500) maps produced within the GASP District Stage 1 Programme are also available.

2. DESCRIPTION OF THE HONG KONG AND KOWLOON STUDY AREA

2.1 Geographical Location

The study area occupies approximately 12 600 ha and consists of Hong Kong Island, Ap Lei Chau, Stonecutters Island and the Kowloon Peninsula, as shown in Figures 1 to 3. It contains the most intensively used and densely populated urban areas of the Territory.

The northern and eastern boundary of the study area follows the main ridgeline of the Kowloon hills from Lai Chi Kok Bay, through Eagle's Nest, Beacon Hill, Lion Rock, Kowloon Peak, Black Hill and Devil's Peak to Lei Yue Mun. In addition to the main islands listed above, the study area also includes the islands of Tai Tau Cha and Ng Fan Chau west of Shek O; Kau Pei Chau, south of Cape D'Aguilar; Lo Chau, west of Stanley Peninsula; Round Island (Ngan Chau), Middle Island (Tong Po Chau) and Tau Chau, off Repulse Bay; and Ap Lei Pei and Magazine Island (Fo Yeuk Chau), south of Aberdeen.

2.2 Topography

The Kowloon Peninsula and the northern part of Hong Kong Island form a natural basin surrounded by granitic and volcanic hills. This basin constitutes an excellent harbour and historically, has been the location of extensive development. Significant modification of the original topography has taken place, and the original form of the terrain is often obscured. Historical maps, photographs and landscape sketches are useful in revealing the predevelopment landscape, particularly when supported by site investigation data. The historical development of this area is well summarised by Tregear & Berry (1959). Some of the historical maps and other plans are reproduced in Plates 15 to 19.

Originally, the northern side of Hong Kong Island was only a narrow strip of coastal lowlands. However, reclamation has enabled intensive development since the beginning of this century. Development of the Kowloon Peninsula commenced in the middle part of the 19th Century. South of a line between Cheung Sha Wan and Diamond Hill, the Kowloon Peninsula originally consisted of a group of low, severely eroded granitic hills. The intervening valleys and coastal areas of both Hong Kong Island and Kowloon were poorly drained and swampy. Large quantities of sandy material were removed from the low hills for reclamation and land-based fill. Urban expansion required a large supply of borrow for reclamation around the harbour foreshores. Much of the material was derived from the footslope terrain of Hong Kong Island and Kowloon.

The distribution of slope gradient within the Kowloon Peninsula and for each of the main islands are summarised in Table 2.1. The general pattern of slope gradient is recorded in the GEOTECS Plot shown in Figure 5. A pie diagram which summarises the distribution of slope gradient is given in Figure 4.

Approximately 27% of the study area consists of platforms, reclamation and slopes of less than 5° in gradient. The largest areas of slope gradient between 5 and 15° also tend to be within the urban areas. More than 37% of the study area consists of slopes steeper than 30° in gradient.

Table 2.1 Distribution of Slope Gradient

Location	Land Area (hectares) with Given Slope Angle					Water Storage	Area Totals
	0–5°	5–15°	15–30°	30–40°	>40°		
Kowloon Peninsula	2 293 (18.2%)	467 (3.7%)	489 (3.9%)	1 073 (8.5%)	230 (1.8%)	2	4 554 (36.2%)
Hong Kong Island	1 104 (8.8%)	1 016 (8.1%)	2304 (18.3%)	2 916 (23.2%)	365 (2.9%)	67 (0.5%)	7 772 (61.7%)
Stonecutters Island	25 (0.2%)	19 (0.2%)	27 (0.2%)	4	0	0	75 (0.6%)
Ap Lei Chau	22 (0.2%)	12 (0.1%)	22 (0.2%)	66 (0.5%)	4	0	126 (1.0%)
Other Islands	2	4	10 (0.1%)	21 (0.2%)	23 (0.2%)	0	60 (0.5%)
Totals	3 446 (27.4%)	1 518 (12.1%)	2 852 (22.7%)	4 080 (32.4%)	622 (4.9%)	69 (0.5%)	12 587 (100.0%)

Upslope of the existing development, the Kowloon hills form a continuous ridge which rises from 312 m at Eagle's Nest, through Beacon Hill (464 m) and Lion Rock (495 m) to the 602 m high Fei Ngo Shan (Kowloon Peak). The highest parts of this ridge are underlain by volcanic rocks of the Repulse Bay Formation, whereas the footslopes of Fei Ngo Shan and the ridge to the west of Tate's Cairn are granitic in nature. The sideslopes are steep with many rock outcrops and boulders. Slope gradients are often greater than 40°.

The ridge between Clear Water Bay Road and Lei Yue Mun is composed of granite on its western side, with volcanic rocks outcropping on the eastern flank. This ridge generally decreases in height southwards from 419 m at Tai Sheung Tok to 221 m at Devil's Peak.

Topographically, Hong Kong Island can be divided into three major zones. The predominantly volcanic terrain west of Wong Nei Chung Gap consists of an irregular east to west trending ridge which forms the main drainage divide in this area. Victoria Peak is the highest (554 m) of a number of summits along this ridge. To the south of the main spine of the Island, minor ridges and spurs extend in a southwesterly direction.

The eastern half of Hong Kong Island can be separated into either granitic terrain or volcanic terrain, northwest and southeast of Mount Parker respectively. The granitic terrain is more dissected, producing shorter slopes, particularly to the north of Mount Butler. Many of the volcanic slopes are much longer, extending with either straight or gently concave profiles from ridgecrest to valley floor or to the sea. Several peaks over 300 m in relief exist to the east of Wong Nei Chung Gap, the highest being Mount Parker at 532 m.

The coastal slopes around Hong Kong and the other islands are generally steep, often in excess of 30°, because of wave action. As a consequence of this, the coastal slopes are often either straight or convex in shape. Mount Johnson on the southern part of Ap Lei Chau is characterised by slopes which are steeper than 30° and reaches an altitude of 196 m. However, the northern half of Ap Lei Chau is only half as high and possesses a more gently rounded ridgecrest at its eastern end. Stonecutters Island consists predominantly of slopes gentler than 30° in gradient which are generally convex in shape.

2.3 Geology

2.3.1 *General*

The regional geology can be described simply as a sequence of faulted, folded, mildly metamorphosed volcaniclastic rocks (Repulse Bay Formation) that are extensively intruded by younger igneous rocks and partially overlain by a variety of superficial deposits. The volcanic rocks occur as roof pendants punctured locally and regionally by the underlying granitic batholith. These relationships are illustrated in the geological cross-sections presented in Figure C1 in Appendix C.

The locations of the various geological materials are presented in the Engineering Geology Map located in the Map Folder of this Report. The general distribution of the major geological units is summarised in the GEOTECS Plot in Figure 6. The Kowloon Peninsula is predominantly granitic, whilst Hong Kong Island has approximately equal proportions of volcanic and granitic terrain.

The geological boundaries for the bedrock geology are based on those mapped by Allen & Stephens (1971) with modifications from recent mapping in the north of Hong Kong Island (Geotechnical Control Office, 1982). The boundaries for the superficial deposits are drawn from aerial photograph interpretation, fieldwork and a review of borehole information carried out for this study (Styles, 1983).

The Geotechnical Control Office is currently preparing a new series of geological maps at a scale of 1:20 000 which will result in a more precise definition of the distribution of the geological units than is presented in this Report. As a precursor to the geological remapping programme Bennett (1984 a, b, c) reviewed the superficial deposits, weathering, stratigraphy, tectonic history and metamorphism in the Territory. Further general geological information is presented by Atherton & Burnett (1986) and Brand (1985).

On the basis of this GASP study, the relative proportions of the geological materials are graphically illustrated in Figure 4, and the percentages are presented in tabulated form in Table B6 in Appendix B.

The bedrock materials have generally been subjected to severe weathering. The depth of decomposition is determined by the relative resistance of the individual lithological units and groundwater regimes in association with the local geological structure. The granitic rocks tend to be the most deeply weathered. Weathering in excess of 80 m below sea level occurs beneath Victoria Harbour. On land, thicknesses of around 30 m of completely decomposed granite are common. Corestones of hard, relatively fresh rock can be found within the weathered profile. Volcanic rocks tend to have a much thinner weathering profile of around 10 m, but corestones may also occur in some of the coarse-grained tuffs.

The nature of the individual rock types is summarised below, but more detailed geological descriptions are given in Appendix C. Their general engineering behaviour and planning significance are discussed in Section 3.1 and summarised in Table 3.1.

2.3.2 *Volcanic Units*

The Repulse Bay Formation within the study area is subdivided on the basis of major lithotypes by Allen & Stephens (1971) into the following classes:

(i) *Sedimentary Rocks and Water-laid Volcaniclastic Rocks (RBs)*
This is a minor class which consists of interbedded shale, siltstone, chert and volcanic sandstones found in the southwest of Hong Kong Island. It is weaker than other members of the Repulse Bay Formation and may be deeply weathered and closely jointed. It occupies approximately 0.5% of the study area.

(ii) *Acid Lavas (RBv)*
This is a minor class which occurs in a band from Pok Fu Lam to Aberdeen. It is a grey, fine-grained, hard, extrusive rock with very shallow weathering and columnar jointing. It occupies approximately 0.3% of the study area.

(iii) *Coarse Tuff (RBc)*
This rock occurs in two broad bands on the west of Hong Kong Island and at Cape D'Aguilar, occupying 1.5% of the study area. It is a coarse volcanic ash that generally has closely spaced joints and moderate to shallow weathering.

(iv) *Pyroclastic Rocks with Some Lavas (RBp)*
This class is the largest member of the Repulse Bay Formation extending over much of Hong Kong Island and the eastern portion of the mainland. It contains a variety of fine volcanic rocks that have a shallow weathering profile and close jointing. This unit outcrops in approximately 27% of the study area.

(v) *Undifferentiated Volcanic Rocks (RB)*
This minor class, which occurs on the western tip of Hong Kong Island, may contain rocks of any of the above lithologies.

2.3.3 *Intrusive Igneous Units*

The igneous rocks which intrude the above volcanics are subdivided by Allen & Stephens (1971) on the basis of lithology, age and intrusive relationships, as follows:

(i) *Tai Po Granodiorite (XT)*
This is the oldest intrusive unit and occurs principally on the Stanley Peninsula. It occupies 0.7% of the study area and is a dark, coarse-grained, grey, intrusive igneous rock that has moderate to deep weathering, widely spaced tectonic joints and rough sheeting joints.

(ii) *Sung Kong Granite (SK)*
This unit occurs in the Kowloon foothills and occupies 1.1% of the study area. It is a pale grey to pink, coarse, porphyritic granite subject to deep weathering with wide, smooth tectonic joints and rough sheeting joints.

(iii) *Cheung Chau Granite (CC)*
This class occurs in the northeast and occupies 2.1% of the study area. It is a pale grey to pink, coarse-grained, porphyritic, strong granite that is subject to deep weathering and contains moderately to widely spaced, smooth tectonic joints and rough sheeting joints.

(iv) *Ma On Shan Granite (MS)*
This is a very small unit which occurs in a dyke on Hong Kong Island and as a minor outcrop near Beacon Hill. It is a pink to grey, fine-grained, porphyritic granite subject to deep weathering and contains moderately to widely spaced, smooth tectonic and rough sheeting joints.

(v) *Feldspar Porphyry (La)*
This rock type occurs as narrow dykes in the Kowloon Peak area and on the Stanley Peninsula on Hong Kong Island. The dykes may be moderately to deeply weathered with close, smooth joints.

(vi) *Quartz Monzonite (Mo)*
This rock type occurs in minor dykes on the mainland, in a series of northeast trending bodies on Hong Kong Island and in a large mass on Cape D'Aguilar. This unit occupies 1.4% of the study area. It is a grey, medium-grained feldspathic igneous rock with moderately spaced, smooth tectonic joints and rough sheeting joints, and is subject to moderately deep weathering. Extensive areas of boulders are visible on the surface.

(vii) *Hong Kong Granite (HK)*
This is the most extensive granitic rock within the study area, occupying 21.2% of the surface. It is a fine to medium-grained, pink, non-porphyritic granite with moderately spaced, smooth tectonic joints and rough sheeting joints, and is subject to very deep weathering. Corestones are common.

(viii) *Hong Kong Granite—Fine-grained Porphyritic Phase (HKf)*
This rock type occurs as an irregular annulus within the main Hong Kong Granite on Hong Kong Island, occupying 1.8% of the study area. It is a fine-grained, pink, porphyritic granite with phenocrysts of quartz and feldspar. Weathering is moderately deep, and jointing is moderately to widely spaced with rough sheeting joints.

(ix) *Hong Kong Granite—Medium-grained Porphyritic Phase (HKm)*
This rock type occurs as the central body within the above rock type and occupies 0.3% of the study area. It is a medium-grained, pink, porphyritic granite, highly erodible and subject to deep weathering. Widely spaced, smooth and rough tectonic joints are characteristic features.

(x) *Granophyric Microgranite (Mc)*
This rock type occurs on Hong Kong Island near Pok Fu Lam and occupies only 0.2% of the study area. It is the youngest granitic phase and is fine-grained and pink in colour. Weathering is moderately deep, and jointing is moderately to closely spaced with some development of sheeting joints.

(xi) *Quartz Porphyry (Pq)*
This rock type also has a very limited occurrence and may be found in dykes on Cape D'Aguilar and on Kau Kei Chau. Weathering and jointing are similar to (viii) and (ix).

(xii) *Dolerite (D)*
This is the youngest intrusive igneous rock within the study area, and it is very limited in extent. It is a dark, medium-grained basic igneous dyke rock that weathers to a deep red clay. Jointing is close and perpendicular to the dyke walls.

In summary, many members of the intrusive igneous rock suite have similar physical properties and, from a general engineering point of view, appear to behave in a similar manner. Intrusive igneous rocks occur in approximately 29% of the study area.

2.3.4 *Superficial Units*

In addition to the solid geology, both natural and man-made superficial deposits constitute over 40% of the land surface. These superficial deposits are classified as follows:

(i) *Colluvium*
The colluvial materials occur over 2 366 ha of the study area. These deposits are formed by gravity transport of rock and soil debris down slope, and occur as recent or relict deposits. They are very heterogeneous in their physical properties and, in this Report, are subdivided only on the basis of the parent rock type as follows:

(*a*) Volcanic colluvium (Cv)—This material occupies 8.2% (1 034 ha) of the study area and is most extensive on Hong Kong Island, where it predominantly occurs as bouldery deposits in drainage channels or as large fan shaped deposits accumulated against hillslopes. The detrital material ranges from fresh boulders to completely weathered granular soil and may be highly permeable. In many locations, the material displays evidence of instability.

(*b*) Granitic colluvium (Cg)—The largest deposits of this material occur on the Kowloon foothills and on the northeast side of Hong Kong Island. It occupies approximately 7.3% (918 ha) of the study area. Large fan deposits of variable age and state of weathering occur and exhibit significant erosion and instability.

(*c*) Mixed colluvium (Cm)—This category contains all colluvium of mixed geological origin and makes no distinction between relative proportions of the parent materials. The largest areas are on Hong Kong Island, in the Mid-levels and in Aberdeen. This unit occupies a total of 3.3% of the study area.

(ii) *Alluvium*
Large areas of the Kowloon Peninsula and lesser areas of Hong Kong Island are covered by alluvium. These deposits occupy a total of 5.4% of the study area. The material consists of poorly sorted, brownish silty sand and subangular gravels.

(iii) *Marine Deposits*
On the seabed and beneath areas of reclamation, deposits of soft marine muds and shelly sands may be found. They do not occur within the onshore portion of the study area.

(iv) *Littoral Deposits*
Littoral deposits of medium dense sands and gravels may be found in isolated areas along the coast of Hong Kong Island and beneath reclamation adjacent to the mainland. They form 0.2% of the study area.

(v) *Reclamation*
Approximately 1 603 ha of the mainland and the northern shoreline of Hong Kong Island exists as reclamation. This figure represents approximately 12.7% of the study area. The material used to form the reclamation is highly variable and may contain weathered and fresh rocks from any of the previously discussed groups, old masonry sea walling and/or refuse.

(vi) *Fill*
During site formation, areas of fill have been placed which now total approximately 4.0 % of the study area. The engineering behaviour of the material is generally dependent on the degree of compaction at the time of placement and any subsequent densification as a result of settlement.

The Hong Kong and Kowloon study area contains a wide variety of geological materials, and the engineering behaviour of foundations and slopes can be expected to vary accordingly.

A description of the geology of the Territory is available in the Report of the Geological Survey of Hong Kong (Allen & Stephens, 1971). A detailed description of the rock units is presented in Appendix C.

2.4 Geomorphology

2.4.1 *General*

The geomorphology of Hong Kong and Kowloon reflects a complex Quaternary history of erosional and depositional response to climatic change and sea level (eustatic) fluctuations superimposed on the major geological units. Individual landforms are continually evolving, as determined by the local balance between rapid weathering rates and denudation from intense seasonal rainfall. A description of the mechanics of the weathering process and its engineering significance are contained in Appendix D.

Table B5 in Appendix B provides data on the distribution of the major landform units.

The various geological materials weather, erode or are deposited in different ways. The regional geomorphology can therefore be described in subdivisions relating terrain type to either bedrock geology or superficial materials. These basic subdivisions refer to granitic, volcanic, colluvial and alluvial terrain.

2.4.2 *Granitic Terrain*

Granitic terrain occupies approximately 29.5% (3 713 ha) of the study area. There are three major areas: the Kowloon Peninsula, the Lion Rock ridgeline from Lai Chi Kok Bay to Tate's Cairn and associated footslopes, and from Happy Valley to Shau Kei Wan on Hong Kong Island.

The Kowloon Peninsula originally consisted of a group of low, rounded, deeply weathered granitic hills which were severely eroded prior to, and during, urban development. Very deep weathering (in excess of 30 m) occurs in parts of this terrain, because of the lack of erosional energy available from the low relief. Lower terrain would probably have consisted either of alluvial or fine colluvial material or eroded granite benches. Major modifications to the terrain have occurred in this area, with fill being used to elevate the general level of the low lying land, which was originally poorly drained and probably swampy in nature. Extensive formation of cut slopes and platforms has also occurred. The delineation of the superficial deposits within the urban area, as shown on the Engineering Geology Map (EGM) and Physical Constraints Map (PCM), should be treated with caution, as the long development history has made delineation of the superficial deposits very difficult in some areas.

Granite outcrops along the Lion Rock range of hills from Lai Chi Kok Bay to near Tate's Cairn, then continues on the footslopes below Fei Ngo Shan and forms the western slopes of the ridge from Clear Water Bay Road to Lei Yue Mun. Much of this terrain consists of rounded foothills with long convex upper slopes. Many of the ridgecrests are subject to gullying of the granular soils. In some cases this gullying may have originated along footpaths. This indicates that, although the natural vegetation is quite effective in controlling erosion, removal of the residual soils can proceed very quickly once the vegetation is removed. Many large rounded corestones exist on the slopes, particularly along spurlines. These boulders may be subject to instability through erosion, resulting in undermining of the granular soils. Although rock outcrops occur sporadically across the terrain, more continuous outcrops can be found along drainage lines and as cliffs on the steeper slopes. The distribution of slopes which are steeper than 30° in gradient is shown on the Physical Constraints Map and is summarised in the GEOTECS Plot in Figure 5.

The third area of granitic terrain can be found on Hong Kong Island between Happy Valley and Shau Kei Wan. Small areas also exist on the Stanley and D'Aguilar Peninsulas. To the south of North Point, the terrain consists of a dissected plateau which is severely eroded in part. Slopes around the plateau are quite steep, yet still possess characteristic rounded morphology. On the two peninsulas at the southern extremity of the Island, the slopes extend from sea cliffs with long, essentially straight profiles up to the narrow convexities of the ridgecrests. Shallower weathering depths are expected here because of the more active basal removal of material by the sea.

2.4.3 *Volcanic Terrain*

Three areas of volcanic terrain can be defined which cover a total of 3 672 ha, or 29.2% of the study area. These are the Fei Ngo Shan to Tate's Cairn ridge and the western and eastern parts of Hong Kong Island on either side of Wong Nei Chung Gap.

The Fei Ngo Shan ridge is formed from the westernmost part of the outcrop of volcanic rocks which extend across the eastern portion of the Territory. It also forms the highest part of the study area. Active erosion is taking place in the form of landslips, including rockfalls, soil creep and slopewash, as the slopes are steep, often in excess of 45°. The terrain is typically irregular in morphology, with large rock exposures through a generally thin veneer of boulder scree deposits and clayey soil with a high percentage of rock fragments. Large boulders of volcanic rock are scattered over these upper slopes. Volcanic bedrock has only a thin weathered veneer on steep slopes, but this increases to in excess of 15 m on shallow slopes, particularly when the rock is closely jointed.

On the western part of Hong Kong Island, the pattern of ridges and drainage is irregular. Many of the coastal slopes are steep, as are some of the inland slopes which are adjacent to incised drainage lines. Some areas with slope angles less than 30° exist, and some of these may be suitable for further development. Soils are generally thin, particularly on the steeper slopes. Some areas of precipitous cliffs exist on High West, Victoria Peak and Mt Nicholson.

To the east of Wong Nei Chong Gap, the terrain exhibits considerable structural control. Two major trends in the orientation of ridges and drainage lines are apparent in this area. The strongest geological control lies in the orientation of the drainage lines, which have tended to follow major lines of weakness such as faults or major joints. These orientations are northeasterly and northwesterly in direction. The major photolineaments are shown on the Engineering Geology Map. Although the ridgelines may be due to the existence of more resistant lithologies, their orientation is often controlled by erosion along the drainage lines. As such, a greater range of directional trends may result, the ridges being subparallel to the valleys. Many of the slopes possess straight or very slightly concave profiles extending from narrow ridge convexities. Soils are thin, as erosion is generally quite active due to the large length of coastline in this area.

2.4.4 *Colluvial Terrain*

Colluvial deposits exist over approximately 18.8% of the terrain in the study area. Deposits are delineated if they are of significance to engineering at a scale of 1:20 000 (Styles, 1983). The mapped distribution is shown on the Physical Constraints Map and, the Engineering Geology Map, and is summarised on the GEOTECS Plot in Figure 7. A breakdown of the 2 381 ha of colluvial terrain according to slope angle is also summarised in Table B5 in Appendix B. Approximately 749 ha is less than 15° in slope angle and 526 ha is steeper than 30°. There is 850 ha within the 15 to 30° slope range. Almost 50% of the deposits which occur within the latter slope range are located on terrain which is subject to possible groundwater flow. Colluvial deposits exist over much of the footslope terrain in the study area. They form extensive blankets over the Kowloon footslopes and in the Mid-levels area. These deposits often contain distinct layers of debris, the layers differing in degree of weathering of the detrital boulders, and in lithological composition. Some deposits display stratification approximately parallel to the slope. Some of the colluvial deposits reach thicknesses of over 30 m. These deposits are often dissected by deep valleys which contain many boulders which have been either exhumed by erosion or deposited by recent landslip activity. Boulders are common on the surface of these deposits.

The amount of incision into the colluvial fans is dependent on the gradient and catchment area of the drainage system. Thus, on the eastern side of Beacon Hill, the colluvial apron is only slightly dissected because the drainage path to the sea is quite long. On the western side, however, the drainage path into Cheung Sha Wan is much shorter and the stream profile steeper, and therefore the erosive power of the streams is much greater. This has resulted in the removal of most of the colluvium from that side of the hill.

Streams which exist in bedrock areas may disappear underground upon reaching colluvial deposits. Large natural 'tunnels' or 'pipes' occur as voids in the colluvium (Nash & Dale, 1983). The build-up of pore water pressures within colluvium during periods of rainfall is an important factor in the stability of the material.

Some areas of colluvium display a hummocky, irregular surface which may reflect potential or previous instability. These areas are identified on the Physical Constraints Map and Engineering Geology Map.

2.4.5 *Alluvial Terrain*

Major alluvial deposits exist in three localities: Cheung Sha Wan, San Po Kong and Happy Valley. They are shown on the Engineering Geology Map held in the Map Folder. The area of these major deposits is approximately 614 ha, or 4.9% of the study area. Some alluvium is obscured by disturbed terrain, and this is not reflected in the area calculations (Table B5 in Appendix B). The terrain in these areas is usually flat or gently sloping but may also have a veneer of fill. Colluvial lenses or more extensive detrital bodies may also exist within the alluvial sequence, and both deposits may extend below the marine deposits.

The alluvial and colluvial deposits started to infill the major valleys following the cessation of downward incision produced by the lowering of sea level during the Pleistocene. As sea level was lowered by up to 80 m, it is probable that the alluvium or colluvium could extend below present sea level to a depth up to this figure. The actual depth is dependent on how far sea level fell and on how much incision occurred before the onset of rising sea level.

Sea level has also been slightly higher than at present, leaving small raised beach and raised alluvial terrace features in various parts of the lowland terrain. Although no such landform has been positively recognised during this study, there is evidence on Lantau and in the northwest New Territories. This possibility should be considered during the interpretation phase of any site investigation.

2.5 Surface Hydrology

The natural drainage pattern in the Hong Kong and Kowloon study area is severely disrupted by extensive development. The Engineering Geology Map shows the location of the major catchments outside of the urban area. Each catchment boundary is annotated with the highest order of stream which exists within it. The system of stream ordering is described in Appendix A. As it is not possible to map the drainage hierachy within the urban area with reliability, the exact locations of the major catchment boundaries in the developed area are uncertain.

Within the extensive built up areas, the principal changes caused by urban development are the channelisation coupled with possible realignment of drainage paths, together with the formation of an impervious surface to the ground. The climate in Hong Kong is characterised by periods of intense rainfall, as illustrated in Appendix C.4, and storm channels in urban areas require a large capacity due to the extremely high volume of runoff. Runoff is quickly removed through a system of storm drains into the main channels with very little infiltration into the ground. Discharges within urban channels are high, and the times to peak discharge are short. Peak discharges under these conditions will be much higher than for a natural drainage system, and proposals for development should take this into account. Also, the extension of reclamation area causes a reduction in overall gradient of a drainage channel or nullah, thus possibly necessitating regrading to maintain a sufficient gradient for efficient discharge. Alternatively, an increase in channel cross section may be required in the lower reaches to accommodate large flows. Many of the channels are covered, and the routes are not necessarily apparent from a visual inspection of an area. Except in the case of some of the major open nullahs, the drainage pattern is not shown within the urban area on maps produced at a scale of 1:20 000.

Outside the urban areas, disturbance of the natural drainage system consists of the channelisation of some major streams, the construction of catchwaters, the creation of reservoirs and the addition of drainage systems to some unstable or problem slopes.

On the mainland portion of the study area, major drainage divides exist south of Beacon Hill, along the Chuk Yuen spur south of Lion Rock and at Diamond Hill. The non-urbanised area south of Fei Ngo Shan does not possess any drainage lines of a high order.

Most of the drainage pattern in Kowloon does not reflect strong structural control, although a few stream courses do follow structural lineaments. The latter are shown on the Engineering Geology Map and may be indicative of deeper weathering, shattered rock and possible locations of subsurface flow.

The drainage pattern on Hong Kong Island is much better delineated because of the narrower urban area. Three drainage regimes are recognised, and these correspond with the three topographic and geomorphological regions described in Sections 2.2 and 2.4. Within the granitic terrain, the drainage pattern is dense. To the west of Wong Nei Chung Gap, the drainage pattern is slightly irregular with only a small amount of structural control. The largest catchment on Hong Kong Island exists south of Mount Parker and drains into the Tai Tam Reservoir and then into Tai Tam Bay. Many of the streams on Hong Kong Island are short because of the strongly indented coastline; thus, the majority of catchments are very small. Moderately sized catchments exist in Pok Fu Lam, Aberdeen and Happy Valley, although the latter is highly urbanised. The area to the east of Wong Nei Chong Gap possesses the greatest structural control, with two major sets of photolineaments, aligned northeast and northwest, intersecting to form a subrectangular pattern.

2.6 Vegetation

The vegetation of the study area is greatly affected by human activities and only relatively small areas of natural vegetation remain undisturbed. In this Report a seven class system is used to classify the vegetation. The spatial distributions of these groups are illustrated in the GEOTECS Plot in Figure 8, whilst Figure 4 shows their relative proportions. Approximately half the area is devoid of vegetation due to man's disturbance, principally through urban development and, to a much lesser extent, erosion.

The vegetation classes are as follows:

(i) *Grassland*
This class generally consists of indigenous or introduced grass species which occur after the clearing of shrubland or woodland. Grassland occupies 8.6% of the study area and occurs principally on the terrain between Beacon Hill and Fei Ngo Shan and on Ap Lei Chau. Minor areas of grassland occur throughout the undeveloped terrain within the study area.

(ii) *Cultivation and Botanical Gardens*
This occupies only 0.1% of the study area. Urban expansion has alienated most of the cultivated land in this area. Small vegetable plots may be found north and east of Wah Fu on Hong Kong Island and around Ma Yau Tong in Kowloon.

(iii) *Mixed Broadleaf Woodland*
This class usually contains a wide variety of introduced and exotic species. Extensive areas of woodland occur on Hong Kong Island and Stonecutters Island. Smaller patches survive along the western portion of the Kowloon foothills. A total of 27.1% of the study area is covered by this class of vegetation.

(iv) *Shrubland (Less than 50% Ground Cover)*
Shrubland occurs as regrowth on areas which have been affected by disturbance of some form or other. Shrubland generally develops after grassland, particularly in areas protected from hill fire. This class forms 2.9% of the study area. On Hong Kong Island, the most extensive areas are in the D'Aguilar Peninsula, near Cape Collinson and also below Mt Butler. Only small areas are developed in Kowloon, with the largest above the Nam Shan Estate.

(v) *Shrubland (Greater than 50% Ground Cover)*
This class is similar to (iv) but is characterised by denser vegetation. It covers 4.9% of the study area and is scattered throughout the undeveloped land. The largest concentrations are on Hong Kong Island on the Stanley and D'Aguilar Peninsulas, at Cape Collinson, above Aldrich Bay and behind Braemar Hill Estate at North Point.

(vi) *No Vegetation due to Man's Disturbance*
Approximately 50.5% of the study area is affected by urban development and associated activities. Existing land use is discussed in Section 2.8.

(vii) *Rock Outcrop*
Areas of general rock outcrop may contain sparse intermittent grass and shrub vegetation but the land surface is predominantly rock with little soil. This class is most common in the southern portion of Hong Kong Island. A total of 5.3% of the study area is classified in this group.

Vegetation cover influences the intensity of denudational processes, both by its effect on hillslope hydrology and by exerting a degree of control on the shear strength of the soil mantle. A well developed vegetation cover acts to trap precipitation on both the plants and in the soil litter, thus reducing both volume and velocity of surface runoff. This protects the soil from erosion but promotes infiltration, which may have a detrimental effect on stability. Evapotranspiration rates are also improved by a healthy vegetation cover. Root systems act to bind the soil together, thus increasing the shear strength of the soil mantle and reducing the hazard of shallow slope failures (Carson & Kirkby, 1972). One significant effect of a substantial vegetation cover is that it reduces the degree of erosion on undisturbed natural terrain. The majority of the erosion observed on the natural terrain is associated either with minor disturbance by man (footpaths triggering gullying) or with minor gullying associated with the headward extension of drainage lines.

The variation in the vegetation pattern across the area is a product of the relationship between the soils, the microclimate (aspect, exposure and elevation) and human influence. Hill fires have reduced woodland vegetation to shrubland or grassland over much of the terrain. Even the low broadleaf woodland which does exist often has a high density of thin young trees, with a dense shrub ground cover associated with regrowth rather than the more open woodland associated with native stands. Aerial photographs taken in 1945 and 1949 illustrate the effects of the Second World War, during which much woodland was cleared either for fuel or for military purposes. Sparse shrubland extends over most of the footslopes of both Kowloon and Hong Kong. Nineteenth Century sketches of the Victoria Peak and Mid-levels area show the sideslope and footslope terrain almost devoid of vegetation of any kind. Over the past forty years, this vegetation has improved in many parts of the area, whereas in others, only low vegetation or grassland tolerate the effects of repeated hill fires.

Vegetation in Hong Kong is characterised by a wide range of species; approximately 2 350 species occur in the Territory, according to Thrower (1970). In fact, there are representatives of some 50% of the world's 441 plant families. This may have implications for the use of vegetation as a means of controlling erosion and surface instability because it indicates that growing conditions, at least for part of the year, are suitable for an extremely large number of species. Many of the strains used successfully to control erosion in other countries may be suitable for use within the Territory.

2.7 Erosion and Instability

2.7.1 *General*

The surface condition of the terrain is classified on the basis of the major forms of erosion. The presence of slope failures or instability is also recorded within this attribute.

Areas subject to erosion are classified as 'sheet', 'rill' or 'gully' erosion. Each of these classes is subdivided into three subclasses: minor, moderate or severe. Instability is subdivided into the basic classes of 'well-defined landslips', 'coastal instability' and 'general instability'. A final category of 'no appreciable erosion' is used for those areas that show no evidence of either instability or erosion.

The areas affected by the severe forms of erosion and slope instability are shown on the Physical Constraints Map and the latter on the Engineering Geology Map. A summary of the distribution of erosion and instability is given in the pie charts in Figures 4 and 13, tabulated in Table B2 at Appendix B, and illustrated in the GEOTECS Plot in Figure 9.

Erosion and instability affect 23.2% (2 915 ha) of the study area. However, approximately 30% (3 700 ha) of the study area is currently developed, with erosion being restricted to unprotected platforms and slopes. Thus, more than one third of the natural terrain is subject to erosion.

2.7.2 *Erosion*

(i) *Sheet Erosion*
This form of erosion produces extensive areas of bare ground devoid of vegetation. Within the study area, it occurs around Kwun Tong in East Kowloon, to the southeast of Happy Valley and on the D'Aguilar Peninsula in and around the quarry at Shek O. It also occurs intermittently in the Kowloon hills and on the western side of Hong Kong Island. A total of 4.8% of the study area is affected by sheet erosion.

(ii) *Rill Erosion*
This form of erosion is usually associated with cut and fill batters but may also occur on natural terrain. It is characterised by numerous subparallel drainage rivulets, which produce a striated appearance and result in significant soil loss. Within the study area, it is a minor class affecting less than 0.1% of the terrain. No geographic pattern is discernable.

(iii) *Gully Erosion*
This form of erosion produces deep dissection of the surface with consequent disruption of drainage and may precipitate slope instability. It affects 6.1% of the study area. There does not appear to be a definite geographic pattern to its distribution, but areas occur above Aldrich Bay, in parts of the Kowloon foothills, and in the southern half of Hong Kong Island.

When all the forms of erosion are considered together, they account for a significant level of soil loss. These erosional forms do not in themselves constitute slope instability, but they indicate areas that may become unstable if adequate consideration is not given to drainage and other geotechnical factors during development and redevelopment.

2.7.3 *Instability*

The term 'instability' is used in this Report to refer to 'well-defined landslips' and terrain over which there is 'general instability'. It provides an indication of the inherent weakness of the terrain and/or the occurrence of unfavourable groundwater conditions. Expensive slope stabilisation works may be required to permit development of natural unstable areas.

The term 'well-defined landslip' refers to the scar and debris associated with a slope failure. Only landslips larger than 1 ha are delineated at the mapping scale of 1:20 000. It is difficult to define very small features and individual landslip scars within a terrain classification system designed for use at 1:20 000 scale, because, often these features are too small in comparison to the size of the basic mapping unit. Therefore, where large numbers of small landslips or other evidence of instability occur on insitu or colluvial terrain, the landform is classified as being subject to 'general instability'.

Slope instability of some form or other is relatively common within the study area. Approximately 1 528 ha of the terrain displays some form of instability, and this represents 12.1% of the study area.

(i) *Well-defined Landslips*
Within the study area, 'well-defined landslips' occupy only 24.5 ha (0.2%) of the land surface but these large landslips have resulted in considerable loss of life and property. The most significant of these landslips occurred at Po Hing Fong in 1925, Mt Nicholson in 1966, Po Shan Road in 1972, and at Sau Mau Ping in 1972 and 1976 (Government of Hong Kong, 1972 a & b, 1977; Vail, 1984; Vail & Beattie, 1985).

(ii) *Coastal Instability*
This form of instability is most prominent on the exposed southern coast of Hong Kong Island and on the east coast of Ap Lei Chau. It is caused by oversteepening of slopes by marine erosion. Only 0.2% (31 ha) of the study area is affected.

(iii) *General Instability—Recent*
This form of instability relates to colluvial and insitu terrain where many failures and other evidence of instability occur, but it is not possible to show them as discrete units on a 1:20 000 scale map due to their small size.

The major class is 'general instability-recent', which occupies 10.8% (1 355 ha) of the area. This occurs over much of the steep terrain, with particularly high concentrations above the Mid-levels and beneath Tate's Cairn.

(iv) *General Instability—Relict*
This form of instability occupies 0.9% (118 ha) of the area, but it does not appear to follow any particular geographical pattern. This class is no less important in terms of constraints upon development than general instability-recent, as it may be reactivated by construction or earthworks.

The general relationships between geology, erosion and instability are discussed in Section 3.1.

2.8 Land Use

2.8.1 *Existing Development*

The pressure for urban development has existed on Hong Kong Island and the Kowloon Peninsula since the Territory became a focus for Asian trade. The commercial and trading centre has expanded along the harbour foreshores on reclamation and low ground with associated high density residential accommodation and local commerce. Supportive light industrial areas are intermixed with these. Residential accommodation spread from the commercial and industrial centres, with lower density housing occurring on more elevated areas. Throughout this expansion, progress has been controlled by economic and social requirements balanced by the difficulties imposed by the terrain. The GEOTECS Plot in Figure 10 shows the approximate distribution of existing land use groups within the study area. The distribution of existing land use with respect to geotechnical limitations (GLUM class) is discussed in Section 2.8.2. The distribution of broad land use groupings is shown in the pie chart at Figure 4 and is summarised in Table B12 in Appendix B.

A rapid influx in population during the last 30 years has created considerable pressure for the production of public housing. Many public housing estates are located in the study area: along the Kowloon footslopes, Sau Mau Ping and towards Kwun Tong, on the northeast coastal margin of Hong Kong Island and around Aberdeen on the southern side of the Island. The general extent of the older squatter areas has not significantly altered over many years, although, during more recent years squatters have markedly increased in the Lam Tin area of East Kowloon. Plate 20 shows the change in intensity of squatters since 1967. Squatters currently occupy about 5% of the study area. The relationship between squatter areas, development and the terrain is discussed in Section 2.8.2.

Transport links have grown and become overloaded as the urban centre has expanded with population increase. In spite of this, major roads occupy in excess of 25% of the intensely developed zones.

In the course of urban expansion, agricultural land has been alienated, and it now occupies only a very minor proportion of the study area. Agricultural production is concentrated in the New Territories.

On Hong Kong Island, only 35% of the terrain is currently developed whilst, by comparison, 70% of the mainland portion of the study area is developed.

Quarry and aggregate requirements in the study area are supplied by Government and contract quarries at six sites. These supply much of the Territory's aggregate, crushed fines, concrete and blacktop. Hong Kong has a high demand for fresh water to supply residential, commercial and industrial needs. In order to maintain water supplies, many parts of Hong Kong Island have been designated as catchment areas. These generally consist of steeper terrain of high relief and are often associated with Country Parks. Within proclaimed catchment areas, strict controls are imposed on land use by the Water Supplies Department. It is possible that the strategic importance of the Island catchment areas may diminish with the completion of the cross-harbour fresh water reticulation scheme. This may result in the possible release of some land for development.

Country Parks occupy approximately 25% (3 200 ha) of the study area. The GEOTECS Plot in Figure 10 shows the distribution of the Country Parks within the study area. A further 19% of the study area consists of undeveloped natural terrain.

2.8.2 *GLUM Class and Existing Land Use*

The expansion of urban development has largely been constrained by the difficult terrain of Hong Kong Island and Kowloon. Existing large scale development currently occupies almost all of the available terrain with low to moderate geotechnical limitations (GLUM Classes I & II).

The distribution of GLUM classes is shown in the Geotechnical Land Use Map contained in the Map Folder. The general distribution pattern of the four classes is shown in the GEOTECS Plot in Figure 11. The relationship between existing land use and GLUM class is tabulated in Table B13 in Appendix B. The following is a summary of the geotechnical characteristics of the terrain associated with the current principal land uses.

(i) *Natural and Undeveloped Areas*

Some 6 400 ha or 50% of the study area is as yet undeveloped, and of this almost 45% is GLUM Class III and nearly 30% is GLUM Class IV, whilst some 20% is GLUM II, and less than 5% is GLUM Class 1. Deducting the areas designated as Country Park, the area available for development is reduced to about 3 200 ha (25%) of the study area, with a similar distribution of GLUM classes.

As can be seen from the GEOTECS Plot in Figure 14, the undeveloped GLUM Classes I & II terrain occurs mainly as small isolated areas and is confined mainly to ridgelines and low angle upper sideslopes. Hence, further expansion of the developed area requires the use of a larger percentage of the terrain with high geotechnical limitations. The suitability and limitations of such terrain are discussed in Sections 4.1 and 4.2 and are shown on the Generalised Limitations and Engineering Appraisal Map (GLEAM) with particular reference to areas of potential for development.

Of the undeveloped natural areas outside the Country Parks, agricultural use occupies about 2%, mostly on GLUM Class III terrain, and squatters constitute a further 20%.

(ii) *Squatters*

Squatters are located on 660 ha, which represents 5% of the study area. Approximately 60% of the terrain occupied by squatters is classified as having high to extreme geotechnical limitations. A breakdown of squatter intensities (assessed using API) and GLUM class is given in Table B13 of Appendix B.

The general distribution of squatters with respect to GLUM class is given in the GEOTECS Plot in Figure 12. Squatter intensity appears to vary with the degree of geotechnical limitations associated with the terrain. There is some 250 ha of squatters located on terrain with low to moderate geotechnical limitations.

(iii) *Residential*

Residential development occupies about 25% of the study area and, as such, is the largest existing land use. Fifty percent of residential development is situated on GLUM Class II terrain. It is significant that 30% of residential development is situated on GLUM Class III terrain. This indicates that, in many parts of the study area, development has been possible on terrain with high geotechnical limitations. Therefore, areas of GLUM Class III on natural terrain should not be discounted for development purely on the grounds of high geotechnical constraint. However, it also highlights that a large proportion of residential development occurs on difficult terrain, and that careful land management and sound engineering practice are necessary to minimise the likelihood of slope failure.

Residential development comprises about 15% of GLUM Class I, 50% of GLUM Class II and 30% of GLUM Class III terrain. Only some 5% of GLUM Class IV terrain is occupied by residential development, and most of this is associated with cut and fill slopes. These figures include residential development intermixed with commercial or industrial use.

(iv) *Commercial and Industrial*

Commercial and industrial areas together occupy less than 5% of the study areas and occur almost entirely on GLUM Class II terrain. This observation seems to be valid for commercial or industrial uses intermixed with predominantly residential activities. This reflects the need for accessibility and for large level sites, and it is generally due to the use made of reclamation for this purpose.

(v) *Recreational*

Sporting facilities and urban recreational areas occupy less than 5% of the study area. They are generally located on terrain of low GLUM class. Parks are the largest component of this group, and only these occupy any measurable amount of GLUM Class IV terrain. Parks occupy about 7% of all the GLUM Class I terrain.

(vi) *Community and Institutional*

Community facilities and institutions such as schools and hospitals occupy less than 5% of the study area. They have an almost equal distribution of GLUM Classes I & III terrain, with a predominance of GLUM Class II. They generally occupy relatively large level sites but, if they are situated on natural terrain as opposed to reclamation, construction has involved the formation of cut and fill slopes which result in the presence of some GLUM Class III terrain.

(vii) *Cemeteries*

These occupy a small proportion of the study area. They involve little disturbance to natural ground profiles but, because they usually are located in 'auspicious' situations (fung shui), they utilise steeper terrain. Hence, they characteristically occur on GLUM Classes II & III terrain.

(viii) *Transportation*

Airport and seaports occupy a small portion of the study area. They occur almost entirely on GLUM Class II terrain because they are often associated with reclamation. Roads usually occupy only a small proportion of the GEOTECS two-hectare grid cell in which they occur; therefore, they are rarely mapped as discrete units.

(ix) *Service Facilities*
Of the community service facilities, service reservoirs occupy the largest area, although it is less than 1% of the study area. Due to the requirement for adequate water pressures, they are located on upper slopes and therefore involve significant areas of high GLUM class. Isolated hills of high GLUM class terrain remain within the developed area of Kowloon.

(x) *Military*
Military uses comprise less than 2% of the study area, utilizing mostly GLUM Classes I & II terrain.

(xi) *Quarries*
These comprise about 2% of the study area. Whilst a pattern of associated high GLUM class is apparent, this is generally a function of quarrying practice. Most other developed land uses tend to be more severely influenced by pre-existing geotechnical limitations.

(xii) *Incomplete Development*
Construction zones, areas of unused reclamation and temporary usage occupy less than 5% of the study area. Most of this is on GLUM Class II terrain, with only construction sites having a significant proportion of GLUM Class III terrain.

2.8.3 *Proposed Future Development*

Development principles for Hong Kong and Kowloon are presented within the 'Hong Kong Planning Standards and Guidelines' (HKPSG). The future development of natural terrain and the upgrading of existing development are expected to achieve these standards, in as much as available land, suitability of terrain and local requirements allow.

The statutory requirements for the type of development, current and proposed, are set out in Outline Zoning Plans (OZP), where they exist, and more detailed intentions are defined in Outline Development Plans (ODP).

Statutory restrictions on development, as in Country Parks and designated 'green belt' areas, together with the natural constraints of the terrain, result in very little future development being proposed on undisturbed natural land. The use of reclamation for future development seems to be the most favoured approach at this time. Such developments are either proposed or are in the construction phases: from Sandy Bay to Kellett Bay, at Aberdeen on the southwest coast, on the northeast coast from North Point to Chai Wan, and at West Point on Hong Kong Island. In Kowloon, development on reclamation is planned at Lai Chi Kok Bay, Cheung Sha Wan, Sham Shui Po, Kowloon Bay and in the Kai Tak area.

New developments which are zoned or proposed on land as opposed to reclamation, as indicated on ODPs and OZPs, are primarily for high class housing at Pok Fu Lam Reservoir and at Stanley Bay. The south side of Hong Kong Island, with the exception of the area from Wah Fu through to Aberdeen towards Wong Chuk Hang and on Ap Lei Chau, is designated for relatively low population densities. Developments are also in progress or proposed along the Kowloon footslopes from Cheung Sha Wan to Kowloon Tong. Progress on the development of Diamond Hill and Anderson Road areas is restricted by current quarrying operations. A number of these proposals are the subject of feasibility studies which relate specifically to the geotechnical difficulty of the terrain for development.

3. ASSESSMENT OF MATERIAL CHARACTERISTICS

3.1 Description and Evaluation of Natural Materials

3.1.1 *General*

Planning and engineering are influenced by the distribution and nature of geological materials. A wide variety of geological materials are present in the study area, and the nature and extent of their influence varies accordingly. The general properties of the rocks occurring in the study area are summarised in Table 3.1. They are described in engineering geological terms and are broadly assessed from an engineering view point. The various geological materials (columns 1 to 4) are described by their lithology (column 5) and their typical topography and weathering pattern (columns 6 and 7). Each material is also evaluated in terms of its engineering properties (column 8) and engineering performance (column 9). The suitability for borrow and possible uses of the material are given in column 10.

Particular attention should be paid to the following points. Firstly, the lithology of the material (column 5) is given for an unweathered sample. Secondly, the topographic form (column 6) with which the material is often associated, may provide a clue for its recognition and may provide an initial indication of the type of material underlying a particular site. Thirdly, the weathering potential of the material (column 7) may assist in estimation of cut and fill volumes, erodibility and vegetation regrowth potential. It should be noted that the depth of weathering may be related to the form of the local terrain. Finally, the quantitative information on engineering properties included in column 8 should be used for preliminary guidance and information only and should not be used for design purposes.

Each rock type has its own range of material characteristics, but many of these overlap. Similar engineering behaviour may occur in dissimilar rock types. The material characteristics which effect the way in which they can be used are:

(i) *Weathering*

Within the regional context, it is important to appreciate the influence of local features on determining the actual depth of weathering at a particular location. The descriptions given in column 7 of Table 3.1 are for general guidance only. For example, granites are normally weathered to a depth of about 20 m, but rock exposures such as Lion Rock are devoid of weathered mantle. Marine drilling north of Stonecutters Island indicates approximately 40 m of completely decomposed granite and 90 m is noted in the Po Shan Road area of the Mid-levels district.

For any given rock type, the depth of weathering is largely controlled by the joint spacing, lithology and rate of erosion. The volume of fresh rock remaining after a weathering front has penetrated a given distance into a joint bounded block will depend on the original spacing of the joints. A larger volume of fresh rock usually remains in a widely jointed rock mass than in one which is narrowly jointed after being weathered for the same length of time. Erosion removes the soft products of weathering and thus reduces the actual thickness of the profile. Major streams, if not filled with colluvium, generally have fresh rock exposed in their beds.

In Hong Kong, weathering is largely a chemical process that transforms hard rock to soft soil, and thus the engineering character of a particular site is affected by its local weathering. On a larger, planning scale, the average depth of weathering influences, the availability of soft borrow materials, the ease of site formation, the general cost of foundations and the stability of slopes.

An idealised weathering profile is presented in Table A3 in Appendix A.

(ii) *Erosion, Instability and Geology*

The different geological materials are subject to various degrees of erosion and instability (Randall & Taylor, 1982; Rodin *et al*, 1982; Richards & Cowland, 1986). This is reflected in the relative proportions of the various geological materials present in eroded or unstable areas and, conversely, the proportions of erosion and instability occurring within each geological class. These factors are illustrated in Figures 4 and 13 and tabulated in Appendix B, Table B11. The Area Instability Index presented in the table indicates the percentage of each rock type affected by instability.

Before interpreting these results, it must be remembered that factors other than geology influence erosion and instability. In the Hong Kong and Kowloon study area, the activities of man have greatly modified the susceptibility of the terrain to erosion and instability. In addition, the proximity to the sea, slope angle, aspect, geology, vegetation and microclimatic variations all contribute to the degree of erosion. There is a wide difference in the extent of the rock units, and consequently the sample size of some material types is too small for generalisation.

(iii) *Material Resources*

The wide variety of geological materials found in the study area all have some potential for use in engineering activities. The geological suitability of these materials is summarised in column 10 of Table 3.1, but other factors also have to be considered when making any recommendation regarding suitability for use. These factors are: suitability of terrain and how it affects adjacent areas (e.g. instability), volume of material available, ratio of hard and soft materials, environmental considerations, accessibility potential for development or reinstatement, and finally, possible effect on water catchments.

A broad division can be based on whether the material is 'soft' or 'hard', and this relates to the mode of extraction. Soft material can be economically extracted in volume by machine methods. Hard material requires blasting prior to extraction.

Soft material in the study area usually result as a by-product of site formation or the stripping of overburden in quarries. Development of areas only for soft borrow within the study area is probably impractical due to the competing demands of land use.

Table 3.1 presents, in summarised form, the general characteristics of the various geological materials and how they influence engineering and planning activities. The characteristics of each material are affected by local conditions, and the comments presented in the table are intended for general guidance only.

In terms of general engineering behaviour, the geological materials of the study area are broadly classified into the four groups:

(*a*) Colluvium.

(*b*) Other superficial deposits—fill, reclamation, alluvium, littoral and marine deposits.

(*c*) Volcanic and volcaniclastic rocks.

(*d*) Intrusive igneous rocks.

3.1.2 *Characteristics of Colluvium*

Colluvium is a complex heterogeneous material which is highly variable in its engineering character. The distribution is described in Sections 2.3 and 2.4 and in Appendix C.1.3.

As well as being derived from a range of rock types, generally colluvium is deposited intermittently over a period of time. This intermittent deposition results in considerable variation in the degree of weathering of its constituent boulders and detrital fragments.

Relict colluvium of granitic origin (Cg) deposited at the base of the Kowloon foothills at Fei Ngo Shan is completely weathered and can only be distinguished from insitu decomposed granite by the absence of both relict joints and continuity of fabric. In many ways, its behavioural nature and engineering characteristics are similar to decomposed granite. In contrast, recent volcanic colluvium (Cv), which occurs in drainage lines below Mt Kellett on Hong Kong Island, consists mainly of large, fresh boulders with very little matrix. In the Mid-levels district, at least three major episodes of colluvial deposition have been reported, with deposits ranging from completely weathered in nature to boulder fields (Huntley & Randall, 1981; Lai, 1982; Lai & Taylor, 1983). Colluvial deposits in the Kowloon foothills display similar complexity (Geotechnical Control Office, 1982). Within a deposit of colluvium, it is possible for material of a number of different ages to occur, and consequently a wide range of engineering properties can be expected.

There is no appreciable difference in susceptibility of the different colluvial groups to erosion based on parent rock type (Figure 13), although granitic colluvium shows a slightly higher incidence than the other forms. Older, more decomposed deposits appear more erodible, as evidenced by the deeply dissected fans southwest of Cheung Sha Wan.

Erosion in colluvium may sometimes result in the undercutting of contained boulders which subsequently move down slope. Internal erosion may also take place within the deposits, and voids may pose a hazard to earthworks and engineering design. These voids may occur as tunnels which act as major subsurface conduits for water movement.

One of the engineering problems associated with or related to colluvium is instability. The most dramatic example of this is the landslip disaster at Po Shan Road on Hong Kong Island in 1972. Colluvium consists of material transported by gravity, and the deposits accumulate at approximately the angle of repose of the detrital material. Although the deposits may settle and become more dense with time, they are liable to slope failure if disturbed either by stream undercutting, ground movements or by man's activities.

Slope failures in colluvium are often characterised by narrow landslip scars (less than 15 m in width) with extensive debris trails. Length to width ratios are generally 4 to 6:1 for colluvium. From the GEOTECS data presented in Table B11 and in Figures 4 and 13, volcanic colluvium appears to have a much higher proportion of instability compared to other colluvial materials. This is possibly a result of the steeper slope angles associated with both the parent rock type and the volcanic colluvial terrain.

Granitic colluvium also shows a moderately high incidence of instability but considerably less than the colluvium derived from volcanic rocks. Mixed colluvium has approximately the same incidence of instability as the average for the study area.

In general, colluvium is unsuitable as a founding material for large structures and it is normal for caissons to be excavated through to the underlying rock. The presence of large boulders in the colluvium can make this a difficult process. Some boulders within colluvial deposits may be in excess of 5 m in diameter and need to be identified as detrital and not as bedrock.

Colluvium is often highly permeable, especially in 'bouldery' colluvial streambeds. Older' weathered deposits may be less permeable, but the presence of internal erosion tunnels may give rise to complex groundwater patterns. Streams which exist over bedrock frequently disappear beneath areas of colluvium. This is illustrated in the Kowloon footslopes below Fei Ngo Shan.

Boreholes and trial pits are used to obtain samples and exposures for the classification of colluvial deposits. Care should be taken, however, to use drilling methods that will not result in a loss of matrix material. Trial pits often provide more reliable information when dealing with colluvium, but these are practical only in shallow deposits. Where the matrix percentage is high, appropriate laboratory tests may be carried out on undisturbed samples to provide strength and compressibility data for design. Where the boulder percentage is high, however, it may be necessary to rely on more empirical relationships for stability assessment.

Colluvium is often up to 30 m thick and is essentially unconsolidated; therefore it has some potential for use as a soft borrow material. The grading of the material in relict weathered fans is generally suitable for use as fill as it has good compaction characteristics.

The more recent bouldery colluvium in stream channels is of limited use, as the major natural constraints, instability and concentrated groundwater flow, restrict their suitability. Within the study area, there are no obvious sites that can be recommended for soft borrow in colluvium. Site formation work may involve the excavation and use of colluvial materials, which should prove satisfactory provided adequate care is taken in the design of cut slopes. Excavation by machine methods could be difficult if large boulders are encountered.

On a planning scale, the presence of large areas of colluvium acts as a major constraint on the overall layout of a project. Problems can be minimised by avoiding designs that require large cut slopes in this material.

3.1.3 *Characteristics of Fill, Reclamation, Alluvium, Littoral and Marine Deposits*

This group includes all superficial materials that generally occur as flat or slightly inclined deposits. These are fill and reclamation, alluvium, littoral and marine deposits. The first two materials are placed by man and are more fully discussed in Appendix D.3.3.

Due to the complex history of sea level change within the study area, these materials can occur together forming a complex subsoil stratigraphy. This is exemplified by the results of drilling for the Mass Transit Railway line near Cheung Sha Wan. In this area, reclamation overlies a complex sequence of marine, alluvial and colluvial materials above the weathered bedrock. Many low-lying areas of alluvium in Kowloon and Happy Valley have been raised by the placement of fill. In coastal regions, marine deposits merge with littoral deposits which are interlayered with alluvium.

In geological terms, all of these materials, are immature, and consequently weathering profiles are not well developed. Some older alluvial materials contain weathered cobbles, but it is not known whether these have been weathered insitu or are detritus from an already weathered source.

Due to their predominantly flat gradient, erosion is not a major problem in these materials in their undisturbed state. Stream flows are normally low or confined to man-made channels or conduits. Littoral deposits are subject to continuous erosion and redeposition by the sea. The GEOTECS data presented in Table B11 and summarised in Figures 4 and 13 indicate that the only incidence of erosion in these materials occurs in man-made fill. It should be noted that all these materials are erodible if hydrological conditions are adversely altered by construction activity.

The data also indicates that there is a low incidence of slope instability in these materials. This is primarily due to the low slope angles associated with most of these deposits. When disturbed, however, these materials are liable to become unstable unless adequate precautions are taken. All steep-sided excavations require strutting or shoring to minimise the likelihood of slope failure, and cut slopes require cutting to low angles or require retaining structures. Serious landslips have been associated with fill within the study area. Major failures have occurred in the past at Sau Mau Ping in 1972 and 1976 (Government of Hong Kong, 1972 a & b, 1977).

There is a wide range in particle size between materials in this group. Alluvial deposits may contain a high proportion of gravel and cobble sized material, whereas littoral deposits consist of a fairly uniform medium to fine sand. Marine materials range from silty well-graded sand, clayey well-graded silt to silty clay.

The shear strength of these materials is extremely variable. The highest strength is developed in well-compacted fill and the least in marine muds. All these materials are characterised by low values of cohesion. The strength values quoted in column 8 of Table 3.1 are approximate guides only and should not be used for design purposes. It has been demonstrated that these materials are extremely variable in physical properties and frequently occur within a complex subsoil stratigraphy. Consequently, appropriate laboratory testing of representative undisturbed samples is required in order to obtain relevant strength parameters for design.

In general, the natural materials in this class have a fairly high permeability due to the general absence of clay fraction. Groundwater levels tend to be high, and problems of tidal response are evident in the basements of buildings on reclamation in the Central District of Hong Kong Island (Tregear & Berry, 1959). Well-compacted fill obtained from completely weathered volcanic rocks has the lowest permeability of this group.

None of the materials in this group have high bearing capacities, and all large loads need to be transferred to underlying bedrock. Low to moderate loads can be accepted on raft foundations, but problems of differential settlement may be experienced. The appropriate piling technique used to transfer high loads is dependent on the overall stratigraphy, but nearly all members of this group are amenable to driven piles. The exception is that some restricted areas of reclamation may contain old masonry walls, large boulders or construction refuse which may require caisson-type construction to overcome penetration problems.

Due to high permeabilities, rates of settlement are often rapid, although fine-grained marine muds and silts may require considerable time. The magnitude of settlement varies depending on the imposed load, local groundwater conditions and the nature of the materials. Settlements in marine and alluvial deposits are discussed by Holt (1962). Settlement can be induced by the alteration of groundwater conditions.

The materials in this class are easily excavated by machine methods and have potential for use as soft fill. Marine deposits of sand are limited, and marine silts and clays are generally unsuitable for hydraulic fill. The extensive urban development on areas of alluvium, and the use of littoral zones for recreation, generally precludes the use of these materials for borrow.

From a planning point of view, this group of materials, although not free of problems, is generally suitable for development, with the exception of littoral deposits which are subject to marine erosion.

3.1.4 *Characteristics of the Volcanics Rocks of the Repulse Bay Formation*

The location and type of volcanic and volcaniclastic rocks found in the study area are discussed in Appendix C.1.1. Excluding the minor sedimentary member, these rocks tend to have similar material characteristics.

The engineering behaviour of the rock mass is controlled by a combination of factors. The major factors are: the frequency, orientation and roughness of joints and other discontinuities; the degree and extent of weathering; cleft water pressures and permeability characteristics.

The volcanic rocks of the Repulse Bay Formation are generally well jointed. Joint spacing (Geological Society of London, 1977) commonly ranges from 'moderately narrow' (20 to 60 mm) to 'wide' (200 to 600 mm) or, more rarely, 'very widely' spaced (600 to 2 000 mm). Small outcrops that have a joint spacing of greater than 2 m tend to stand out on hillsides and ridges as tors. Locally, the joint spacing is very variable, often ranging from wide to narrow over distances of less than 10 m. Most exposures contain several sets of joints, each set exhibiting a range of orientations. This range is generally related to the persistence of the joints, with less persistent joints being the most variable in orientation. Joints can sometimes be seen to curve in larger exposures. An example of a curved joint occurs in the cutting at the southern end of Wing Ling Street on Hong Kong Island. Persistent joints which exist in well-defined sets tend to be fairly smooth, although they are occasionally striated. Smaller, discontinuous joints are often irregular and stepped and are of less engineering significance. Many of the joints are steeply inclined and may result in 'unfavourable' orientations in relation to construction. Small wedge failure scars are visible in many of the cuttings along Cape Collinson Road, particularly downslope of the Chinese Permanent Cemetery and on many other road cuts on Hong Kong Island.

In these rocks, weathering tends to be relatively shallow, with average depths in the order of 10m. The sedimentary rocks are generally more deeply weathered, and up to 20 m of weathered material is common. As discussed in Section 3.1.1, the depth of weathering is largely dependent on the joint spacing. Along photolineaments (shown on the Engineering Geology Map), very close jointing may be encountered which locally depress the weathering profile. Existing borehole information and excavations for caissons for the Chai Wan Estate indicate that the major photolineament which traverses the Roman Catholic Cemetery to Lin Shing Road is caused by a shear zone or fault. Highly fractured volcanics which are weathered to a dense silt to depths in excess of 40 m occur in these excavations. The subsurface characteristics of the other photolineaments are not well known at present, but it is apparent that large depths of decomposition, unusual water flows, intense fracturing and the possibility of differential movement are common problems.

Table 3.1 Description and Evaluation of Geological Materials

MATERIAL DESCRIPTION							EVALUATION OF MATERIAL		
Type	Age	Symbol	Map Unit	General Lithological Description	Topographic Form	Weathering and Soil Development	Material Properties	Engineering Comment (Stability, Foundation, Hydrogeology)	Material Uses and Excavation Characteristics
SUPERFICIAL DEPOSITS	QUATERNARY – RECENT?	R	RECLAMATION/FILL	Generally local or imported borrow of colluvium, decomposed volcanics or plutonics. Often a mixture of silt, sand, gravel and cobbles. Some building waste or sanitary fill also included.	Extensive planar deposits adjacent to coast (reclamation) or as platforms and adjacent slopes (fill) in otherwise undulating terrain.	These materials placed by man have no soil (pedogenic) or weathering profile but may contain weathered rocks or be underlain by natural superficial deposits and/or a pre-existing weathered profile.	These materials are highly variable dependent on source of fill. Generally they can be described as low fines, low plasticity granular cobbly soils. Relative density is dependent on method and degree of compactive effort. $\phi \cong 25° \longrightarrow 35°$. Properties for sanitary landfill cannot be quantified.	Few problems if properly compacted. Old fill slopes may be poorly compacted and subject to failure. Steep excavations require support. High groundwater requires special drainage. Low bearing pressures can be accepted directly, high loads need raft, spread of pile foundations. Settlement problems minor except in sanitary fill, which may have associated leachate and gas problems.	These areas when properly formed provide platforms with high development potential. Care should be taken in excavation of sanitary landfill when biodegradation is incomplete.
SUPERFICIAL DEPOSITS	QUATERNARY – RECENT?	L	LITTORAL DEPOSITS	Essentially beach and dune sand with occasional gravel horizons.	Deposits are very local in nature and generally confined to the intertidal zone forming beaches and sandbars. Occasional raised beaches may occur.	Nil	Generally sand sized granular material, often uniformly graded and well rounded.	Too restricted in size and distribution to be of significance	Main development potential is as beaches for recreational purposes. Excavation of these materials usually prohibited.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	A	ALLUVIAL DEPOSITS	Generally brownish-grey silty sand with subangular gravel horizons.	Material forms broad floodplains with local fan deposits upslope. May be present more continuously as horizons interdigitated with marine muds or forming channel infill deposits.	In subaerial locations very minor development of soil (pedogenic) horizon. Relict deposits may be more weathered.	Very variable soil type which is often sandy and gravelly at its base and clayey towards its top. Clay fraction varies from 5 - 40% and silt 15 - 55%. SPTs range from 5 to 15 as depth and granular content increase. Material varies from medium to non-plastic. $c' \cong 0 - 10$ kPa, $\phi' \cong 20 - 25°$.	Materials are usually saturated and of a low density - clay layers are normally consolidated. Buried channels may pose local problems of high water flows into tunnels or excavations. Steep excavations require support.	Land deposits easily excavated. Marine deposits often form reasonable hydraulic fill. Excavation by cutter, suction or bucket dredger.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	M	MARINE SEDIMENTS	Usually dark grey silty clay or clayey silt with traces of shell fragments and some sand horizons especially near shore. A four fold succession is generally present.	Seabed sediments of variable thickness (0-10's of metres) below low tide mark.	Nil	Usually a soft to very soft normally consolidated soil with a high moisture content and high plasticity (LL > 50%), clay content ranges from 20 - 35%, silt content from 50 - 70%. Cu < 10 kPa, $c' \cong 0 - 5$ kPa, $\phi' \cong 25°$. SPT < 10, but increases with depth.	Material is poor to unsatisfactory for hydraulic fill. It is also poor as a foundation because of settlement and bearing capacity problems. Will probably be susceptible to mud wave if fill is end tipped onto it. Consolidation may be aided by wick drains and/or surcharge loading.	Easily excavated using bucket or possibly suction dredger where necessary. Sandy deposits may be used in construction but silt and clay may pose problems of disposal.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	C	COLLUVIUM: VOLCANIC DERIVED GRANITIC DERIVED MIXED	Composed of a range of materials which vary from boulder colluvium, to gravelly colluvium with clay and sand, to finer textured, gravelly sands and clay slopewash. The boulder colluvium with sand and gravel occurs on the higher sideslopes, while the gravelly sands and sandy silts and clays are to be found on the middle to lower sideslopes and footslopes.	Mainly occupies the lower sideslope and footslope terrain and may underlie much of the alluvial floodplain. Generally gentle to moderately steep, broad, low, rounded dissected outwash-fans and interfluves with undulating and hummocky surfaces; elsewhere irregular planar-to-shallow concave colluvial footslopes, leading upslope to gentle to moderately steep outwash slopes.	Colluvium can occur as independent deposits of a unique age such that one deposit overlies another. The older deposits may be subject to severe weathering and may be completely decomposed to a mottled coloured sandy silt or clayey silt similar to the insitu residual deposits of their parent materials. The depth of such weathering may be in the order of 10 m or more.	Only very general guidelines can be given for the matrix or finer components of this variable material. MC's average 20 - 30%, DD varies from 1 300 to 1 700 kg/m³. Grading ranges from 2 - 40% clay, 10 - 60% silt, 40 - 80% sand and med. gravel. Plasticity varies from PL 22 - 28%, LL 28 - 40%. Typical shear strength values are $c' \cong 0 - 5$ kPa, $\phi' \cong 29° - 42°$. Standard compaction values : OMC ≅ 17 - 20%, MDD ≅ 1 630 - 1 750 kg/m³. CBR ≅ 3 - 8%.	Material that has moved in its geologic past and is prone to protection reactivation if not carefully treated by such measures as low batter angles, drainage, and surface protection, expecially when saturated. Has low to moderate bearing capacity characteristics but should always be carefully drained because it may be susceptible to failure when wet. Voids may cause settlement of roads, services and buildings. Tunnelling probably difficult. SI difficult and expensive.	May be used for borrow due to its ease of excavation by machine, broad grading characteristics and relative ease of access on hillsides. Some stream fill bouldery deposits will be of limited use. Large boulders may require blasting or splitting.
BEDROCK	CRETACEOUS TERTIARY	D	INTRUSIVE IGNEOUS ROCKS – DYKE ROCKS: DOLERITE	Black to very dark grey, fine to medium grained rock. Smooth joints normal to boundaries result from cooling.	Forms linear shallow depressions or ridges due to differential weathering compared to country rocks.	Weathers deeply to a dark red silty clay.	No laboratory information available. Weathered mantle will contain a high proportion of clay and iron oxides leading to low ϕ' values. Intact rock strength will be very high.	Restricted extent precludes detailed comment. Weathered mantle will have low relative permeability and will affect near-surface groundwater hydrology by forming barriers, divides and boundary conditions. Sub vertical dykes may dam groundwater leading to unnaturally high groundwater levels.	Restricted extent precludes deliberate borrow or quarry activities - weathered material would make poor fill but fresh rock would make suitable high density aggregate or railway ballast.
BEDROCK	UPPER JURASSIC	Mc	INTRUSIVE IGNEOUS ROCKS (PLUTONIC): GRANOPHYRIC MICROGRANITE	Pink to grey fine grained non-porphyritic rock. Pink and white feldspars with quartz with granophyric texture. Jointing similar to other granitic rocks.	Forms local areas of moderate relief with broad convex hillcrests.	Weathers to produce a clayey silty sand with corestones. Depth of weathering similar to other granites. Fresh rock outcrops in stream beds on occasions.	Few test results available. Grading of weathered material has given clay ≅ 10%, silt ≅ 30% and sand ≅ 60%.	As for all Hong Kong rock types weathered material may be unstable if undercut. Joints control stability in any rock cutting.	Weathered material could be machine excavated for use as fill but limited outcrop and urban proximity restricts borrow potential to local site preparation. Fresh rock will require blasting.
BEDROCK	UPPER JURASSIC	HK	INTRUSIVE IGNEOUS ROCKS (PLUTONIC) – HONG KONG GRANITE: MEDIUM GRAINED PHASE	Pink to grey medium grained equigranular, non-porphyritic rock. Minerals include quartz, potassium feldspar, plagioclase, biotite and muscovite. Rough sheeting joints and widely spaced tectonic joints present.					
BEDROCK	UPPER JURASSIC	HKf	INTRUSIVE IGNEOUS ROCKS (PLUTONIC) – HONG KONG GRANITE: FINE GRAINED PORPHYRITIC PHASE	Pink to grey, fine grained porphyritic. Phenocrysts of quartz and feldspar to 5 mm. Mineralogy as for medium grained phase. Rough sheeting joints and moderately widely spaced tectonic joints present.	Forms extensive areas of moderate to steep concavo-convex slopes. High level infilled valleys are common. Drainage pattern is often dendritic in nature and is commonly dislocated by major tectonic discontinuities. These units are characterised by moderate to severe gully and sheet erosion associated with hillcrest and upper sideslope terrain.	Shallow to deep residual soils over weathered granites. Local development of less weathered outcrop in stream beds and occassional cliff faces. Residual core boulders common on surface of sideslopes and gullies. Weathering depths in excess of 20 m occur.	As with all Hong Kong rock types but particularly the granitic varieties material properties vary with depth within the weathering profile. For completely weathered granite (Grade V) typical values are : $\phi' \cong 31° - 43°$, $c' \cong 0 - 25$ kPa, permeability ≅ $10^{-5} - 10^{-8}$ m/s, DD ≅ 1 500 kg/m³, MC ≅ 15% near surface ≅ 30% at depth. Fresh rock has a unconfined compressive strength in the range 125 - 175 MPa. Rockmass strength essentially dependent on joint characteristics, roughness angles for tectonic joints 5 - 10°, for sheet joints 10 - 15°. Basic friction angle 39°.	Weathered mantle is subject to sheet and gully erosion and even to landslides in steep regions or if severely undercut. Perched tables conform with highly permeable upper weathered zones. Rock is prone to discontinuity controlled failures in fresh to moderately weathered state (Grades I - III). Streams and drainage lines tend to align with geological weaknesses. Large structures may require deep, hand dug foundations. Cut slope design may be governed by large depths of weathered material In shallow weathering, raft foundations may be subject to differential settlement.	Extensively quarried and used as concrete aggregate. Weathered material widely used as fill as it is easily excavated with machines. Core boulders can cause problems during excavation.
BEDROCK	UPPER JURASSIC	HKm	INTRUSIVE IGNEOUS ROCKS (PLUTONIC) – HONG KONG GRANITE: MEDIUM GRAINED PORPHYRITIC PHASE	Pink to grey, medium grained porphyritic rock. Phenocrysts of quartz or feldspar. Rough sheeting joints and widely spaced tectonic joints present.					
BEDROCK	UPPER JURASSIC	Mo	INTRUSIVE IGNEOUS ROCKS (PLUTONIC): QUARTZ MONZONITE	Grey to pinkish-grey, fine to medium grained, porphyritic, strong acid plutonic igneous rock. Phenocrysts are plagioclase. Generally displays wide rough joints.	Dissected essentially planar-concave terrain forming strong relief.	Shallow to deep residual soil over moderately weathered rock. Corestones extensive.	Coarser grained fresh rock has an unconfined compressive strength of 100 - 150 MPa and a DD of 2 600 - 2 750 kg/m³. Point Load Is(50) ≅ 5 - 8 MPa.	Relatively unknown rock type - comments as for granites but more care required with weathered materials because likely to be slightly more clayey. Several troublesome case histories noted.	Material can be scrapped for borrow when weathered. Fresh rock must be blasted. Not often used for aggregate but after testing to establish characteristics should be satisfactory. Should have good asphalt adhesion characteristics.

Table 3.1 Description and Evaluation of Geological Materials *(Continued)*

MATERIAL DESCRIPTION									EVALUATION OF MATERIAL		
Type	Age	Symbol			Map Unit	General Lithological Description	Topographic Form	Weathering and Soil Development	Material Properties	Engineering Comment (Stability, Foundation, Hydrogeology)	Material Uses and Excavation Characteristics
BEDROCK	UPPER JURASSIC	P_q	INTRUSIVE IGNEOUS ROCKS	DYKE ROCKS	QUARTZ PORPHYRY	Grey to greenish grey when fresh, weathers to a pale pink. Fine groundmass with up to 20% large phenocrysts of quartz and minor feldspar.	Generally occur as linear structural features transecting the volcanic and granite units. May be of slightly depressed or elevated topographic form due to variable resistance to erosion compared to country rocks. This geological structure often controls local surface runoff and may act as for subsurface water concentration.	Weathers more rapidly than country rocks. Develops a thick reddish soil. Weathering depths are generally in the range 7 - 15 m.	No laboratory information available. Weathered mantle should contain coarse quartz sand along with silt and clay. Fresh rock parameters should be similar to granites.	Due to restricted outcrop, these rocks are unlikely to affect engineering activity to any great extent. The surface hydrology can be affected by these rocks with drainage network aligning with the strike of the dykes. Subsurface hydrology and foundation levels will be affected by the variable rockhead.	Restricted extent precludes deliberate borrow or quarry activities. May be suitable as aggregate when fresh. Excavation conditions may be difficult and expensive.
		L_a			FELDSPAR PORPHYRY	Grey to greenish grey. Fine grained groundmass with up to 20% large (8-10 mm) phenocrysts of feldspar.			Little laboratory information available. Parameters should be similar to granite but with a higher proportion of clay.		
		MS	INTRUSIVE IGNEOUS ROCKS (PLUTONIC)		MA ON SHAN GRANITE	Grey to pinkish grey fine grained porphyritic strong granite. Phenocrysts are quartz and feldspar. Generally displays smooth tectonic joints.	Forms extensive areas of moderate relief, broad convex hillcrests are common with high level in.illed valleys. Occasionally occurs as steep to precipitous terrain. Drainage is dendritic in nature although structural control does dislocate the general pattern. Sheet and gully erosion is common on hillcrest and sideslope terrain.	Rock sometimes produces a poor, thin (< 1 m) soil (pedogenic) horizon. In depth the decomposed rock is a silty sand with variable fine gravel content. Depth of weathering i.e. soft material, is often great and an average of 18 m has been quoted. Weathering to produce corestones is common.	The near surface completely decomposed material has a DD ≅ 1 200 - 1 400 kg/m^3 and is usually only 35 - 50% saturated. The material is a silty sand containing up to 20% silt with some fine gravel. Typical shear strength values are c' ≅ 0 - 10 kPa, Ø' ≅ 32 - 40°. Strength characteristics of fresh rock are dependent on joint strength as unconfined compressive strength in order of 100 - 150 MPa. DD ≅ 2 500 - 2 600 kg/m^3, tangent modulus ≅ 30 000 - 60 000 MPa. Point Load Is(50) ≅ 5 - 8 MPa. Joint c' ≅ 0 kPa, Ø' ≅ 40°, roughness angles 5 - 10° (tectonic joints), 10 - 15° (sheet joints).	Stability of the weathered material can be suspect, i.e. Zones A & B, where soil type failures may occasionally occur. Insitu material is subject to severe erosion. Bearing capacity characteristics are good for moderate to high loads. Generally free draining. Rock is prone to discontinuity controlled failure in the fresh to moderately weathered state. Special care must be taken in establishing adequate surface protection on newly formed slopes.	When weathered, the material can be machine excavated to considerable depth and is thus strongly favoured as a source of granular borrow. When fresh or slightly weathered, blasting is required. These rocks are highly favoured for aggregate production.
		CC			CHEUNG CHAU GRANITE	Pale grey or pink, medium to coarse grained, sparingly porphyritic, strong granite. Potassium feldspar is prevalent in this widely spaced rough jointed rock which is difficult to distinguish from Hong Kong Granite.					
		SK			SUNG KONG GRANITE	Pale grey or pink, coarse grained porphyritic strong granite. Medium grained and non-porphyritic phases exist. Generally displays widely spaced joints. Quartz is often very abundant.					
		XT			TAI PO GRANODIORITE	Grey to dark grey, coarse to medium grained, porphyritic granitoid rock. Large well formed crystals of white feldspar up to 15 mm are present in coarse grained matrix. Matrix minerals are potassium feldspar, plagioclase, biotite and minor quartz. Xenoliths are common. Jointing is similar to granites in that rough sheeting joints and widely spaced tectonic joints are present.	Forms extensive areas of moderate relief with colluvial and boulder cover. Broad convex hillcrests and well vegetated slopes.	Average depth to Zone C is approximately 15 m but can be over 40 m. Boulders and corestones are common in weathered zones. Weathering product is subangular silty sand.	Little test data available for study area but decomposed granodiorite from Tai Po has the following general properties: DD ≅ 1 300 - 1 400 kg/m^3, clay content 2 - 8%, silt content 30 - 55%, sand 40 - 60%. Plasticity varies from non plastic to PL 27 - 37%, LL 40 - 50%. c' ≅ 0 - 14 kPa, Ø' ≅ 33 - 42°. Standard compaction values : OMC 16 - 21%, MDD 1 690 - 1 780 kg/m^3, CBR ≅ 8 - 20% Fresh granodiorite has an unconfined compressive strength of 125 - 175 MPa and a DD of 2 600 - 2 700 kg/m^3. Point Load Is(50) ≅ 6 - 9 MPa.	Relatively unknown rock type in study area, comments as for granites but a little more care required with weathered materials because they are likely to be slightly more clayey. Special care must be taken in establishing adequate surface protection on newly formed slope.	Because of the low to moderate content of quartz in the clay, weathered zone could be used for making bricks. Weathered zone material may be used for fill. Fresh rock is suitable for aggregate. Lower quartz content makes this material suitable for ashphaltic concrete.
	LOWER TO MIDDLE JURASSIC	RB	SEDIMENTARY VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS	REPULSE BAY FORMATION	UNDIFFERENTIATED VOLCANICS	Rock types uncertain but probably similar to RBp unit (see below)	Massive volcanic peaks with deeply dissected slopes forming a system of subparallel ridges and spurs. Crests are narrow and sharply convex with steep to very steep valley slopes. Rock outcrops are common on the upper slopes.	Rock usually produces a thin (< 1 m) soil horizon, followed downwards, especially on lower slopes, by yellowish brown sandy completely weathered material overlying less weathered, locally strongly jointed rock below an average depth of 11 m. On steep, high slopes considerable rock exposure, with thin soil or thin weathering covering occurs.	The near surface completely decomposed material has a DD ≅ 1:500 kg/m^3 and a saturation greater than 70%. Gradings are variable but 20 - 40% silt, 10 - 20% clay and 40 - 60% fine sand is common. Plasticity varies from PL 22 - 32%, LL 35 - 60%. Typical shear strength values are : c' ≅ 0 - 10 kPa, Ø' ≅ 30 - 35°. Fresh rock properties are approximately as follows : unconfined compressive strength ≅ 150 - 250 MPa. Joint strength parameters are c' ≅ 0 kPa, Ø' ≅ 30°, roughness angles ≅ 5 - 10°. DD ≅ 2 500 - 2 700 kg/m^3. Point Load Is(50) ≅ 6 - 12 MPa. Tangent modulus ≅ 30 000 - 60 000 MPa.	Stability of weathered material and also of highly jointed rock masses may be suspect, especially during or immediately after prolonged heavy rainfall. Failures are quite common, expecially in over-steepened slopes. Rapid surface runoff is common. Stability of rock slopes controlled by relatively close spaced discontinuities in moderately weathered to fresh rock mass. - Few opportunities for creation of platforms; usable sites may be small and fragmented, - Access route selection hampered by terrain, - Tunnelling probably easier than in granitoids. Deep weathering and close jointing should be anticipated near structural geological lineaments.	Material can be used for fill if it is weathered locally. It is possible to quarry, although very hard and not generally favoured. Coarse crystal tuff horizons may provide good aggregate.
		RB_c			SEDIMENTS OF WATER-LAID VOLCANICLASTICS	Generally a hard, thinly banded black and grey siltstone and black shale, interbedded with volcanic sandstones and tuffs, sometimes cherty. Very closely spaced joints in some units.	Forms areas of moderate to low relief.	Shallow to moderately deep, reddish to brown, fine, sandy to silty clay, i.e. residual soil sometimes with ferruginous gravel and weathered rock fragments, overlying completely to highly weathered rock which grades into less weathered strongly jointed volcanic rock at depths from 5 - 20 m.	No test data available but likely to be variable, dependent on individual stratigraphic unit.	The limited extent of these rock types make it unlikely they will be encountered to any significant degree. The sediments are bedded and fissile and weather relatively rapidly when exposed, to a grey silt. Some stability problems may arise. Groundwater regime may be controlled by the bedded character of the rock.	Can be scraped and ripped when weathered. Fresh rock will need pneumatic machines or blasting. Due to highly variable properties and presence of chert bands this material would not make a good source of aggregate but is well suited for filling.
		RB_v			ACID LAVAS	Dark green or bluish grey, fine grained with light phenocrysts, banded strong rhyolite. The rock often displays closely spaced smooth joints.	Forms steep narrow ridges with deep structurally controlled gullies. Rock outcrop common.	Rock usually develops a thin (< 1 m) soil horizon and a thin (< 10 m) weathered zone before passing rapidly into moderately to slightly weathered bedrock.	No laboratory results available but should be similar to other volcanics as below.	Stability of weathered material and also of highly jointed rock masses may be suspect, especially during or immediately after prolonged heavy rainfall. Failures are quite common, especially in over-steepened slopes. Rapid surface runoff is common. Stability of rock slopes controlled by relatively close spaced discontinuities in moderately weathered to fresh rock mass. - Few opportunities for creation of platforms: usable sites may be small and fragmented, - Access route selection hampered by terrain, - Tunnelling probably easier than in granitoids. Deep weathering and close jointing should be anticipated near structural geological lineaments.	Very hard and abrasive when fresh, will require blasting which may result in brittle fracture. Inadvisable for aggregate unless tested for silica/cement reaction.
		RB_c			COARSE TUFF	Grey to dark grey, fine matrix with coarse well formed crystals of feldspar and quartz. Forms massive beds of crystal tuff with no internal stratification. Jointing tends to be moderately closely spaced and smooth.	Massive volcanic peaks with deeply dissected slopes forming a system of subparallel ridges and spurs. Crests are narrow and sharply convex with steep to very steep valley slopes. Rock outcrops are common on the upper slopes.	Rock usually produces a thin (< 1 m) soil horizon, followed downwards, especially on lower slopes, by yellowish brown sandy completely weathered material overlying less weathered, locally strongly jointed rock below an average depth of 11 m. On steep, high slopes considerable rock exposure, with thin soil or thin weathering covering occurs.	The near surface completely decomposed material has a DD ≅ 1:500 kg/m^3 and a saturation greater than 70%. Gradings are variable but 20 - 40% silt, 10 - 20% clay and 40 - 60% fine sand is common. Plasticity varies from PL 22 - 32%, LL 35 - 60%. Typical shear strength values are : c' ≅ 0 - 10 kPa, Ø' ≅ 30 - 35°. Fresh rock properties are approximately as follows : unconfined compressive strength ≅ 150 - 250 MPa. Joint strength parameters are c' ≅ 0 kPa, Ø' ≅ 30°, roughness angles ≅ 5 - 10°. DD ≅ 2 500 - 2 700 kg/m^3. Point Load Is(50) ≅ 6 - 12 MPa. Tangent modulus ≅ 30 000 - 60 000 MPa.		Material can be used for fill if it is weathered locally. It is possible to quarry, although very hard and not generally favoured. Coarse crystal tuff horizons may provide good aggregate.
		RB_p			DOMINANTLY PYROCLASTICS	The principal rock type is grey to dark grey fine grained rhyodacitic tuff but welded tuffs, coarse tuffs, lavas and sedimentary rocks may also be found in this unit. Jointing is usually smooth and closely spaced.					

* The property values presented are only approximate and are given without prejudice for general information. These properties should not be taken as design values. The latter should be determined where necessary by separate careful site investigation and laboratory analysis.

Abbreviations

c' - effective cohesion - kPa - kilopascal
Ø' - effective angle of internal friction - ° - degree
Cu - undrained shear strength - kPa - kilopascal
OMC - optimum moisture content - kg/m^3 - kilogram per cubic metre
MDD - maximum dry density - kg/m^3 - kilogram per cubic metre
DD - dry density - kg/m^3 - kilogram per cubic metre
CBR - California Bearing Ratio - % - percent
SI - Site Investigation
Is(50) - point load strength index - MPa - megapascal
LL - liquid limit - % - percent
PL - plastic limit - % - percent
MC - moisture content - % - percent
SPT - standard penetration test value
m/s - metres per second
≅ - about equal to

On weathering, the volcanic rocks tend to produce a clayey silt with minor sand and a fairly uniform profile. The coarse tuffs, if widely jointed, may produce corestones and boulders in a similar manner to granitic rocks.

The higher clay contents of the weathered materials tend to reduce the incidence of erosion in these rocks even though they occur on steep slopes. The GEOTECS data in Tables B10 and B11 and Figures 4 and 13 indicate that the Repulse Bay Formation rocks show a general trend of relatively low incidence of erosion. Due to the large statistical sample and the relative lack of urban development on these rocks, this is probably a reflection of the erodibility of these materials. The incidence of instability, as measured by GEOTECS, is about average compared to the mean for the Hong Kong and Kowloon study area. The morphological forms associated with slope failure in volcanics are similar to those in colluvium, in that they are characterised by small landslip scars with extensive debris deposits. That is, they are characterised by large length to width ratios (4 or 5:1).

When fresh, these rocks generally have a high strength, but the presence of joints substantially reduces the effective mass strength. Due to their fine grain and relatively high strength, these rocks are difficult to crush and are not currently used for aggregate production. The narrow joint spacing in many of the volcanic rocks may produce fragments unsuitable for aggregate when crushed. The weathered mantle may be suitable for soft borrow, but the shallow weathering depths will limit the potential yield from most sites.

The steep terrain and thin weathered mantle may make many areas of volcanic rock unsuitable for intensive development. Large volumes of excavation, much of it requiring blasting, would be necessary for site formation, and the resulting slopes may be subject to joint-controlled instability. However, where these rocks occur on flat to gently sloping terrain, their foundation depths are fairly shallow. These aspects are illustrated by the large-scale developments on Ap Lei Chau.

Site investigations in the pyroclastic rocks should be designed to determine the depth and degree of weathering, the frequency and orientation of jointing and the position and seasonal fluctuations of the water table. The Standard Penetration Test can be a useful indicator of the depth of successive zones of decomposition of the rock mass. Direct shear tests on the discontinuities of Zone C/D rocks, and direct shear and triaxial tests on Zone A/B rocks, can be used to determine the shear strengths of joints and soil matrix. It should be noted that, because most failures of insitu material are shallow, the overburden pressure on a failure plane is probably quite low. Representative shear strength parameters should therefore be obtained from laboratory triaxial tests carried out at appropriately low confining pressures.

3.1.5 *Characteristics of the Intrusive Igneous Rocks*

The intrusive igneous rocks that underlie much of the urbanised portion of the study area are of similar origin and consequently have similar engineering characteristics. A large amount of site investigation and laboratory information is already available, and these materials are generally quite well understood (Lumb 1962 a & b, 1965, 1983).

Amongst these rocks, a division can be made between dyke rocks and those occurring in large intrusive bodies. The dyke rocks generally are of limited width although they may cause localised variations in weathering depths and groundwater conditions.

The various granite intrusions, along with monzonite and granodiorite, all tend to have similar jointing patterns. Joints in these rocks generally range from medium to very widely spaced but tend to be widely spaced overall. Two distinct joint groups are present: sheeting joints and tectonic joints. The sheeting joints tend to be rough and wavy, orientated subparallel to the topography and spaced at about 1 to 3 m intervals. They are best developed near the surface. Tectonic joints are generally orientated normal to the sheeting joints, smooth to moderately rough and spaced in the order of 1 m apart. On weathering, both joint groups are often preserved as relict features with coatings of limonite, manganese dioxide or thin layers of clay.

As with the volcanic rocks, the frequency of tectonic joints increases markedly in the vicinity of photolineaments. Due to the impermeability of the fresh rock, joints are probably the major conduits of groundwater flow below the weathered mantle.

Despite the wider joint spacing compared to the volcanics, the intrusive igneous rocks of this study area tend to weather to a greater extent and depth. This is primarily due to the higher porosity and rock permeability of the granitic rocks. Weathering in these rocks has been the subject of recent study in Hong Kong (Hencher & Martin, 1982); consequently, only a summary is presented here.

As stated in Section 3.1.1, an extremely wide range of depths of weathering of intrusive igneous rocks occurs within the study area. In general, for similar locations in the terrain, these rocks are weathered to approximately twice the depth of volcanic rocks.

The intrusive igneous rocks normally weather inwards away from discontinuities, and quite thick weathering zones may occur along joints even in Zone C rock. Within the profile, large boulders are developed due to the wide joint spacing, and these may be concentrated on the surface by the erosion and removal of the soft completely decomposed material. The monzonite exposure on Cape D'Aguilar is a particularly good example. As a result of weathering, joints lose their effective roughness which, combined with the concentration of clay minerals, leads to a reduction in shear strength. The intact rock becomes weaker and more porous.

The completely decomposed rock disintegrates into a silty clayey sand, with the grading depending on the original rock type. Weathered monzonite and Tai Po Granodiorite have higher concentrations of clay compared to other members of this group with the exception of dolerite. This is due to the lower free quartz content of the original rocks.

As the residual soil is predominantly sandy, it is highly erodible in nature. The GEOTECS data presented in Figures 4 and 13 and in Tables B10 and B11 indicate a general increase in erosion within the intrusive igneous rocks when compared to the other rock types, although there appear to be significant differences between the individual intrusive rocks. Tai Po Granodiorite appears to be generally uneroded on Stanley Peninsula, but experience elsewhere in the Territory indicates that it can be highly erodible if vegetation is removed. The Cheung Chau Granite which outcrops in Kowloon exhibits approximately twice the average occurrence of erosion. The medium-grained porphyritic phase of the Hong Kong Granite shows a very much increased incidence of erosion. This could, in part, be a reflection of the proximity of urban development and the use of this terrain as a recreation area by residents of North Point.

Due to extensive urban development, the area of potential erosion of the major phase of Hong Kong Granite has been severely reduced, but the GEOTECS data indicate a higher than average occurrence of 'appreciable erosion'.

In general, instability in these rocks is not as extensive as in colluvium or volcanic materials. Landslips do not appear to have the same impact on the terrain and tend to form small rotational or joint-controlled failures associated with natural terrain or cut slopes. Length to width ratios are generally 1 to 2:1. Of the rocks in this group, the GEOTECS data indicate that Quartz Monzonite has the greatest incidence of instability. Much of this could be attributed to marine undercutting on the D'Aguilar Peninsula. However, experience in construction of the Aberdeen Tunnel indicates that this material, when weathered, has a higher clay content and a lower angle of shearing resistance compared to the granitic rocks.

Permeability in these materials varies with weathering. Completely decomposed rock that has been eluviated (clay content washed out) may be highly permeable. A transition from porous flow to joint-controlled flow occurs from weathered to unweathered rock. These materials may be subject to tunnel erosion (piping), especially in the residual soils or newly exposed completely weathered material (Nash & Dale, 1983).

The bearing capacity of the highly weathered granite will probably be satisfactory for low to moderate loading, but on occasions an open porous structure may result in low insitu densities, resulting in settlement problems for surface footings. Artificial lowering of groundwater during construction can also adversely affect steep cuttings and predicted settlements. A further problem for the construction of deep foundations or trench excavations below the groundwater table is the potential for piping within the coarse-grained, loose or medium dense decomposed granite. This may lead to problems with bored piles and other foundation problems.

Site investigations in the granite should identify weathering grades as well as the nature and orientation of joints. Standard Penetration Tests (SPT) can give useful information in those materials, which can be difficult to sample and test, and which collapse on loading or wetting. Block sampling and air-foam drilling may be of particular value in these circumstances. (Brand & Phillipson, 1984; Phillipson & Chipp, 1981, 1982). Where deep foundations are envisaged, boreholes should be drilled to well below the proposed bearing level, as weathering can be irregular with zones of completely weathered soil underlying less weathered material.

For the construction of slopes in Zone D or Zone C granite, which has high intact rock strength and relatively lower discontinuity strength, direct shear tests should be carried out to determine shear strengths of discontinuities. In Zone A or B, the strength and compressibility of the intact decomposed materials are more important, and these should be investigated by appropriate laboratory tests.

This group of rocks is extensively used for construction materials. The deeply weathered material is easily extracted by machine methods for use as soft borrow, and the underlying rock is highly favoured for the production of crushed aggregate. Granite quarries on Hong Kong Island and the mainland within the study area annually produce 70% of the crushed rock used in the construction industry.

Granitic rocks are generally favoured for aggregate production due to the relative ease of crushing and shape characteristics (Brand et el, 1984). Problems, however, have been experienced with poor asphalt adhesion when these materials are used for road pavement. This is primarily due to the high free quartz content. Rock types such as monzonite and the Tai Po Granodiorite, which have a significantly lower quartz content and similar crushing characteristics, may be more suitable for this purpose and should be considered for quarrying.

From a planning point of view, granitic rocks are generally favoured. They require more site formation compared to the flat superficial deposits, but the moderate slope angles, ease of excavation, high yield of fill and general stability of slopes is reflected in the extensive development which already exists on these rocks.

4. GEOTECHNICAL ASSESSMENT FOR PLANNING PURPOSES

4.1 Geotechnical Limitations and Suitability for Development

4.1.1 *Introduction*

The Geotechnical Land Use Map (GLUM) indicates the general levels of geotechnical limitation associated with the terrain. These in turn reflect the basic suitability of the land for development from a geotechnical point of view. A copy of the Geotechnical Land Use Map is described in detail in Appendix A7 and is enclosed in the Map Folder which accompanies this Report.

The distribution of the four GLUM classes is shown in a series of GEOTECS plots presented in Figures 14 to 16. These plots highlight the developed and undeveloped terrain associated with each class.

4.1.2 *Land with Low to Moderate Geotechnical Limitations*

Within the study area' there exists a relatively small area (1 092 ha) of land with low geotechnical limitations. Another 4 859 ha is subject to moderate geotechnical limitations. Both these classes (GLUM Classes I & II) occupy 47.3% of the study area and are shown schematically in the GEOTECS Plot in Figure 14. Some 76% of the GLUM Class I land is already developed, as is 69% of the GLUM Class II terrain. This leaves approximately 1 750 ha of terrain which is undeveloped with low to moderate geotechnical limitations.

Land with a low degree of geotechnical limitations is expected to require only normal geotechnical investigation, with the costs of site formation, foundation and drainage work being relatively low. This terrain consists typically of gently sloping untransported (insitu) rock or residual soil. Development of land with moderate geotechnical limitations probably requires a normal site investigation but, in certain situations, foundation conditions could be more complex than for GLUM Class I, and costs of site formation, foundation and drainage works should not be high. GLUM Class II terrain includes those areas where instability or erosion are not problems: insitu terrain of moderate steepness or flat or gently sloping alluvial terrain. Areas of reclamation are also included in GLUM Class II.

Figure 14 shows that GLUM Classes I & II occupy almost all of the developed area of Kowloon. Isolated patches of GLUM Class II terrain exist, mostly on the higher sections of the Kowloon footslopes, or on isolated ridgecrests.

Similarly, on Hong Kong Island, the extensive areas of low GLUM class terrain, mostly GLUM Class II, occur within the developed areas. The extensive areas of GLUM Class II reflect the large areas of reclamation and alluvial terrain. The more isolated areas of low GLUM class terrain near the coasts are generally developed, but more extensive areas of GLUM Class II terrain are evident in Tai Tam Country Park and on the ridge and western upper slopes of the D'Aguilar Peninsula. In Tai Tam Country Park, this is associated with rugged, moderately sloping insitu terrain. The slopes of the D'Aguilar Peninsula are generally smoother in profile but are dissected by structurally controlled drainage lines. The areas of GLUM Class II terrain above Pok Fu Lam and Aberdeen, south of the principal ridgeline, are associated with breaks-in-slope and with the drainage basin of the Pok Fu Lam Reservoir.

GLUM Class I & II terrain is considered to have potential for development on the GLEAM. A discussion of the development opportunities within the study area is presented in Section 4.2.

4.1.3 *Land with High Geotechnical Limitations*

Approximately 35% (4 441 ha) of the study area has a high level of geotechnical limitation (GLUM Class III). The general pattern is shown in the GEOTECS Plot in Figure 15. Some 37% of this terrain is already developed.

GLUM Class III terrain is expected to require intensive geotechnical investigation, and the costs associated with site investigation, site formation, foundation and drainage work will probably be high. Typical GLUM Class III land is steeper than 30° on insitu terrain without evidence of instability, and at gentler gradients where instability or colluvium are present. GLUM Class III terrain is likely to exhibit subsurface variations in material profile and drainage regime which need to be determined during site investigation.

In Kowloon, the areas of GLUM Class III mostly occur in the north and east of the developed area. These areas correspond with bouldery colluvial terrain of moderate gradient on the south facing slopes and the steeper insitu terrain on the southwest facing slopes. Isolated areas of GLUM Class III terrain occur within the developed area, some of which are associated with locally steep slopes.

The distribution of this Class III land on Hong Kong Island is more general, with few definite patterns. Some areas are associated with the coast at Chung Hom Kok, Stanley and D'Aguilar Peninsulas, but the distribution is fairly random because it is principally related to the drainage pattern.

Notable areas of GLUM Class III terrain include the colluvial slopes of the Mid-levels district and the steep, eroded granite terrain above North Point and Quarry Bay. Further steep insitu terrain accounts for the predominance of GLUM Class III terrain on the slopes between Repulse Bay and Tai Tam Bay. Fairly steep slopes separate the Pok Fu Lam Reservoir and Aberdeen drainage basins and account for the concentration of Class III in these areas.

4.1.4 *Land with Extreme Geotechnical Limitations*

Approximately 17% (2 097 ha) of the area is classified as GLUM Class IV. This terrain should not be developed if alternatives exist. The general pattern is indicated in the GEOTECS Plot in Figure 16. Some 16% of this terrain occurs within areas of current development.

Intensive site investigation would be required at the planning stage and prior to detailed design to minimise the hazard of slope failure. Although investigation costs are expected to be very high, they would probably be relatively minor in comparison to the costs of site formation, foundation and drainage works and the costs associated with maintenance and remedial treatment.

Terrain attributes which contribute to the designation of GLUM Class IV include steep insitu and colluvial terrain and areas with evidence of instability.

In most cases, it will be obvious from the topography alone that GLUM Class IV terrain would present extreme geotechnical difficulties. The steep to precipitous slopes of Beacon Hill, Lion Rock, Fei Ngo Shan and Victoria Peak are examples. Isolated GLUM Class IV terrain within the developed area is associated with locally steep slopes. On Hong Kong Island, the steep slopes above the colluvial footslopes in the Mid-levels district and the long steep slopes with evidence of instability above Shau Kei Wan are classified as GLUM Class IV. The east to west band of Class IV across the D'Aguilar Peninsula is the result of drainage-influenced instability on the east of the ridge and long straight slopes with instability on the west. Active coastal erosion increases the rate of degradation of these slopes.

Other isolated areas of GLUM Class IV terrain are the consequence of locally steep areas of drainage across colluvium, or the presence of instability or steep cut slopes. Such features are emphasized on the Physical Constraints Map.

4.2 Potential Development Areas

4.2.1 *General Planning Considerations*

Land utilisation is governed by development requirements, which are based on demand, potential and constraint. Many of the fundamentals which influence planning decisions are not directly influenced by geotechnical considerations. However, geotechnical considerations are implicit in efficient and secure engineering. Section 4.1 has briefly discussed some of the constraints associated with the terrain within the study area which cause geotechnical problems for engineering works. Some of these problems are initiated during development. For this reason, the interaction between engineering and the terrain should be an important consideration during the planning process, since not only efficient construction is important but long term serviceability and safety should be fundamental aims.

From a geotechnical viewpoint, land with potential for development should generally be free of constraints. Engineering design, if possible, should be unrestricted by geotechnical limitations. Within the Hong Kong and Kowloon study area, few such areas are available for development. In the Kowloon Peninsula, less than 30% of the land area remains undeveloped and the majority of this presents severe geotechnical constraints to further expansion. On Hong Kong Island, over 60% of the land area remains undeveloped and, whilst most of this is geotechnically unsuitable, large portions of the area are designated as Country Park and Green Belt. The nature of possible development, discussed in Section 2.8.3, appears to leave little scope for future expansion.

Thus, it is essential that a cautious and integrated approach is adopted in order to optimise the use of the remaining areas. This Report attempts to delineate the major geotechnical and terrain-related problems and to define their magnitude for planning and engineering purposes.

In dealing with land which is as yet undeveloped, the Generalised Limitations and Engineering Appraisal Map (GLEAM) is valuable at two levels. At the planning stage, it identifies broad areas in which an integrated approach to large-scale development could be adopted. Subsequently, at the engineering feasibility stage, it enables possible problems to be anticipated for the design of site investigations, preliminary layout and other more detailed aspects of design. The importance of the GLEAM as a tool for integrated planning and engineering feasibility in the study area is outlined in Section 4.2.2.

The Geotechnical Land Use Map, Physical Constraints Map and Engineering Geology Map enable the extent and nature of local engineering problems to be incorporated in the planning process for the whole of the study area. These maps are introduced in Section 1.5, and their background, derivation and use is described in detail in Appendix A.

4.2.2 *Generalised Limitations and Engineering Appraisal Map (GLEAM) and Development Potential*

The GLEAM identifies 56 areas within the study area which have potential for development from a geotechnical point of view. This represents approximately 1 250 ha or 10% of the total area. The areas range in size from about 5 ha up to 100 ha. They occur on different types of terrain, which are not necessarily suitable for the same type of development.

The areas of potential are delineated from the interpretation of terrain and geological features which reflect various levels of difficulty of geotechnical engineering.

Where individual features or constraints are of local significance to the planning and engineering feasibility of a 'potential' area, they are indicated on the GLEAM. The Generalised Limitations and Engineering Appraisal Map is enclosed in the Map Folder. A description of the derivation of the map is presented in Appendix A.9.

In addition to the geotechnical constraints, the potential of a site for development is governed by other factors such as: existing land use (Green Belt or Country Park), proposed development intensity, proximity to services, access routes and intrusion on the natural landscape. Economic factors are a major consideration. Some of these factors may ultimately rule out development of a particular area but, unless the overall practicalities of development render a site unfeasible (i.e. a small site on a remote hilltop), they are shown on the GLEAM.

Each area with potential for development is numbered and presented on the GLEAM. They are summarised in the GEOTECS Plot in Figure 17. Areas 1 to 13 occur on the mainland and Areas 14 to 56 on Hong Kong Island.

The comments for each area reflect the general strategic considerations which influence planning and engineering feasibility. In the main, they relate to the suitability of the areas for intensive development. Reference should be made to the Geotechnical Land Use Map, Engineering Geology Map and Physical Constraints Map (PCM) for identification of factors influencing development opportunities. In particular, the PCM shows the nature of any constraint. If a constraint is identified on the PCM and the constraint occurs within a potential development area, then the area of constraint is also shown on the GLEAM.

4.2.3 *Development Opportunities in Kowloon*

There are 13 areas within the mainland portion of the study area which have potential for development from a geotechnical point of view. These areas constitute approximately 265 ha of land.

Area 1 (12 ha approx.) Development is already proposed above Tai Wo Ping on this site with good access. Cutting is restricted by concave sideslopes with some instability adjacent to the stream courses.

Area 2 (14 ha approx.) Platformed sites could be created in Kowloon by borrow and quarrying in the partly weathered granite hills and spurs above Shek Kip Mei, between Sham Shui Po and Yau Yat Tsuen, and west of Wang Tau Hom. These last two sites are occupied by service reservoirs which restrict their opportunities.

Area 3 (30 ha approx.) Construction is in progress on part of this site and is proposed on the remainder, west of the Kowloon-Canton Railway at Kowloon Tong. The site offers the potential for the production of a considerable volume of fill in the creation of large platforms.

Area 4 (10 ha approx.) There is a possibility for partial extension of this site beyond the development in progress above Lung Cheung Road. The extensive colluvium is liable to instability, particularly in drainage lines, and requires careful engineering with drainage entrainment and stabilisation measures. Boulders are present above the area.

Area 5 (60 ha approx.) Large-scale development is possible on the footslopes of Middle Hill below Jat's Incline by the creation of cut and fill platforms following the general footslope profile and removal of isolated spurs. The natural drainage in this area is intense, and extensive entrainment measures will be necessary if the site is developed. Stabilisation of the colluvium will also be necessary.

Area 6 (25 ha approx.) The village and squatter areas adjacent to Diamond Hill have potential for extensive development. They are currently restricted by quarrying operations. Development is already proposed in this area. Subsurface water problems and uneven settlement are probable on the low angle alluvial and colluvial terrain. Planned extraction in the quarry would make extensive development of the quarries possible in the future.

Area 7 (10 ha approx.) This site occurs at the base of Jat's Incline on the footslopes of Fei Ngo Shan in an area of extensive, thick, bouldery colluvium with hidden drainage, incision and surface instability. Any development should follow the slope profile and incorporate drainage measures to prevent slope instability.

Area 8 (16 ha approx.) Development platforms in cut and fill at Ngau Tau Kok should realise an extensive development opportunity. Part of this site can be developed without extensive formation work, but this would restrict the opportunities for use of the remainder. A portion of this area has already been used for controlled tipping.

Areas 9 and 10 (30 ha approx.) Opportunities exist for limited platforming in weathered rock along slopes below Anderson Road Quarry. Drainage lines are structurally controlled and require entrainment. Foundation depths are likely to be variable. Development of Area 9 is restricted by current quarrying operations.

Area 11 (10 ha approx.) Large-scale development opportunities exist in the village area at Ma Yau Tong but are partially restricted by quarrying operations. This visually intrusive location currently has poor access. Local foundation problems are likely due to structural control in the geological contact zone.

Area 12 (20 ha approx.) Cut and fill operations would be necessary to create development platforms and to realise the potential of the otherwise unsuitable terrain above Lei Yue Mun Road next to Lam Tim Estate. There is good access to these weathered incised slopes, which show evidence of subsurface water flow. Erosion and boulders on the upper slopes need consideration in design.

Area 13 (28 ha approx.) Development opportunities at Lei Yue Mun could be created by platforming in weathered terrain on the middle slopes. Founding levels will be controlled by any structural discontinuities or variation in the weathered profile. The narrow reclamation on the coast is occupied by old villages, and the scale of redevelopment potential may be limited by Kai Tak Airport height restrictions.

4.2.4 *Development Opportunities on Hong Kong Island*

There are 43 areas on Hong Kong Island which have potential for development from a geotechnical point of view. These areas constitute approximately 1 000 ha of land.

Areas 14 and 15 (15 ha approx.) The ridge and spurs of Mount Davis offer opportunities for small platforms, but access is poor and development would be visually intrusive. Some thin colluvial cover may require removal or stabilisation. Small steep sites exist above the southwest facing coast road.

Area 16 (12 ha approx.) Limited possibilities exist for small developments following the profile of the steep exposed slopes of High West. Access is influenced by the adjacent colluvium in drainage lines.

Area 17 (35 ha approx.) Several development opportunities exist for platforming on spurs adjacent to Pok Fu Lam Reservoir and above Pok Fu Lam Village. No major geotechnical difficulties are anticipated for a stepped development, but filling of the existing drainage lines may provide an alternative.

Area 18 (15 ha approx.) There is considerable scope for development on the coastal hill west of Wah Fu Estate. Potential for development also exists in the valley, but foundation levels may be variable due to the controlling structural discontinuities and depth of alluvium/colluvium. Groundwater flow can be expected in the superficial material.

Area 19 (30 ha approx.) The slopes southwest of Victoria Gap may offer scope for small sites, but the situation is very exposed with poor access. The steep slopes restrict platforming, and incised colluvium in the stream courses is liable to instability.

Area 20 (5 ha approx.) Small sites are possible on the steep spur above Shek Pai Wan Road, but access from below would be severely constrained by the road widening.

Area 21 (20 ha approx.) Concave slopes and intense drainage limit the development potential of the valley above Tin Wan Estate. The area has poor access. Foundation and drainage problems are likely due to structural control beneath colluvial debris. Some instability is likely in incised drainage lines.

Area 22 (30 ha approx.) Small-scale development opportunities exist above the drainage confluence south of Mount Gough. Some access is possible from above, but the area is restricted by drainage and potential instability.

Area 23 (50 ha approx.) Good sites are available by platforming on gently sloping weathered terrain in the Country Park adjacent to Aberdeen Reservoir. Fair opportunities exist for access. Some local foundation problems are likely due to infilled hidden drainage and the major lineaments which influence the local rock structure and weathering depth. Construction is already proposed on part of the area immediately outside the Country Park. Extension of this site onto steep incised slopes up to the ridge above Aberdeen is restricted by lack of access.

Area 24 (14 ha approx.) The problem of access, on steep incised sideslopes, is the major constraint to development of a number of potential sites north of Aberdeen.

Area 25 (14 ha approx.) Limited development potential exists on the slopes above Wong Chuk Hang, but site access is possible only where slopes are steep and straight. Little platforming would be possible.

Area 26 (14 ha approx.) No access exists to the visually intrusive hillcrest terrain of Brick Hill. However, the west facing slopes can be accessed from Nam Long Shan Road to create small sites. Construction is in progress above Tai Shue Wan.

Area 27 (15 ha approx.) No access exists at present to the steep straight slopes above Nam Fung Road. Some boulders occur, in addition to the catchwater above small potential sites.

Area 28 (12 ha approx.) Development opportunities exist on the lower (colluvial) footslopes below Nam Fung Road.

Area 29 (16 ha approx.) Extensive development is possible in the Shouson Hill area by platforming in weathered rock. Construction is in progress in part of this area. Similar opportunities exist above Deep Water Bay but with shallower weathering depth and greater evidence of structural control by discontinuities. The area has good access.

Area 30 (16 ha approx.) Opportunities for development in the valley from Wong Nai Chung Gap to Deep Water Bay are limited by the drainage-controlled concave possibly colluvial terrain and poor access. Instability may occur in colluvial deposits unless they are well drained. Local foundation problems are possible on the major lineaments.

Area 31 (50 ha approx.) The hill-top area above North Point offers extensive development potential but is currently occupied by radio masts. The terrain is undulating with potential for cut and fill platforming in the deeply weathered rock. The peripheral ridges provide a visual screen for this exposed location. Foundation problems may result from the depth of weathering and the intersecting lineaments, and from occasional corestones, boulders and tors.

Area 32 (10 ha approx.) Small difficult sites are possible adjacent to the Country Park access road above Quarry Bay.

Area 33 (18 ha approx.) Ribbon development of moderate size is possible in the valley south of Quarry Bay, but it is restricted in width by the steep bouldery sideslopes. Local foundation problems are likely on the intersecting lineaments, and long-term problems are probable due to flood flows and surface wash from erosion.

Area 34 (26 ha approx.) Extensive development is possible with some borrow and platforming in the village areas above Aldrich Bay. Protection measures are necessary against the exposed boulders and against long debris slides in the drainage lines. The sporadic colluvial cover is liable to some instability in cut slopes.

Area 35 (8 ha approx.) Considerable potential for redevelopment exists in the military area opposite Lei Yue Mun.

Area 36 (22 ha approx.) Narrow sites are possible above Tai Tam Road at Chai Wan but are restricted by the straight steep upper slopes and the colluvial cover.

Area 37 (4 ha approx.) Small sites are possible on the road above Sui Chai Wan. Incised stream courses on the structurally controlled terrain require entrainment for the development of larger site formation works. Extensive development is possible in the deeply weathered terrain on Cape Collinson Peninsula.

Area 38 (30 ha approx.) Difficulties of access and the exposed location restrict the opportunities for development of the Pottinger Peak ridge. The bedrock is generally shallow, but the depth may be influenced by local structural weaknesses.

Area 39 (36 ha approx.) Cut and fill is possible in this area of weathered eroded terrain in Tai Tam Country Park. Access is possible from Wong Nai Chung Gap. A large platform development could be created, but cuts are restricted by peripheral steep bouldery slopes. Local foundation problems are likely due to structural control and hidden drainage, and particularly due to high groundwater in the colluvium at the stream confluences.

Area 40 (8 ha approx.) Cut platforms are possible, but would be visually intrusive, in the weathered, eroded, irregular spur terrain adjacent to the steep road southwest of Tai Tam Reservoir. Foundation depths are likely to be variable due to structural control of weathering and drainage incision.

Area 41 (10 ha approx.) Access is not readily available to the steep concave colluvial terrain north of Tai Tam Reservoir. Upslope of the area, some boulders and possible instability may affect development.

Area 42 (28 ha approx.) Development is possible, but with poor access, on the low lying terrain between Tai Tam and Tai Tam Tuk Reservoirs. Intense structural geological control with converging drainage and valley floor colluvium is likely to result in drainage entrainment and foundation problems. Opportunities for cutting are restricted by adjacent steep slopes.

Area 43 (30 ha approx.) Some small sites are possible in weathered volcanic terrain around Tai Tam Tuk Reservoir. Most locations are exposed but offer good opportunities of access. Local foundation problems are likely on the extensive lineaments.

Area 44 (40 ha approx.) The ridge and sideslope terrain between Repulse Bay and Tai Tam Bay generally offers only small steep sites in exposed locations.

Area 45 (5 ha approx.) Small-scale development is in progress on the sites above Chung Wan. Larger-scale development is possible on the spur south of Nam Wan.

Area 46 (10 ha approx.) Chung Hom Kok Peninsula offers the potential for development of the ridgeline, but is very exposed to the weather. The bedrock is generally shallow.

Area 47 (40 ha approx.) Development is possible to the west of Stanley Village. This area offers considerable potential with good access on the shallow slopes. Platforming of the sideslopes is restricted by their concave nature. Surface and subsurface drainage is influenced by the numerous intersecting lineaments, and groundwater problems are likely in deep foundations. Entrainment of several streams is necessary.

Area 48 (18 ha approx.) The west and north facing sideslopes of Stanley Peninsula offer some potential for further development. Bedrock is generally shallow, but weathered rock cuttings are liable to rapid erosion on west facing slopes.

Area 49 (26 ha approx.) The southern exposure of Stanley Peninsula offers potential for development on uniform slopes. Some foundation and stability problems are likely due to the structural geological control.

Area 50 (20 ha approx.) The rounded weathered ridge and sideslopes of Obelisk Hill have potential for development and good access from Shek O Road. The footslopes offer development possibilities on low angle terrain but have no current access. Structural control will influence cuts and foundations.

Area 51 (44 ha approx.) Platforming is possible to create small sites on the southwest slopes of Mount Collinson, but there is poor access to the upper slopes. The irregular slopes have a dense drainage pattern which may require entrainment. Bedrock is generally shallow.

Area 52 (95 ha approx.) The irregular terrain from the coast of the D'Aguilar Peninsula to Shek O Road offers limited opportunities for development. It is controlled by the geological structure, which influences drainage and stability. The steeper slopes have poor access, and lower slopes are possibly threatened by boulders.

Area 53 (50 ha approx.) Development of the ridge through the D'Aguilar Peak is restricted by the generally steep slopes, poor access and the remote location. Rockhead is shallow.

Area 54 (25 ha approx.) The uniform south-facing lower slopes of the D'Aguilar Peninsula offer considerable development potential, but it is a remote area with poor access. The coastline is relatively undisturbed by development. Local stability and foundation problems are anticipated due to geological contacts and structural discontinuities.

Area 55 (46 ha approx.) The development opportunities of the valley converging on Big Wave Bay are limited by poor access. Deep weathering overlain by alluvium and colluvium is likely on the valley floor, giving foundation problems. Drainage is intense on the upper concave colluvial slopes. The poor access of these slopes and the likelihood of instability renders development difficult.

Area 56 (15 ha approx.) Small sites are possible along the lower slopes above Shek O. The steep upper slopes, and local instability in drainage lines, limit site formation possibilities.

4.2.5 *Assessment of Planning Strategies Using GEOTECS*

Any search for areas suitable for a proposed land use requires an initial shortlisting of potential sites. Where the initial assessment of suitability can be defined in terms of the existing terrain and the existing land use, GEOTECS may be used to prepare computer-generated plots which indicate areas fulfilling any given strategy (Styles et al, 1986). Computer-generated plots are used to illustrate various aspects of this Report. GEOTECS is discussed in Section 1.5.9 and described in detail in Appendix A.11.

The following considerations are important for the satisfactory use of the system:

(*a*) The highlighting of areas using GEOTECS provides only an initial assessment of potential or suitability. The results do not necessarily reveal all the options available.

(*b*) Factors other than those included in GEOTECS will influence any planning decision.

(*c*) The applicability of any such assessment depends on the selection of relevant GEOTECS attributes for the strategy.

(*d*) Each two-hectare grid cell in the GEOTECS system is independent of adjacent cells.

(*e*) The land information stored within GEOTECS is designed for geotechnical, geological and engineering applications. It should be used to gauge the general distribution of specific attributes and/or combinations of attributes.

One of the advantages of the GEOTECS approach is that it enables a set of primary options to be derived regardless of individual local knowledge or preference. It assesses the terrain in a systematic manner according to the criteria selected from the various terrain-related attributes. Three examples are provided to illustrate the application of GEOTECS for planning and engineering purposes.

(i) *Development Potential in Squatter Areas*
An initial assessment of the suitability of the terrain for development is used as the basis for the GLEAM (see Appendix A.9). Using the GLEAM criteria to determine 'potential' terrain and relating it to the presence of squatters, the GEOTECS Plot in Figure 18 has been produced. The squatter areas which could be cleared to provide land suitable for development are shown.

Squatters occur on approximately 660 ha within the study area. Some 360 ha of this terrain has potential for development from a geotechnical point of view. The GEOTECS symbol (+) also shows the general location of 710 ha of land with development potential on undesignated natural terrain outside of the Country Parks. Squatters occur on approximately 301 ha of geotechnically difficult terrain (GLUM Classes III & IV).

A number of options could be derived for squatter management using GEOTECS. In this example, opportunities for new development of terrain adjacent to existing squatter areas or squatter areas with potential for redevelopment are highlighted.

(ii) *Potential Quarry Sites*
The GEOTECS Plot in Figure 19 indicates other areas which exhibit quarry potential on the basis of several terrain attributes. The selection criterion for areas without intensive existing land use is primarily those units with convex, straight or cliff slopes less than 40° in gradient. As a secondary criterion, areas are also selected on the basis of slope angle alone. These selection criteria enable quarry potential to be maximised between the existing ground surface and the final quarry face. Thus, groups of several units with optimum potential or with occasional secondary potential may make suitable sites. Bedrock geology is not used in the initial assessment presented in the GEOTECS Plot in Figure 19, although it must be incorporated for advanced planning. Once potential rock types are selected, they can be added to the GEOTECS strategy for the production of a further plot. Hence, the refinement of alternative quarry sites is possible.

Approximately 2 850 ha of undesignated natural terrain has potential for quarry sites. A further 3 060 ha with potential for quarrying occur within existing Country Parks or are under cultivation. These figures indicate that many options exist, but these options would be severely reduced when rock type is specified.

(iii) *Development Opportunities in Areas of Existing Low Density Housing*
The GEOTECS Plot presented in Figure 20 indicates areas which are occupied by existing low density housing and which could be redeveloped for more intensive use. The general locations of low density housing were identified by aerial photograph interpretation in the land use survey for this study. They consist of single and double storey developments and resettlement areas.

The strategy presented is very general in nature but indicates that approximately 71 ha of existing single storey development has potential for redevelopment from a geotechnical point of view. A further 94 ha of Temporary Resettlement Areas and 318 ha of two storey development also have potential for redevelopment.

5. CONCLUSIONS

The findings reached during the Hong Kong and Kowloon area study are presented on a series of physical resource, planning and engineering maps produced at a scale of 1:20 000. The major maps are: the Geotechnical Land Use Map (GLUM), the Physical Constraints Map (PCM), the Engineering Geology Map (EGM), and the Generalised Limitations and Engineering Appraisal Map (GLEAM).

The major conclusions fall very broadly into two categories which relate firstly to materials and land resource distribution, and secondly to, land management associated with planning and engineering feasibility.

5.1 Materials and Land Resource Distribution

(*a*) Slope instability of some form or other is relatively common within the study area. Approximately 1 528 ha of the terrain (12%) is associated with or affected by instability. Instability is associated with most of the geological materials. Failures in the colluvium and volcanics are generally characterised by small landslip scars with extensive debris trails. This is probably due to the relatively steep slopes on which failure occurs. Landslips on the granites are also common but tend to be relatively small rotational failures on natural terrain or joint-controlled failures associated with cut slopes. Granitic failures generally cause less impact on the terrain than failures in volcanics and colluvium.

(*b*) The geology of the area is complex, and several aspects require careful investigation. Weathering depths are variable, with very deep weathering occurring in some granitic areas. The competition from alternative land uses restricts the future excavation of borrow and rock materials, and the study area is a net importer of borrow materials. There are numerous photolineaments present, many of which are likely to be faults, shear zones, major joint zones or dykes. Surface erosion is more pronounced on the granitic terrain than on the volcanics.

(*c*) Approximately 2 366 ha of the footslope terrain is covered by extensive colluvial deposits; 30% of the colluvium is affected by instability. Significant geotechnical limitations should be anticipated on zones of runoff and surface drainage across the colluvium.

(*d*) The granitic terrain has a slightly higher proportion of GLUM Classes I & II (48%) than the volcanics (41%). Of the 2 366 ha of colluvial terrain which occurs within the study area, some 93% is subject to high to extreme geotechnical constraints (GLUM Classes III & IV).

(*e*) Approximately 40% of the study area is characterised by slopes which have gradients between 0 and 15°. A further 55% of the terrain has slope gradients between 15 and 40°.

(*f*) Granitic terrain is generally suitable as a source of borrow and aggregate. Future expansion of existing quarries is not restricted by geological constraints but by urban development.

(*g*) There is approximately 1 600 ha of reclamation (13%) within the study area. The siting of development on extensive reclamation that is underlain by thick compressible marine sediments may give rise to foundation problems and settlement of services. This aspect will require careful design and control during construction.

(*h*) Approximately 50% of the study area is currently developed in some form or other. Squatters occupy 5% of the area, and 25% is allocated to Country Park. The remaining 20% consists of undeveloped natural terrain.

5.2 Land Management Associated with Planning and Engineering Feasibility

(*a*) A number of large landslips during the last 20 years have resulted in considerable loss of life and very substantial property damage (So, 1971; Lumb, 1975; Brand, 1984). Landslips at Mt Nicholson, Sau Mau Ping (Government of Hong Kong, 1972 a & b), Po Shan Road (Government of Hong Kong, 1972 a & b, 1977), Lam Tin Village and Glenealy Valley have occurred in developed areas, squatter villages and natural terrain. Slope instability not only poses a threat to life and property but also diminishes the viability for development of the natural terrain which remains undeveloped. In the Territory, the geotechnical constraints associated with the terrain are important factors for land management purposes and engineering feasibility.

(*b*) Opportunities do exist for urban expansion in the study area, but it is unrealistic to envisage that future development can avoid areas with geotechnical limitations. The Generalised Limitations and Engineering Appraisal Map (GLEAM) recognises this fact and delineates 56 areas which have overall potential for development from a geotechnical point of view. Approximately 1 000 ha of Hong Kong Island and 260 ha of Kowloon has potential for development. Some areas of GLUM Class III, and possibly Class IV, terrain occur within these areas, but an integrated approach to planning and engineering design should minimize the hazard of slope failure.

(*c*) If areas are selected for intensive development on GLUM Classes III & IV terrain, they should be subject to terrain classification at a scale of 1:2 500 (District Study, Stage 1) or a comparable level of investigation.

(*d*) This study indicates that there is 2 400 ha of currently undisturbed natural terrain, which does not include Country Park. Of this figure, GLUM Classes I & II occur on some 23% of the terrain, and the remaining 1 830 ha is associated with high to extreme geotechnical limitations (GLUM Classes III & IV). There is approximately 3 200 ha of land within the boundaries of the Country Parks.

(*e*) Squatters occur on some 660 ha within the study area. At the time of data collection, 62% of this terrain was affected by high to extreme geotechnical limitations.

(*f*) Physical land resources are considered basic input for planning and land use management. The other constraints on the suitability of an area for development should be assessed in sympathy with the physical land resource information.

6. REFERENCES

Allen, P. M. & Stephens E. A. (1971). *Report on the Geological Survey of Hong Kong.* Hong Kong Government Press, 116 p. (& 2 maps).

Atherton, J. M. & Burnett, A. D. (1986). *Hong Kong Rocks.* Urban Council, Hong Kong, 151 p.

Bennett, J. D. (1984a). *Review of Superficial Deposits and Weathering in Hong Kong.* Geotechnical Control Office, Hong Kong, 51 p. (GCO Publication no. 4/84).

Bennett, J. D. (1984b). *Review of Hong Kong Stratigraphy.* Geotechnical Control Office, Hong Kong, 62 p. (GCO Publication no. 5/84).

Bennett, J. D. (1984c). *Review of Tectonic History, Structure and Metamorphism of Hong Kong.* Geotechnical Control Office, Hong Kong. (GCO Publication no. 6/84).

Brand, E. W. (1984). Landslides in Southeast Asia: a state-of-the-art report. *Proceedings of the Fourth International Symposium on Landslides,* Toronto, vol. 1, pp. 17–59. (Addendum, vol. 3, pp 105–106).

Brand, E. W. (1985). *Bibliography on the Geology and Geotechnical Engineering of Hong Kong to December 1984.* Geotechnical Control Office, Hong Kong, 76 p. (GCO Publication no. 1/85).

Brand, E. W., Burnett, A. D. & Styles, K. A. (1982a). The Geotechnical Area Studies Programme in Hong Kong. *Proceedings of the Seventh Southeast Asian Geotechnical Conference,* Hong Kong, vol. 1, pp 107–123.

Brand, E. W., Maunder, C. A. & Massey, J. B. (1984). Aggregates in Hong Kong. *Proceedings of the International Symposium on Aggregates,* Nice, France. (Published in *Bulletin of the International Association of Engineering Geology,* no. 29, pp 11–16).

Brand, E. W. & Phillipson, H. B. (1984). Site investigation and geotechnical engineering practice in Hong Kong. *Geotechnical Engineering,* vol. 15, pp 97–153.

Brand, E. W., Styles, K. A. & Burnett, A. D. (1982b). Geotechnical land use maps for planning in Hong Kong. *Proceedings of the Fourth Congress of the International Association of Engineering Geology,* New Delhi, vol. 1, pp 145–153.

Burnett, A. D. Brand, E. W. & Styles, K. A. (1985). Terrain evaluation mapping for a landslide inventory in Hong Kong. *Proceedings of the Fourth International Conference and Field Workshop on Landslides,* Tokyo, pp 63–68.

Burnett, A. D. & Styles, K. A. (1982). An approach to urban engineering geological mapping as used in Hong Kong. *Proceedings of the Fourth Congress of the International Association of Engineering Geology,* New Delhi, vol. 1, pp 167–176.

Carson, M. A. & Kirkby, M. J. (1972). *Hillslope Form and Process.* Cambridge University Press, London, 475 p.

Davis, S. G. (1952). *The Geology of Hong Kong.* Government Printer, Hong Kong, 210 p.

Geological Society of Hong Kong (1984). *Abstracts of the Conference on Geological Aspects of Site Investigation,* Hong Kong, edited by W. W. S. Yim & I. M. McFeat-Smith Geological Society of Hong Kong, 50 p.

Geological Society of London (1970). The logging of rock cores for engineering purposes. (Geol. Soc. Working Party Report). *Quarterly Journal of Engineering Geology,* vol. 3, pp 1–24.

Geological Society of London (1972). The preparation of maps and plans in terms of engineering geology. (Geol. Soc. Working Party Report). *Quarterly Journal of Engineering Geology,* vol. 5, pp 295–382.

Geological Society of London (1977). The description of rock masses for engineering purposes. (Geol. Soc. Working Party Report). *Quarterly Journal of Engineering Geology,* vol. 10, pp 355–388.

Geotechnical Control Office (1982). *Mid-levels Study: Report on Geology, Hydrology and Soil Properties.* Geotechnical Control Office, 265 p. (& 54 drgs).

Geotechnical Control Office (1984). *Geotechnical Manual for Slopes.* (Second edition). Geotechnical Control Office, 292 p. (& 40 plates).

Geotechnical Control Office (1986). *1:20 000 Geological Map Sheet 11,* Hong Kong Geological Survey Map Series HGM20.

Geotechnical Control Office (1987). *1:20 000 Geological Map Sheet 15,* Hong Kong Geological Survey Map Series HGM20.

Government of Hong Kong (1972a). *Interim Report of the Commission of Inquiry into the Rainstorm Disasters, 1972.* Hong Kong Government Printer, 20 p.

Government of Hong Kong (1972b). *Final Report of the Commission of Inquiry into Rainstorm Disasters, 1972.* Hong Kong Government Printer, 91 p.

Government of Hong Kong (1977). *Report on the Slope Failures at Sau Mau Ping, August 1976.* Hong Kong Government Printer, 104 p. (& 8 drgs).

Hansen, A. (1984a). Landslide hazard analysis. *Slope Instability*, edited by D. Brunsden & D. B. Prior, pp 523–602. John Wiley & Sons, Chichester, UK.

Hansen, A. (1984b). Engineering geomorphology: the application of an evolutionary model of Hong Kong's terrain. *Zeitschrift für Geomorphologie*, supplementary vol. 51, pp 39–50.

Hansen, A. & Nash, J. M. (1984). A brief review of soil erosion in Hong Kong—causes, effects and remedial measures. *Proceedings of the Conference on Geological Aspects of Site Investigation*, Hong Kong, pp 139–150.

Hencher, S. R. & Martin, R. P. (1982). The description and classification of weathered rocks in Hong Kong for engineering purposes. *Proceedings of the Seventh Southeast Asian Geotechnical Conference*, Hong Kong, vol. 1, pp 125–142. (Discussion, vol. 2, pp 167–168).

Holt, J. K. (1962). The soils of Hong Kong's coastal waters. *Proceedings of the Symposium on Hong Kong Soils*, Hong Kong, pp 33–51.

Huntley, S. L. & Randall, P. A. (1981). Recognition of colluvium in Hong Kong. *Hong Kong Engineer*, vol. 9, no. 12, pp 13–18.

Lai, K. W. (1982). Discussion on the colluvium of Hong Kong (8th October 1980). *Hong Kong Baptist College Academic Journal*, vol. 9, pp 139–158.

Lai, K. W. & Taylor, B. W. (1983). The classification of colluvium in Hong Kong. *Proceedings of the Meeting on the Geology of Surficial Deposits in Hong Kong*, Hong Kong, pp 75–85.

Lau, R. (1972). Seismicity of Hong Kong. *Royal Observatory, Hong Kong, Technical Note* no. 33, 30 p. (Reprinted with revisions, 1977).

Leach, B. (1982). The development of a groundwater recharge model for Hong Kong. *Journal of Hydrological Sciences*, vol. 4, pp 469–491.

Leach, B. & Herbert, R. (1982). The genesis of a numerical model for the study of the hydrogeology of a steep hillside in Hong Kong. *Quarterly Journal of Engineering Geology*, vol. 15, pp 243–259.

Lumb, P. (1962a). General nature of the soils of Hong Kong. *Proceedings of the Symposium on Hong Kong Soils*, Hong Kong, pp 19–32 (& 1 drg).

Lumb, P. (1962b). The properties of decomposed granite. *Geotechnique*, vol. 12, pp 226–243 (& 2 plates).

Lumb, P. (1964). *Report on the Settlement of Buildings in the Mong Kok District of Kowloon, Hong Kong.* Hong Kong Government Printer, 22 p. (& 8 drgs).

Lumb, P. (1965). The residual soils of Hong Kong. *Geotechnique*, vol. 15, pp 180–194. (Discussion, vol. 16, 1966, pp 78–81 & 359–360).

Lumb, P. (1972). Building settlements in Hong Kong. *Proceedings of the Third Southeast Asian Conference on Soil Engineering*, Hong Kong, pp 115-121. (Discussion, pp 394–396).

Lumb, P. (1975). Slope failures in Hong Kong. *Quarterly Journal of Engineering Geology*, vol. 8, pp 31–65.

Lumb, P. (1983). Engineering properties of fresh and decomposed igneous rocks from Hong Kong. *Engineering Geology*, vol. 19, pp 81–94.

Moye, D. G. (1955). Engineering geology for the Snowy Mountain Scheme. *Journal of the Institution of Engineers Australia*, vol. 27, pp 281–299.

Nash, J. M. & Dale, M. J. (1983). Geology and hydrogeology of natural tunnel erosion in superficial deposits in Hong Kong. *Proceedings of the Meeting on the Geology of Surficial Deposits in Hong Kong*, Hong Kong, pp 61–72.

Phillipson, H. B. & Chipp, P. N. (1981). High quality core sampling—recent developments in Hong Kong. *Hong Kong Engineer*, vol. 9, no. 4, pp 9–15.

Phillipson, H. B. & Chipp, P. N. (1982). Airfoam sampling of residual soils in Hong Kong. *Proceedings of the ASCE Speciality Conference on Engineering and Construction in Tropical and Residual Soils*, Honolulu, Hawaii, pp 339–356.

Randall, P. A. & Taylor, B. W. (1982). Engineering geology in the Mid-levels Study, Hong Kong. *Proceedings of the Seventh Southeast Asian Geotechnical Conference*, Hong Kong, vol. 1, pp 189–204.

Richards, L. R. & Cowland, J. W. (1986). Stability evaluation of some urban rock slopes in a transient groundwater regime. *Proceedings of the Conference on Rock Engineering and Excavation in an Urban Environment*, Hong Kong, pp 357–363.

Rodin, S., Henkel, D. J. & Brown, R. L. (1982). Geotechnical study of a large hillside area in Hong Kong. *Hong Kong Engineer*, vol. 10, no. 5, pp 37–45.

Ruxton, B. P. (1960). The geology of Hong Kong. *Quarterly Journal of the Geological Society of London*, vol. 115, pp 233–260 (& 2 plates & 1 map).

Ruxton, B. P. (1980). Slope problems in Hong Kong: a geological appraisal. *Hong Kong Engineer*, vol. 8, no. 6, pp 31–39.

Ruxton, B. P. & Berry, L. (1957). Weathering of granite and associated erosional features in Hong Kong. *Bulletin of the Geological Society of America*, vol. 68, pp 1263–1291 (& 1 plate).

So, C. L. (1971). Mass movements associated with the rainstorm of June 1966 in Hong Kong. *Transactions of the Insitute of British Geographers*, no. 53, pp 55–65.

Strahler, A. N. (1952). Dynamic basis of geomorphology. *Bulletin of the Geological Society of America*, vol. 63, pp 923–938.

Strange, P. J. & Shaw, R. (1986). *Geology of Hong Kong Island and Kowloon, 1:20 000 Sheets 11 and 15.* Geotechnical Control Office, Hong Kong, 136 p. (Hong Kong Geological Survey Memoir, No. 2).

Styles, K. A. (1982). Aerial photograph interpretation—terrain classification. *Proceedings of the Seventh Southeast Asian Geotechnical Conference*, Hong Kong, vol. 2, pp 149–158.

Styles, K. A. (1983). Delineation of colluvial deposits in Hong Kong using the technique of terrain classification. *Proceedings of the Meeting on the Geology of Surficial Deposits in Hong Kong*, Hong Kong, pp 103–113.

Styles, K. A. & Burnett, A. D. (1985a). The assessment of hydrogeological features using the technique of terrain classification. *Proceedings of the ESCAP-RMRDC Workshop on Hydrogeological Mapping*, Bandung, Indonesia, vol. 7, pp 121–144.

Styles, K. A. & Burnett, A. D. (1985b). Geotechnical Area Studies Programme and land planning in Hong Kong. *Planning and Development*, vol. 1, no. 2, pp 13–23.

Styles, K. A., Burnett, A. D. & Cox, D. C. (1982). Geotechnical assessment of the terrain for land management and planning purposes in Hong Kong. *Proceedings of the First International Symposium on Soil, Geology and Landforms: Impact on Land Use Planning in Developing Countries*, Bangkok, pp F16.1–F16.9.

Styles, K. A., Hansen, A. & Burnett, A. D. (1986). Use of a computer-based land inventory for delineation of terrain which is geotechnically suitable for development. *Proceedings of the Fifth International Congress of the International Association of Engineering Geology*, Buenos Aires, Argentina, vol. 6, pp 1841–1848.

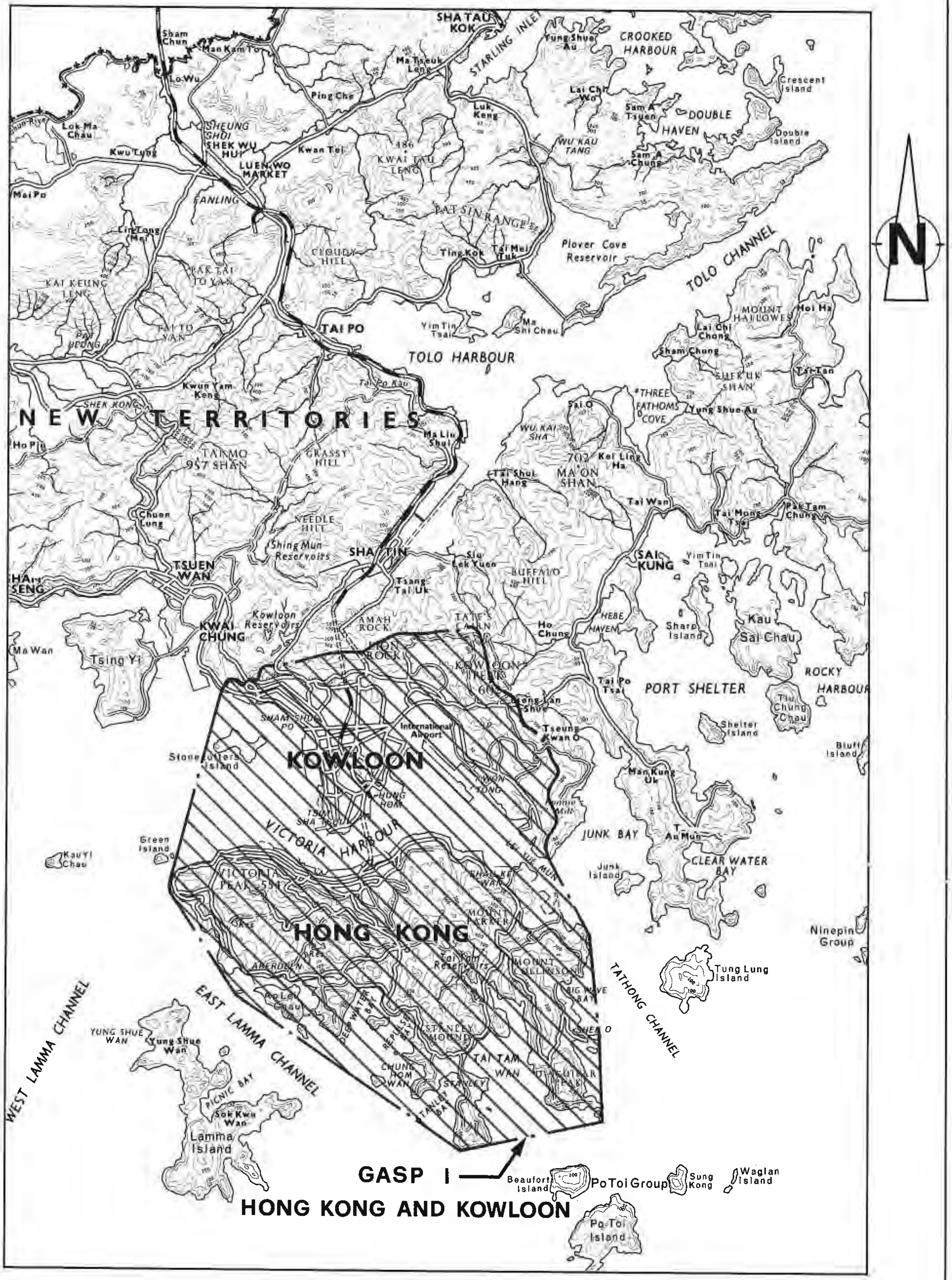
Styles, K. A., Hansen, A., Dale, M. J. & Burnett, A. D. (1984). Terrain classification methods for development planning and geotechnical appraisal: a Hong Kong case. *Proceedings of the Fourth International Symposium on Landslides*, Toronto, vol. 2, pp 561–568.

Thrower, L. B. (1970). The vegetation of Hong Kong. *Proceedings of the Royal Asiatic Society*, vol. 10, pp 21–43.

Tregear, T. R. & Berry, L. (1959). *The Development of Hong Kong and Kowloon as Told in Maps.* Hong Kong University Press, 35 p. & 1 map. (Reprinted with revisions from Far Eastern Economic Review, vol. 25, 1958, pp 33–36, 65–69, 97–100, 131–135, 168–169, 201–203, 289–293 and 321–323).

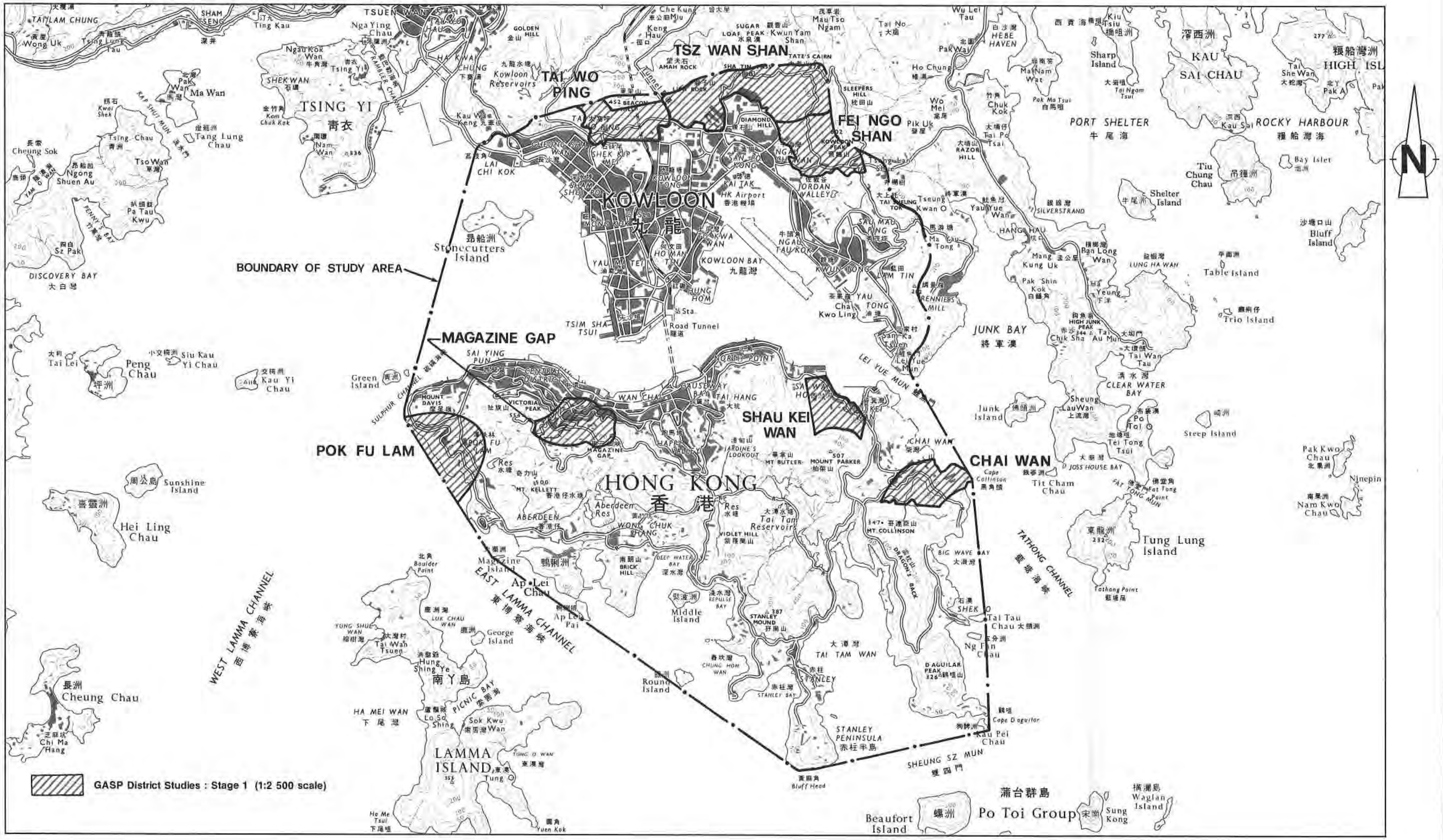
Vail, A. J. (1984). Two landslide disasters in Hong Kong. *Proceedings of the Fourth International Symposium on Landslides*, Toronto, vol. 1, pp 717–722.

Vail, A. J. & Beattie, A. A. (1985). Earthworks in Hong Kong—their failure and stabilisation. *Proceedings of the International Symposium on Failure in Earthworks, London, pp 15–28.*

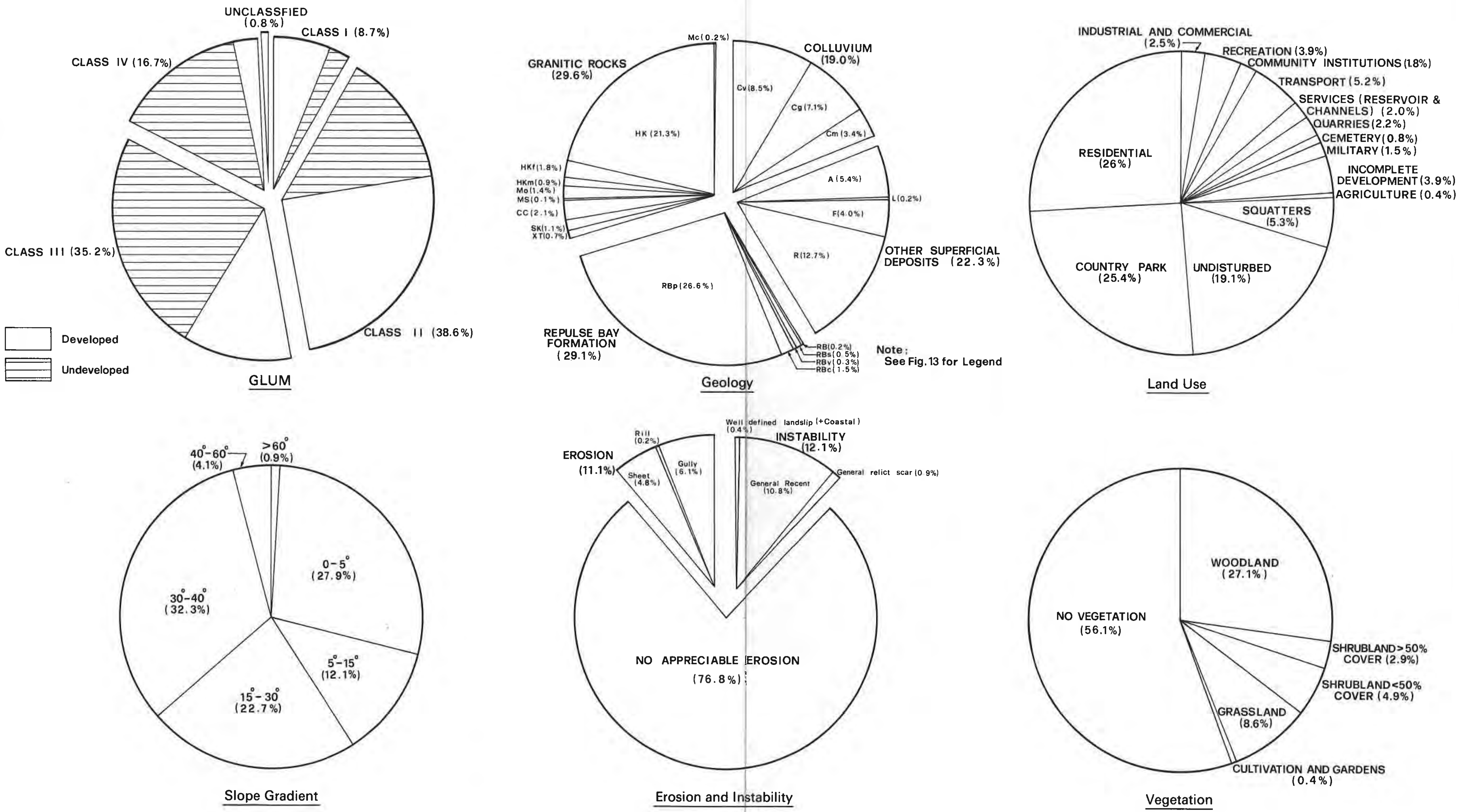


Scale 1:200 000	Location Map of the Hong Kong and Kowloon Study Area	Fig. 1

Scale 1:89 000	Aerial Photomosaic of the Hong Kong and Kowloon Study Area	Fig. 2

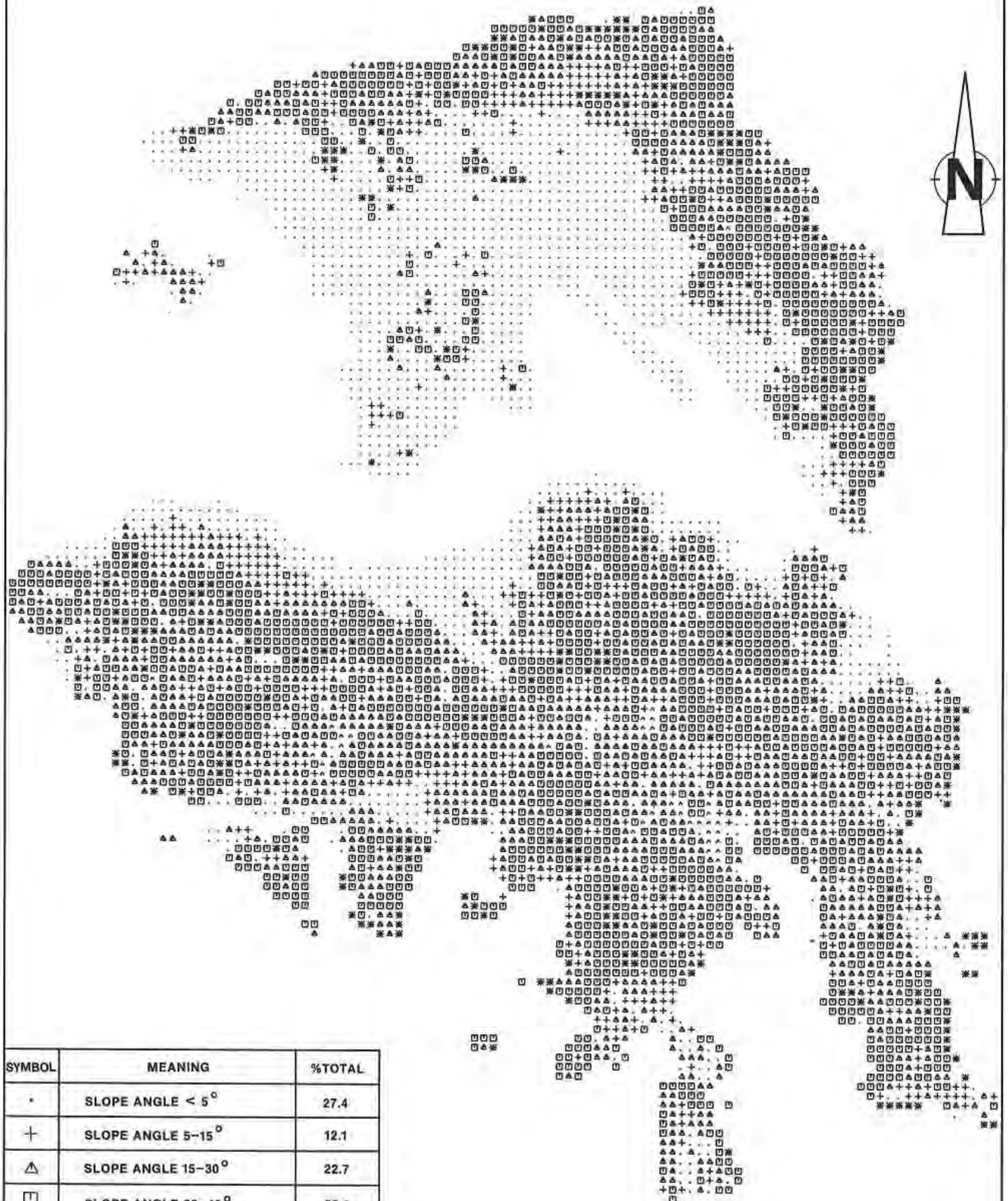


Scale 1:100 000	Hong Kong and Kowloon Study Area	Fig. 3



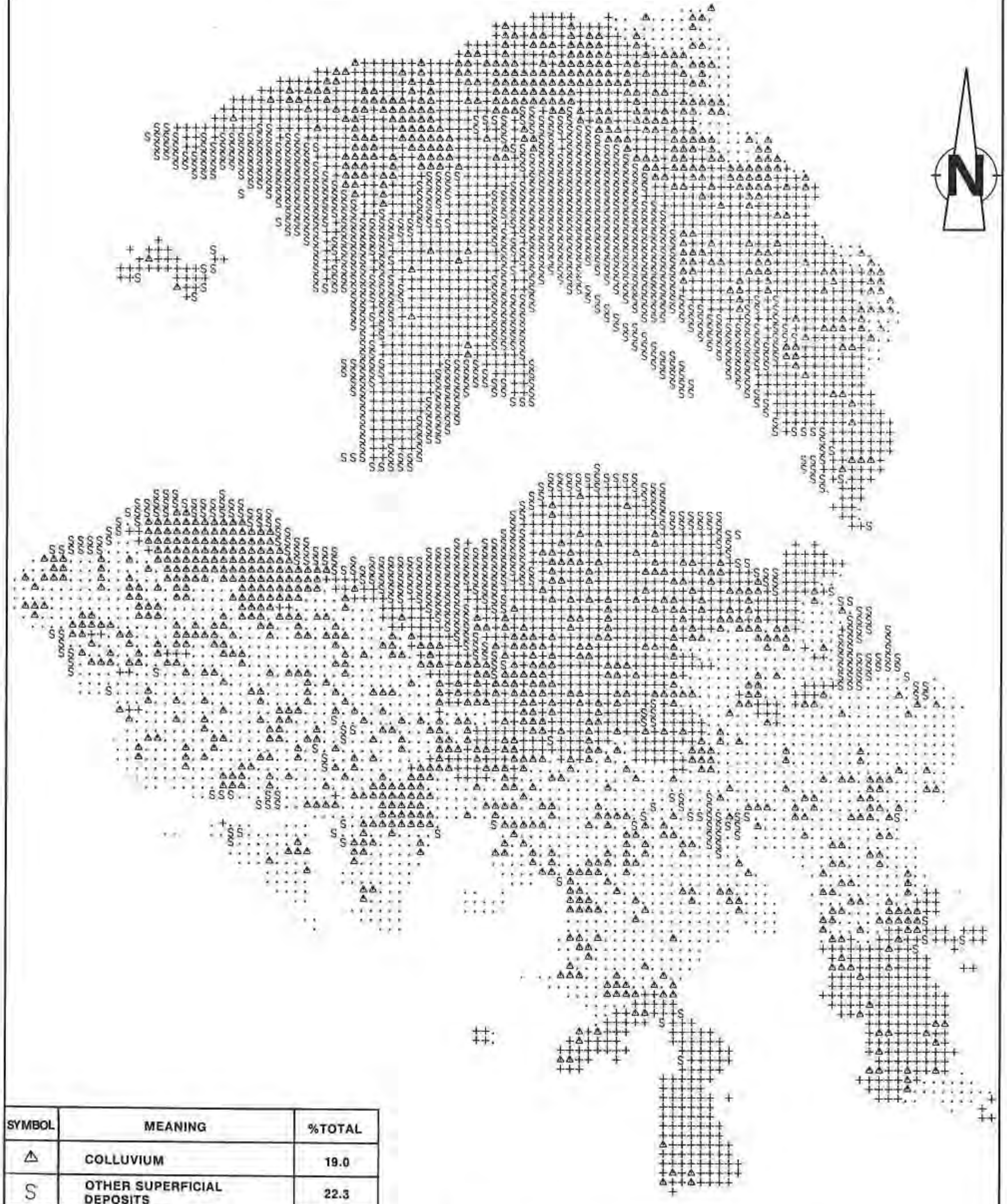
Pie Charts of Selected Attributes of Hong Kong and Kowloon

Fig. 4



SYMBOL	MEANING	%TOTAL
·	SLOPE ANGLE < 5°	27.4
+	SLOPE ANGLE 5–15°	12.1
△	SLOPE ANGLE 15–30°	22.7
◻	SLOPE ANGLE 30–40°	32.3
✳	SLOPE ANGLE > 40°	5.0
^	RESERVOIR OR POND	0.5

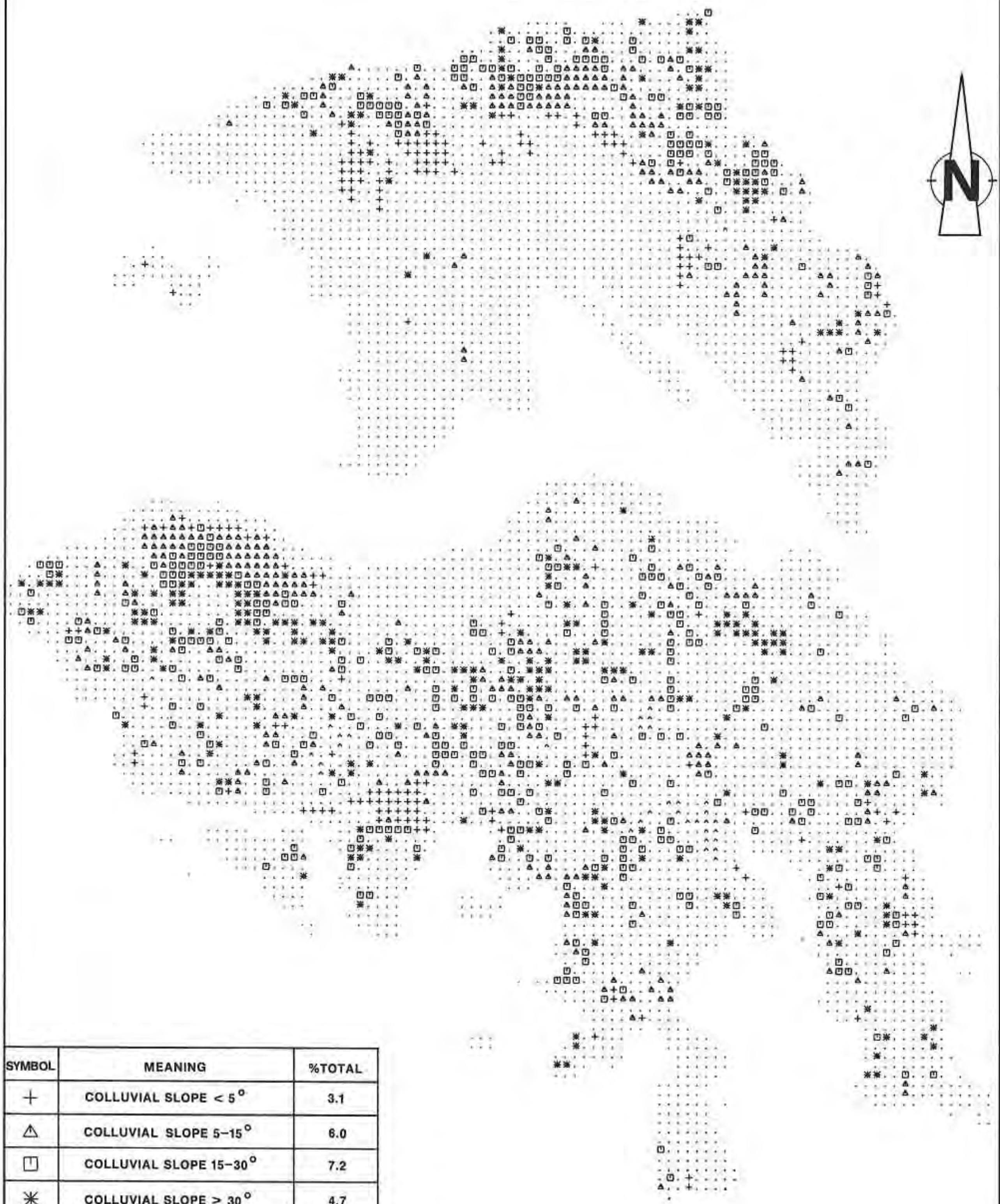
Scale 1:85 000	GEOTECS Plot - Slope Gradient	Fig. 5



SYMBOL	MEANING	%TOTAL
△	COLLUVIUM	19.0
S	OTHER SUPERFICIAL DEPOSITS	22.3
·	* VOLCANIC ROCK (REPULSE BAY FORMATION)	29.1
+	* INTRUSIVE IGNEOUS ROCKS	29.6

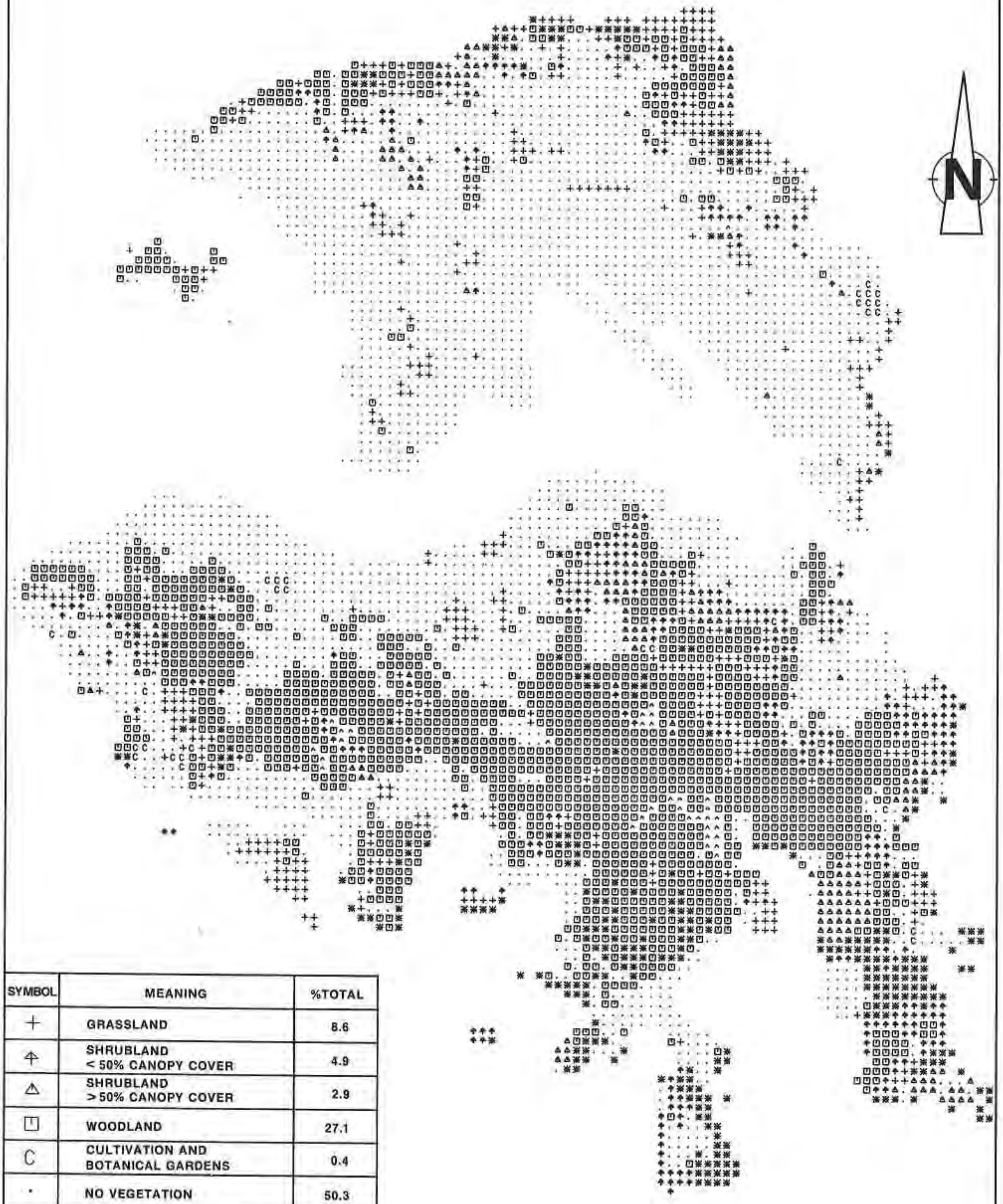
Note: * Includes areas identified as fill overlying bedrock

Scale 1:85 000	GEOTECS Plot - Geology	Fig. 6



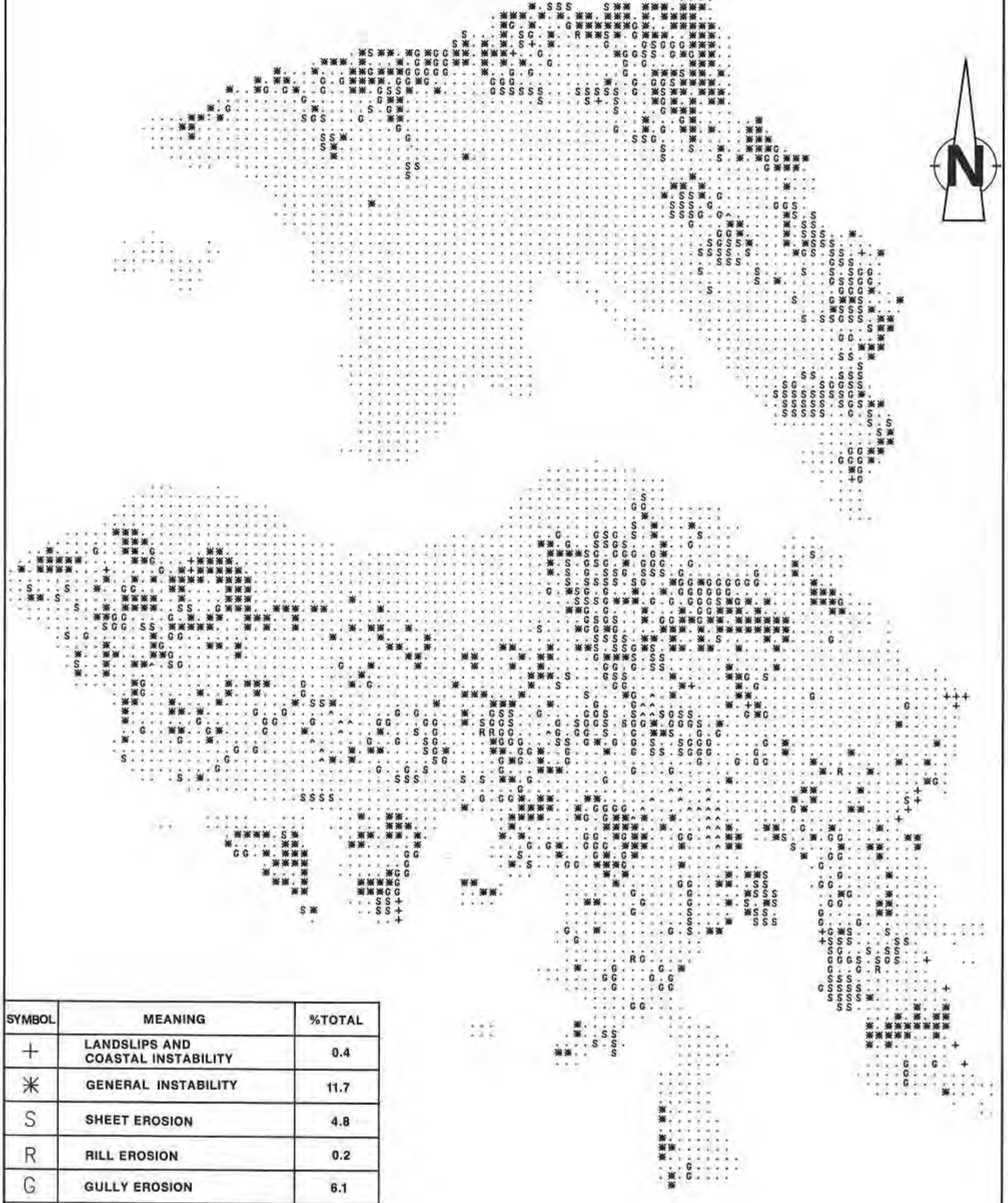
SYMBOL	MEANING	%TOTAL
+	COLLUVIAL SLOPE < 5°	3.1
△	COLLUVIAL SLOPE 5–15°	6.0
□	COLLUVIAL SLOPE 15–30°	7.2
✳	COLLUVIAL SLOPE > 30°	4.7
·	NO COLLUVIUM	78.5
^	RESERVOIR OR POND	0.5

Scale 1:85 000	GEOTECS Plot - Colluvium and Slope Gradient	Fig. 7



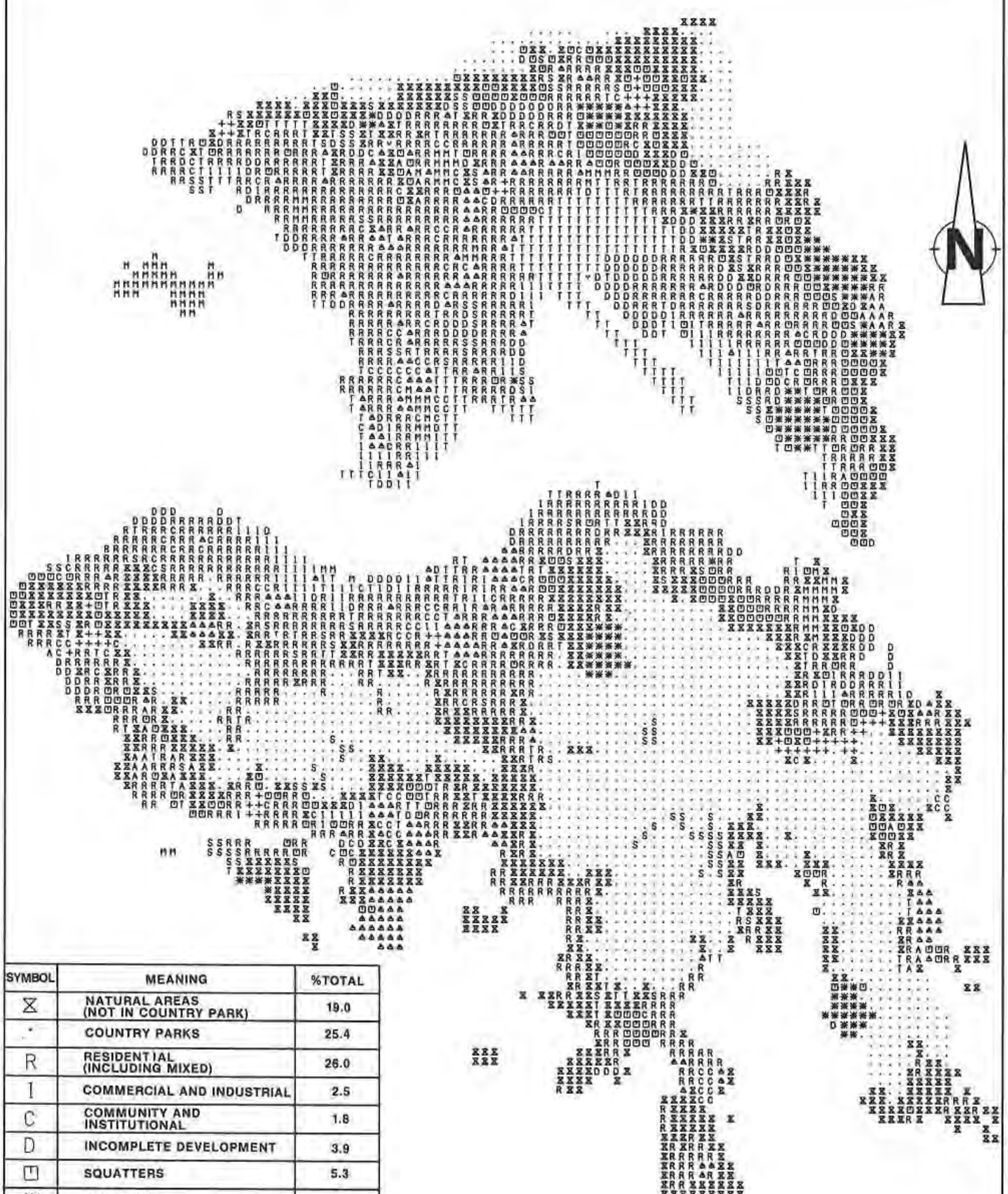
SYMBOL	MEANING	%TOTAL
+	GRASSLAND	8.6
♣	SHRUBLAND < 50% CANOPY COVER	4.9
△	SHRUBLAND > 50% CANOPY COVER	2.9
⊡	WOODLAND	27.1
C	CULTIVATION AND BOTANICAL GARDENS	0.4
·	NO VEGETATION	50.3
✳	ROCK OUTCROP	5.3
^	RESERVOIR OR POND	0.5

Scale 1:85 000	GEOTECS Plot - Vegetation	Fig. 8



SYMBOL	MEANING	%TOTAL
+	LANDSLIPS AND COASTAL INSTABILITY	0.4
✳	GENERAL INSTABILITY	11.7
S	SHEET EROSION	4.8
R	RILL EROSION	0.2
G	GULLY EROSION	6.1
·	NO APPRECIABLE EROSION	76.3
^	RESERVOIR OR POND	0.5

Scale 1:85 000	GEOTECS Plot - Erosion and Instability	Fig. 9



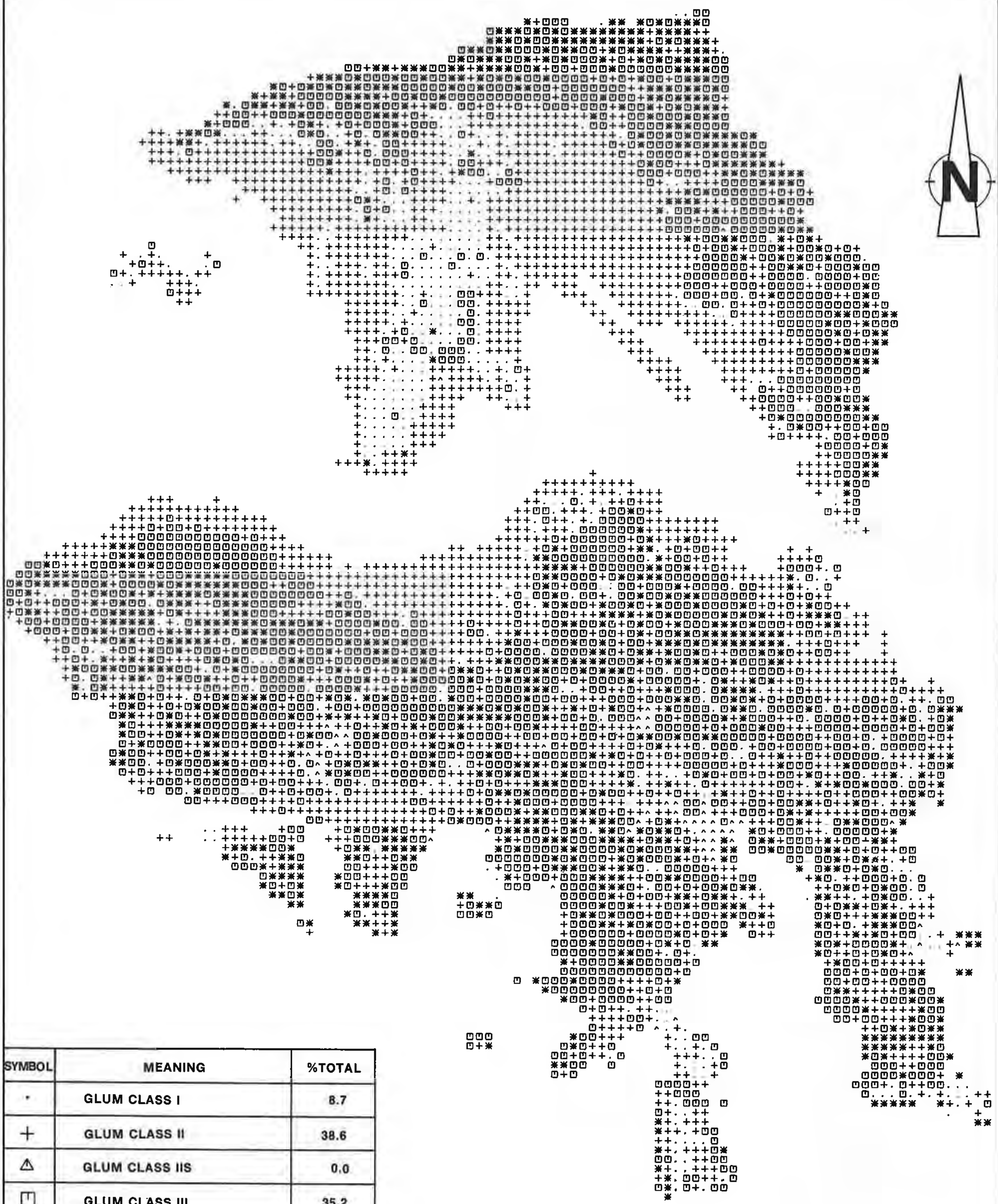
SYMBOL	MEANING	%TOTAL
⧖	NATURAL AREAS (NOT IN COUNTRY PARK)	19.0
·	COUNTRY PARKS	25.4
R	RESIDENTIAL (INCLUDING MIXED)	26.0
I	COMMERCIAL AND INDUSTRIAL	2.5
C	COMMUNITY AND INSTITUTIONAL	1.8
D	INCOMPLETE DEVELOPMENT	3.9
⊡	SQUATTERS	5.3
✳	QUARRIES	2.2
△	RECREATIONAL	3.9
A	AGRICULTURAL	0.4
+	CEMETERIES	0.8
S	SERVICES (INCLUDING RESERVOIRS)	2.0
T	TRANSPORTATION	5.2

SYMBOL	MEANING	%TOTAL
v	MAJOR STREAM CHANNEL	0.1
M	MILITARY	1.5

Scale 1:85 000

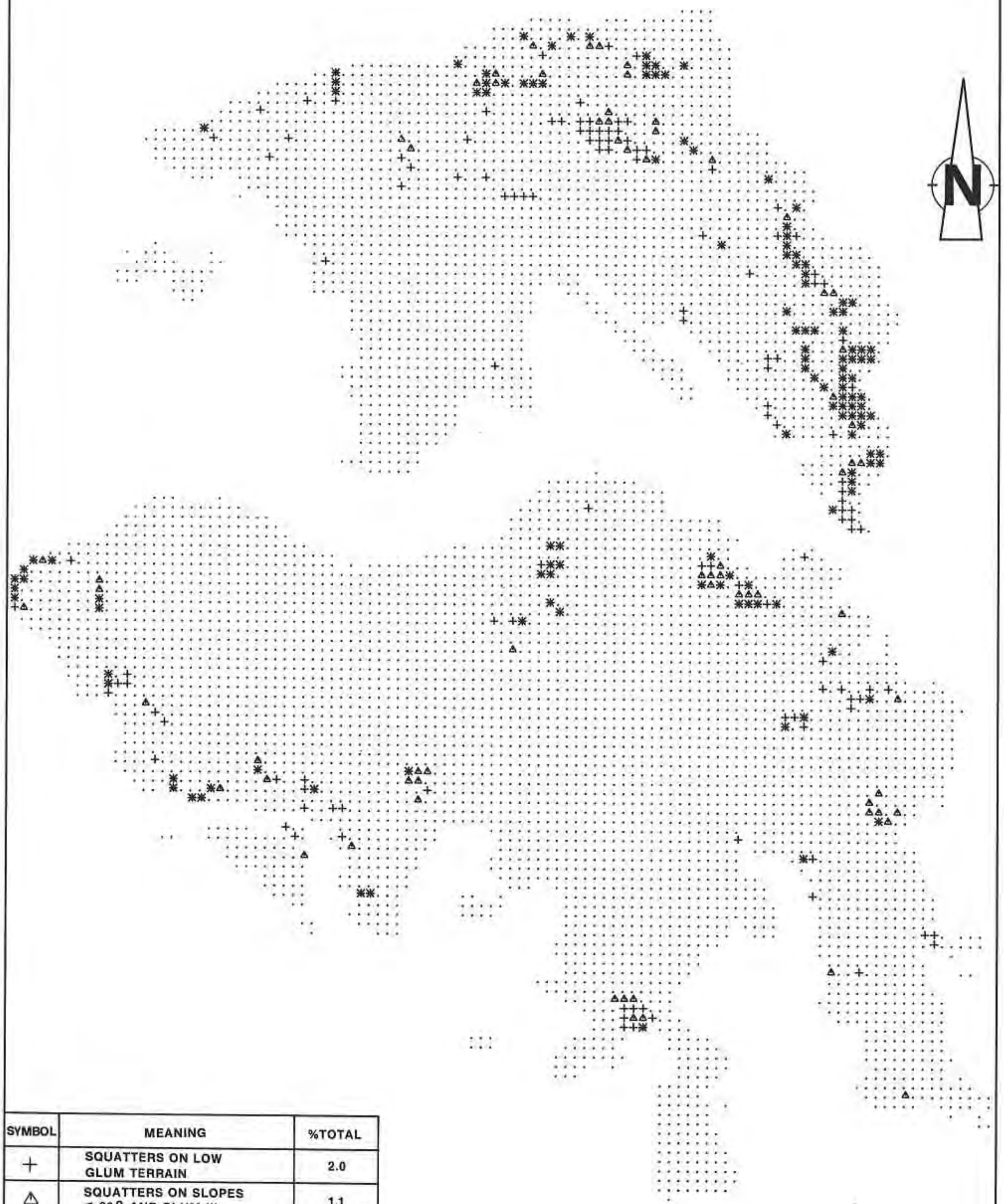
GEOTECS Plot - Land Use

Fig. 10



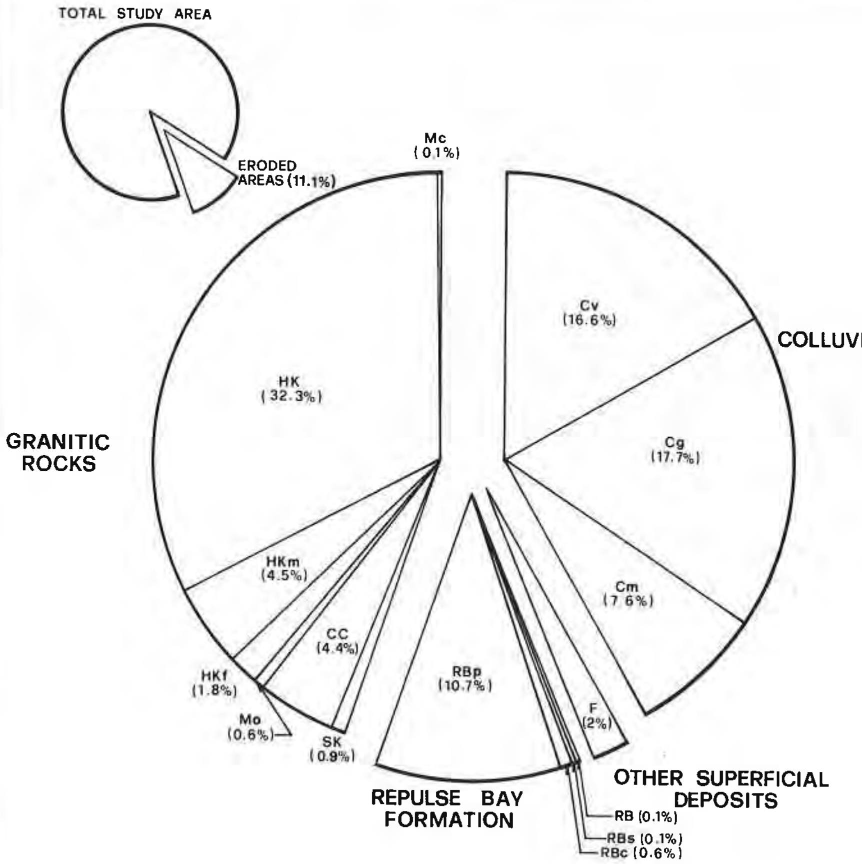
SYMBOL	MEANING	%TOTAL
·	GLUM CLASS I	8.7
+	GLUM CLASS II	38.6
⚠	GLUM CLASS IIS	0.0
◫	GLUM CLASS III	35.2
✳	GLUM CLASS IV	16.7
^	UNCLASSIFIED	0.8

Scale 1:85 000	GEOTECS Plot - Geotechnical Land Use Map	Fig. 11

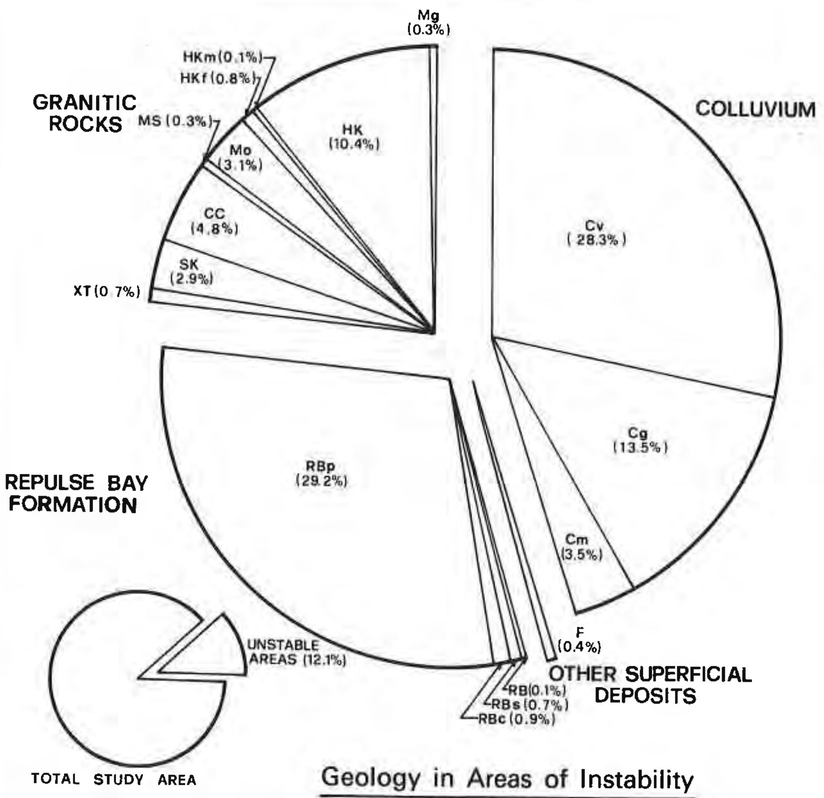


SYMBOL	MEANING	%TOTAL
+	SQUATTERS ON LOW GLUM TERRAIN	2.0
△	SQUATTERS ON SLOPES < 30° AND GLUM III	1.1
✳	SQUATTERS ON SLOPES > 30° OR ON GLUM IV	2.2
·	NO SQUATTERS	94.7

Scale 1:85 000	GEOTECS Plot - Distribution of Squatters and Terrain	Fig. 12



Geology in Areas of Appreciable Erosion



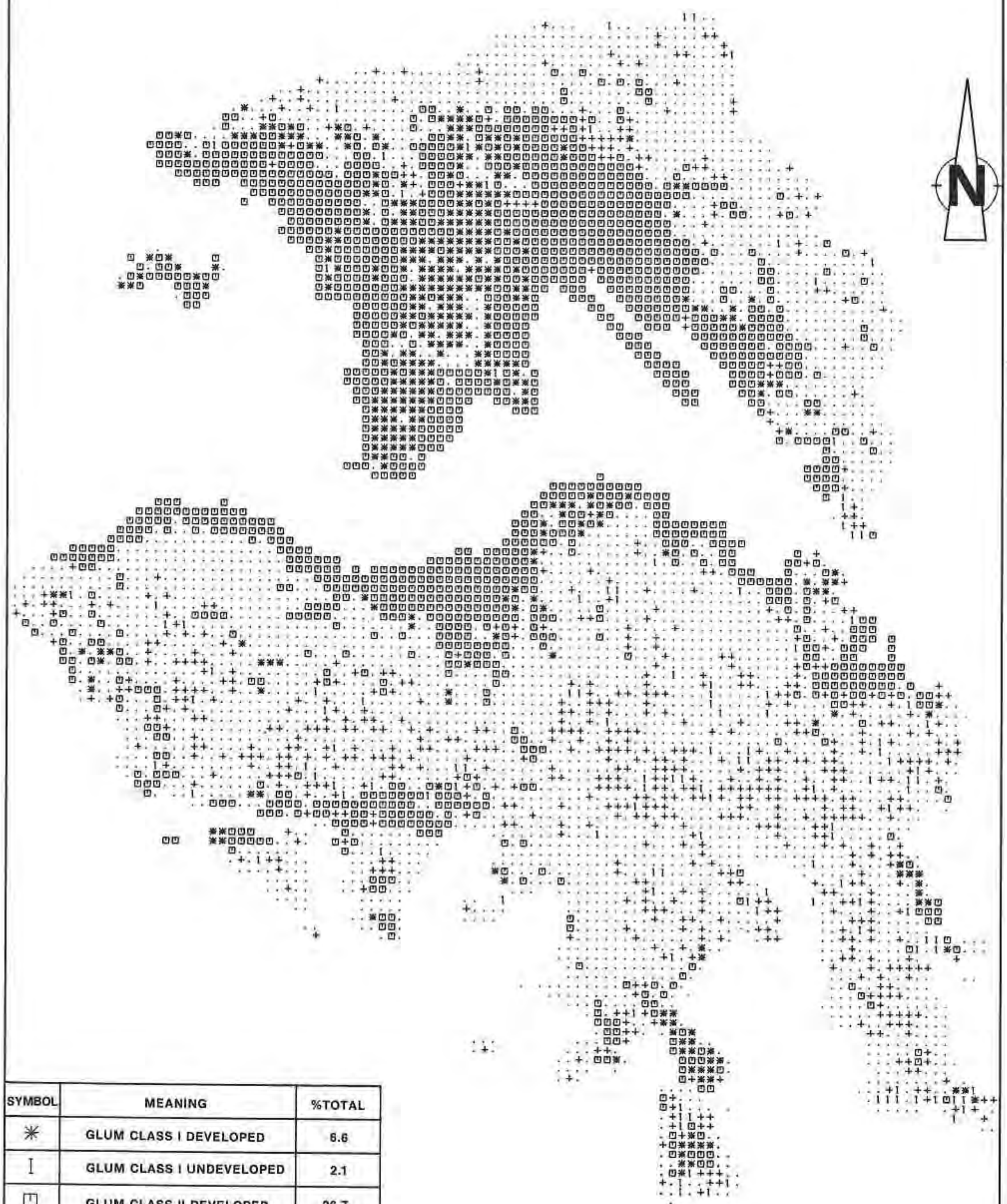
Geology in Areas of Instability

F	Fill
Cv	Volcanic Colluvium
Cg	Granitic Colluvium
Cm	Mixed Colluvium
Mc	Granophyric microgranite
HK	Hong Kong Granite
HKf	Hong Kong Granite (fine-grained)
HKm	Hong Kong Granite (medium-grained)
Mo	Quartz monzonite
Ms	Ma On Shan Granite
CC	Cheung Chau Granite
SK	Sung Kong Granite
XT	Tai Po Granodiorite
RB	Undifferentiated volcanic rocks
RBs	Sedimentary and volcaniclastic rocks
RBv	Acid lavas
RBc	Coarse tuff
RBp	Pyroclastic rocks and lavas

(after Allen and Stephens 1971)

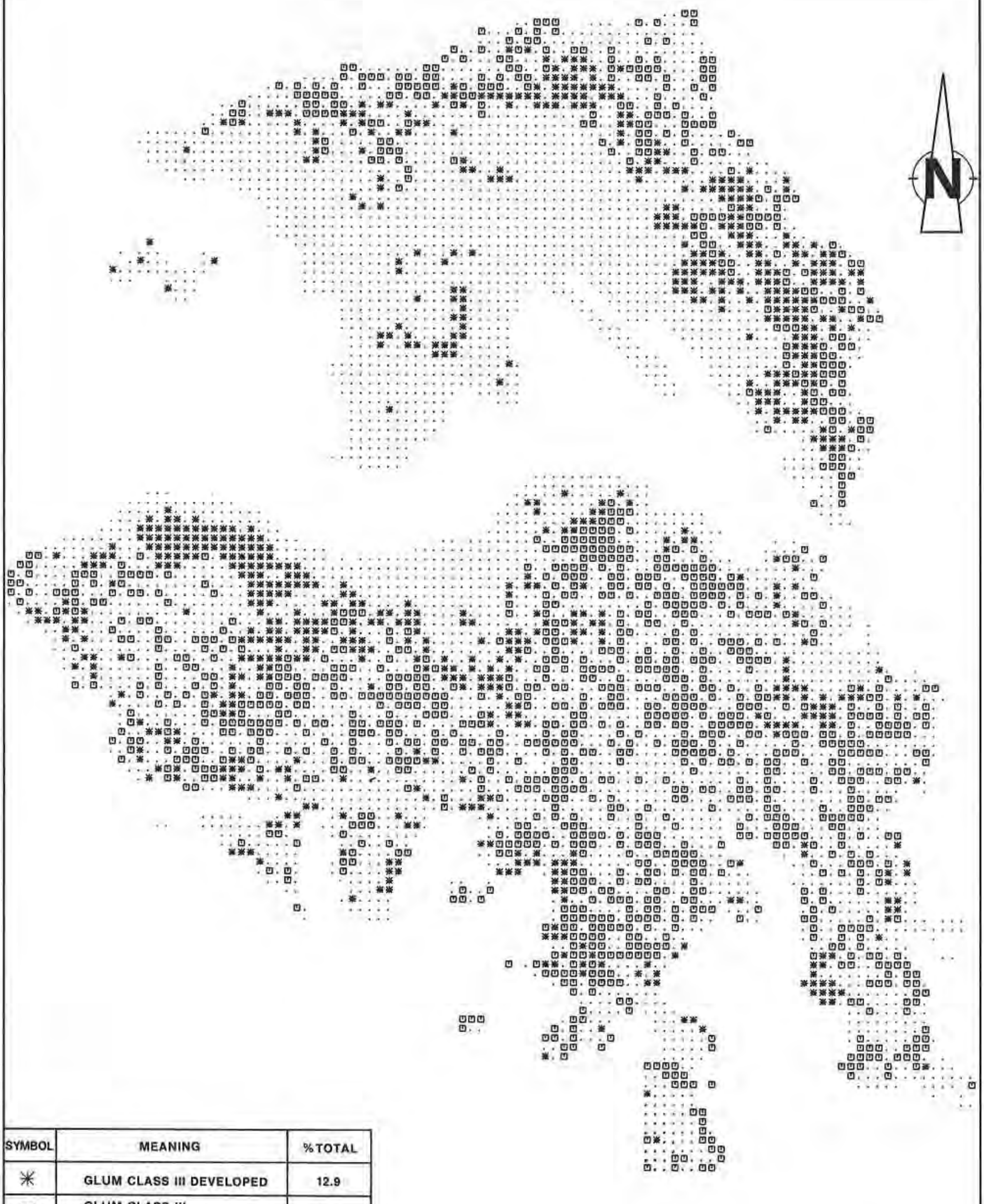
Distribution of Geology in Areas of Erosion and Instability

Fig. 13



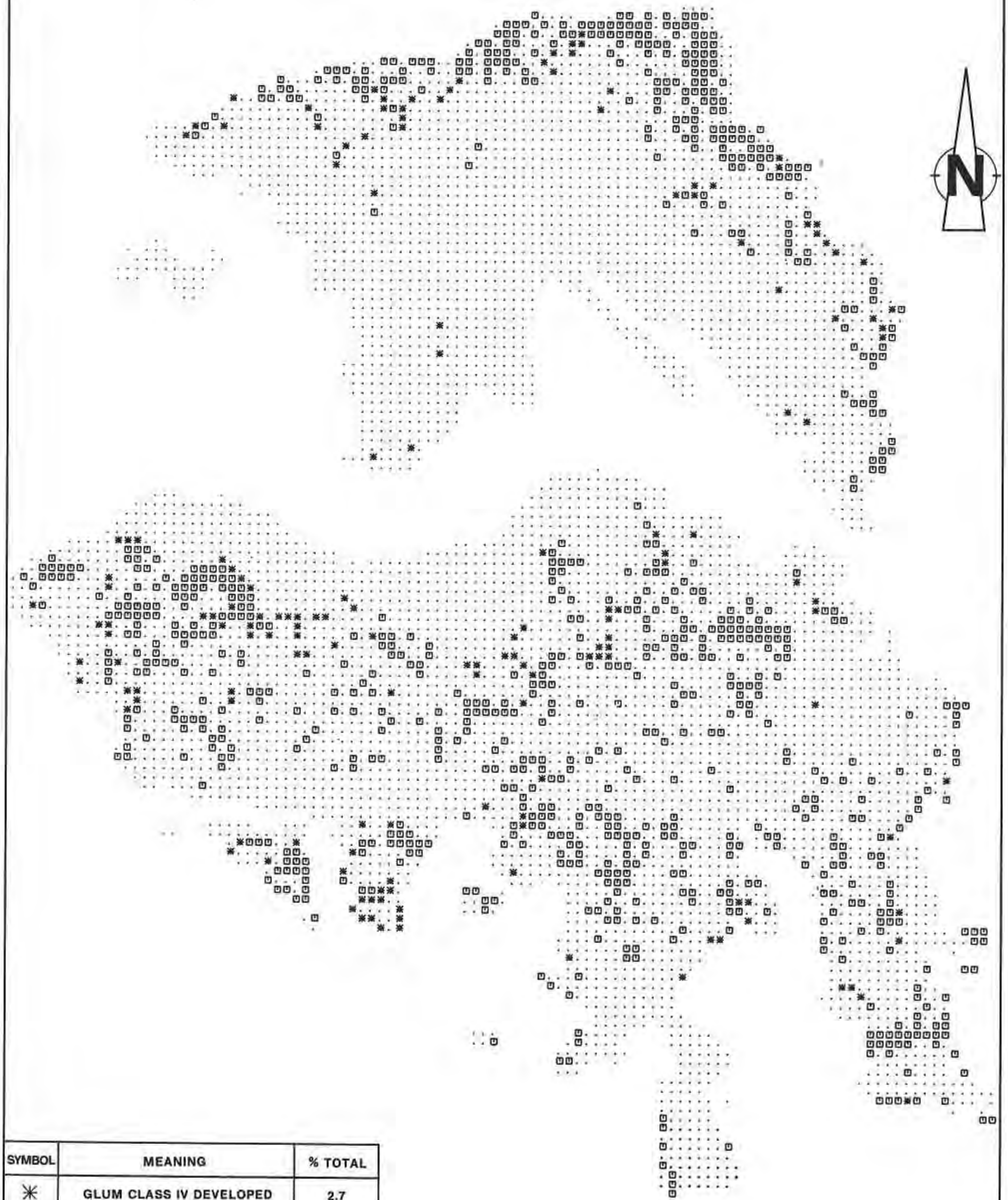
SYMBOL	MEANING	%TOTAL
*	GLUM CLASS I DEVELOPED	6.6
I	GLUM CLASS I UNDEVELOPED	2.1
⊡	GLUM CLASS II DEVELOPED	26.7
+	GLUM CLASS II UNDEVELOPED	11.9
·	NOT CLASS I OR II	52.7

Scale 1:85 000	GEOTECS Plot - GLUM Classes I and II / Development	Fig. 14



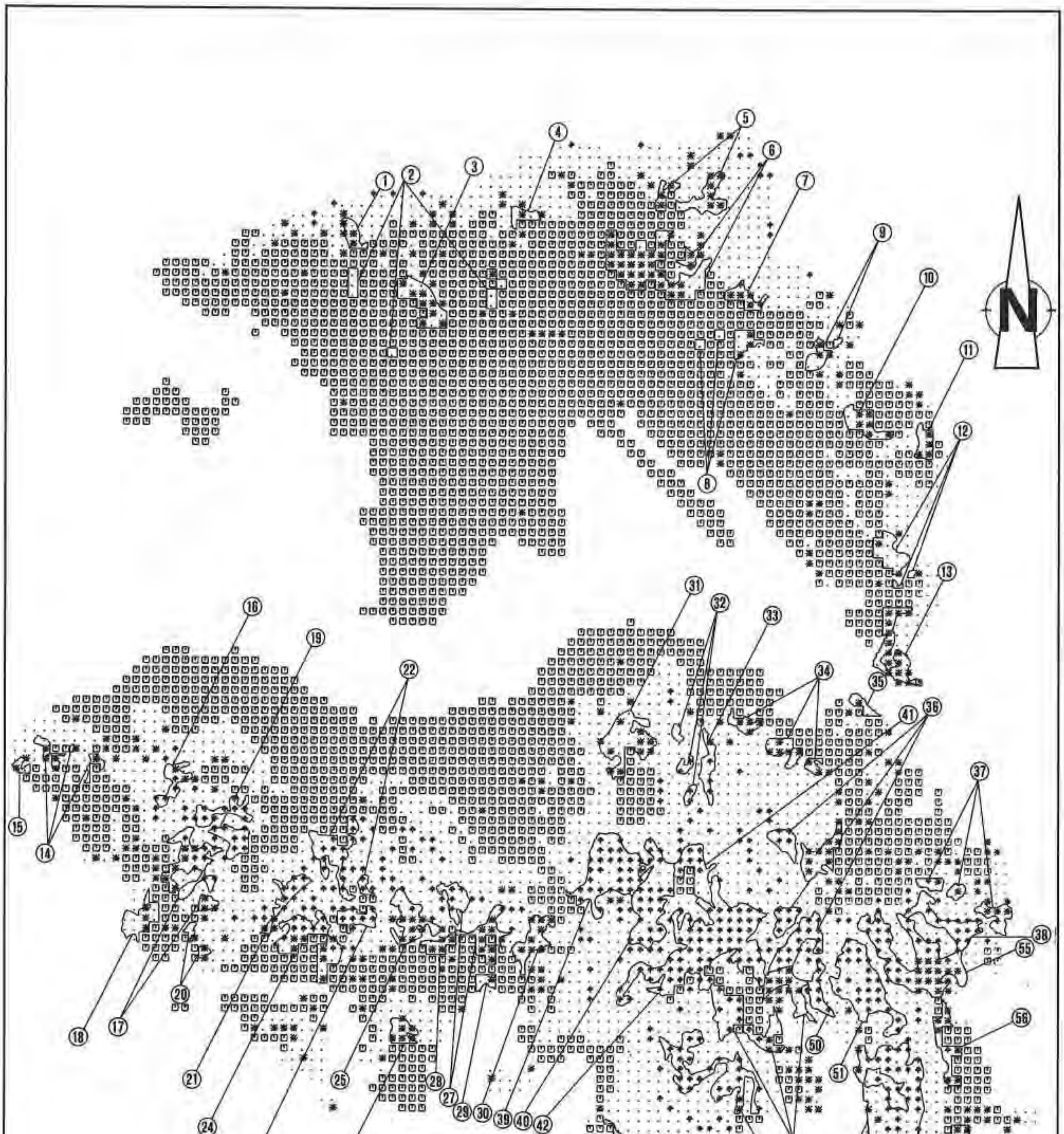
SYMBOL	MEANING	% TOTAL
✳	GLUM CLASS III DEVELOPED	12.9
☐	GLUM CLASS III UNDEVELOPED	22.3
·	NOT CLASS III	64.8

Scale 1:85 000	GEOTECS Plot - GLUM Class III / Development	Fig. 15



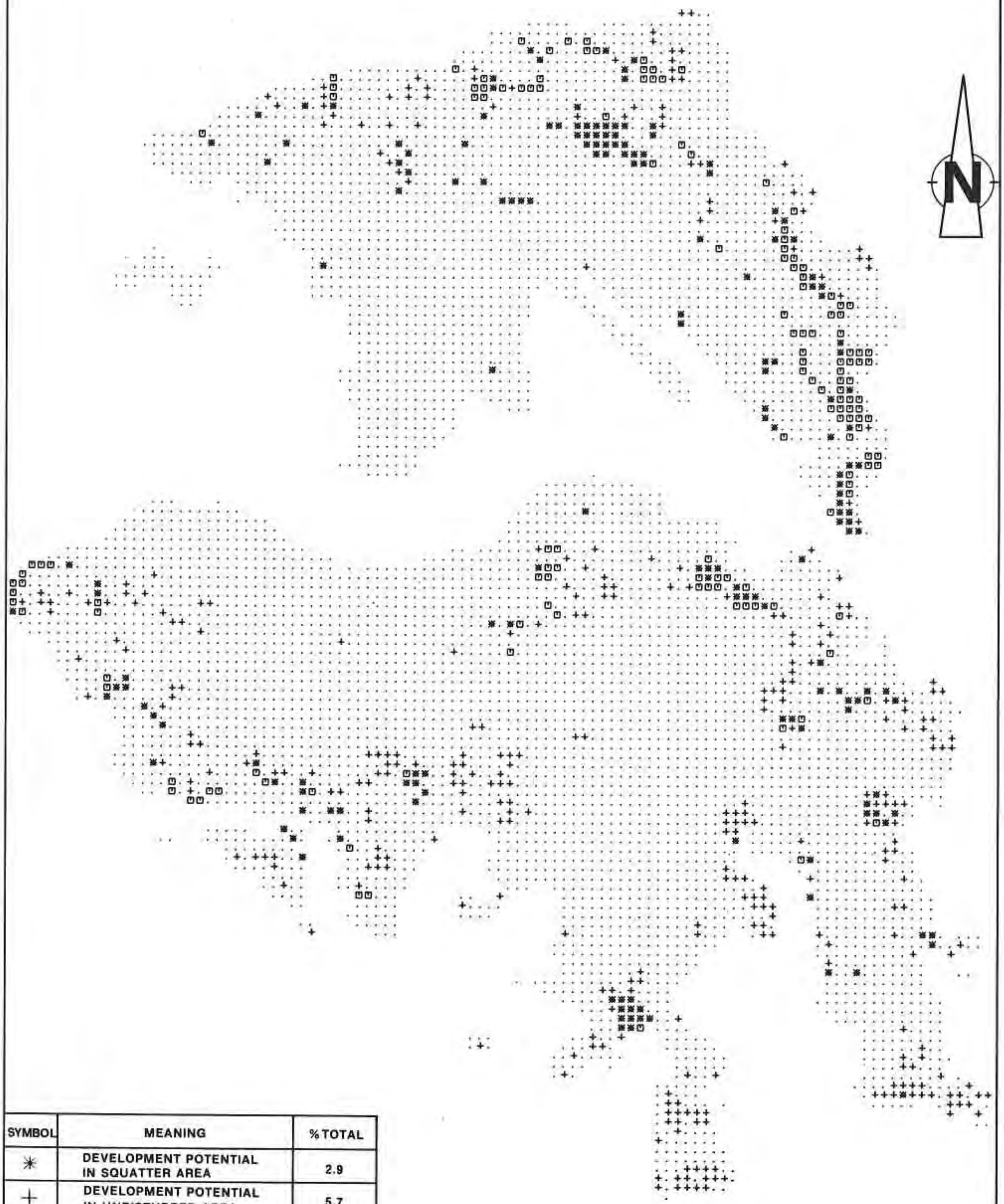
SYMBOL	MEANING	% TOTAL
✳	GLUM CLASS IV DEVELOPED	2.7
⊡	GLUM CLASS IV UNDEVELOPED	14.0
·	NOT CLASS IV	83.3

Scale 1:85 000	GEOTECS Plot - GLUM Class IV / Development	Fig. 16



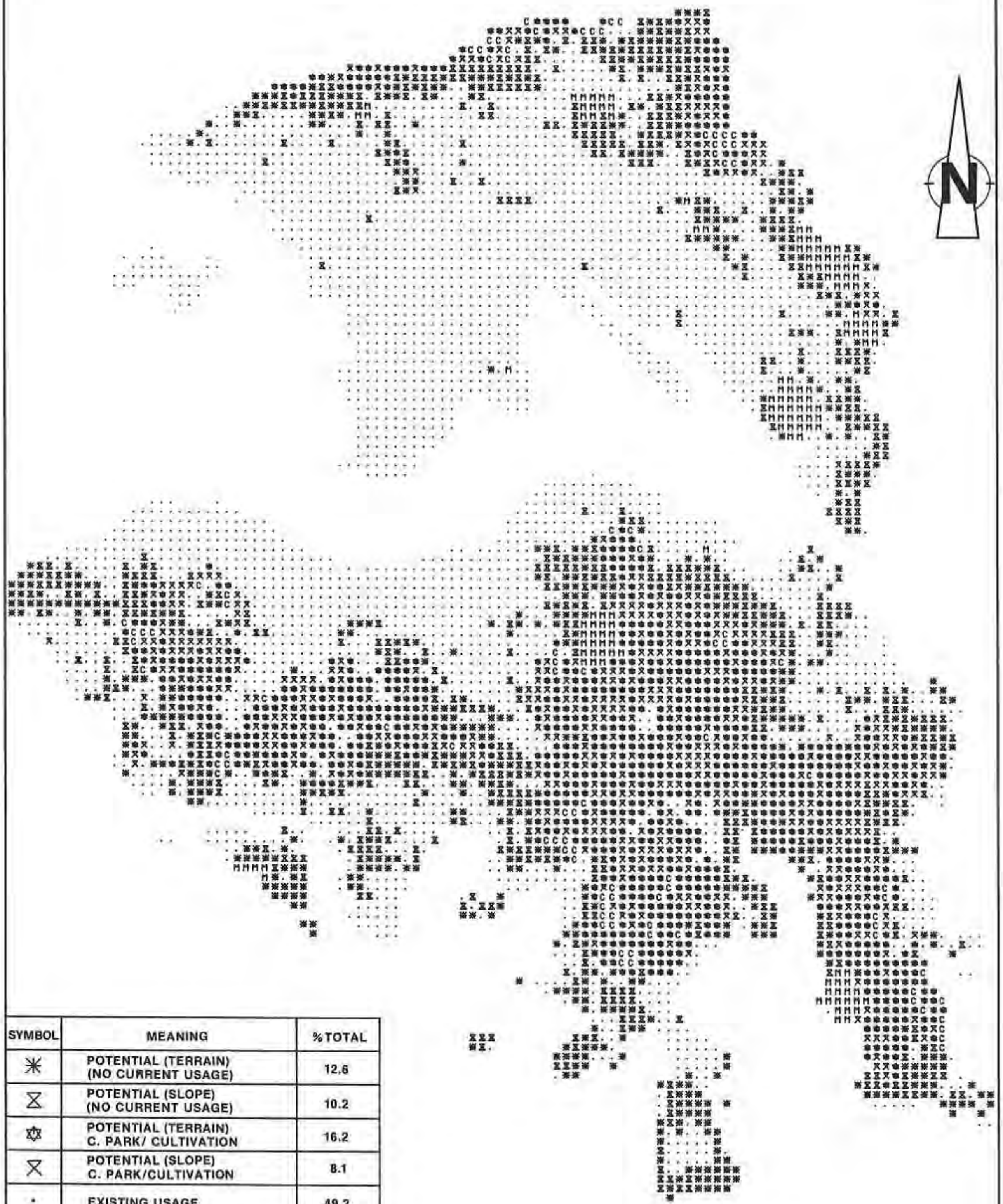
SYMBOL	MEANING	%TOTAL
⍏	GLEAM POTENTIAL COUNTRY PARK	8.4
✳	GLEAM POTENTIAL AGRICULTURE OR NO USAGE	8.8
⍞	EXISTING DEVELOPMENT OR WATER STORAGE	49.7
·	GLEAM CONSTRAINT	33.1

Scale 1:85 000	GEOTECS Plot - Areas of Development Potential, Summarised from the GLEAM	Fig. 17



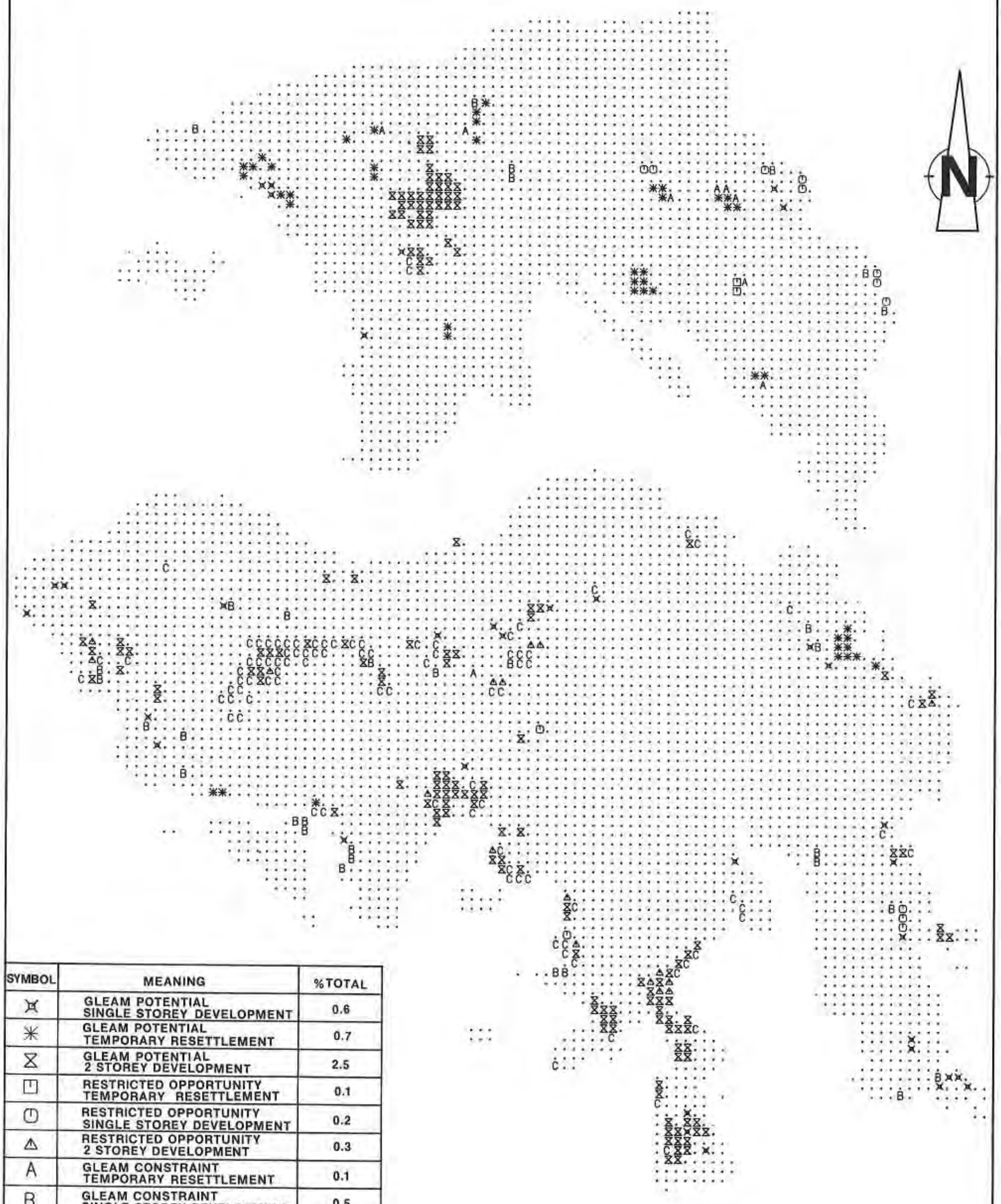
SYMBOL	MEANING	% TOTAL
*	DEVELOPMENT POTENTIAL IN SQUATTER AREA	2.9
+	DEVELOPMENT POTENTIAL IN UNDISTURBED AREA	5.7
⊡	DEVELOPMENT CONSTRAINT IN SQUATTER AREA	2.4
·	NOT APPLICABLE	89.0

Scale 1:85 000	GEOTECS Plot - Squatters on Land with Potential for Development	Fig. 18



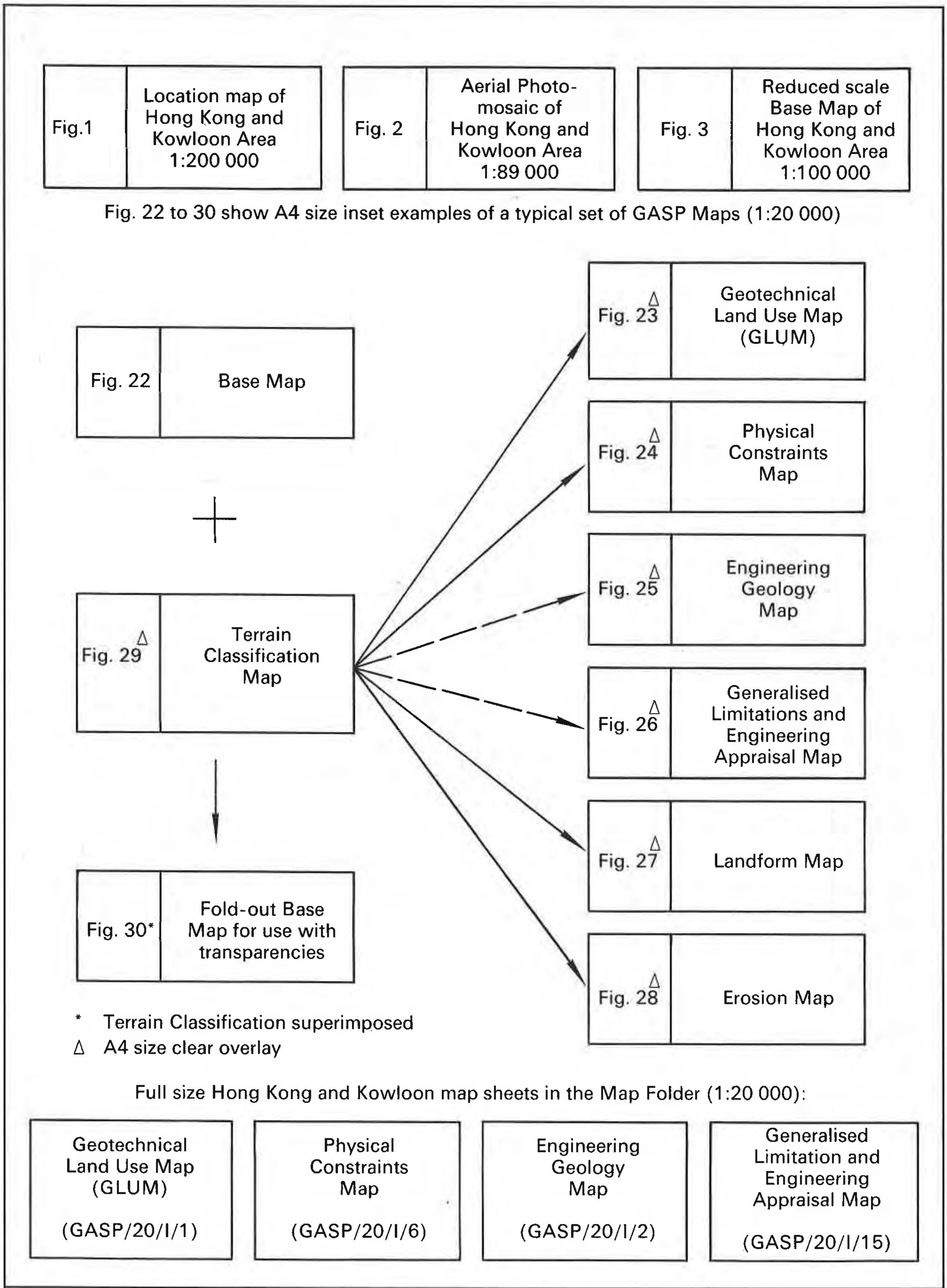
SYMBOL	MEANING	% TOTAL
✳	POTENTIAL (TERRAIN) (NO CURRENT USAGE)	12.6
⧖	POTENTIAL (SLOPE) (NO CURRENT USAGE)	10.2
✡	POTENTIAL (TERRAIN) C. PARK/ CULTIVATION	16.2
⧗	POTENTIAL (SLOPE) C. PARK/CULTIVATION	8.1
·	EXISTING USAGE	49.2
M	EXISTING QUARRY	2.2
C	COUNTRY PARK OR CULTIVATION	1.5

Scale 1:85 000	GEOTECS Plot - Distribution of Areas with Potential Use as Quarries	Fig. 19

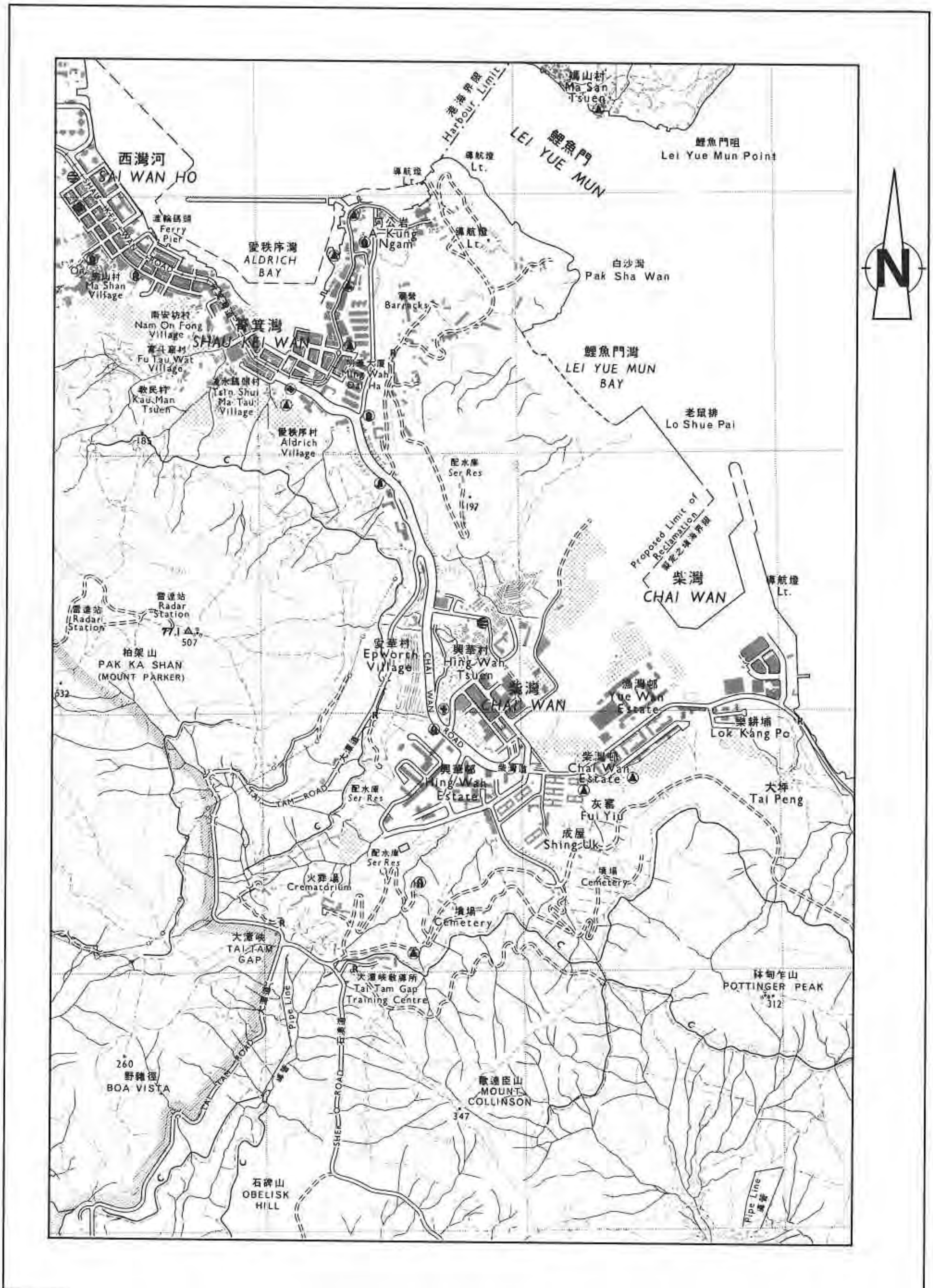


SYMBOL	MEANING	%TOTAL
⌘	GLEAM POTENTIAL SINGLE STOREY DEVELOPMENT	0.6
✳	GLEAM POTENTIAL TEMPORARY RESETTLEMENT	0.7
⧖	GLEAM POTENTIAL 2 STOREY DEVELOPMENT	2.5
⊡	RESTRICTED OPPORTUNITY TEMPORARY RESETTLEMENT	0.1
⏀	RESTRICTED OPPORTUNITY SINGLE STOREY DEVELOPMENT	0.2
⚠	RESTRICTED OPPORTUNITY 2 STOREY DEVELOPMENT	0.3
A	GLEAM CONSTRAINT TEMPORARY RESETTLEMENT	0.1
B	GLEAM CONSTRAINT SINGLE STOREY DEVELOPMENT	0.5
C	GLEAM CONSTRAINT 2 STOREY DEVELOPMENT	1.5
·	NOT APPLICABLE	93.5

Scale 1:85 000	GEOTECS Plot - Low Density Housing Redevelopment Opportunities	Fig. 20



Presentation of Maps and Overlays | Fig. 21



Scale 1:20 000	Example of the Base Map	Fig. 22

LEGEND FOR GEOTECHNICAL LAND USE MAP (Fig. 23)

- Class I - Low Geotechnical Limitations
- Class II - Moderate Geotechnical Limitations
- Class IIS - Moderate Geotechnical Limitations (including flooding)
- Class III - High Geotechnical Limitations
- Class IV - Extreme Geotechnical Limitations

LEGEND FOR PHYSICAL CONSTRAINTS MAP (Fig. 24)

- Colluvium
- Zones of colluvium which are subject to overland flow and periodic inundation. Evidence of unusual groundwater regime (delineated as drainage plain on Landform Map)
- Floodplain - subject to overland flow and regular inundation. Evidence of unusual groundwater regime (delineated as floodplain on Landform Map)
- Zones of general instability associated with predominantly colluvial terrain
- Zones of general instability associated with predominantly insitu terrain
- Slopes on insitu terrain which are generally steeper than 30° (other than those delineated as colluvial or unstable)
- Disturbed terrain - extensive cut and fill batters which generally exceed 30°
- Instability on disturbed terrain
- Water bodies (streams, man-made channels, storage dams)
- Ponds
- Moderate or severe gully erosion (may be superimposed upon other constraints)
- Littoral zone (generally subject to tidal action)

LEGEND FOR ENGINEERING GEOLOGY MAP (Fig. 25)

- Fill
- Reclamation
- Littoral Deposits
- Alluvium (Undifferentiated)
- Colluvium (Undifferentiated)
- Hong Kong Granite
- Hong Kong Granite : Fine-grained Porphyritic Phase
- Hong Kong Granite : Medium-grained Porphyritic Phase
- Quartz Monzonite
- General Instability
- Feldspar Porphyry Dyke
- Pq Quartz Porphyry Dyke
- D Dolerite Dyke
- Geological Boundary (solid)
- Geological Boundary (superficial)
- Photogeological Lineament
- Fault
- Ma On Shan Granite
- Cheung Chau Granite
- Sung Kong Granite
- Granophyric Microgranite
- Repulse Bay Formation:
  - Undifferentiated Volcanic Rocks
  - Sedimentary Rocks and Water-laid Volcaniclastic Rocks
  - Acid Lavas
  - Coarse Tuffs
  - Dominantly Pyroclastic Rocks with Some Lavas
  - Tai Po Granodiorite
- 30 Strike and Dip of Beds
- Strike and Dip of Schistosity
- Strike of Bedding - Dip Unknown
- Vertical Bedding
- Catchment Boundary
- -30- Isopachs of submarine superficial deposits
- -5- - Depth in Fathoms

LEGEND FOR GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP (Fig. 26)

DEVELOPMENT PLANNING ZONES :

- Zone of potential for development (assessed in geotechnical terms)
- Zone of local geotechnical constraints (identified on PCM) within general PDA
- Zone of constraints for development (assessed principally in geotechnical terms)
- Zone of existing development (based on principal use of GEOTECS 2 ha unit)
- Country Park boundary
- —C— Catchwater

NOTE: Numerals on map refer to relevant general planning/engineering notes

ABBREVIATIONS :

cont.	control
dev^{t}	development
form^{n}	site formation
inf.	influence/influencing
nec.	necessary
opp^{y}	opportunity
poss.	possible/possibilities
pot.	potential
N, S, NE, etc.	North, South, Northeast, etc.
PDA	Potential Development Area

FEATURES OF ENGINEERING SIGNIFICANCE :

—•—	Photogeological lineament
—R—	Ridge line
=D=Di=	Drainage, incised drainage
C	Colluvium (also in 'zone of local constraint', and PCM)
Str	Structure
W	Weathering
B	Boulders
	Instability influencing area
	Steeper slopes influencing area (orientation of symbols indicates downslope direction)
	Potential for borrow or extensive cut and fill : opportunity to create site formation in 'constrained' area, or larger site formation in 'potential' area.

NOTES
i) Features are generally indicated only where of significance to identified potential areas
ii) For explanation of significance of identified features, see Report Appendix A, Table A5, and Section 4.2.
iii) Geological boundaries and photolineations are shown in full on the EGM. Those lineations indicated represent the surface expression of obvious structural discontinuities which affect the PDA's.

LEGEND FOR LANDFORM MAP (Fig. 27)

SLOPE GRADIENT	CODE
0 - 5° (gently sloping)	1
5 - 15° (gently-moderately sloping)	2
15 - 30° (moderately sloping)	3
30 - 40° (steep)	4
40 - 60° (mountainous)	5
> 60° (precipitous)	6

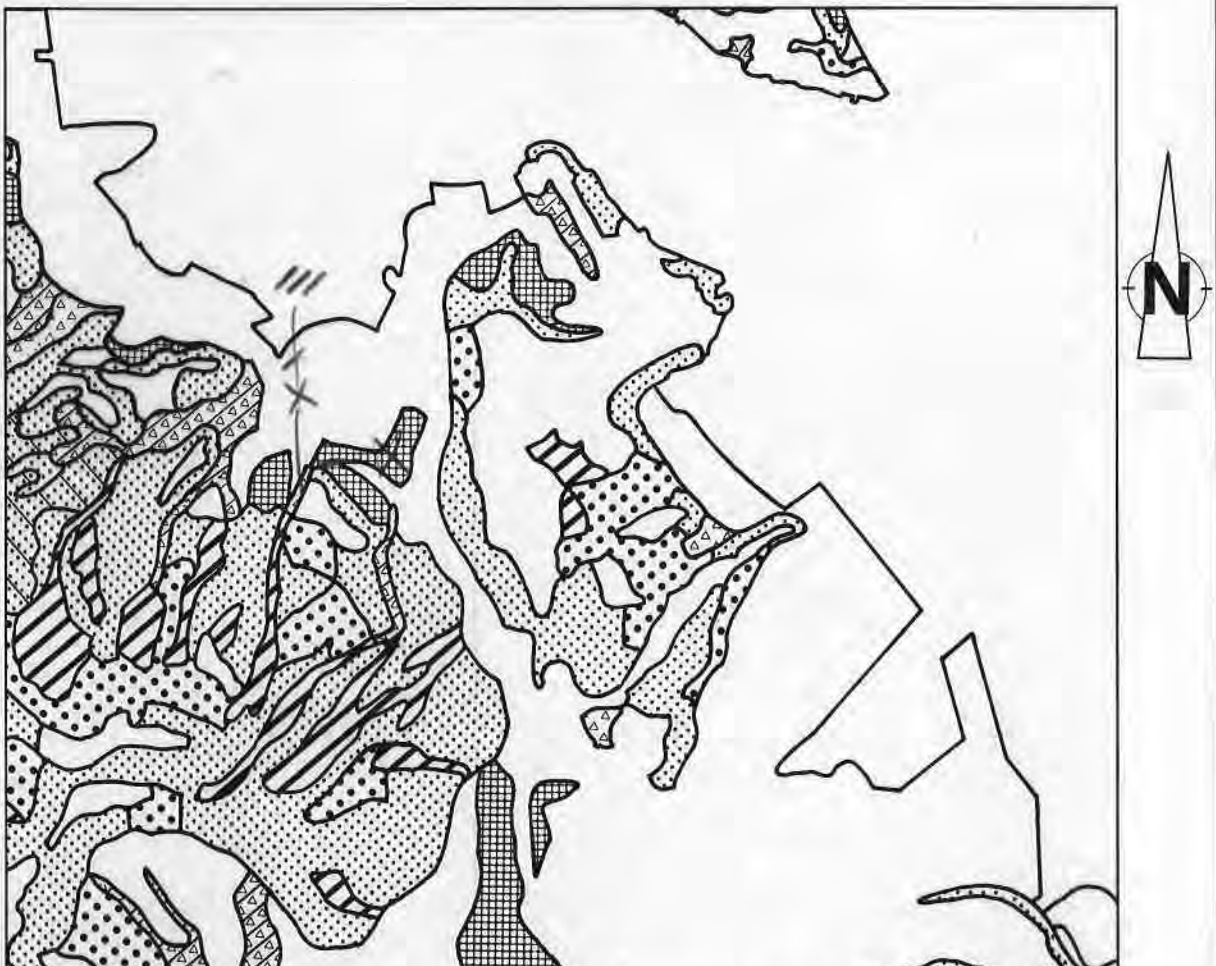
DESCRIPTION	CODE
Crest or ridge	1
Sideslope - insitu	2
Footslope - colluvium	3
Drainage plain - colluvium subject to overland flow and regular inundation. Unusual groundwater regime.	4
Alluvial plain - includes raised terraces.	5
Flood plain - portion of alluvial plain subject to overland flow and regular inundation. Unusual groundwater regime.	6
Disturbed terrain - cut	7
Disturbed terrain - fill	8
Cliff and rock outcrop	9
Reclamation	
Waterbodies	
Ponds	
Littoral zone	

LEGEND FOR EROSION MAP (Fig. 28)

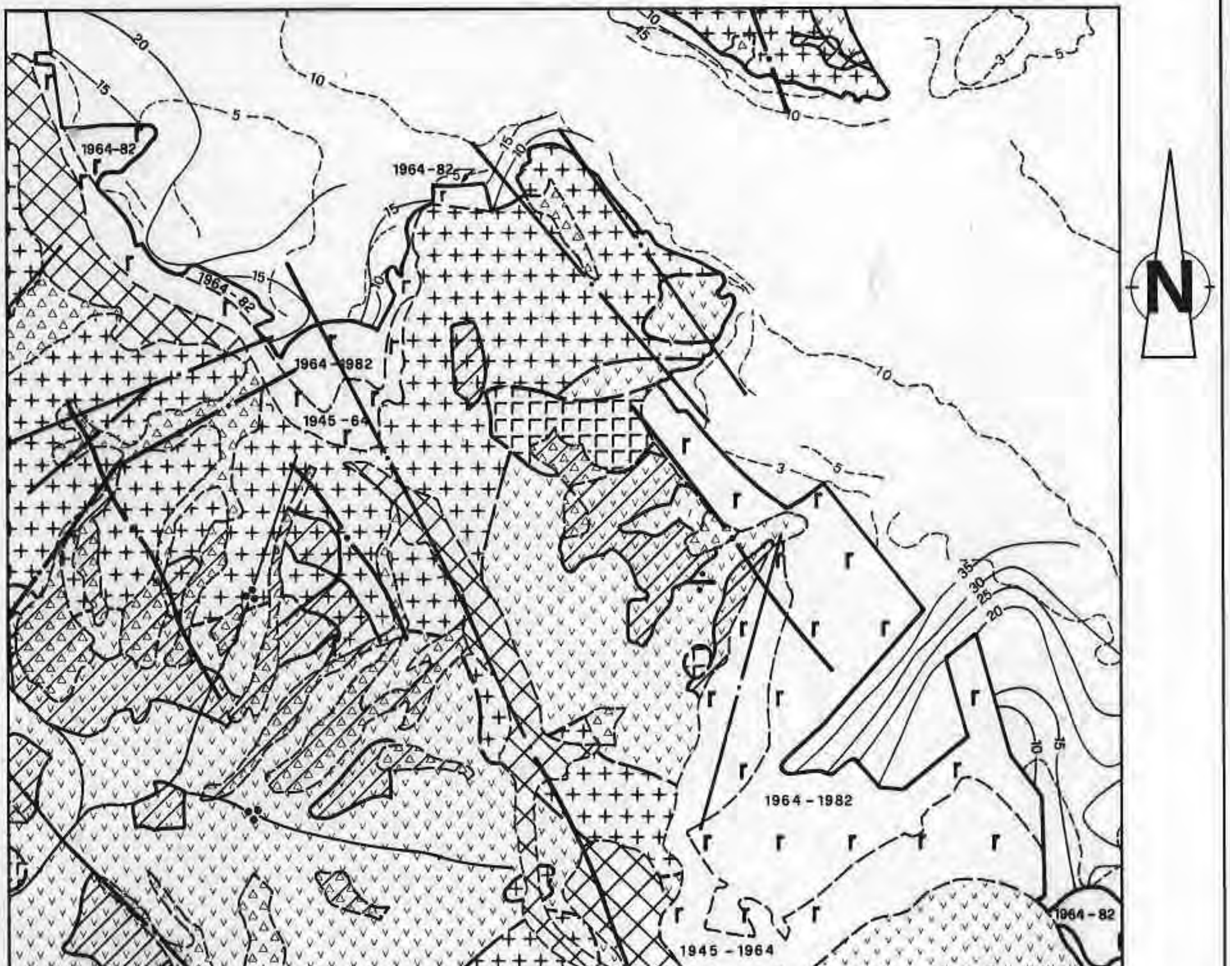
Symbol	Description
	No appreciable erosion
1	Minor sheet erosion
2	Moderate sheet erosion
3	Severe sheet erosion
4	Minor rill erosion
5	Moderate to severe rill erosion
6	Minor gully erosion
7	Moderate to severe gully erosion
	Zones of general instability associated with predominantly insitu terrain
	Zones of general instability associated with predominantly colluvial terrain
	Waterbodies (streams, man-made channels, storage dams)
	Ponds
	Littoral zone (generally subject to tidal action)

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 29)

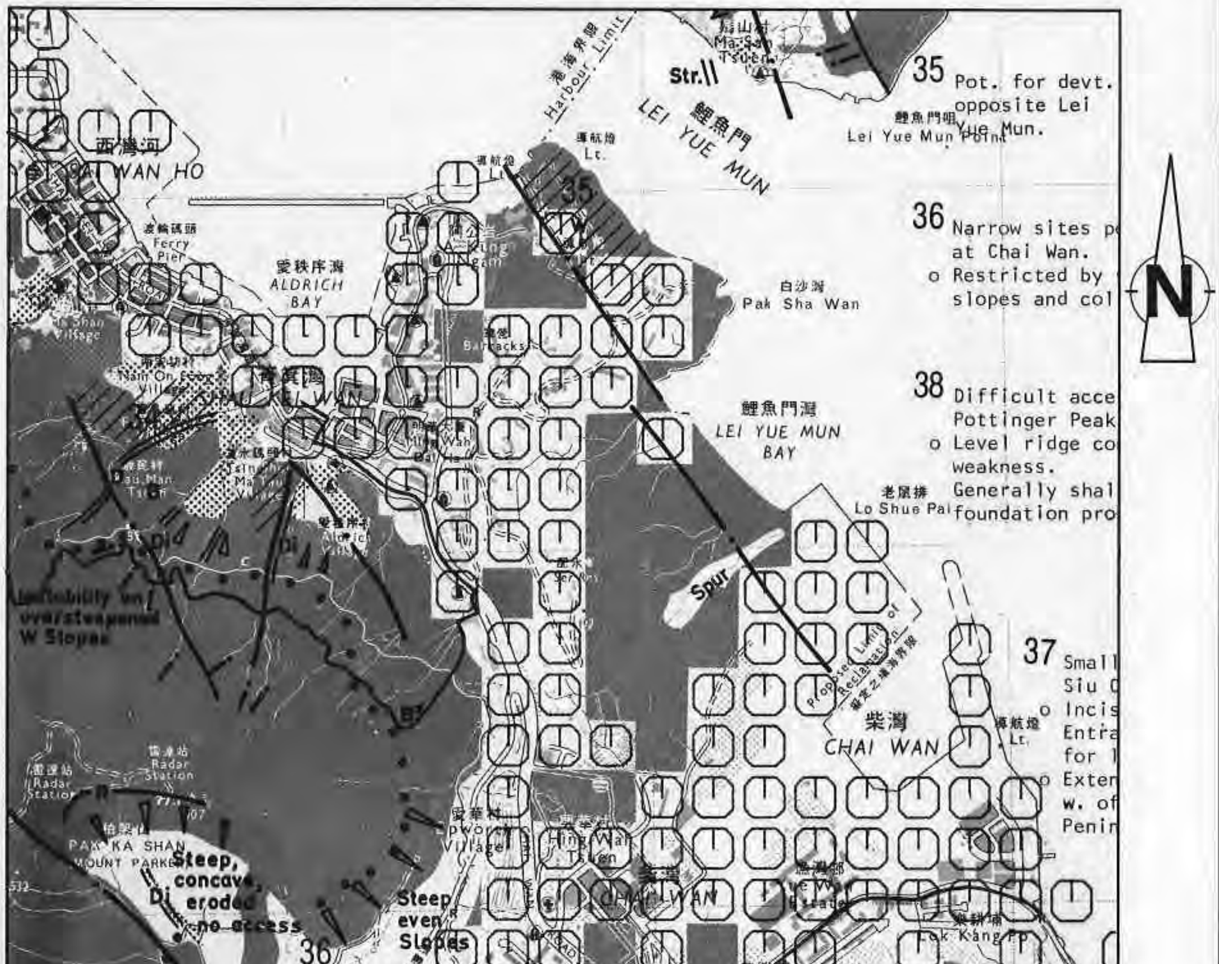
SLOPE GRADIENT	CODE	TERRAIN COMPONENT	CODE	EROSION	CODE
$0 - 5^{o}$	1	Crest or ridge	A	No appreciable erosion	.
$5 - 15^{o}$	2	Sideslope-straight	B	Sheet erosion-minor	1
$15 - 30^{o}$	3	-concave	C	-moderate	2
$30 - 40^{o}$	4	-convex	D	-severe	3
$40 - 60^{o}$	5	Footslope-straight	E	Rill erosion - minor	4
$> 60^{o}$	6	-concave	F	- moderate	5
		-convex	G	- severe	6
		Drainage plain	H	Gully erosion-minor	7
		Floodplain	I	-moderate	8
		Coastal plain	K	-severe	9
		Littoral zone	L	Well-defined landslip	a
		Rock outcrop	M	> 1ha in size	
		Cut - straight	N	General) recent	n
		- concave	O	instability) relict	r
		- convex	P	Coastal instability	w
		Fill-straight	R		
		-concave	S		
		-convex	T		
		General disturbed terrain	V		
		Reclamation	Z		
		Alluvial plain	X		
		Waterbodies - Natural stream	1		
		- Man-made channel	2		
		- Water storage dam	3		
		- Fish pond	4		



Scale 1:20 000	Example of the Physical Constraints Map	Fig. 24



Scale 1:20 000	Example of the Engineering Geology Map	Fig. 25

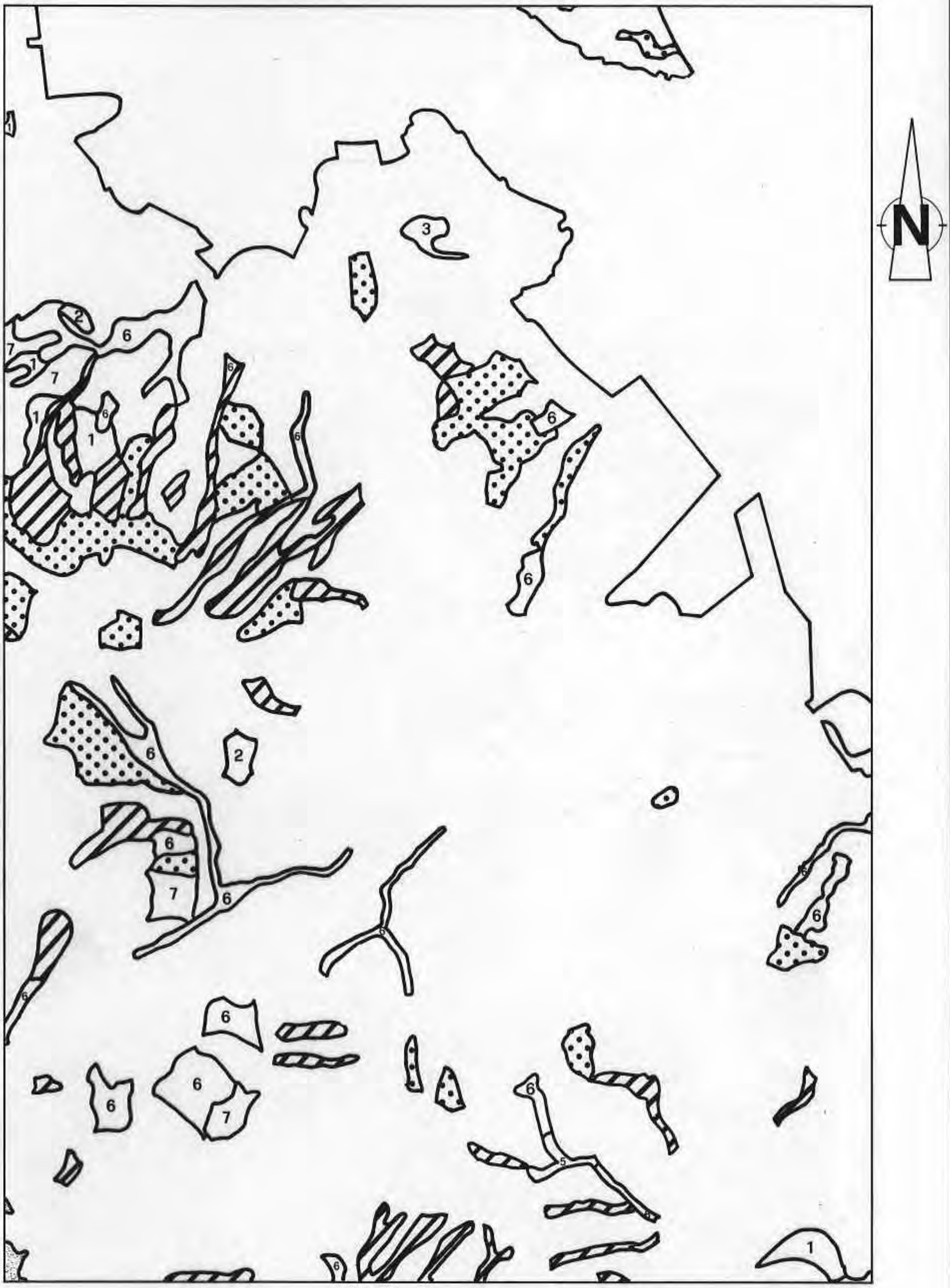


Scale 1:20 000	Example of the Generalised Limitations and Engineering Appraisal Map	Fig. 26

Scale 1:20 000

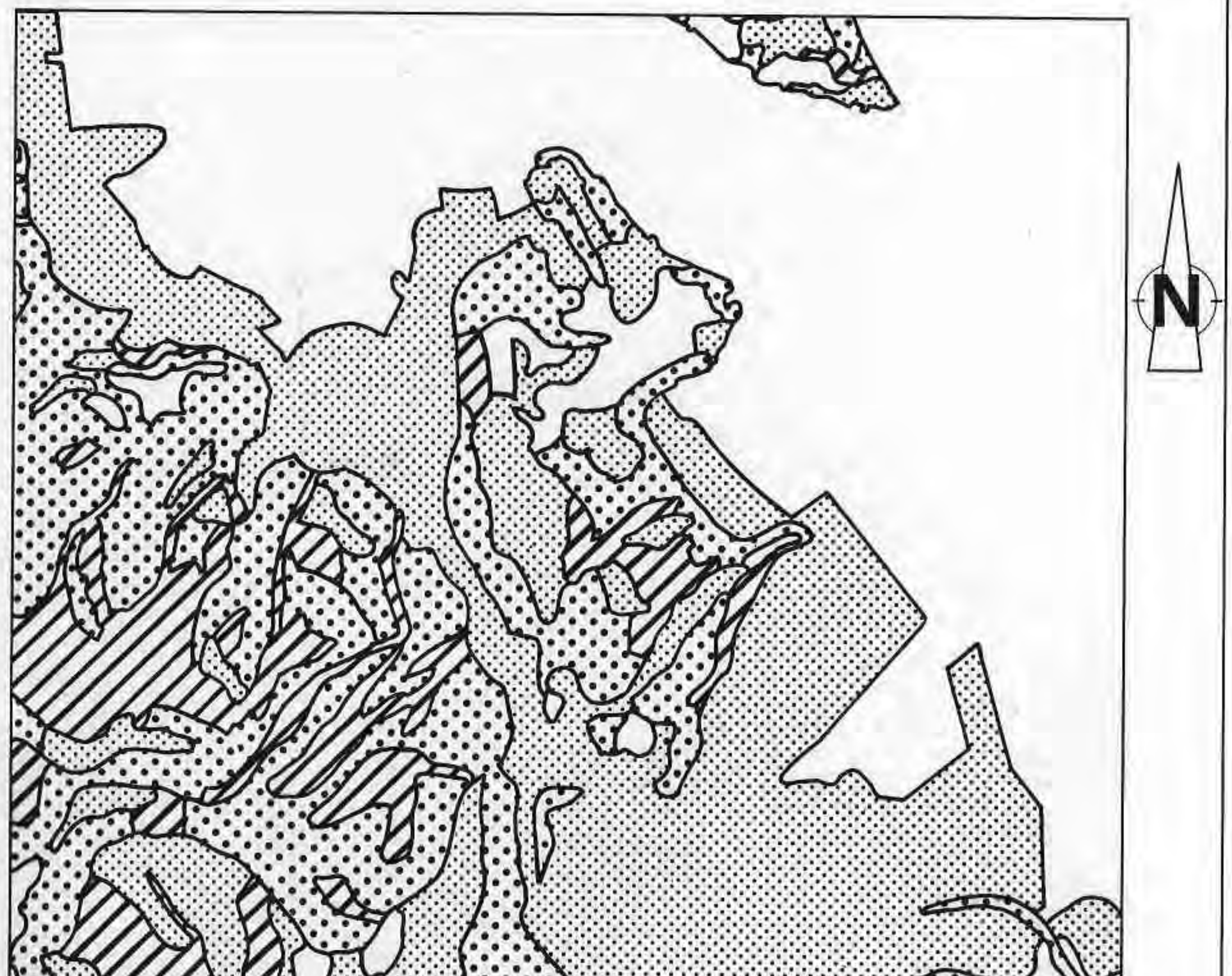
Example of the Landform Map

Fig. 27

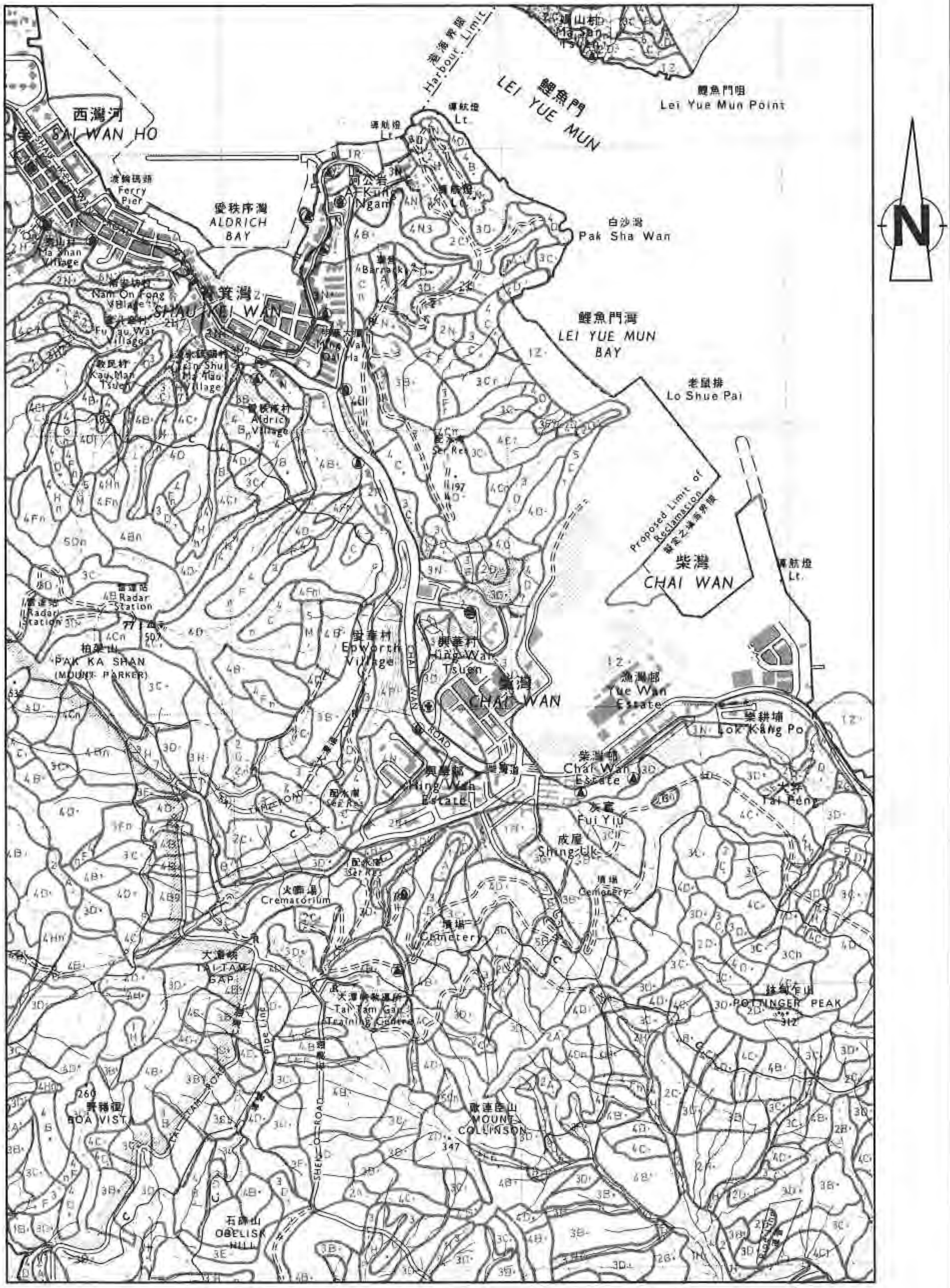


Scale 1:20 000	Example of the Erosion Map	Fig. 28

Scale 1:20 000	Example of the Terrain Classification Map	Fig. 29



Scale 1:20 000	Example of the Geotechnical Land Use Map	Fig. 23



Scale 1:20 000	Fold-out Base Map for Use with Transparencies with Terrain Classification Superimposed	Fig. 30

Plate 1. High Oblique Aerial Photograph Looking East across Victoria Harbour towards Lei Yue Mun. Development on the southern tip of Kowloon Peninsula and the northern coast of Hong Kong Island is visible. (1983/48142)

Plate 2. High Oblique Aerial Photograph Looking East from the Western End of Hong Kong Island. (1983/48137)

Plate 3. High Oblique Aerial Photograph Looking East across Kowloon Peninsula and the Sha Tin Valley. (1983/48139)

Plate 4. High Oblique Aerial Photograph Looking South from the Sha Tin Valley over Kowloon towards Hong Kong. (1979/25851)

Plate 5. High Oblique Aerial Photograph Looking South towards the Eastern End of Victoria Harbour across Happy Valley, Causeway Bay and North Point towards the D'Aguilar Peninsula and Stanley. (1983/48155)

Plate 6. High Oblique Aerial Photograph Looking Northeast across Kowloon towards Sha Tin New Town. (1983/48150)

Plate 7. High Oblique Aerial Photograph Looking South over Magazine Gap towards Aberdeen. (1983/48147)

Plate 8. Oblique Aerial Photograph of the Po Shan Road Landslip Disaster in 1972.

Plate 9. Oblique Aerial Photograph of the Po Shan Road Landslip after Remedial Works.

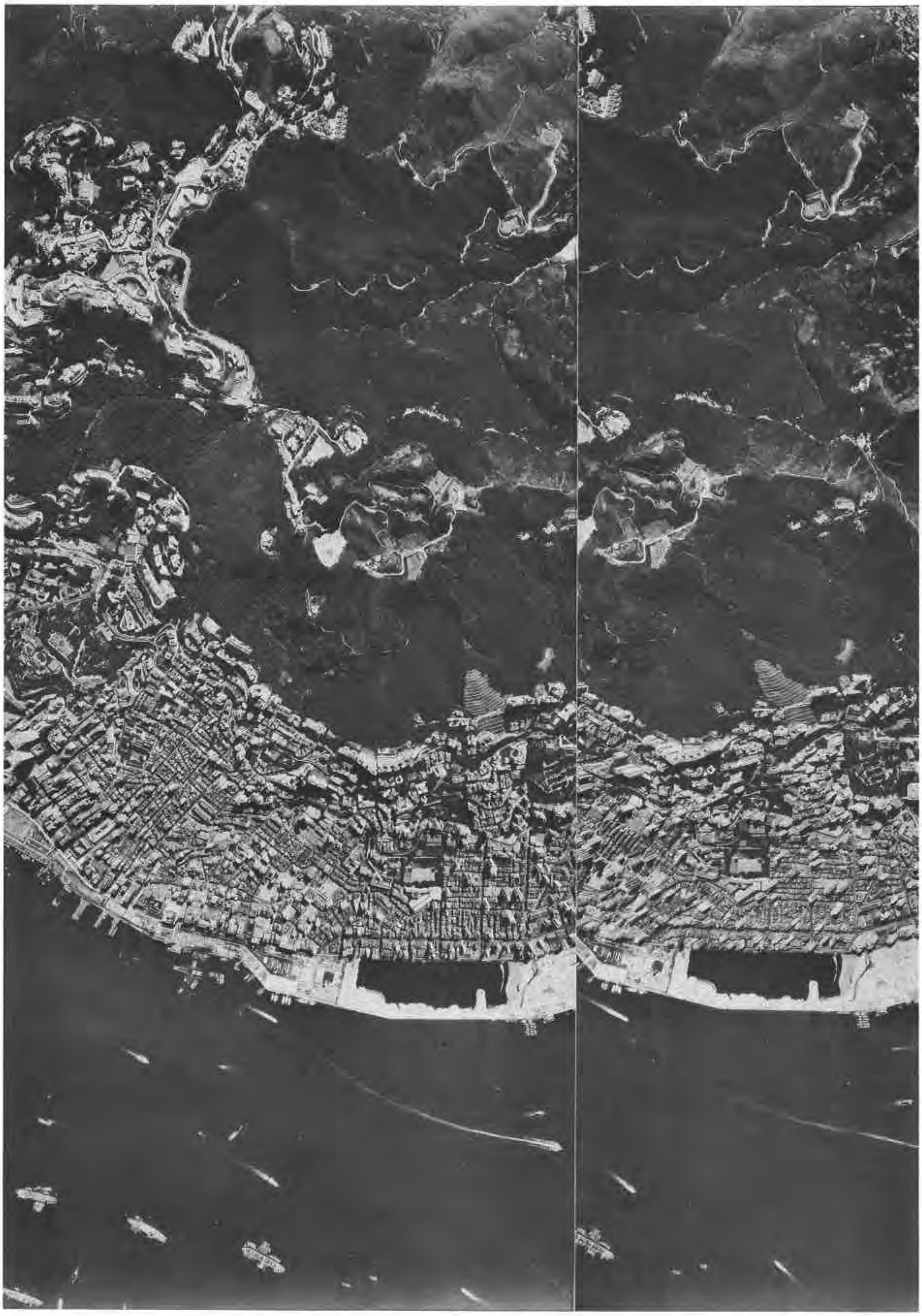


Plate 10. Stereopair of Aerial Photographs of the Mid-levels District of Hong Kong Island Showing Intensive Development and the Po Shan Road Landslip Scar. (1982/44473–74)

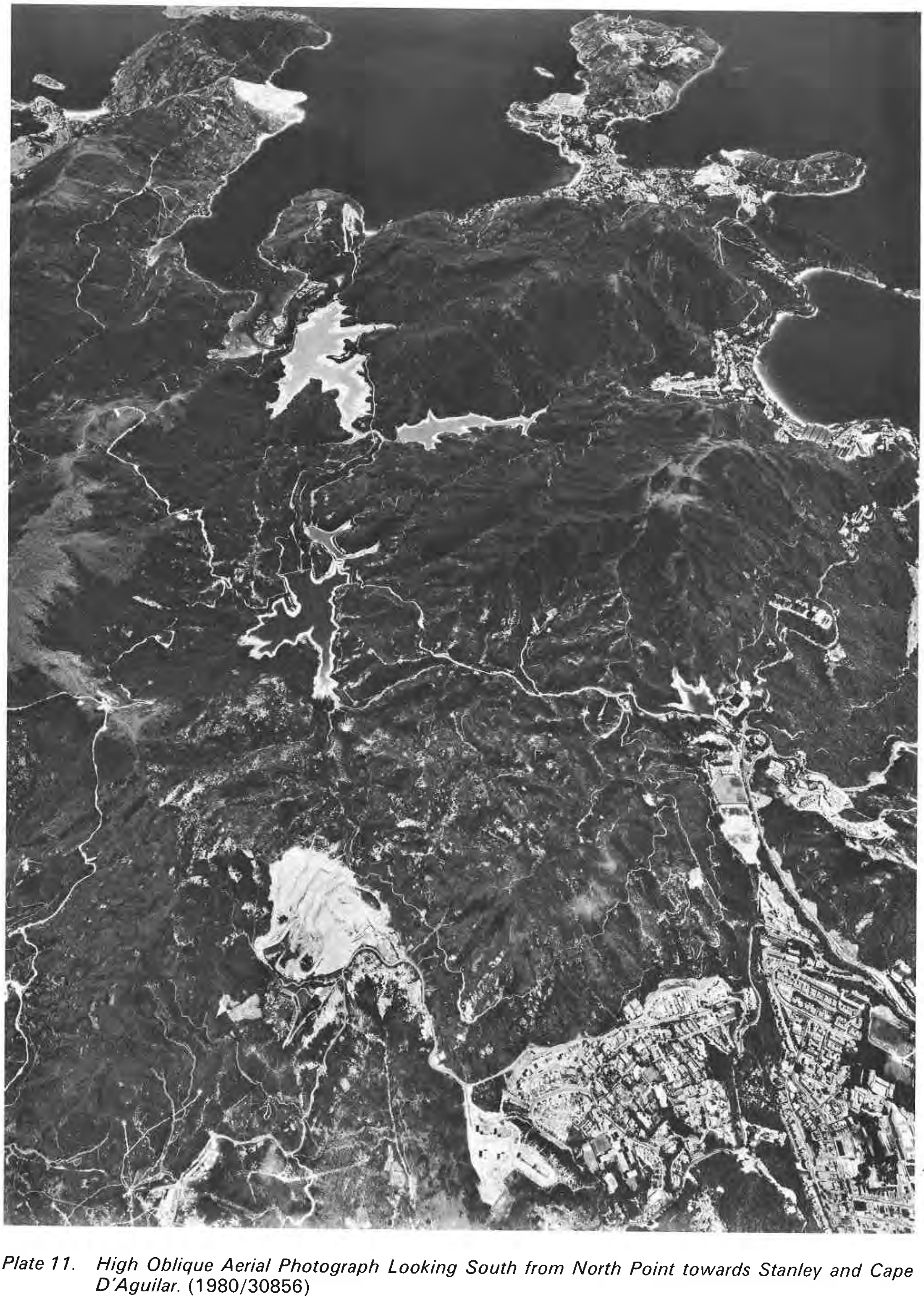


Plate 11. High Oblique Aerial Photograph Looking South from North Point towards Stanley and Cape D'Aguilar. (1980/30856)

Plate 12. Stereopair of Aerial Photographs of the Eastern Side of Hong Kong Island Showing the Inset Area (Figures 22 to 30) *at Chai Wan.* (1982/44467–68)

Plate 13. Aerial Photograph in 1924 Showing Part of the Mid-levels District. (1924/H19/9)

Plate 14. Aerial Photograph in 1949 Showing Part of the Mid-levels District. (1949/81A/128)

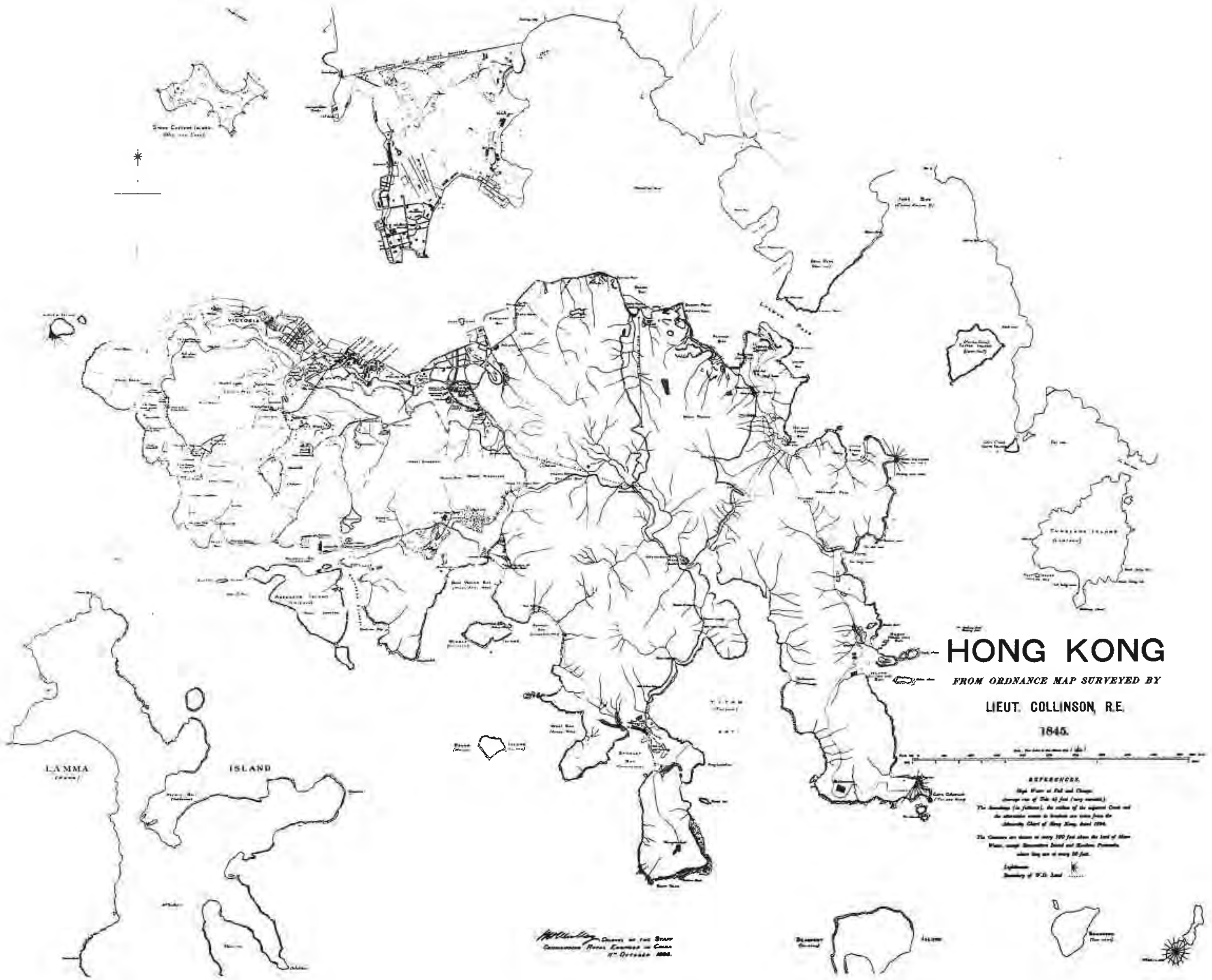


Plate 15. *Reproduction of the Map of Hong Kong and Kowloon Produced by Lt Collinson in 1845.*

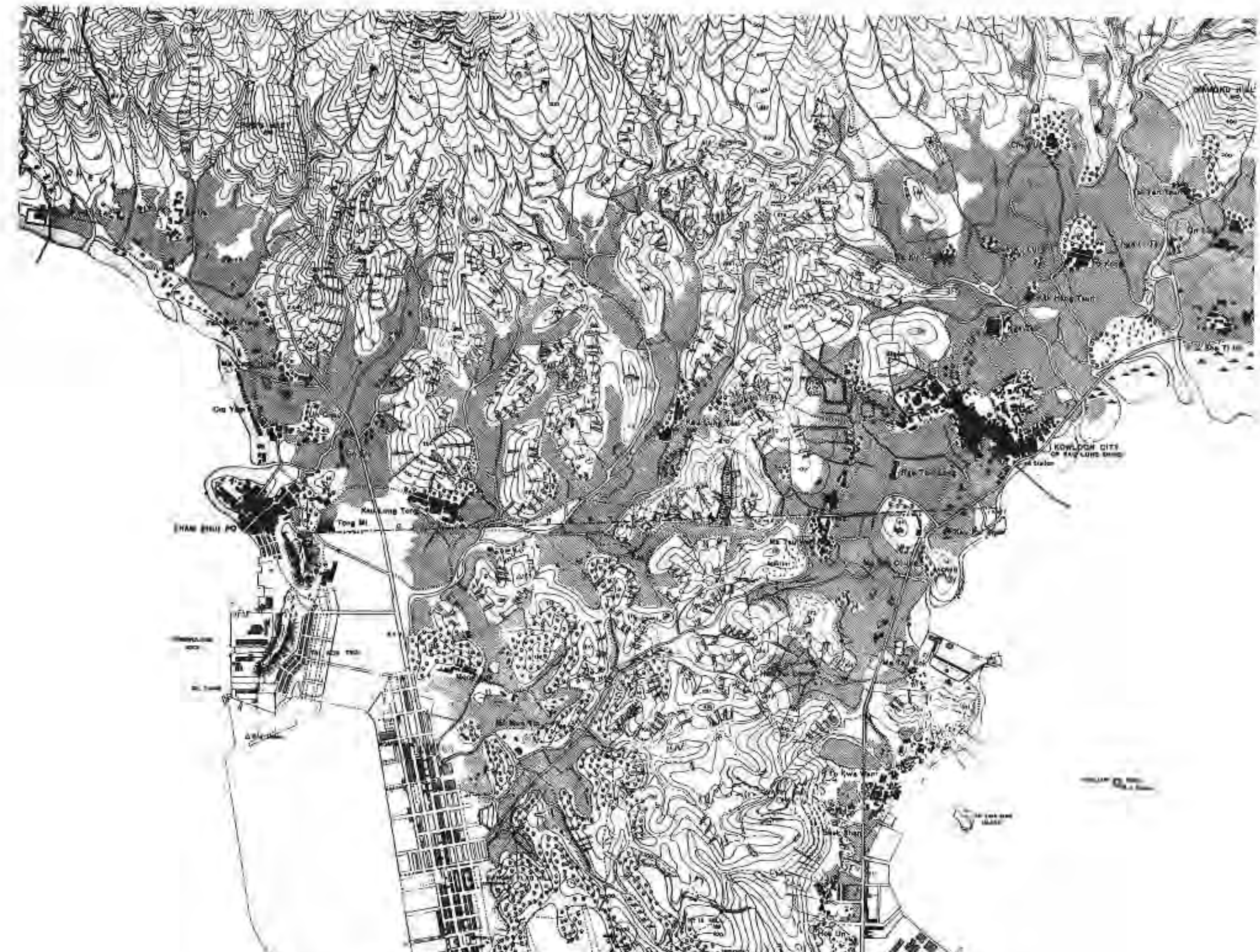


Plate 16. Reproduction of the 1901 Map of Kowloon Peninsula.

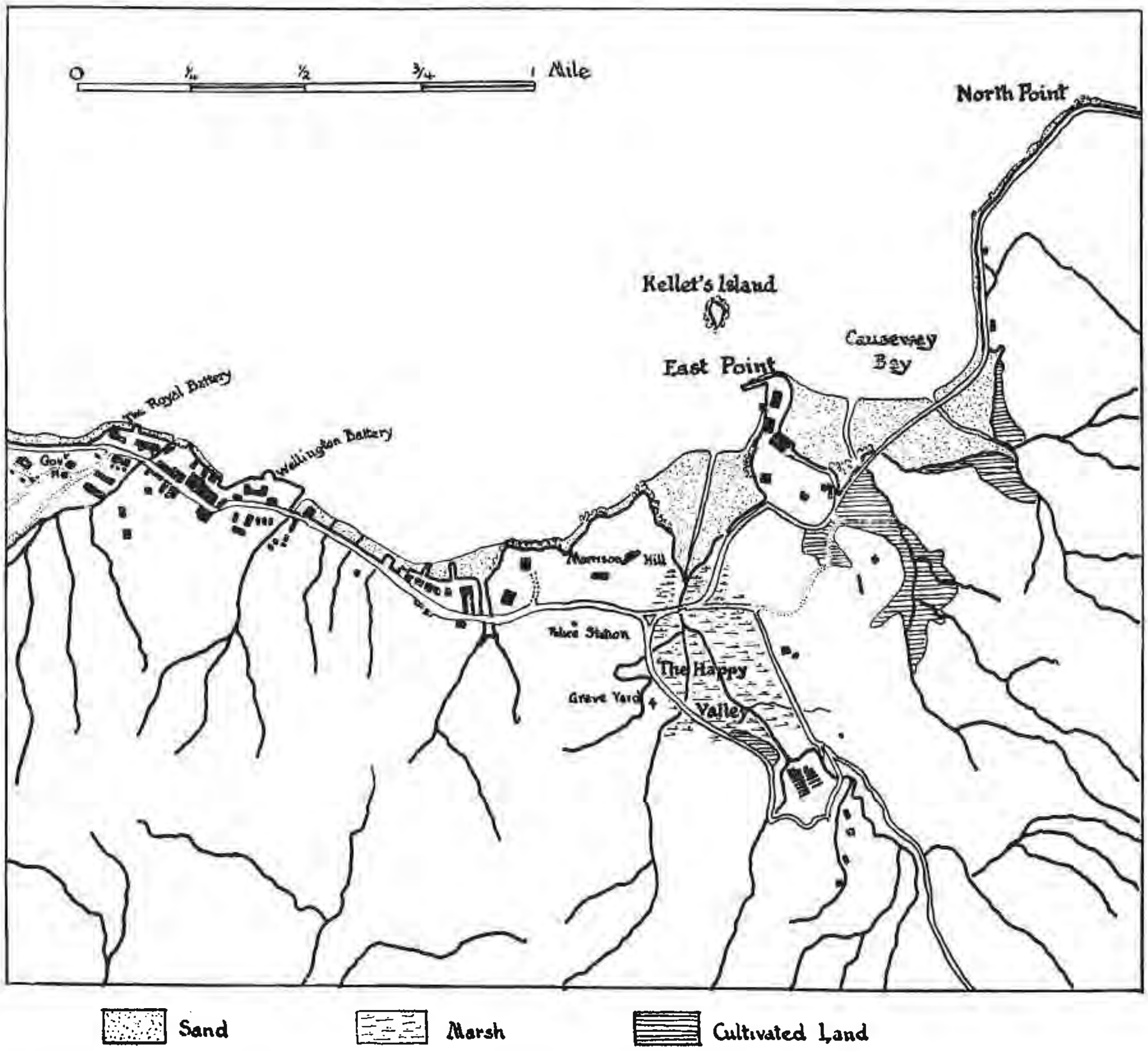


Plate 17. Victoria, Causeway Bay and Happy Valley in 1845 (after Tregear & Berry, 1959).

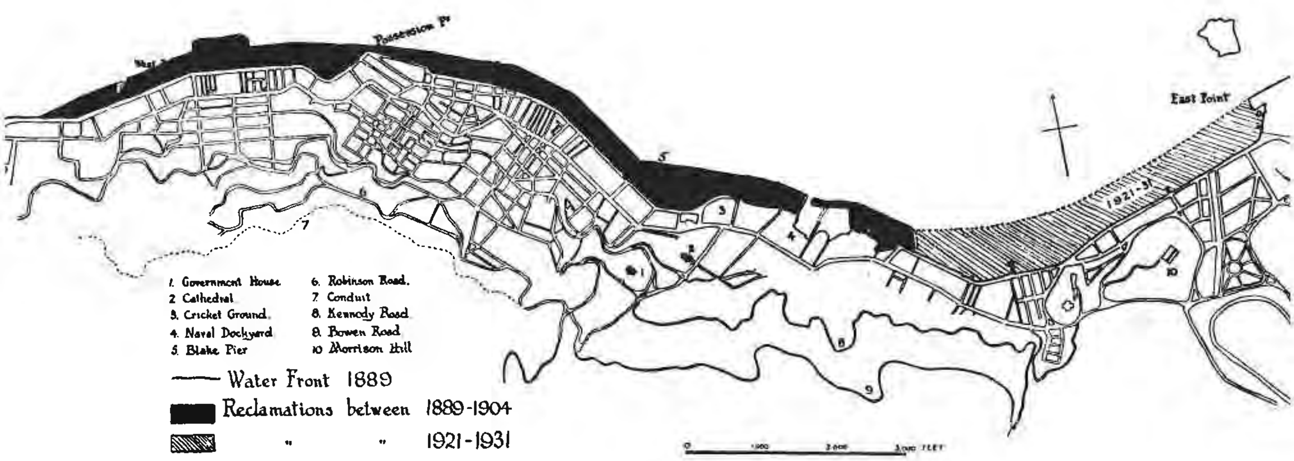


Plate 18. Victoria in 1889 Showing Subsequent Stages of Reclamation (after Tregear & Berry, 1959).

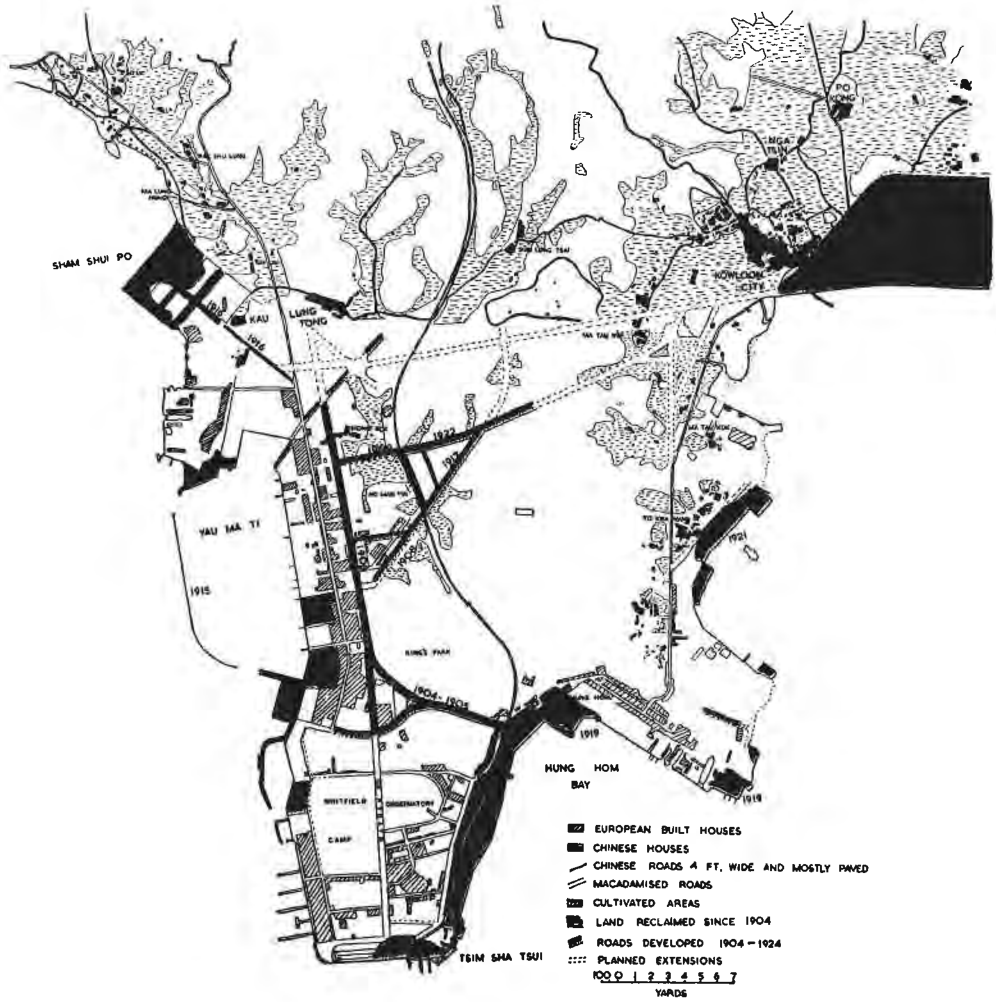


Plate 19. Kowloon Reclamation and Development between 1904 and 1924 (after Tregear & Berry, 1959).

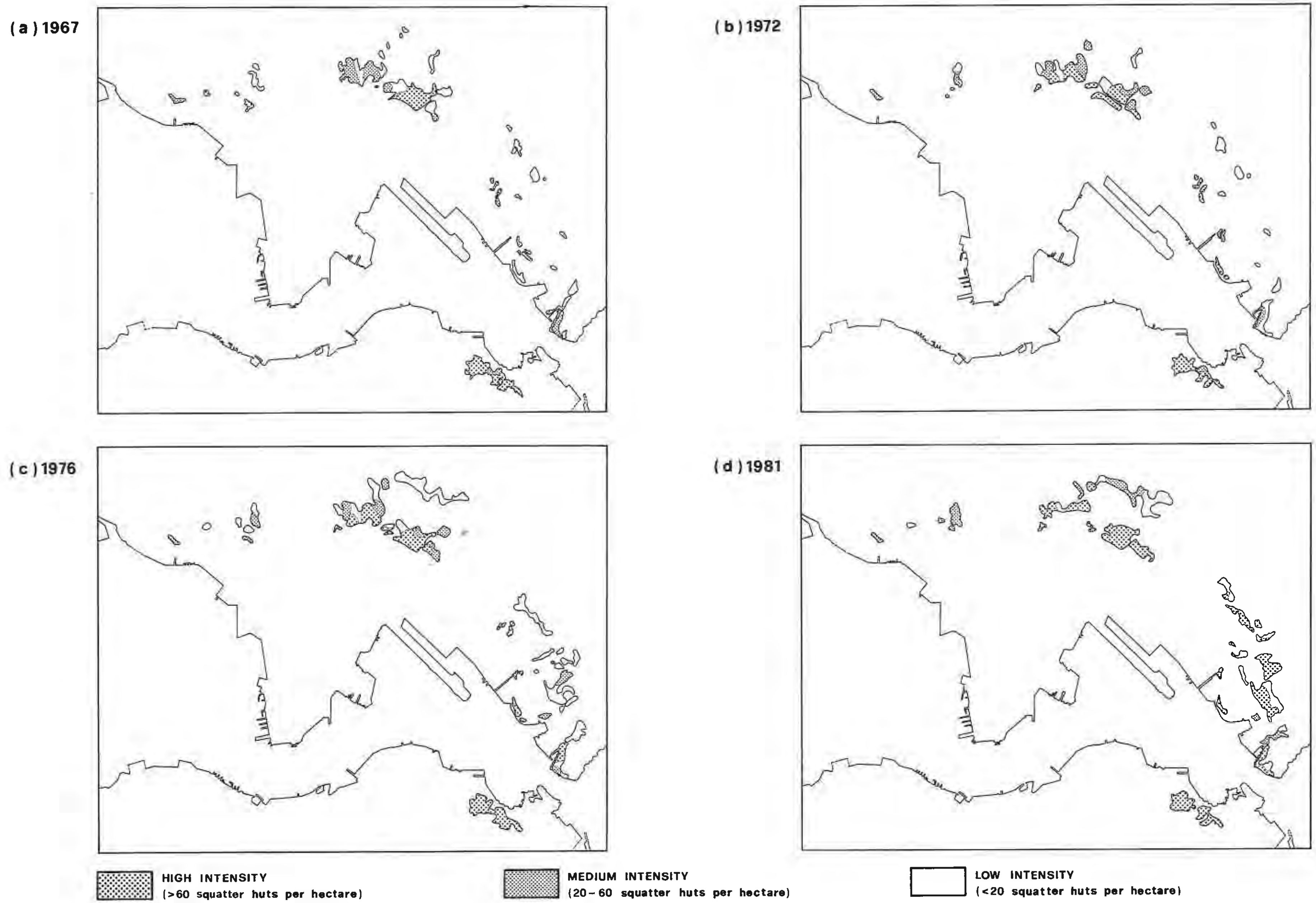


Plate 20. Change in Intensity of Squatters since 1967.

APPENDIX A

SYSTEM OF TERRAIN EVALUATION AND ASSOCIATED TECHNIQUES

List of Figures

List of Tables

APPENDIX A

SYSTEM OF TERRAIN EVALUATION AND ASSOCIATED TECHNIQUES

A.1 Background

Terrain evaluation involves the identification of landform and terrain related features. This technique is used both to identify land use limitations and to assess in broad terms overall land use suitability. It is used as a planning tool and has a major application in the field of geotechnical engineering. In this Geotechnical Area Study, a systematic approach is used to collect, characterise and rationalise the natural variations which occur across the terrain. The structure and presentation of the terrain evaluation system used in this Report is illustrated in Figure 21.

The mechanism of producing a summary or inventory of physical land resources is known as *terrain classification.* This involves the systematic classification of the terrain to form a two-dimensional landform model. The Terrain Classification Map forms:

(*a*) The framework for the evaluation of the basic physical resource data designed specifically for geotechnical engineering purposes.

(*b*) The basis for the user-oriented derivative maps, particularly the Geotechnical Land Use Map (GLUM), the Physical Constraints Map (PCM) and the Generalised Limitations and Engineering Appraisal Map (GLEAM). These maps are designed specifically for planning and land use management purposes and do not require specialist geotechnical interpretation.

A flow-chart depicting the basic technique of data acquisition and map production is shown in Figure A1. The GAS Programme is discussed by Styles & Burnett (1985 a & b), Styles et al (1982, 1984, 1986), Brand et al (1982 a & b), Burnett & Styles (1982) and Burnett et al (1985).

A.2 Technique of Terrain Classification

Terrain classification involves the systematic mapping and delineation of terrain characteristics. The major tool for the collection of these data is *aerial photograph interpretation* (API). This technique enables the stereoscopic examination of the terrain in a uniform and systematic manner. Aerial photograph interpretation greatly aids the collection of physical resource information, the types of data which can be derived from aerial photographs being many and varied. Any object or feature which can be recorded as a photographic image can be identified using API. The techniques are well established in the earth sciences for the delineation of resource data.

The main benefit of API lies in the significant reduction in the amount of field work, with consequent increased speed and uniformity of data acquisition (Styles, 1982). Access into, and evaluation of, difficult terrain can also be simplified using API.

In systematic mapping studies, the fundamental requirements for efficient API and terrain classification are thorough ground control and field reconnaissance.

In this study, three characteristics (attributes) are delineated on the 1:20 000 scale Terrain Classification Map, of which an example is given in Figure 29. The three terrain attributes adopted for the analysis are:

(*a*) Slope gradient.

(*b*) Terrain component and morphology.

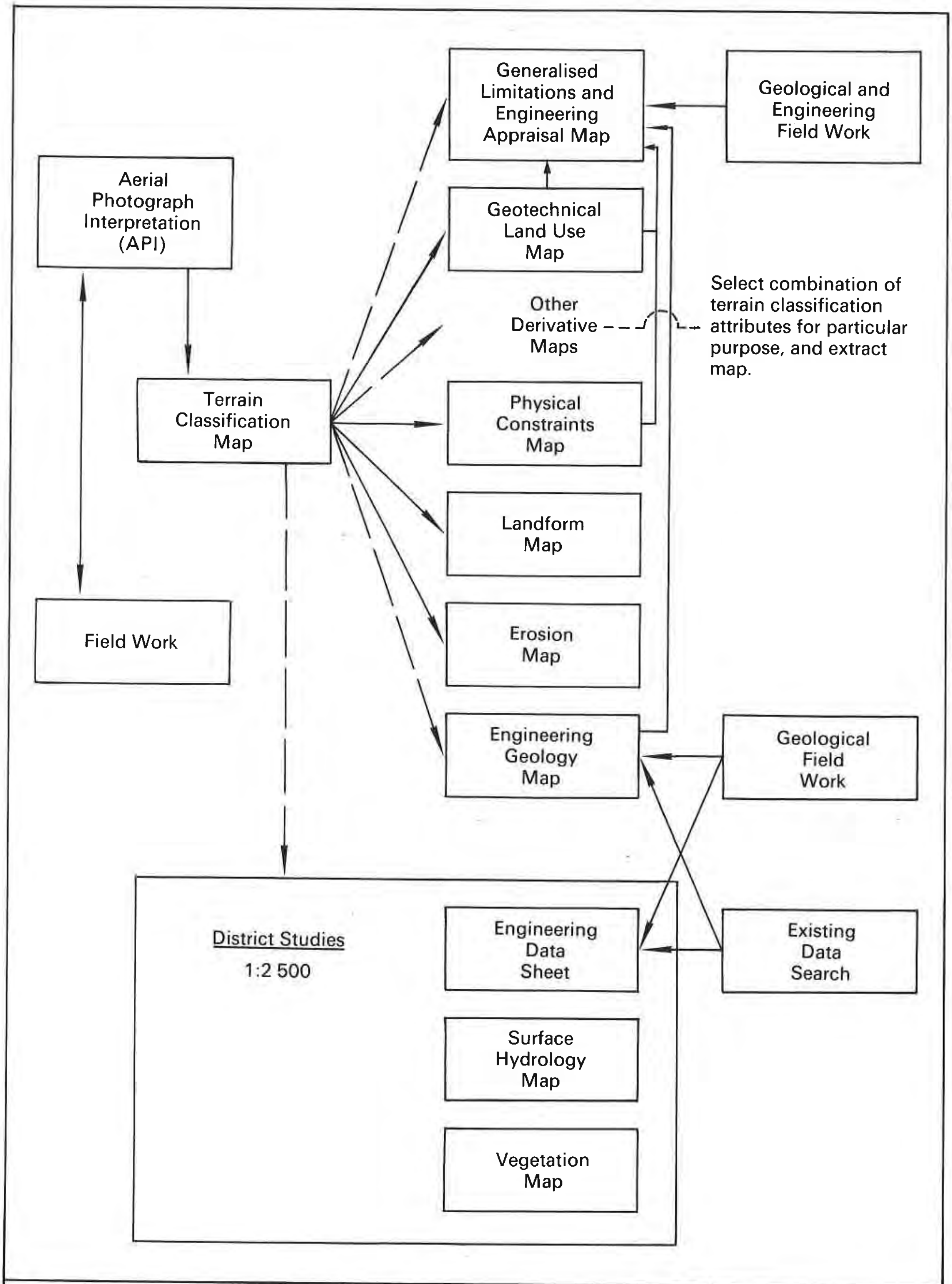
(*c*) Erosion and instability.

The complete terrain classification schedule is presented in Table A1. The information is presented in alphanumeric form, which enables the efficient delineation of multi-attribute map units. This method minimises the possibility of misinterpretation of map units by reducing the number of work sheets and by simplifying the production of derivative maps. As an example, a map unit designated as '2Ga' represents a convex slope, at an angle of 5–15°, composed of colluvium, in a footslope location, which contains a well-defined recent landslip.

The data collected in this study forms part of the Territory-wide programme of systematic terrain classification at a scale of 1:20 000. The physical resource information is integrated into a data bank management system known as the Geotechnical Terrain Classification System (GEOTECS). GEOTECS is discussed briefly in Sections 1.5.9 and A.11.

A.3 Terrain Classification Map

A brief description is given below of the three terrain attributes which are included in the terrain classification (refer to Table A1). The Terrain Classification Map is a work sheet and data base for the collection of land resource data and is not intended for use outside the GCO.



Technique of Data Acquisition and Derivation of Maps

Fig. A1

Table A1 Terrain Classification Attributes

Slope Gradient	*Code*	*Terrain Component*	*Code*	*Erosion and Instability*	*Code*
0– 5°	1	Hillcrest or ridge	A	No appreciable erosion	.
5–15°	2	Sideslope —straight	B	Sheet erosion —minor	1
15–30°	3	—concave	C	—moderate	2
30–40°	4	—convex	D	—severe	3
40–60°	5	Footslope —straight	E	Rill erosion —minor	4
>60°	6	—concave	F	—moderate	5
		—convex	G	—severe	6
		Drainage plain	H	Gully erosion —minor	7
		Floodplain	I	—moderate	8
		Coastal plain	K	—severe	9
		Littoral zone	L	Well-defined recent landslip, >1 ha in size	a
		Rock outcrop	M	Development of general instability —recent	n
		Cut —straight	N		
		—concave	O	Development of general instability —relict	r
		—convex	P	Coastal instability	w
		Fill —straight	R		
		—concave	S		
		—convex	T		
		General disturbed terrain	V		
		Alluvial plain	X		
		Reclamation	Z		
		Water bodies:			
		Natural stream	1		
		Man-made channel	2		
		Water storage dam	3		
		Fish pond	4		

Notes: 1. In this classification, all footslope and drainage plain terrain corresponds to colluvium (terrain components E, F, G, H).
2. Disturbed colluvial terrain is indicated by underlining the landform code (terrain components N, O, P, R, S, T, V).
3. Disturbed alluvial terrain is indicated by double underlining the landform code (terrain components N, O, P, R, S, T, V).

A.3.1 *Slope Gradient*

Slope gradient is classified in degrees and is divided into six groups according to the schedule defined in Table A1. The slope angle of each terrain unit is measured along the direction of greatest declivity. This direction, which is normal to the contour, enables the identification of the most limiting slope angle.

A.3.2 *Terrain Component and Morphology*

The terrain component attribute describes the physical appearance of the slope. The terms used are essentially morphological descriptions and do not necessarily infer the geomorphological processes which are occurring on a slope. The terrain definitions adopted in this study are presented in the Glossary of Terms in Appendix E.

There are the following 13 major terrain component classes:

(*a*) Hillcrest (Code A).

(*b*) Sideslope (Codes B, C, D).

(*c*) Footslope (Codes E, F, G).

(*d*) Drainage plain (Code H).

(*e*) Alluvial plain (Code X).

(*f*) Floodplain (Code I).

(*g*) Coastal plain (Code K).

(*h*) Littoral zone (Code L).

(*i*) Cliff or rock outcrop (Code M).

(*j*) Cut slope (Codes N, O, P).

(*k*) Fill slope (Codes R, S, T).

(*l*) General disturbed terrain (Code V).

(*m*) Reclamation (Code Z).

In this study, all the footslope and drainage plain terrain consists of colluvium, and all the flood and alluvial plains consist of alluvium, whereas all the sideslope terrain consists of insitu geological materials. Other colluvial and alluvial subclasses occur in the cut slope, fill slope and general disturbed terrain components (see Table A1).

The terrain component classes also indicate the general shape of the slope profile. The basic morphological classes are straight, concave and convex.

A.3.3 *Erosion and Instability*

These attributes describe the surface condition of the terrain on the basis of the major forms of terrain denudation. Slope failure and slope instability are indicated under this attribute. The five major erosion classes are:

(*a*) No appreciable erosion. (Code .).

(*b*) Sheet erosion (Codes 1, 2, 3) is divided into three subclasses. Where vegetation is absent, the soil surface is subject to sheet erosion. Minor to severe sheet erosion appears as varying tones in aerial photographs. Severe sheeting appears as a highly reflectant white tone, which indicates the absence of almost all ground cover. Sheet erosion is classified in terms of the approximate proportion of bare ground. This type of erosion usually precedes rill and gully erosion.

(*c*) Rill erosion (Codes 4, 5, 6) is a form of denudation which occurs typically on exposed cut and fill slope batters. It is characterised by subparallel drainage rivulets which produce a typically striated appearance and result in significant soil loss.

(*d*) Gully erosion (Codes 7, 8, 9) often results in severe disruption of the terrain surface. Gully erosion produces significant hydrological problems due to infiltration and concentration of water flow, and may lead to slope failure. This class is divided into the three subclasses: minor, moderate and severe.

(*e*) Instability (Codes a, n, r, w) is divided into subclasses which relate to well-defined landslips and zones of general instability. The latter term relates to colluvial and insitu terrain where many failures and other evidence of instability occur, but due to their small size, it is not possible to delineate them as discrete map units on a 1:20 000 scale map.

A.4 Landform Map

The Landform Map provides a simple model of the broad geomorphological classes and delineates the extent and distribution of the major terrain units within the study area. The Landform Map (example in Figure 27) extracts from the Terrain Classification Map the significant terrain component and slope gradient classes. This information is presented as a separate map. In this form it is easier to appreciate, understand and interpret the pattern of landform distribution.

The Landform Map uses a numeric code to classify the study area into parcels or zones of particular landform character. The broad terrain features are:

(*a*) Hillcrest or ridge.

(*b*) Sideslope (by definition consisting of insitu materials).

(*c*) Footslope (by definition consisting of colluvial materials).

(*d*) Drainage plains (colluvial areas subject to overland flow and regular inundation often associated with unusual groundwater regimes).

(*e*) Alluvial plain (including raised terraces).

(*f*) Floodplain (those portions of the alluvial plains which are subject to overland flow and regular inundation and possibly unusual groundwater regimes).

(*g*) Disturbed cut terrain (by definition man-made cuts, e.g. construction sites, quarries, borrow areas, utility corridors).

(*h*) Disturbed fill terrain (by definition man-made fills, e.g. construction sites, fill platforms).

(*i*) Cliff and rock outcrop.

It should be noted that areas of alluvium are indicated with a light stipple on the map. Floodplain within the alluvium is shown with a diagonal hatch.

In addition to these broad landform units, the map also shows slope gradient information. This is incorporated into the landform classes so that it is possible to establish the average slope angle of the terrain.

Finally, the Landform Map shows by means of various symbols: reclamation, waterbodies (i.e. streams, channels and dams), ponds and the littoral zone.

A.5 Erosion Map

The Erosion Map is derived from the Terrain Classification Map and delineates the major forms of erosion within Hong Kong and Kowloon. The pattern of erosion can be related to the weathering characteristics of the geological units and to land use (Hansen & Nash, 1984). An example of this type of map is given in Figure 28.

The map is important because it presents the general pattern of instability associated with the colluvial and insitu terrain. The following features are also shown:

(*a*) No appreciable erosion (Code .).

(*b*) Minor sheet erosion (Code 1).

(*c*) Moderate sheet erosion (Code 2).

(*d*) Severe sheet erosion (Code 3).

(*e*) Minor rill erosion (Code 4).

(*f*) Moderate to severe rill erosion (Code 5).

(*g*) Minor gully erosion (Code 6).

(*h*) Moderate to severe gully erosion (Code 7).

(*i*) General instability associated with insitu terrain (Codes a, n, r, w).

(*j*) General instability associated with colluvial terrain (Codes a, n. r, w).

In common with all the other maps in the series, the areas of waterbody, pond and littoral zone are also shown.

The Erosion Map provides a simple reference, not only to those areas showing general instability in the form of landslips, but also to the other forms of denudation.

A.6 Physical Constraints Map

The Physical Constraints Map (PCM) presents the major physical constraints which will influence development in the area. It is extracted from the Terrain Classification Map and is designed specifically to supplement the GLUM. An example is presented in Figure 24.

This is an interpretative map which synthesizes the natural physical constraints for land use management, planning and engineering purposes. The GLUM is a basic assessment of the geotechnical limitations associated with the terrain, whereas the Physical Constraints Map delineates the type of constraint. Obviously, areas that remain unclassified (blank) on the PCM are most suitable for development from a geotechnical point of view. These areas will correspond to Class I and Class II in the GLUM system.

The major constraints which are shown on the map are:

(*a*) Zones of general instability associated with predominantly colluvial terrain.

(*b*) Zones of general instability associated with predominantly insitu terrain.

(*c*) Colluvium.

(*d*) Zones of colluvium which are subject to overland flow and periodic inundation (delineated as drainage plain on the Landform Map).

(*e*) Slopes on insitu terrain which are generally steeper than 30° (other than those delineated as colluvium or unstable).

(*f*) Floodplain (subject to overland flow and regular inundation and delineated as floodplain on the Landform Map).

(*g*) Disturbed terrain (extensive cut and fill batters which generally exceecd 30°).

(*h*) Major waterbodies.

(*i*) Moderate and severe gully erosion.

(*j*) Instability on disturbed terrain.

A.7 Geotechnical Land Use Map

The Geotechnical Land Use Map (GLUM) represents a systematic method of interpreting and synthesizing terrain classification and geotechnical data into a format suitable for land management purposes (Table A2). The GLUM is therefore suitable *only for planning purposes.* Further limitations on the use of the GLUM are presented later in this section and must not be overlooked.

Table A2 GLUM Classification System

Characteristics of GLUM Classes	Class I	Class II	Subclass IIS	Class III	Class IV
Geotechnical Limitations	Low	Moderate		High	Extreme
Suitability for Development	High	Moderate	Moderate – Low	Low	Probably Unsuitable
Engineering Costs for Development	Low	Normal	Normal – High	High	Very High
Intensity of Site Investigation Required	Normal	Normal		Intensive	Very Intensive
Typical terrain characteristics (Some, but not necessarily all of the stated characteristics will occur in the respective Class)	Gentle slopes and insitu soils. Minor erosion on flatter slopes. Undisturbed terrain (minor cut & fill only).	Flat to moderate slopes. Colluvial soils showing evidence of minor erosion. Insitu soils which may be eroded. Reclamation. Rock outcrops. Poor drainage. Cut & fill slopes of low height.	Floodplain subject to periodic flooding and inundation.	Steep slopes. Colluvial & insitu soils showing evidence of severe erosion. Poor drainage. Cut & fill slopes of moderate height.	Combination of characteristics such as steep to very steep slopes, general instability on colluvium, severe erosion, poor drainage, high cut & fill slopes.

Note: This classification system is intended as a guide to planners and is not to be used for a detailed geotechnical appraisal of individual sites.

The GLUM is derived from the Terrain Classification Map. The slope, terrain component and erosion attributes described in Table A1 are considered in evaluating the general level of geotechnical limitation. A GLUM class is assigned to each combination of attributes to represent the limitation which is likely to be imposed on development. An appropriate GLUM class can therefore be allocated to each landform unit identified during the terrain classification of the study area. These are represented on the GLUM, an example of which is presented in Figure 23. There are four GLUM Classes.

(i) *Class I—Low Geotechnical Limitations*

These areas are characterised by a low level of geotechnical limitation, and consequently have the highest suitability for development. Costs of site formation, foundation works and drainage works are expected to be low. Only normal geotechnical investigations will probably be required and investigation costs are expected to be low.

(ii) *Class II—Moderate Geotechnical Limitations*

These areas are characterised by moderate geotechnical limitations, and consequently are of moderate suitability for development, although the terrain conditions are more complex than in Class I. Costs of site formation, foundation works and drainage works will not be high. It is probable that normal geotechnical investigations only will be required, and investigation costs are not expected to be high.

Class IIS is a subclass defined specifically for the 1:20 000 scale studies. These areas are likely to be affected by periodic inundation and flooding. Although this factor alone will not significantly affect the geotechnical constraints associated with this flat, low lying terrain, the general suitability for development can be considered moderate to low.

(iii) *Class III—High Geotechnical Limitations*

These areas are characterised by high geotechnical limitations, and consequently are of low suitability for development. Costs of site formation, foundation works and drainage works can be expected to be high. Intensive geotechnical investigations will be necessary, and investigation costs will be high.

(iv) *Class IV—Extreme Geotechnical Limitations*

These areas are characterised by extreme geotechnical limitations, and consequently development should be avoided if possible. In normal circumstances these areas would not be considered for development. If development of these areas is unavoidable, the costs of site formation, foundation works and drainage works will be very high. It is unlikely that the threat to development from natural hazards can be completely eliminated. Very intensive geotechnical investigations will be necessary both at the planning stage and prior to detailed design, and investigation costs will be extremely high.

The above descriptions are summarized in Table A2. Typical terrain characteristics which may be expected in each class are also given in the table, but it should be noted that not all of these characteristics need necessarily be present in any one particular map unit.

The following *important aspects* of the GLUM must be noted:

(*a*) The GLUM contains geotechnical information adequate *only for planning purposes.*

(*b*) The descriptions of the four GLUM classes should be taken *only as a guide* to the general level of geotechnical limitations associated with the terrain and consequent suitability for development.

(*c*) The GLUM class system assists in the assessment of the suitability of land for development from a geotechnical point of view. 'Development' is taken to mean high density residential, industrial, institutional and community uses. Further assistance in identifying larger areas with development potential is available within the GLEAM.

(*d*) The GLUM should not be used for engineering judgement of individual sites, nor does it obviate the need for adequate site investigation prior to the development of a particular parcel of land. When used in conjunction with the Engineering Geology Map and Physical Constraints Map, however, the GLUM will help to identify the major constraints which are present or are likely to occur on a particular parcel of land. The GLEAM will assist in evaluating the impact of local geotechnical constraints on those areas with development potential.

(*e*) The GLUM classes provide *only an indication* of the extent and relative costs of the geotechnical investigations required for the development of a parcel of land. The particular local ground conditions, the nature of the intended development and existing knowledge of the site and its surroundings will govern the final extent and cost of investigation.

(*f*) A GLUM class is assigned to a parcel of land directly from the terrain classification. In assigning the GLUM class, *no consideration is given to the nature of adjoining parcels of land.* In using the GLUM, therefore, it must be remembered that a parcel of land will be affected by the classes of land along its boundaries. Again, reference to the PCM and EGM will assist in determining more general conditions.

(*g*) The GLUM system is based essentially on the classification of the terrain by its *surface* features. Therefore, the GLUM does not provide reliable information about the deep subsurface geology or the subsurface hydrology, and detailed site investigation at a particular location might reveal subsurface conditions not predicted by the GLUM.

(*h*) Conservative GLUM classes are assigned to fill areas.

(*i*) In this Report, the GLUM is designed as a broadscale planning tool for use at a scale of 1:20 000. It should only be used to assess the *general level* of geotechnical limitations associated with a relatively large parcel of land rather than with an individual site. As a general rule, it should not be used to evaluate parcels of land smaller than 3 ha in size. An area designated a particular class at 1:20 000 scale (Regional Study) may consist, in part, of very small areas of other classes if examined at 1:2 500 scale (District Study). This is due to the size of the terrain classification map units at 1:20 000 scale as opposed to 1:2 500. At the latter scale, the average area of each map unit is approximately 0.7 ha, whereas the average area of each map unit at 1:20 000 scale is approximately 2 ha. Therefore, *the GLUM presented in a Regional Study must never be interpreted, reproduced or enlarged to scales larger than 1:20 000.* Failure to heed this warning will result in serious misinterpretation of the GLUM.

In the derivation of GLUM class, the pre-existing slope angles of the terrain are inferred where the natural slope profile is destroyed by cut and fill operations. The pre-existing slopes are determined from aerial photography of the site (if available) taken before disturbance, or by extrapolation from undisturbed slopes above, below or adjacent to the disturbed area. However, where quarry or construction operations increase the gradient of the constructed slope, the new slope gradient is recorded. Modification of the natural terrain may increase the geotechnical limitations, with a resultant increase in the costs associated with its use.

In the terrain classification mapping of Hong Kong and Kowloon, an *exception* to the above criterion occurs for the part of Kowloon Peninsula, south of Lung Cheung and Ching Cheung Roads. The gradient of the constructed slope is mapped, instead of the pre-existing slope. Much of the construction on the southern part of Kowloon Peninsula pre-dates World War II, whilst areas immediately south of Lung Cheung and Ching Cheung Roads were developed soon after World II. Aerial photograph coverage for these areas either does not exist, is insufficient, or is of a scale which is not suitable for the interpretation of the pre-existing slope profiles. Only a few sites remain undisturbed, making it impossible to infer the pre-existing slopes from adjacent areas.

A.8 Engineering Geology Map

A.8.1 *Background*

The compilation and assessment of data for the Engineering Geology Map is undertaken during and after the terrain classification phase of a Geotechnical Area Study.

The comments made in this Report with regard to the engineering geology of Hong Kong and Kowloon are intended for use at a planning level and are based on the following:

(*a*) Extraction of selected information from the API source data; this was supplemented by limited field reconnaissance.

(*b*) Records of a limited amount of reliable site investigation data; this assisted the establishment of a three-dimensional appreciation of the geology and hydrology of the study area.

A.8.2 *Production of the Engineering Geology Map*

The Engineering Geology Map was compiled from selected information from the Terrain Classification Map, to which was added various existing data (Appendix C) and information collected during the field reconnaissance. The object of the Engineering Geology Map is to present on one map the bedrock and superficial geology of the area.

The Engineering Geology Map for the Hong Kong and Kowloon GASP is contained in the Map Folder accompanying this Report. Note that this map will be superseded during the remapping of the geology of the Territory (See Section 1.1).

The data selected for inclusion on the Engineering Geology Map in this Report are:

(*a*) Boundaries of major lithologies and superficial deposits.

(*b*) Major photolineaments.

(*c*) Major topographic features.

(*d*) Isopachs of submarine superficial deposits.

(*e*) Boundaries of major catchments.

(*f*) Zones of reclamation.

The catchment boundaries are indicated on the Engineering Geology Map according to the method suggested by Strahler (1952). By this system, all streams without tributaries are designated 'first order' streams. When two first order streams join, the resulting stream rises to second order status, and two second order streams, on joining, produce a third order stream. Thus, a unit increase in order takes place downstream of the junction of two streams with the same order. A stream of higher order has a larger number of tributaries, a higher discharge, and usually a broader valley than a stream of lower order.

A.8.3 *Colluvium Classification System*

A simple classification system is used to aid in the delineation and the description of colluvial deposits. This classification system is a simplified form of the system which was originally used in the colluvium mapping project undertaken on a Territory-wide basis by the GCO in 1979. The system is based on the origin of the major (usually the cobble and boulder) component of the colluvium and is divided into materials which are:

(*a*) Essentially volcanic derived.

(*b*) Essentially granite derived.

(*c*) Essentially metasediment derived.

(*d*) Mixed origin.

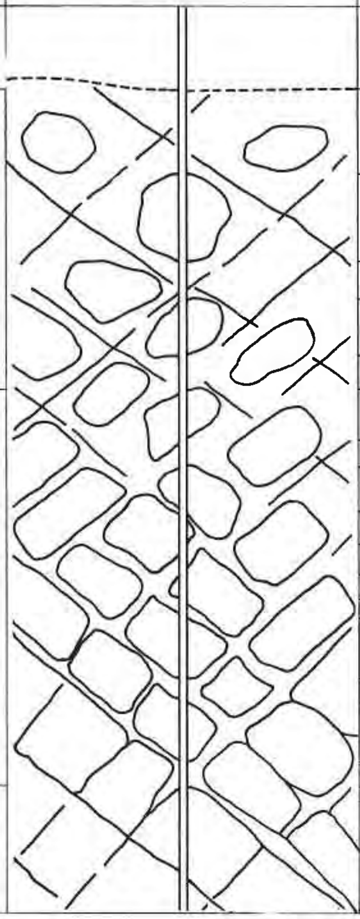
This classification is applied to the colluvial deposits on the basis of the parent geology. The classification is based on API and is not extensively field checked. These classes are not presented on the Engineering Geology Map but are included in the GEOTECS data bank.

A.8.4 *Data Collection*

The information presented on the Engineering Geology Map is a compilation of data gathered from a brief study of available Geotechnical Information Unit (GIU) site investigation reports, from field reconnaissance and from the extraction of the pertinent components of the terrain classification mapping and the Allen & Stephens (1971) geological mapping.

Details of the aerial photographs used for the terrain classification are given in Appendix C.3 and Table C.2.

Table A3 Rock Weathering System

Zones of Decomposition Seen in Exposures (based on Ruxton & Berry, 1957)	Drillhole	Material Grade (see table below)	Probable Judgement of Zones Based on Drillcore Only
Zone A—Structureless sand, silt and clay. May have boulders concentrated at the surface.		VI	Zone A
Zone B—Predominantly grades IV or V material with core boulders of grades I, II or III material. The boulders constitute less than 50% of the mass and are rounded and not interlocked.		V III V III V	Zone B
Zone C—Predominantly core boulders of grades I, II and III material separated by seams of grades IV and V. The core boulders constitute more than 50% of the mass and are rectangular.		III V II III IV III IV II IV I IV II	Zone C
Zone D—Material of grades I or II constitutes more than 90% of the mass.		I	Zone D

Classification of Weathering Profile of Igneous Rock, as Seen in Exposures and Drillcores

Grade	Degree of Decomposition	Diagnostic Features in Samples and Cores
VI	Soil	No recognisable rock texture; surface layer contains humus and plant roots.
V	Completely decomposed	Rock completely decomposed by weathering in place, but texture still recognisable.
IV	Highly decomposed	Rock weakened so that fairly large pieces can be broken and crumbled in the hands.
III	Moderately decomposed	Large pieces (e.g. NX drill core) cannot be broken by hand.
II	Slightly decomposed	Strength approaching that of fresh rock – slight staining.
I	Fresh rock	

Classification of the Degree of Decomposition from Weathered Rock of Igneous Origin (after Moye, 1955).

A.9 Generalised Limitations and Engineering Appraisal Map

A.9.1 *Introduction*

Long-term strategic development planning requires an early and fundamental appreciation of areas suitable for extensive and/or intensive development. Development in the study area has been influenced by the geotechnical constraints associated with the terrain since the start of urban expansion in Hong Kong. With the obvious shortage of suitable terrain and the continuing pressure for expansion, it is essential that geotechnical influences are considered in detail at the start of any planning or engineering project. The maps produced within the GAS Programme are fundamental to this approach.

The Generalised Limitations and Engineering Appraisal Map (GLEAM) is intended to extend the guidance on geotechnical problems given in the GLUM, the PCM and the EGM. It enables the planner or engineer to take a broader view of the opportunities for development in geotechnical terms. In addition, it highlights the features of the terrain which represent geotechnical constraints but are not considered detrimental to the overall development potential of the terrain.

The derivation of the GLEAM and its implications for planning and engineering are described below.

A.9.2 *Derivation of the GLEAM*

The GLEAM is derived from the Terrain Classification Map with further detailed aerial photograph interpretation and fieldwork. During its production, use is made of the GLUM, the PCM and the EGM. The general sequence is summarised in flowchart form in Figure A2.

The GLEAM identifies areas of potential for development. Continuous areas of already developed land are excluded from comment. 'Man-made' restrictions such as Country Parks, catchwaters and catchments are delineated, and principal access routes which would ease expansion are also shown.

An initial estimate of the boundary between geotechnical potential and constraint is made from the Terrain Classification Map. Potential areas are those generally less than 30° in insitu materials and 15° in fill and colluvium, where instability is not identified and erosion is limited. Slopes steeper than 30° would require extensive cuts or high retaining structures to provide useful platforms, and platforms constructed in fill or colluvial slopes would require long back slopes to achieve a suitable level of safety. Instability indicates that the natural slope is liable to present a hazard, and lines of excessive erosion would require entrainment of stream courses to avoid the risk of blockage, flooding and destabilising infiltration. The criteria used for initial assessment of the potential or constraint boundary are shown in Table A4.

To a certain extent, the constraints outlined above are similar to those identified in the Physical Constraints Map and in GLUM Classes III & IV, but their interpretation depends on the local situation and the nature of the engineering problem which is present.

In generalising the boundary between potential and constraint, small areas which have geotechnical constraint are included where they do not contradict the overall assessment of potential. In these cases, the nature of the constraint is reflected in the engineering notes, and the area is highlighted on the map as a stipple.

Further interpretation of the engineering geology and physical constraints is made using oblique and vertical aerial photographs. In this way, the boundaries are refined, and the basic engineering notes are prepared for the GLEAM.

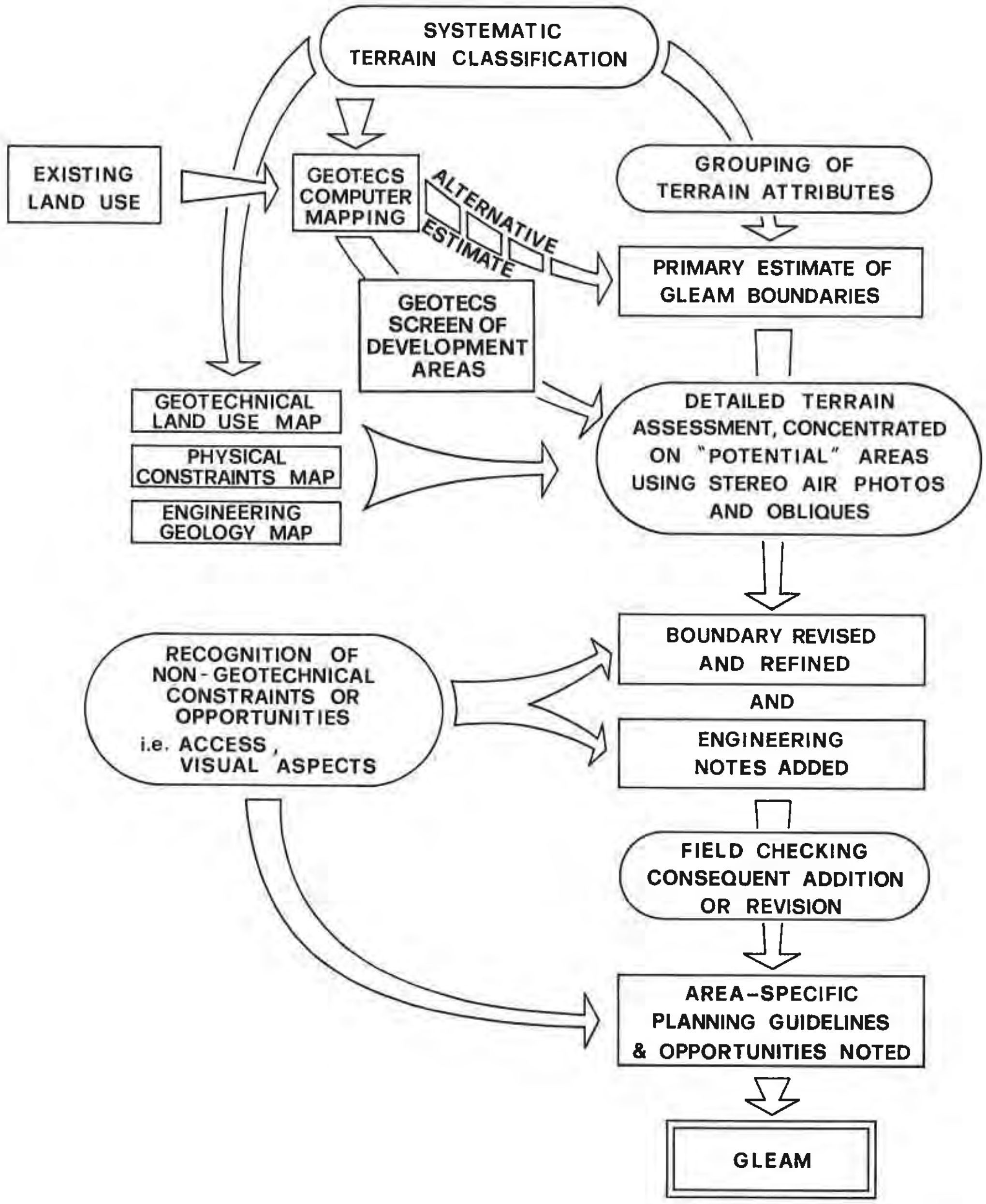
The engineering notes are presented in the form of standard symbols which are described in the legend. They highlight local geotechnical constraints which would influence layout or the design details of a project. General constraints identified on the Physical Constraints Map are shown as a background to these notes. The features indicated on the GLEAM are described and discussed in note form in Table A5. The production of the GLEAM is supplemented by field checks of pertinent areas.

An appreciation of the non-geotechnical considerations of the potential development areas and of the implications of geotechnical suitability on planning considerations enables specific planning opportunities to be highlighted. These factors include the necessity for access across difficult terrain, visual intrusion or severe influence on natural environment resulting from construction works.

Hence, the GLEAM is a map that is designed to provide a broad indication of development opportunities assessed from a geotechnical point of view and to identify geotechnical considerations with local implications for planning and engineering.

A.9.3 *Application of the GLEAM in Strategic Planning*

The general boundaries between areas of 'Potential' and 'Constraint' should be used at a strategic planning stage to enable new development to be placed where it can most effectively use the opportunities provided by the terrain, and where it will be relatively unhindered by geotechnical difficulties. Where difficulties cannot be avoided, they are clearly indicated. Where large areas are suitable for development, the nature and scale of development should be planned to utilize all available opportunities.



Derivation of Generalised Limitations and Engineering Appraisal Map | Fig. A2

Table A4 Criteria for Initial Assessment of GLEAM Potential/Constraint Boundaries

Terrain Component*	Slope Gradient*	Erosion/Instability Classification		
		Erosion*		Instability*
		(., 1, 2, 3, 4, 5, 6, 7)	(8, 9)	(a, n, r, w)
A	1	Yes	Yes	No
	2, 3	Yes	No	No
B, C, D, M N, O, P	1, 2, 3	Yes	No	No
	4, 5, 6	No	No	No
E, F, G, H, I^{Δ} K^{Δ}, R, S, T, X^{Δ}	1, 2	Yes	No	No
	3, 4, 5, 6	No	No	No
<u>N</u>, <u>O</u>, <u>P</u>** <u>R</u>, <u>R</u>, <u>S</u> <u>T</u>, V, <u>V</u>	1, 2	Yes	No	No
	3	Subject to interpretation	No	No
	4, 5, 6	No	No	No
Z	1, 2	Yes	Yes	No

Yes = Potential development

No = Constraint†

Note: * See Table A1 for description of terrain classification codes.

Δ Terrain components I, K and X are only mapped at slope gradients of 1 and 2.

** The potential/constraint boundary is subject to interpretation. These terrain components are generally unlikely to occur outside developed or developing areas which are not considered in the GLEAM.

† All initially derived potential/constraint boundaries are subject to revision on assessment of the overall area, in particular erosion classifications 8 and 9. Instability is generally assessed as constraint.

Piecemeal development often results in considerable wastage of potential development land. Individual developers could be encouraged to conform to an outline site layout which maximises the use of the site resources.

Notes are incorporated on the GLEAM which assess in general, but in geotechnically based terms, the development opportunities of potential areas. These are prepared without detailed consideration of other planning constraints (political, socio-economic, aesthetic) which may influence the area but, nevertheless, the geotechnical constraints are of fundamental significance to the potential of an area for development.

A.9.4 *Application of the GLEAM in Engineering Feasibility and Detailed Planning*

After the identification of areas for development, planners, architects and engineers prepare the form, layout and design details of the scheme. At this stage, the GLEAM is also of value because it indicates the particular nature of local geotechnical difficulties which influence the design aspects of the project and which require consideration in preliminary layout and design. Details such as the limitations on site formation and the requirement for retaining structures, the optimum foundation type, special provisions for subsurface drainage and entrainment of natural drainage, the threat of boulders or rock instability, inconsistency in soil properties or local rock structures, are all important for planning and design. They must be considered in the initial stages of planning if the optimum development of sites is to be achieved. Often, designs reach an advanced stage before major geotechnical constraints are identified.

Table A5 incorporates notes on the engineering implications of local features highlighted on the GLEAM. Further discussion of the engineering aspects of terrain features and of the interaction between landforming processes of relevance to construction work are included in this Report.

Table A5 Notes on Features Indicated on the GLEAM

1. Colluvium
   - indicated where expected to be deep or irregular.
   - extent of colluvium is shown on PCM & EGM.
   - notes on colluvium are given in Sections 3.1.2 and Apprendix D.3.5.
2. Drainage
   - indicated where expected to be subject to large flows,
   - masked drainage or hidden drainage indicated where ephemeral flows may cause problems or where original drainage pattern may still exist beneath surface disturbance.
   - may pose the risk of piping pressures or leaching of materials.
   - ephemeral flows together with smooth surface contours may indicate deeper weathering and may be associated with a structural weakness, thus forming a geological photolineament.
3. Incised drainage
   - may be associated with structural weakness.
   - in weathered material, may present local oversteepening.
4. Structure
   - local surface indication of jointing pattern, or localised resistance to weathering or movement, and therefore not necessarily a weakness.

     NOTE: When 'terrain associated with Drainage and Structure' or similar is noted – this is the surface result of drainage forming a 'pattern', recognisable from vertical aerial photographs, associated with a jointing or local faulting pattern.
5. Weathering
   - indicated where surface features, i.e. smoothness of terrain, or extensive gullying, show that deep weathering may be expected.
   - in general, deeper weathering is associated with granitic terrain, and occurs beneath ridge and spur lines.
6. 'Control'
   - terrain influenced by features as noted. i.e. D & S cont. = Drainage & Structure Control
7. Instability
   - indicated where the natural landform exhibits instability which poses a threat to development unless accommodated.
8. Steep slopes
   - indicated where the presence of a steeper slope would result in extensive cuts or high walls being necessary to produce a platform.
   - tends to restrict site formation possibilities.
9. Lineament
   - identified from aerial photography.
   - indicates a structural weakness or strength through an anomaly in the surface features.
   - lineaments (some) also shown on EGM.
   - further notes on lineaments in 2.

The information presented in the GLEAM, because it is interpretative in nature, cannot be conclusive in its application to a particular engineering project; nor from the nature and scale of the study can the comments be exhaustive. The GLEAM does indicate areas of potential for development whilst clearly defining the major geotechnical restrictions which are likely to influence planning and engineering feasibility.

A.9.5 *Production of the GLEAM and Evaluation of Planning Strategies*

Using the Geotechnical Terrain Classification System (GEOTECS) described in Section 1.5.9, it is possible to construct various strategies based on priorities of land utilisation in combination with the systematic data collected in the terrain classification process.

Particular types of existing land use can be isolated, and the engineering suitability or potential for an intended use can be evaluated. This can be achieved by the selection of appropriate terrain attributes. The attributes include: geology, slope angle, aspect, terrain component, erosion and instability, GLUM, relief, vegetation and land use.

Typical strategies and the computer maps are described in Section 4.2.5. The potential for development of squatter areas or possible quarry sites assessed in geotechnical terms are provided as examples.

The maps produced using GEOTECS are conceptual in nature, and further study of any potential development area is essential. Nevertheless, the mechanism of land resource appraisal afforded by the GEOTECS approach provides a powerful tool for land management purposes and engineering feasibility.

A.10 General Rules for the Use of the Maps and Associated Data

There are several basic rules regarding the use of the maps produced in the GAS Programme. Failure to heed these rules may result in the serious misinterpretation of the maps produced in this Report. The rules are:

(*a*) The maps are designed for use at a scale of 1:20 000. They should never be enlarged to scales larger than the published scale.

(*b*) The type of information shown on the map is designed for users who require data at 1:20 000 scale. The information presented on the 1:20 000 maps may not be valid at larger scales.

(*c*) The conventional line maps produced for use at a scale of 1:20 000 should not be used to evaluate parcels of land smaller than about 3 ha in size.

(*d*) The GEOTECS plots must never be used to evaluate specific small sites (less than 5 ha in size). They are designed for broad planning and engineering feasibility studies. GEOTECS plots should not be used at a scale larger than 1:20 000.

A.11 Measurement, Analysis and Storage of Data (GEOTECS)

A data bank has been established for each of the GASP areas. This facilitates the examination and analysis of the distribution of the physical resource attributes occurring in the area and their planning and engineering implications. It also provides a method of investigating the interrelationships among various attributes which occur within the areas.

The terrain classification for this study is part of the small-scale (1:20 000) systematic terrain classification which has been completed for the entire Territory of Hong Kong. The GASP I data bank consists of 6 170 grid cells, each of which covers approximately 2.04 hectares (49 cells per grid kilometre square) and is referenced to the Hong Kong Metric Grid. This programme, which is known within the Geotechnical Control Office as the Geotechnical Terrain Classification System (GEOTECS), is discussed briefly in Section 1.5.9. Nine natural resource attributes are recorded for each grid cell. The attributes are: slope gradient, terrain component, erosion and instability, aspect, relief, superficial and bedrock geology, existing land use, and vegetation.

The area measurements are calculated on the number of grid cells which occur within the study area. The area occupied by a particular attribute is measured by recording the Terrain Classification Map unit which occupies the largest proportion of each cell.

The measurement of irregular shaped map units by a regular graticule inevitably results in some inaccuracies in area calculation. However, there is an overall 'averaging' effect which minimise the errors inherent in this method. Errors are limited to a few percent in total and, in comparison with inaccuracies prevalent in the area measurement of steeply sloping terrain are considered insignificant.

On completion of the manual coding process, the data is stored for use in the computer. The attribute measurements are sorted, correlated and tabulated. The resulting tables can be broadly classified into three groups:

(*a*) Single attribute tables which present the total area of each attribute under consideration, e.g. slope gradient (Tables B1, B2, B3, B5, B6, B7, B9 and B12).

(*b*) Single attribute correlations which present the tabulated relationships between one single attribute and another, e.g. slope gradient versus aspect (Tables B4, B8 and B13).

(*c*) Multiple attribute correlations which present the relationship between a combination of two or more attributes and a third attribute, e.g. slope gradient/aspect versus erosion (Tables B10 and B11). Within the framework of these tables, it is possible to define a multi-attribute unit based on any user-defined combinations of attributes.

APPENDIX B

DATA TABLES FOR THE HONG KONG AND KOWLOON GEOTECHNICAL AREA STUDY

Table B1 Slope Gradient

Slope Gradient	% of Total Area	Area (ha)
0– 5°*	27.9	3 515
5–15°	12.1	1 518
15–30°	22.6	2 852
30–40°	32.4	4 080
40–60°	4.1	512
>60°	0.9	110
	100.0	12 587

* Approximately 69 ha of uncovered reservoirs and ponds are included in the 0–5° Class.

Table B2 Erosion and Instability

Erosion		% of Total Area	Area (ha)
Instability			
—well-defined landslips		0.4	55
—general instability		11.7	1 473
Appreciable Erosion	Sheet erosion—minor	1.7	214
	—moderate to severe	3.1	390
	Rill erosion —minor	0.1	4
	—moderate to severe		8
	Gully erosion—minor	4.7	594
	—moderate to severe	1.4	177
No Appreciable Erosion*		76.9	9 672
		100.0	12 587

* Approximately 69 ha of uncovered reservoirs are included within No Appreciable Erosion.

Table B3 Aspect

Aspect	% of Total Area	Area (ha)
North	6.4	800
Northeast	8.7	1 096
East	5.0	636
Southeast	10.0	1 267
South	10.7	1 342
Southwest	14.8	1 863
West	8.2	1 028
Northwest	8.3	1 040
Flat/Unclassified*	27.9	3 515
	100.0	12 587

* Approximately 69 ha of uncovered reservoirs are included in the Flat/Unclassified category.

Table B4 Aspect and Slope Gradient

Aspect	Slope Gradient					Total Area (ha)
	5–15°	15–30°	30–40°	40–60°	>60°	
North	168	224	349	49	10	800
Northeast	182	302	559	45	8	1 096
East	71	196	322	34	13	636
Southeast	208	435	520	90	14	1 267
South	310	461	479	98	14	1 342
Southwest	320	616	798	96	33	1 863
West	126	298	541	53	10	1 028
Northwest	133	320	512	67	8	1 040
0–5° (Flat/Unclassified)						3 515
						12 587

Table B5 Landform

Terrain (Landform)	Slope Gradient	% of Total Area	Area (ha)
Hillcrest		2.0	251
Sideslope	0– 5°	1.7	216
"	5–15°	2.9	359
"	15–30°	12.6	1 586
"	30–40°	21.3	2 682
"	>40°	1.5	195
Cliff/Rock outcrop	0–30°	1.2	150
"	>30°	5.3	667
Footslope (colluvium)	0– 5°	0.3	31
"	5–15°	2.0	257
"	15–30°	3.4	428
"	30–40°	2.6	328
"	>40°	<0.1	6
Drainage plain (colluvium)	0– 5°	0.9	114
"	5–15°	2.8	347
"	15–30°	3.4	422
"	30–40°	1.5	188
"	>40°	<0.1	6
Alluvial plain } not differentiated	0– 5°	0.1	14
Floodplain } not differentiated	>5°	4.8	600
Littoral zone	0–15°	0.2	29
Cut platforms : insitu	0– 5°	3.4	426
: colluvium	0– 5°	0.5	59
Cut slopes : insitu	>5°	6.8	853
: colluvium	>5°	1.4	180
Fill platforms : insitu	0– 5°	0.7	94
: colluvium	0– 5°	1.3	169
Fill slopes : insitu	>5°	1.0	123
: colluvium	>5°	0.9	115
Reclamation	0–15°	12.7	1 603
General distrubed terrain/slope: insitu	>5°	<0.1	6
: colluvium		<0.1°	6
General disturbed terrain/platforms: colluvium	0– 5°	<0.1	8
Water storage		0.6°	69
		100.0	12 587

Table B6 Geology

Geological Unit	% of Total Area	Area (ha)
Alluvium: undifferentiated	5.4	683
Colluvium: volcanic	8.2	1 034
: granitic	7.3	918
: mixed	3.3	414
Littoral zone	0.2	29
Reclamation	12.7	1 603
Fill	4.1	521
Repulse Bay Formation: undifferentiated volcanics	0.2	23
: sedimentary rocks and waterlaid volcanics	0.5	62
: acid lavas	0.3	43
: coarse tuff	1.5	188
: dominantly pyroclastic and some lavas	26.7	3 356
Hong Kong Granite	21.2	2 670
Hong Kong Granite: medium-grained	1.0	114
: fine-grained	1.8	229
Quartz Monzonite	1.4	178
Granophyritic Microgranite	0.2	18
Ma On Shan Granite	0.1	8
Cheung Chau Granite	2.1	267
Sung Kong Granite	1.1	143
Tai Po Granodiorite	0.7	86
	100.0	12 587

Table B7 Vegetation

Vegetation	% of Total Area	Area (ha)
Grassland	8.6	1 077
Cultivation	0.4	51
Mixed broadleaf woodland	27.1	3 417
Shrubland (<50%)	2.9	365
Shrubland (>50%)	4.9	620
No vegetation on natural terrain	0.2	27
No vegetation due to disturbance of terrain by man*	50.5	6 353
No vegetation due to rock outcrop	5.3	667
Zoological and botanical gardens	0.1	10
	100.0	12 587

* Approximately 69 ha of uncovered reservoirs are included in this class.

Table B8 Geology and GLUM Class

Geological Unit	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Alluvium: undifferentiated	0	614	0	0	69
Colluvium: volcanic	0	10	420	604	0
: granitic	0	137	424	357	0
: mixed	0	10	320	84	0
Littoral deposits	0	0	0	0	29
Reclamation	0	1 601	2	0	0
Fill	0	323	192	6	0
Repulse Bay Formation: undifferentiated volcanics	0	13	8	2	0
: sedimentary rocks and waterlaid volcanics	8	23	21	10	0
: acid lavas	4	23	10	6	0
: coarse tuff	27	65	78	18	0
: dominantly pyroclastics and some lavas	196	1 118	1 481	561	0
Hong Kong Granite	732	667	1 055	216	0
Hong Kong Granite: medium-grained	8	22	78	6	0
: fine-grained	23	63	116	27	0
Quartz Monzonite	19	43	65	51	0
Granophyritic Microgranite	0	12	2	4	0
Ma On Shan Granite	0	2	2	4	
Cheung Chau Granite	30	51	102	84	0
Sung Kong Granite	18	29	49	47	0
Tai Po Granodiorite	27	33	16	10	0
	1 092	4 859	4 441	2 097	98

Table B9 GLUM Class

GLUM Class	% of Total Area	Area (ha)
I	8.7	1 092
II	38.6	4 859
IIS	—	—
III	35.2	4 441
IV	16.7	2 097
Unclassified	0.8	98
	100.0	12 587

Table B10 Slope Gradient, Aspect, Geology, Erosion and Instability

Slope Gradient	Aspect	Surface Geology*	No Appreciable Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Area (ha)	Area Instability Index
				Sheet	Rill	Gully	WDL*	GI*		
0–5°	Flat	V	80	2	0	0	0	0	82	0
		G	648	8	0	0	0	0	656	0
		C	155	0	0	49	0	0	204	0
		A	671	0	0	0	0	0	671	0
		L	29	0	0	0	0	0	29	0
		F	1 856	17	0	0	0	0	1 873	0
5–15°	N	V	25	0	0	0	0	0	25	0
		G	57	0	0	0	0	0	57	0
		C	76	0	0	6	0	0	82	0
		F	4	0	0	0	0	0	4	0
	NE	V	20	2	0	0	0	0	22	0
		G	23	4	0	0	0	0	27	0
		C	96	4	0	14	0	2	116	0.02
		F	17	0	0	0	0	0	17	0
	E	V	27	0	0	0	0	0	27	0
		G	20	2	0	2	0	0	24	0
		C	12	0	0	4	0	2	18	0.11
		F	2	0	0	0	0	0	2	0
	SE	V	55	2	0	0	0	0	57	0
		G	39	2	0	0	0	0	41	0
		C	41	0	0	51	0	0	92	0
		F	18	0	0	0	0	0	18	0
	S	V	53	2	0	2	0	0	57	0
		G	59	4	0	0	0	0	63	0
		C	65	8	0	62	0	4	139	0.03
		A	8	0	0	0	0	0	8	0
		F	41	2	0	0	0	0	43	0
	SW	V	75	4	0	0	0	0	79	0
		G	73	4	0	2	0	0	79	0
		C	86	0	0	37	0	0	123	0
		A	2	0	0	0	0	0	2	0
		F	33	4	0	0	0	0	37	0
	W	V	22	0	0	0	0	0	22	0
		G	45	2	0	0	0	0	47	0
		C	27	0	0	20	0	0	47	0
		A	2	0	0	0	0	0	2	0
		F	8	0	0	0	0	0	8	0
	NW	V	23	0	0	0	0	0	23	0
		G	47	2	0	0	0	0	49	0
		C	33	0	0	22	0	0	55	0
		F	6	0	0	0	0	0	6	0
15–30°	N	V	55	0	0	0	0	2	57	0.04
		G	76	6	0	2	0	0	84	0
		C	49	0	0	14	0	18	81	0.22
		F	2	0	0	0	0	0	2	0
	NE	V	92	6	0	2	0	10	110	0.09
		G	86	8	2	4	0	2	102	0.02
		C	63	0	0	10	0	15	88	0.16
		F	2	0	0	0	0	0	2	0
	E	V	74	6	0	0	0	6	86	0.07
		G	35	10	0	8	0	2	55	0.04
		C	14	0	0	25	0	16	55	0.30
	SE	V	163	11	0	10	0	10	194	0.05
		G	92	27	2	8	0	2	131	0.02
		C	45	2	2	37	0	22	108	0.21
		F	2	0	0	0	0	0	2	0
	S	V	157	12	0	0	0	2	171	0.01
		G	84	21	0	6	0	8	119	0.07
		C	67	8	0	51	2	37	165	0.23
		F	6	0	0	0	0	0	6	0
	SW	V	267	4	0	2	0	10	283	0.04
		G	116	25	2	4	0	8	155	0.05
		C	80	0	0	51	2	35	168	0.22
		F	8	2	0	0	0	0	10	0
	W	V	106	0	0	0	0	0	106	0
		G	57	8	0	2	0	4	71	0.06
		C	57	0	0	29	0	35	121	0.29
	NW	V	112	4	0	0	0	6	122	0.05
		G	78	2	0	0	0	0	80	0
		C	51	0	0	26	0	35	112	0.31
		F	4	2	0	0	0	0	6	0

* For legend see Table B10 (continued) on page 130.

Table B10 Slope Gradient, Aspect, Geology, Erosion and Instability *(Continued)*

Slope Gradient	Aspect	Surface* Geology	No Appreciable Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Area (ha)	Area Instability Index
				Sheet	Rill	Gully	WDL*	GI*		
30–40°	N	V	102	0	0	0	0	35	137	0.25
		G	92	6	0	6	0	18	122	0.15
		C	6	0	0	0	2	76	84	0.93
		F	6	0	0	0	0	0	6	0
	NE	V	192	0	0	0	0	43	235	0.18
		G	167	8	0	25	0	28	228	0.13
		C	10	0	0	4	0	76	90	0.84
		F	4	2	0	0	0	0	6	0
	E	V	126	8	0	15	2	35	186	0.20
		G	61	6	0	10	0	14	91	0.16
		C	4	0	0	4	0	37	45	0.82
	SE	V	235	10	2	15	2	38	302	0.13
		G	104	24	0	12	0	27	167	0.16
		C	10	0	0	4	0	33	47	0.70
		F	2	0	0	0	2	0	4	0.50
	S	V	141	2	0	6	0	33	182	0.18
		G	82	57	0	22	0	55	216	0.25
		C	20	0	0	4	0	45	69	0.65
		F	12	0	0	0	0	0	12	0
	SW	V	251	19	0	6	0	69	345	0.20
		G	165	96	0	15	0	57	333	0.17
		C	9	0	0	8	0	61	78	0.77
		F	32	6	0	2	0	2	42	0.50
	W	V	186	0	0	0	2	35	223	0.17
		G	141	29	0	22	2	45	239	0.20
		C	10	0	0	4	2	59	75	0.81
		F	2	2	0	0	0	0	4	0
	NW	V	173	0	0	0	0	49	222	0.22
		G	126	16	0	19	0	35	196	0.18
		C	10	2	0	4	2	64	82	0.80
		F	2	10	0	0	0	0	12	0
>40°	N	V	14	0	0	0	2	27	43	0.67
		G	12	2	0	0	0	2	16	0.13
		C	0	0	0	0	0	0	0	0
	NE	V	12	0	0	0	0	2	14	0.14
		G	29	0	0	0	4	2	35	0.18
		C	0	0	0	0	0	4	4	1.00
	E	V	12	0	0	0	4	4	20	0.40
		G	17	0	0	0	2	4	23	0.27
		C	0	0	0	0	0	4	4	1.00
	SE	V	69	0	0	0	13	2	84	0.17
		G	16	0	0	0	0	0	16	0
		C	4	0	0	0	0	0	4	0
	S	V	33	0	0	2	2	8	45	0.23
		G	25	6	0	0	0	14	45	0.32
		C	0	0	2	0	0	0	2	0
	SW	V	51	2	0	0	2	4	59	0.10
		G	43	17	0	0	0	8	68	0.12
		C	2	0	0	0	0	0	2	0
	W	V	16	2	0	0	0	2	20	0.10
		G	21	10	0	0	2	8	41	0.25
		C	0	0	0	0	0	2	2	1.00
	NW	V	16	2	0	0	2	12	32	0.44
		G	16	21	0	0	0	0	37	0
		C	2	0	0	0	0	2	4	0.50
		F	0	0	0	0	2	0	2	1.00

Note: V=volcanic rocks G=granitic rocks C=colluvium
A=alluvium L=littoral deposits F=fill and reclamation
WDL=well defined landslips and coastal instability
GI=general instability

Table B11 Geology, Erosion and Instability

Geological Unit	No Apprecia-able Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Total Area (ha)	Area Instability Index
		Sheet	Rill	Gully	WDL	GI		
Reclamation	1 603	0	0	0	0	2	1 603	0
Fill	467	46	0	2	4	2	521	0.01
Alluvium:								
—undifferentiated	683	0	0	0	0	0	683	0
Littoral Zone	29	0	0	0	0	0	29	0
Colluvium:								
—volcanic	381	4	2	220	6	421	1 034	0.41
—granitic	452	21	2	227	4	212	918	0.24
—mixed	271	0	0	94	0	49	414	0.12
Repulse Bay Formation:								
—undifferentiated volcanics	19	2	0	0	0	2	23	0.09
—sedimentary rocks and waterlaid volcanics	49	2	0	0	0	11	62	0.17
—acid lavas	43	0	0	0	0	0	43	0
—coarse tuff	165	6	0	2	2	13	188	0.08
—dominantly pyroclastics and some lavas	2 670	90	2	57	29	418	3 356	0.13
Hong Kong Granite	2 076	310	6	121	8	149	2 670	0.06
Hong Kong Granite:								
—medium-grained	49	45	0	18	0	2	114	0.02
—fine-grained	192	19	0	6	0	12	229	0.05
Quartz Monzonite	123	8	0	0	2	45	178	0.26
Granophyric Microgranite	12	0	0	2	0	4	18	0.22
Ma On Shan Granite	4	0	0	0	0	4	8	0.50
Cheung Chau Granite	132	43	0	18	0	74	267	0.27
Sung Kong Granite	86	8	0	4	0	45	143	0.31
Tai Po Granodiorite	76	0	0	0	0	10	86	0.12

Table B12 Existing Land Use (From aerial photograph interpretation by the Geotechnical Control Office in 1982)

Existing Land Use	Area (ha)	Existing Land Use	Area (ha)
Government housing estate	708	Quarries – government	75
Private development	1 377	Quarries – private	175
2 Storey development	541	Quarries – borrow	31
1 Storey development	164	Oil storage	20
Temporary resettlement area	117	Power station	16
Intermixed	226	Cemetery	104
Industrial	171	Prison	31
Commercial	149	Service reservoir	112
Commercial/residential	153	Incinerator	10
Park	327	Horticulture	45
Sports complex	82	Undefined agriculture	8
Golf course	45	Dairy Farm	8
Race course	27	Undisturbed areas	2 414
Beach	4	Country park	3 197
Zoological & botanical gardens	10	Water storage	69
School	94	Dam	4
Hospital	57	Natural stream	2
Temple	10	Man-made channel	2
Police/fire station	33	Squatters – low intensity	165
Airport runway	116	Squatters – medium intensity	177
Airport facilities	182	Squatters – high intensity	318
Wharves	67	Construction	165
Railway	16	Reclamation	177
Roads	290	Temporary land fill	16
Sewerage works	6	Temporary land use	84
Military	190		
		Total	12 587

Table B13 Existing Land Use and GLUM Class

Existing Land Use	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Government housing estate	84	322	277	25	0
Private development	212	673	418	72	2
2 Storey development	98	218	184	39	2
1 Storey development	19	53	74	18	0
Temporary resettlement area	19	76	18	4	0
Intermixed	24	202	0	0	0
Industrial	8	161	2	0	0
Commercial	15	120	14	0	0
Commercial/residential	37	108	8	0	0
Park	80	169	43	35	0
Sports complex	21	47	14	0	0
Golf course	12	14	19	0	0
Race course	0	25	2	0	0
Beach	0	0	0	0	4
Zoological and botanical gardens	0	4	6	0	0
School	26	39	29	0	0
Hospital	12	31	10	4	0
Temple	4	2	2	2	0
Police/fire station	4	21	4	4	0
Airport runway	4	112	0	0	0
Airport facilities	0	182	0	0	0
Wharves	4	63	0	0	0
Railway	0	16	0	0	0
Roads	10	157	90	33	0
Sewerage works	0	2	4	0	0
Military	55	115	16	4	0
Quarries – government	0	14	37	24	0
Quarries – private	8	25	118	24	0
Quarries – borrow	0	6	19	6	0
Oil storage	2	16	0	2	0
Power station	10	4	2	0	0
Cemetery	8	35	57	4	0
Prison	10	13	6	2	0
Service reservoir	10	20	59	23	0
Incinerator	0	10	0	0	0
Horticulture	2	12	23	8	0
Undefined agriculture	0	2	6	0	0
Dairy farm	0	4	2	2	0
Undisturbed areas	104	463	1 053	775	19
Country park	102	812	1 420	863	0
Water storage	0	0	0	0	69
Dam	0	0	2	2	0
Natural stream	0	0	0	2	0
Man-made channels	0	2	0	0	0
Squatters – low intensity	8	31	79	47	0
Squatters – medium intensity	10	51	96	20	0
Squatters – high intensity	33	118	128	37	2
Construction	14	59	78	14	0
Reclamation	0	173	4	0	0
Temporary land fill	0	6	8	2	0
Temporary land use	23	51	10	0	0
Total 12 587	1 092	4 859	4 441	2 097	98

APPENDIX C

SUPPLEMENTARY INFORMATION

List of Figures

List of Tables

APPENDIX C

SUPPLEMENTARY INFORMATION

C.1 Description of Geological Units

C.1.1 *Volcanic Rocks—The Repulse Bay Formation*

The Repulse Bay Formation consists of a succession of coarse tuffs, welded tuffs and lavas rich in quartz which were deposited during regional volcanic activity in the Middle Jurassic period (approximately 160 million years ago). During periods of volcanic inactivity, thin sequences of sedimentary rocks were deposited in steams and lakes. These sedimentary rocks are now irregularly distributed throughout the volcanics.

With the cessation of volcanic activity, the Repulse Bay Formation has been faulted, folded and subjected to local metamorphism by the intrusion of a large multi-phase granitic batholith.

Within the study area, the Repulse Bay Formation was subdivided into four units together with a category of 'Undifferentiated Volcanic Rocks' by Allen & Stephens (1971). Each of these units is discussed below. The boundaries presented in the Engineering Geology Map (EGM) are subject to revision as investigation proceeds on the detailed remapping of this complex volcanic sequence. Due to the variable mode of formation and the heterogeneous nature of volcanic deposits, rapid horizontal and vertical changes in rock lithology are common.

(i) *Sedimentary Rocks and Water-laid Volcaniclastic Rocks (RBs)*
These rocks occupy only a small proportion of the study area (0.5% or 61 ha), outcropping on Ap Lei Chau and nearby on Hong Kong Island. There is evidence that a 200 m thick unit may be repeated due to folding, as illustrated in Figure C1. Areas of undifferentiated volcanics may also contain rocks of sedimentary origin.

Within the areas mapped as RBs, the sedimentary rocks may not be continuous as a stratigraphic unit but rather consist of relatively thin units of cross-bedded siltstone, grey silty shale and chert intercalated with thick successions of tuffs, some of which are water-laid. Water-laid tuffs also occur on the west coast of Brick Hill and near the Country Club, where the succession, some 20 m thick, consists of beds of coarse-grained and fine tuffs, siltstone and breccia which range from 20 mm to 2 m in thickness.

The general engineering properties of this unit are summarised in Table 3.1. It is generally more variable in properties than other units, and a wide range in strength and weathering depth is expected.

(ii) *Coarse Tuff (RBc)*
This rock type occurs in two major elongate outcrops, 250 to 500 m wide, from Mt Kellett to Kennedy Town and from Kung Mon Tsuen to Pok Fu Lam. A large outcrop also occurs at Cape D'Aguilar and a minor one at Bluff Point on the Stanley Peninsula. They represent a total of 1.5% (188 ha) of the study area.

This rock unit generally forms thick massive beds of coarse-grained crystalline tuff with no internal stratification. Small and medium sized volcanic bombs are frequently found in this unit along with lithic lapilli. The origin of these units may be attributed to episodes of explosive volcanicity.

The rock is generally grey, with large, well-formed crystals of quartz and white feldspar which are clearly visible, set in a fine grey irregular groundmass.

(iii) *Dominantly Pyroclastic Rocks with Some Lavas (RBp)*
These rocks form the dominant volcanic unit on Hong Kong Island and occupy 26.6% (3 354 ha) of the study area. It is a broad group of rock types comprising welded tuffs (ignimbrites), lapilli tuffs, fine tuffs, banded tuffs, and coarse tuffs, as well as lavas and sediments. It contains lithologies found in most other volcanic units of the Repulse Bay Formation. The principal rock type is a fine-grained, grey to dark grey rhyodacitic tuff.

The field exposures are generally closely jointed with extensive planar, smooth joints forming a number of distinct sets. These joints have a dominant influence on the engineering behaviour. The weathering depth varies with grain size and topography but is generally shallower than encountered in the granitic rocks. It weathers to produce a pale coloured clayey silty soil.

(iv) *Acid Lavas (RBv)*
The majority of lava flows within the volcanics of the Repulse Bay Formation are too thin or irregularly exposed to be mapped as separate units and are included in the previous rock category, RBp. Within the study area, there are two areas where lavas form units of mappable size. One exposure is at Cape D'Aguilar and the other extends from Bennett's Hill to Pok Fu Lam Reservoir.

The rock is generally greenish black, very fine-grained, massive and sometimes porphyritic with phenocrysts of quartz and feldspar up to 2 mm in length. It is frequently banded with fine dark lines. The rock is resistant to weathering, but often it is closely jointed, occasionally in columnar form. When fresh, the rock is strong to very strong.

(v) *Undifferentiated Volcanic Rocks (RB)*
On Green Island, Magazine Island, Ap Lei Pai and a small area on the northwest of Hong Kong Island, areas are delineated as Undifferentiated Volcanic Rocks due to difficulties in mapping through thick vegetation or boulder cover. Although the exact nature of these rocks is uncertain, they may be similar to the suite of rocks described as the 'Dominantly Pyroclastic Rocks with Some Lavas' (RBp).

C.1.2 *Intrusive Igneous Rocks*

A number of distinct intrusive rock types occur within the study area which constitute the complex multi-phase batholith which underlies most of the Territory. They form a succession of phases of injection which began with the Tai Po Granodiorite and concluded with the emplacement of doleritic dykes. Five discrete phases are summarised in Table C1. The Needle Hill Granite and the Fan Lau Porphyritic Granite are the only intrusive rock types not exposed within the Hong Kong and Kowloon study area.

Table C1 Intrusive Igneous Rock Types in Hong Kong (Allen & Stephens, 1971)

Phase	Igneous Rock Type	Present in Study Area
1	Tai Po Granodiorite	Yes
2	Fan Fau Porphyritic Granite Ma On Shan Granite Cheung Chau Granite Sung Kong Granite	No Yes Yes Yes
3	Quartz Monzonite Feldspar Porphyry Dyke Swarm	Yes Yes
4	Granophyric Microgranite Needle Hill Granite Hong Kong Granite	Yes No Yes
5	Dolerite	Yes

(i) *Tai Po Granodiorite (XT)*
This rock type forms a large intrusion on Stanley Peninsula and on Round Inland, covering 86 ha in total. It is the oldest intrusive rock type and it is intruded by all the younger phases.

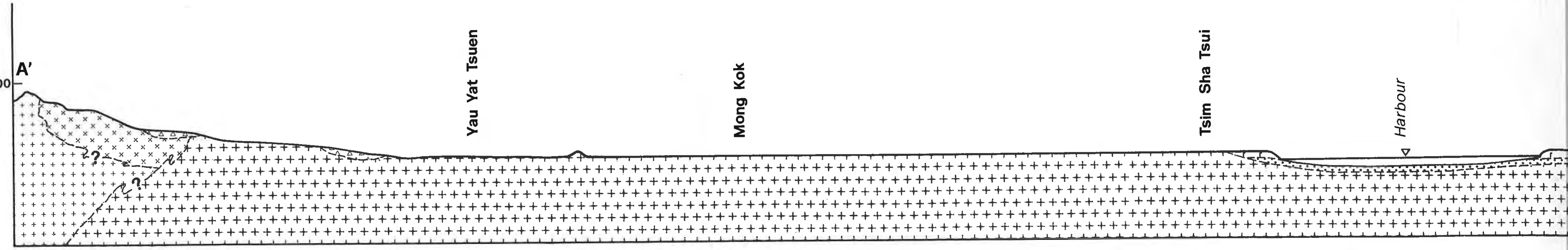
The rock is usually coarse or medium-grained, grey to dark grey and porphyritic in nature. Large well-formed crystals of white feldspar up to 15 mm in length are present in a coarse matrix of 2 to 5 mm crystals of potassium feldspar, plagioclase, biotite, amphibole and of occasional remnants of volcanic boulders and cobbles that are partly absorbed by the magma (xenoliths). These appear as patches of fine-grained dark rock rarely larger than 600 mm in size.

The jointing in the Tai Po Granodiorite is similar to other granitic rocks in that it is widely spaced and irregular. In addition to the tectonic joints, sheeting joints that are subparallel with topography are also present as a result of vertical stress relief.

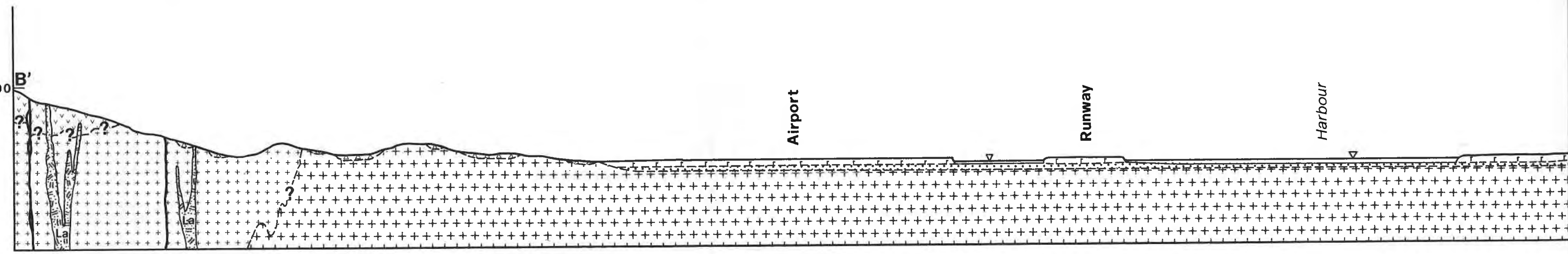
The weathering is generally deep and produces a sandy clayey silt. The slightly lower quartz content, compared to granite, reduces the quantity of sand sized fragments and slightly increases the plasticity of the soils, which are usually red in colour due to the high content of iron-rich minerals.

(ii) *Sung Kong Granite (SK)*
Sung Kong Granite occurs in the northern area of the Kowloon Peninsula as a roof pendant of younger granite in a similar manner to the volcanic rocks of the Repulse Bay Formation.

The rock is usually pale grey or pink when fresh, coarse-grained and porphyritic in nature. It is difficult to distinguish from other granites except when weathered, because the coarse quartz particles are prominent. As with other granitic rocks, it has widely spaced irregular tectonic joints and shallow open irregular sheeting joints. The weathering may be deep and tends to form large boulders as corestones.



Section A-A'



For legend, see Figure 25

- These cross-sections are scaled schematic diagrams only. The illustrated relationships are consistent with those presented in Allen & Stephens (1971).
- All heights are in metres above Principal Datum which is approximately 1.20m below Mean Sea Level.

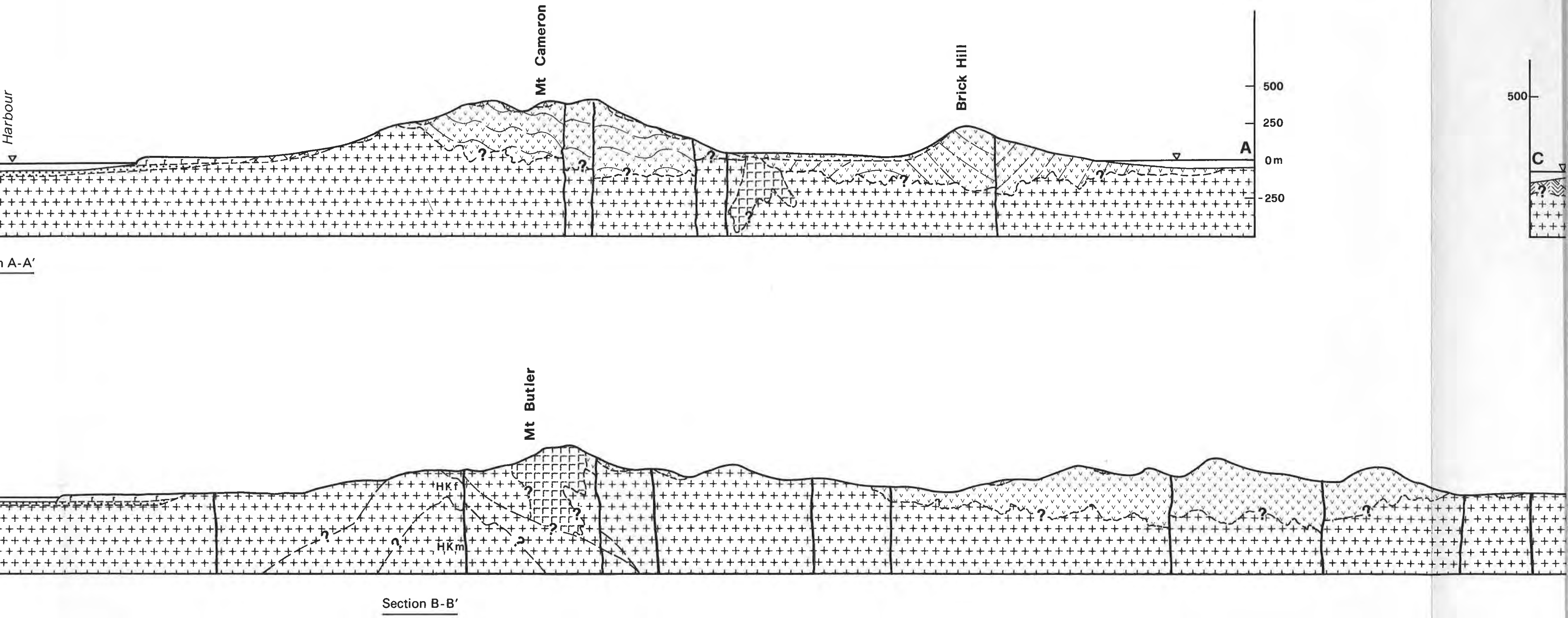
ATTENTION : USERS

The bedrock geology shown on this sheet is that of Allen & Stephens (1971). Geological remapping of the Territory is currently underway and new geological maps at a scale of 1:20 000 and their accompanying memoirs should be consulted where available.

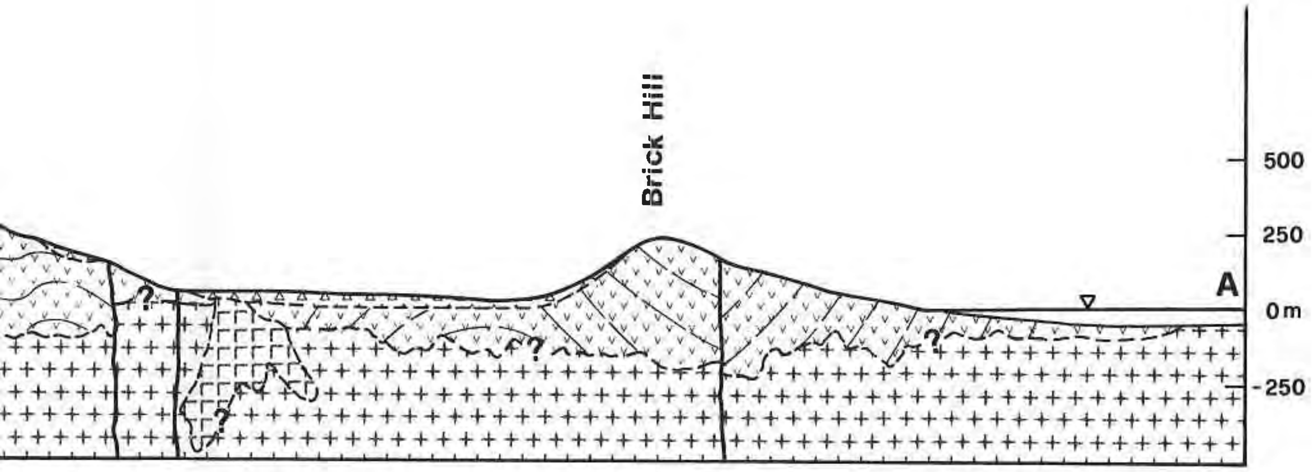
Scale 1:20 000

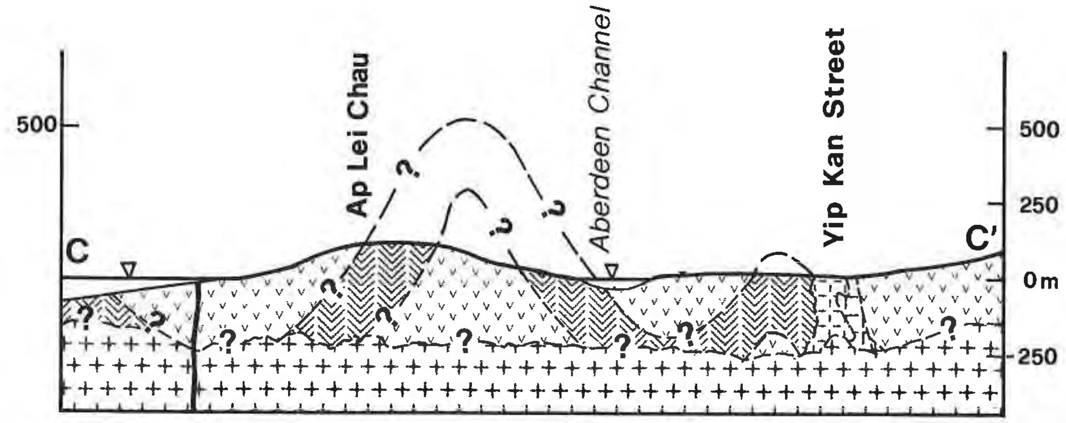
METRES 500 0 1 000 2 000 3 000 METRES

$\frac{V}{H} \simeq 1.25$

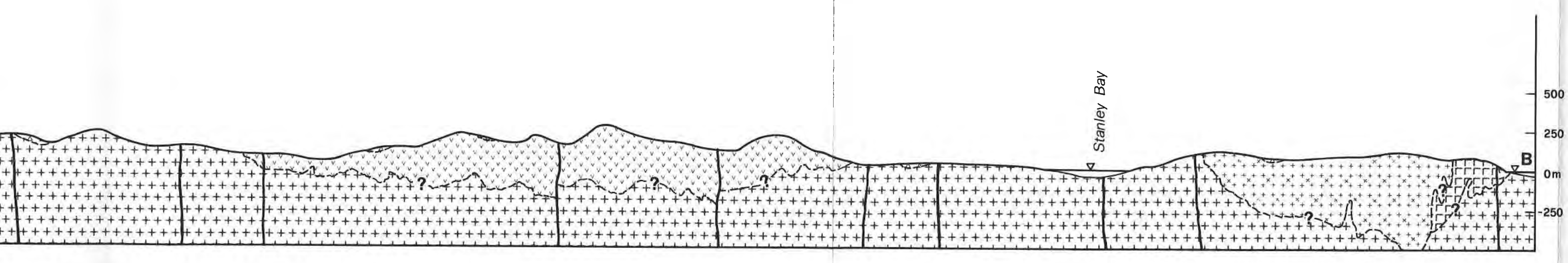


Geological Cross-sections – Hong Kong and Kowloon





Section C-C′



l Cross-sections – Hong Kong and Kowloon	Compiled: R. Purser	Drawn: S. B. Ho	Fig. C1
	Scale: 1:20 000	Date: December 1982	

(iii) *Cheung Chau Granite (CC)*

In the north and northeast of the study area, the Cheung Chau Granite outcrops over 267 ha. It is younger than the Sung Kong Granite and probably extends beneath it, as illustrated in Section A-A[1] of Figure C1.

The rock is pale grey or pink when fresh and is generally medium to coarse-grained (3 to 5 mm) with very few feldspar phenocrysts. It contains similar minerals to the other granites and is distinguished only by its relationship and boundaries with other intrusive phases. It tends to be characterised by a more extensive system of quartz veins, some of which contain mineralisation. Molybdenite and wolframite are commonly associated with these veins.

In common with other granites, the Cheung Chau Granite weathers rapidly and deeply to produce a pale brown to white silty sand. The resulting topography is particularly susceptible to erosion, with ridgelines incised by numerous gullys, whose formation is pronounced where the ridgecrests are denuded of vegetation. Jointing is similar to the other granitic rocks.

(iv) *Ma On Shan Granite (MS)*

This granite outcrops in only two isolated locations in the study area. To the north of the area around Lion Rock, an elongate outcrop occurs and, at Aberdeen, a small body of Ma On Shan Granite occurs adjacent to a monzonitic intrusion. The total extent of this unit is only about 8 ha.

The rock is pale pink to grey, fine-grained porphyritic with phenocrysts of feldspar up to 8 mm in length. Dark minerals such as biotite cannot normally be seen with the un-aided eye. The finer grain size of the groundmass assists in distinguishing it from the previously discussed granitic rocks.

The Ma On Shan Granite tends to weather rapidly to produce a fine sandy clay soil which is subject to sheet and gully erosion. Jointing is similar to other granitic rocks.

(v) *Quartz Monzonite (Mo)*

The largest outcrop occurs on the D'Aguilar Peninsula, but a number of small to medium sized outcrops occur along a northeast trending line from Ap Lei Chau to Lei Yue Mun Bay on Hong Kong Island. Two small dykes of quartz monzonite may also be found at So Uk on the mainland. Quartz monzonite extends across 177 ha of the study area.

The rock is grey or pinksh grey, fine to medium-grained and porphyritic in nature. The coarse-grained phenocrysts are composed of pink or white feldspar with occasional quartz. The rock is uniform in appearance from one outcrop to another.

The monzonite is more resistant to weathering and erosion than any of the granites, and areas of outcrop are characterised by an abundance of boulders. These are especially prominent on the D'Aguilar Peninsula. The weathering products of this rock have high plasticity and are often troublesome when encountered during construction.

(vi) *Hong Kong Granite (HK)*

The Hong Kong Granite forms a large circular intrusion incorporating Kowloon Peninsula, Kwun Tong and northern Hong Kong Island. Parts of a second large intrusion are exposed on the Stanley and D'Aguilar Peninsulas. The Hong Kong Granite is the largest granitic intrusion in the study area and probably underlies most of the units previously discussed.

This granite is composed of three distinct concentric phases of similar age. The outer and most extensive phase is represented by a medium-grained, nonporphyritic, equigranular, pink to grey granite. It contains quartz, potassium feldspar, plagioclase, biotite and muscovite.

The second phase consists of finer-grained porphyritic granite (HKf), in which the minerals are similar to the above granite, but is a mixture of coarse and fine crystals.

The circular inner zone is medium-grained (HKm) but is porphyritic in nature as it contains coarse phenocrysts of feldspar.

All three phases behave similarly on weathering and decompose rapidly to form a thick regolith of brown to red silty sandy soil containing occasional boulders. Jointing is similar to other granitic rocks.

(vii) *Granophyric Microgranite (Mc)*

Fine-grained porphyritic granite is exposed in three places near Pok Fu Lam, where it occurs as circular shaped bodies which are the surface expression of small local stocks.

The rock is a fine-grained granophyric alkali granite that is similar to the fine-grained porphyritic phase of the Hong Kong Granite. Mineralogically, it is composed of a fine granophyric groundmass of quartz and feldspar with phenocrysts of potassium feldspar, quartz and minor biotite.

It is younger than the Hong Kong Granite and Allen & Stephens (1971) consider that it represents the very last phase of igneous intrusion in Hong Kong before the post-tectonic dolerites. Tectonic jointing tends to be moderately narrowly spaced, and sheeting joints are present.

(viii) *Dyke Rocks*

A number of different types of dyke rocks occur in the study area. One of these has already been discussed under the section on quartz monzonite. The others are quartz porphyritic, feldspar porphyritic, doleritic, aplitic and microgranitic in nature.

Quartz porphyry dykes are common near Cape D'Aguilar and on Kau Pei Chau. The rock is grey to greenish-grey or mauve when fresh but weathers to a pale pink colour. It contains phenocrysts (rarely more than 20% of the rock) of quartz and feldspar up to 8 mm in size. The dykes vary in thickness from a few centimetres to over 25 m in width.

Feldspar porphyry dykes occur in areas of Kowloon Peak on the mainland and on the Stanley Peninsula on Hong Kong Island. They are very limited in extent within the study area. Mineralogically, they are similar to the quartz porphyry with the exception that the phenocrysts are principally white or pink feldspar. Weathering characteristics also appear to be similar.

Dolerite dykes form an igneous phase independent of the previously discussed rocks. They are common in the southern tip of Cape D'Aguilar. Dolerite is mineralogically and chemically different from the granitic suite of rocks in that it is undersaturated in silica. No free quartz or potassium (orthoclase) feldspar are present. The rock is fine to medium-grained, black in colour and has a chilled margin about 10 mm in thickness. Dolerite dykes are rarely more than 10 m wide and on weathering decay to dark red clayey soils.

Depending on the type of country rock through which the dykes are emplaced, their topographic expression may be as ridges or as depressions due to the effects of differential weathering. Dykes often influence the pattern of surface and subsurface hydrology.

C.1.3 *Superficial Deposits*

Overlying bedrock and its residual mantle, natural and man-made superficial deposits may occur. These form the surface material over a large proportion of the study area and are of significant engineering importance.

(i) *Colluvium*

Colluvium results from the concentration of material that is transported down slope through the influence of gravity. Deposits may be formed by soil creep, slope failure, boulder fall and local slope wash. Colluvium is distributed primarily as broad fan deposits on footslopes associated with steep mountainous terrain, but it is frequently found in lenticular deposits associated with drainage lines.

Colluvial deposits consist of a wide range of materials, from silty and sandy fine slopewash typical of the granites, through sandy cobble and sandy boulder deposits to boulder fields. In some cases, voids and tunnels occur within the colluvium along drainage paths and beneath stream courses. There is usually little or no surface expression of these subsurface features.

The colluvium derived from the volcanics (Cv) is characterised by a diverse variety of cobble and boulder size fragments within a matrix of fine material. There is generally no apparent uniformity in weathering of the detrital fragments, although in some of the older (relict) deposits, complete weathering may be evident.

Within the study area, extensive deposits occur on the north and northwest of Hong Kong Island in the Mid-levels area and around Chuk Yuen on Kowloon Peninsula. Numerous broad fan deposits are noted, and stream lines are often filled with detritus of colluvial origin. Borehole information suggests that colluvial deposits extend beneath the harbour and some areas of reclamation.

(ii) *Alluvial Deposits*

Within the study area, alluvial deposits occupy 5.4% (683 ha) of the land surface, with major areas on either side of Kowloon Peninsula and lesser deposits on Hong Kong Island at Happy Valley and Shek O. They occupy the low-lying coastal plains. There is evidence to suggest that they are not all fluvial in nature but that some deposits are lacustrine (lagoonal or deltaic) in origin.

The alluvial deposits on Kowloon Peninsula are typically 5 to 10 m thick and are composed of brown silty sand to sandy clay with minor gravel. Gravel material is more common along old or existing stream alignments and may form lenticular deposits within the alluvium. Alluvial materials encountered in boreholes are described as being loose or soft near the surface, increasing to medium density with depth.

(iii) *Marine and Littoral Deposits*

Dark coloured marine deposits of sand and silt containing shell fragments may be found in variable thickness under areas of reclamation and on the existing seabed. Beneath the reclamation, marine deposits are typically medium to coarse sands and gravels, corresponding to beach deposits. They grade seawards into sandy silt and clayey silt (marine muds).

Littoral beach deposits of coarse to gravelly sand are also found in isolated areas along the coast of Hong Kong Island and Stonecutters Island.

Most marine or littoral sediments encountered in boreholes are described as loose or soft. Where these deposits are thicker than about 3 m, they may present difficult founding and settlement conditions.

(iv) *Reclamation*

Due to the constraints of the natural topography and intense population pressure, reclamation of land from the sea has been widely practiced in Hong Kong since 1841. The northern shore of Hong Kong Island and the coast of Kowloon Peninsula have been intermittently extended by a large number of reclamation schemes. Fill has been derived from a wide variety of sources within the Territory. In addition to the fill, old buried concrete or masonry sea walls exist along stretches of previous shorelines, thus making these areas extremely varied in their engineering behaviour.

Historically, a common source of fill resulted from the removal of nearshore topographic features such as Morrison Hill, and these areas of reclamation contain material varying from the deeply weathered granite to fresh rock. In addition, domestic and industrial refuse may occur in some of the older areas. Fill, from elsewhere in the Territory, has also been transported and thus material from any of the geological units may be intermixed.

The degree of compaction and the quality of placed material varies according to the date and method of placement.

The most extensive area of reclamation within the study area is in Kowloon Bay. There, the principal source of material was from the granite hills, resulting in a predominantly clayey sand to sandy clay fill of up to 10 m thickness overlying marine sands and muds.

The permeability of the placed fill varies with both material type and compaction technique. Problems of tidal response are noted for parts of the Central District of Hong Kong, thus indicating very high permeabilities in some areas.

(v) *Fill*

Large areas of the study area are now covered by man-made structures. In order to form land which can be utilized for development, large areas are modified by cut and fill activities. This has resulted in large tracts of the natural terrain either covered by fill or removed by borrow.

In addition, areas of low lying previously swampy ground, such as the northern end of Happy Valley and the Jordan Valley, have been raised by the placement of fill.

Fill for the preparation of most onshore sites is generally derived from within the vicinity of the site itself. However, areas of land fill have required material to be transported from further afield and often contain geological and man-made materials quite different from those occurring on or adjacent to the site.

The engineering characteristics of fill will vary dependent on the quality and type of material and the method of placement.

C.2 Site Investigation Data

Due to the intensive development within the study area, a very large number of investigations have been carried out by the Public and Private Sectors over the years. Geological Society of Hong Kong, 1984). By 1982, over 3 000 reports and in excess of 16 000 borehole records are held within the Geotechnical Information Unit (GIU) of the Geotechnical Control Office that relate to the study area. This volume of information precludes presentation in this Report, but Figure C2 summarises the general intensity of investigation data available within the reference grid blocks used in the GIU.

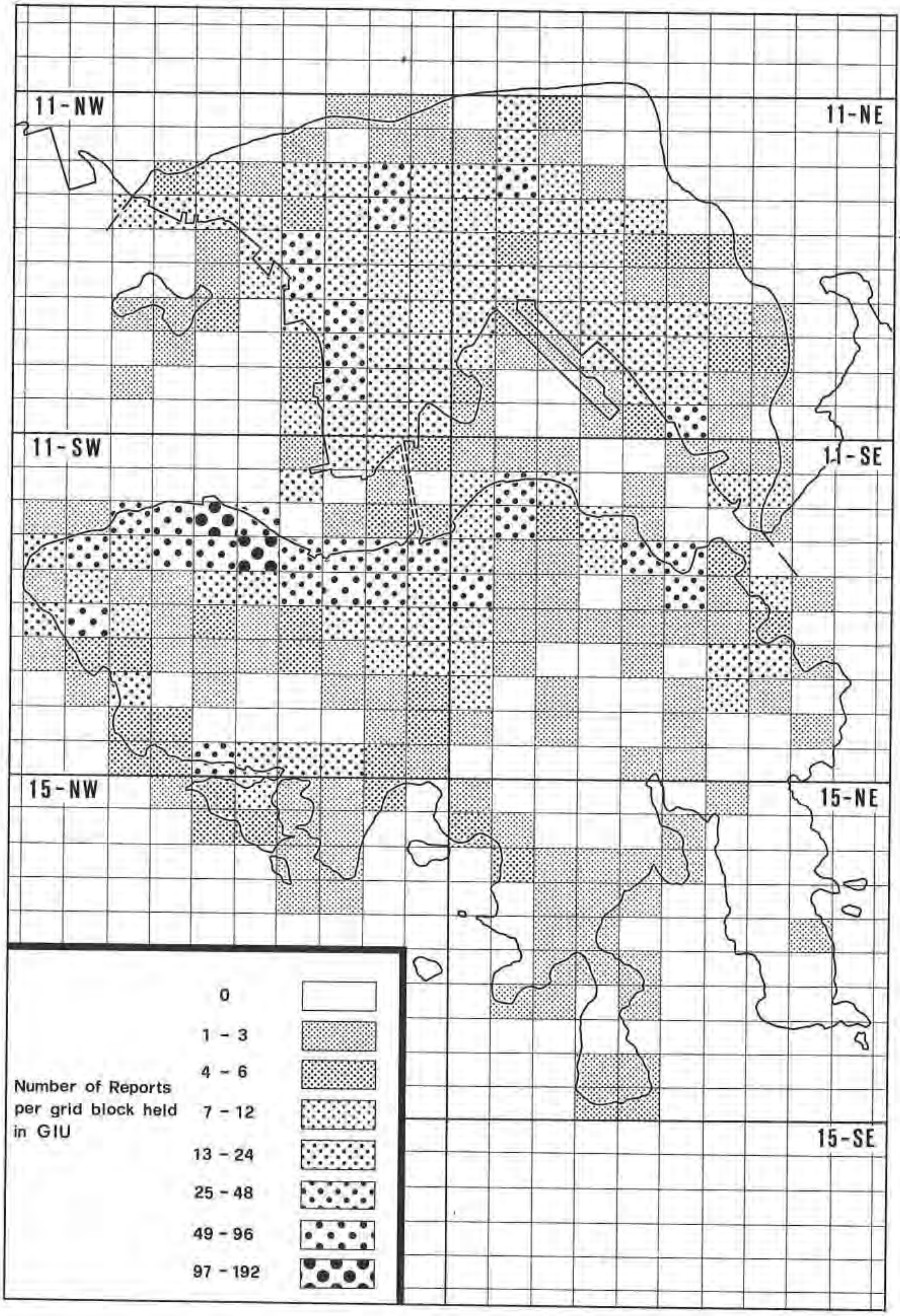
The Geotechnical Control Office GIU report entry and retrieval system is based on a master grid marked on reference sheets. Each grid block is provided with an index card listing all the reports held within that individual grid block.

C.3 Aerial Photographs

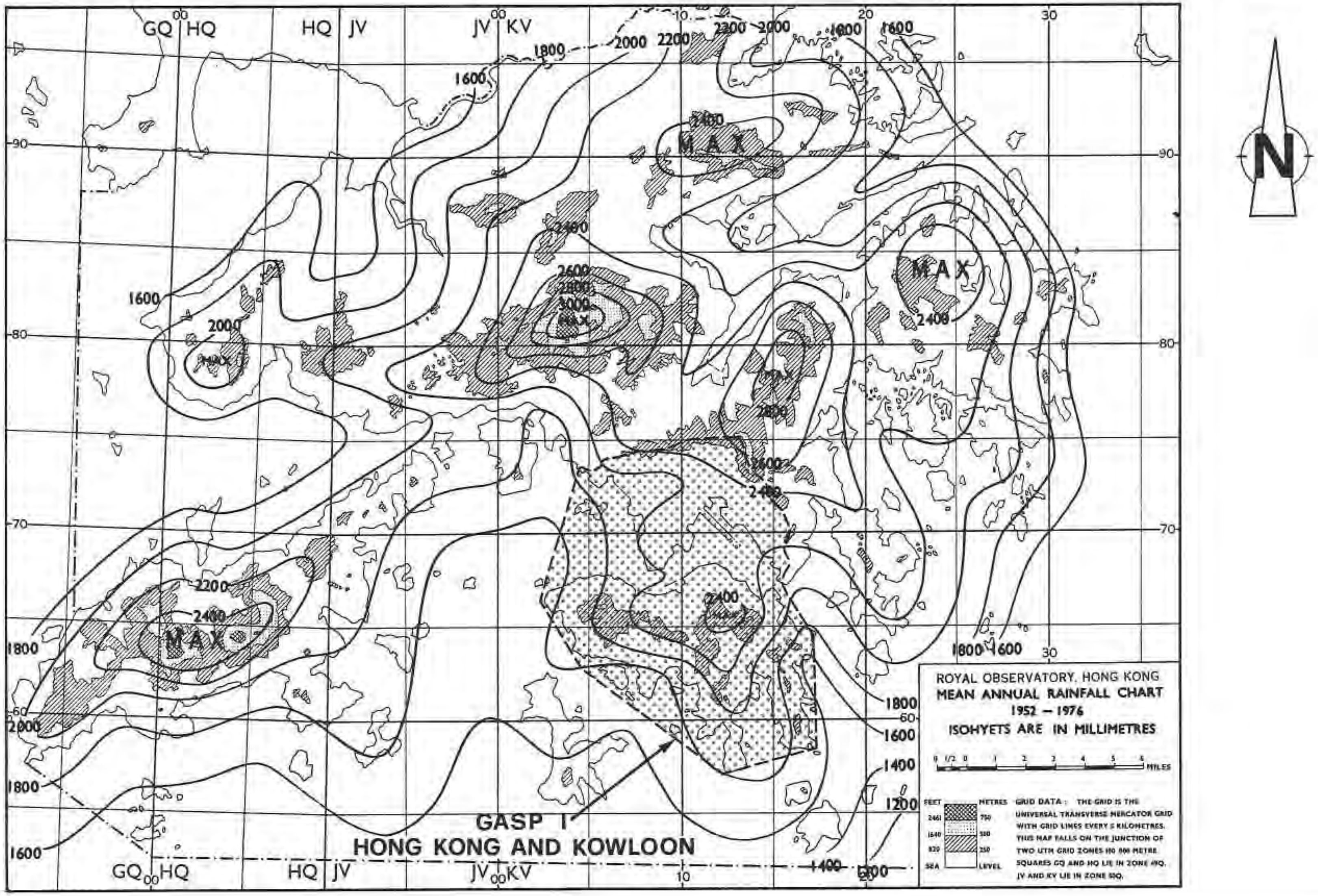
The Hong Kong and Kowloon study area has been extensively photographed from the air, and a very large number of vertical and oblique photographs are available from the Map Sales Office of the Buildings & Lands Department. An abbreviated list of photographs is presented in Table C2.

C.4 Rainfall Data Relevant to the Hong Kong and Kowloon Study Area

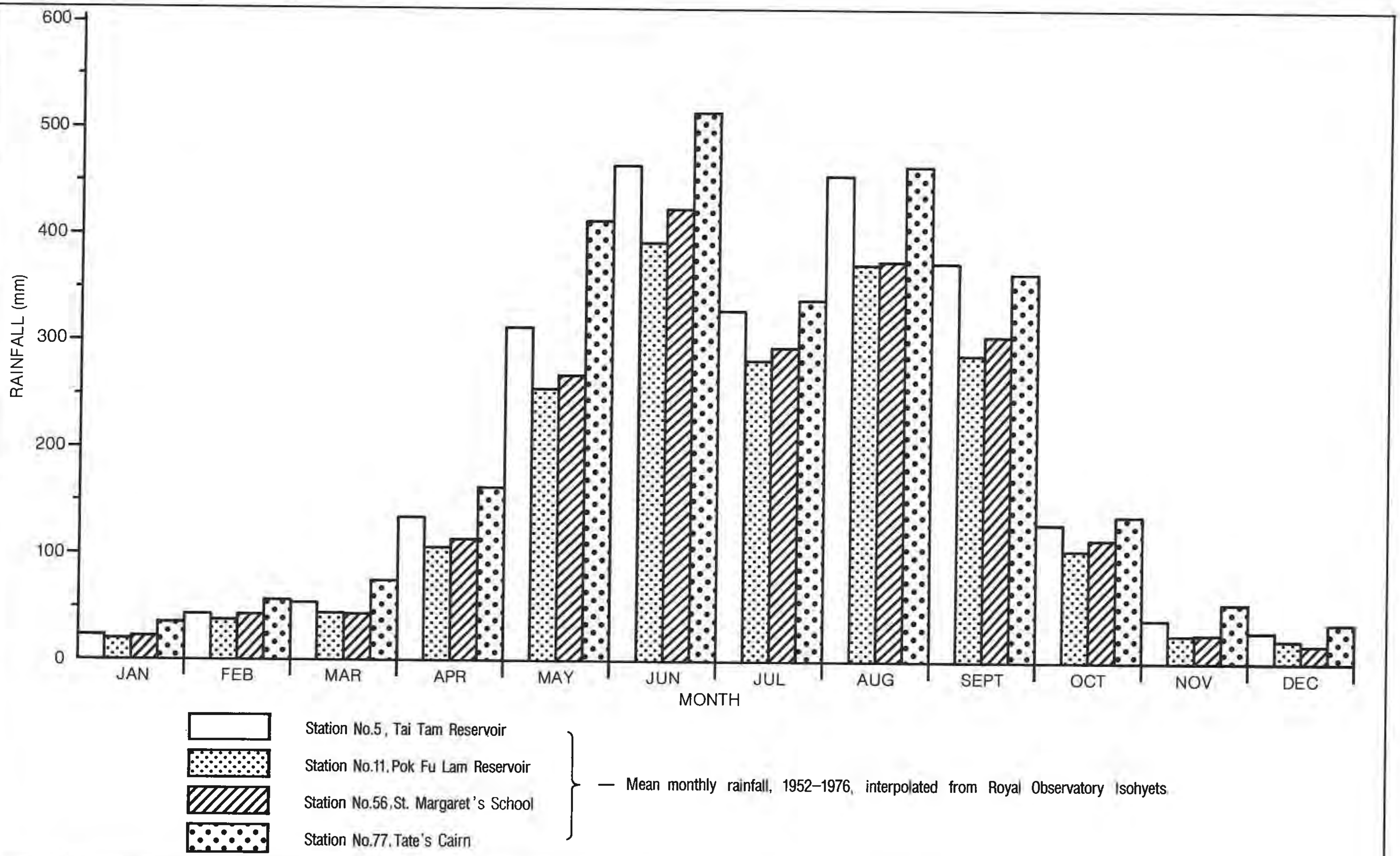
A general appreciation of the annual and monthly rainfall distributions for Hong Kong and Kowloon can be obtained from Figures C3 and C4. Figure C3 is a reproduction of the mean annual rainfall isohyets for the years 1952 to 1976, published by the Royal Observatory. Figure C4 is a histogram of monthly rainfall for four selected Royal Observatory rainfall stations. There are a total of 28 rainfall stations within the study area the locations of which are indicated on Figure C5. Detailed monthly and annual rainfall information for these stations is available from the Royal Observatory.



Scale 1:100 000	Distribution of Site Investigation Reports Held in the Geotechnical Information Unit (GIU)	Fig. C2

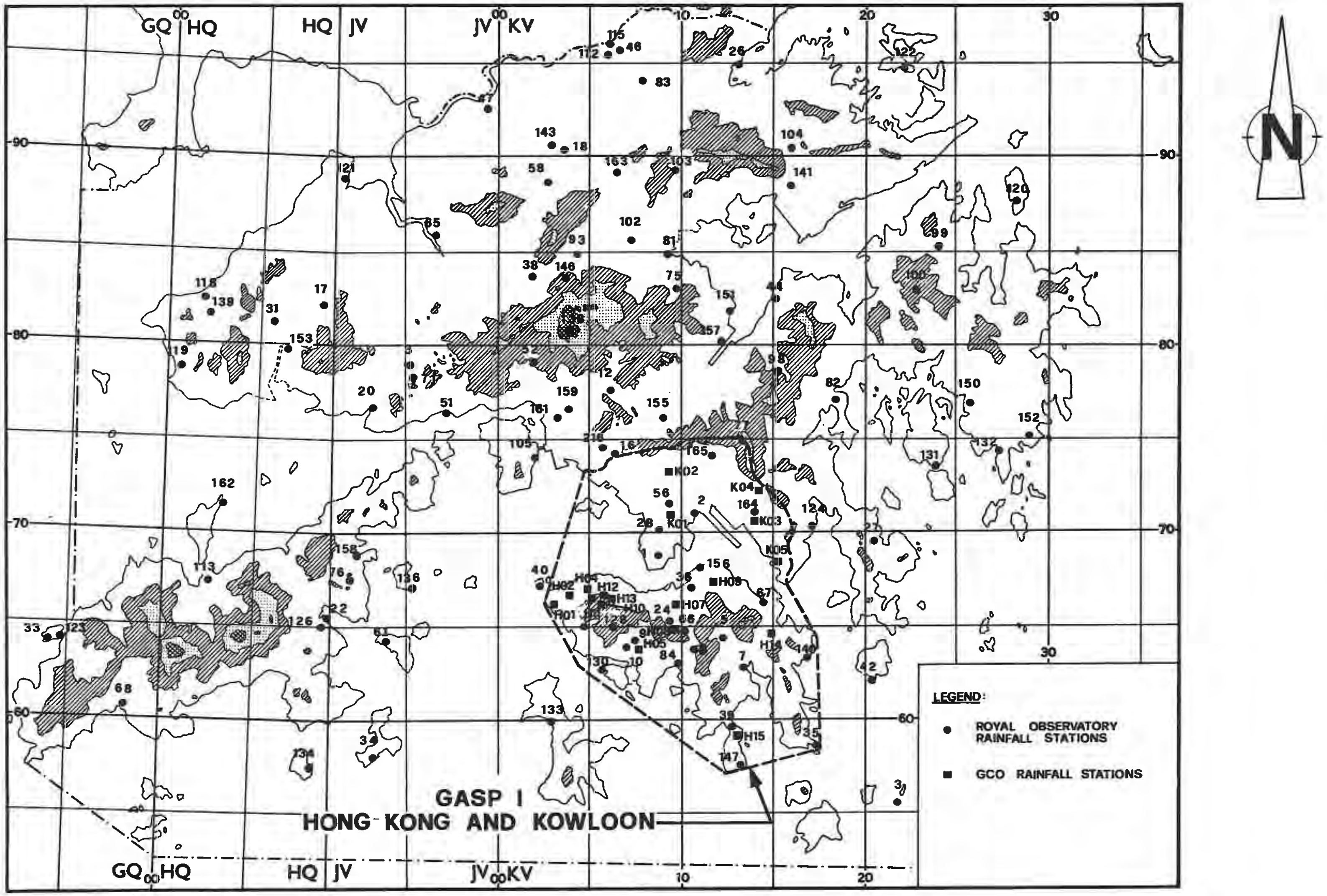


Mean Annual Rainfall Isohyets (1952–1976)	Fig. C3



Summary of Mean Monthly Rainfall Data

Fig. C4



Locations of Rainfall Stations

Fig. C5

Table C2 Selection of Aerial Photographs

Year	Photograph Serial Number	Photograph Scale (Approx.)
1982	42216–42222	1:10 000
	41495–41507	1:8 000
	41236–41242	1:8 000
	41203–41121	1:8 000
	40867–40989	1:8 000
	40689–40692	1:8 000
	40627–40681	1:8 000
	40584–40603	1:8 000
1981	40144–40154	1:8 000
	39862–39995	1:8 000
	39809–39854	1:8 000
	39755–39804	1:8 000
	39347–39355	1:10 000
	39068–39078	1:20 000
	39038–39046	1:20 000
	39013–39022	1:20 000
	38966–38974	1:20 000
	38942–38952	1:20 000
	38895–38904	1:20 000
	38875–38877	1:20 000
	38867–38870	1:20 000
	38649–38656	1:8 000
	38216–38227	1:8 000
	37454–37567	1:8 000
	37383–37446	1:8 000
	37139–37167	1:8 000
	37097–37123	1:8 000
	36996–37004	1:8 000
	36639–36640	1:10 000
	36615–36634	1:11 000
	36232–36240	1:8 000
1980	35402–35424	1:8 000
	33467–33475	1:20 000
	33437–33444	1:20 000
	33416–33424	1:20 000
	33375–33384	1:20 000
	33210–33234	1:20 000
	33181–33188	1:20 000
	32791–32854	1:8 000
	32762–32777	1:8 000
	32738–32755	1:8 000
	32691–32721	1:8 000
	32594–32672	1:8 000
	32481–32588	1:8 000
	32402–32463	1:8 000
	32241–32270	1:8 000
	32202–32224	1:8 000
	32176–32188	1:8 000
	32068–32081	1:8 000
	31995–32066	1:11 000
	31795–31810	1:20 000
	31712–31720	1:8 000
	31449–31468	1:8 000
	30871–30884	1:8 000
	30830–30841	1:18 000
	30285–30308	1:10 000
	30258–30266	1:10 000
	30200–30252	1:8 000
	30078–30148	1:8 000
	29988–30056	1:8 000
	29861–29962	1:8 000
	29802–29848	1:8 000
	29766–29784	1:8 000
	29738–29740	1:8 000
	29459–29483	1:8 000
	29210–29214	1:10 000
	29196–29204	1:10 000
	29007–29024	1:8 000
	28992–29001	1:8 000
	28831–28846	1:8 000
	28811–28819	1:8 000
1979	28070–28080	1:20 000
	28029–28038	1:20 000
	28005–28016	1:20 000
	27955–27966	1:20 000
	27765–27776	1:20 000
	27726–27742	1:20 000
	27701–27709	1:20 000
	27633–27654	1:8 000
	27573–27574	1:8 000
	27260–27331	1:8 000

Table C2 Selection of Aerial Photographs *(Continued)*

Year	Photograph Serial Number	Photograph Scale (Approx.)
1979	27083–27169	1:10 000
	26998–27001	1:12 000
	26901–26925	1:8 000
	26745–26886	1:8 000
	26720–26731	1:18 000
	26620–26660	1:8 000
	26502–26525	1:8 000
	26489–26496	1:8 000
	26455–26474	1:8 000
	26427–26442	1:8 000
	25988–25989	1:8 000
	25824–25831	1:10 000
	25780–25790	1:8 000
	24573–24578	1:19 000
1978	24370–24376	1:18 000
	24363–24369	1:8 000
	24322–24336	1:8 000
	24152–24222	1:8 000
	24096–24130	1:8 000
	23975–23989	1:8 000
	23939–23953	1:8 000
	23837–23933	1:8 000
	23639–23807	1:8 000
	23465–23467	1:8 000
	23355–23367	1:8 000
	23146–23147	1:8 000
	23081–23093	1:8 000
	22187–22214	1:8 000
	22178–22180	1:8 000
	22170–22173	1:8 000
	21011–21041	1:8 000
	20968–20976	1:8 000
1977	20537–20579	1:8 000
	20360–20500	1:8 000
	20327–20348	1:8 000
	20298–20320	1:8 000
	20244–20268	1:8 000
	19741–19742	1:8 000
	19685–19697	1:18 000
	19286–19495	1:8 000
	18900–18903	1:8 000
	18722–18727	1:8 000
	18300–18322	1:8 000
	18157–18280	1:8 000
	18109–18121	1:8 000
1976	16136–16188	1:8 000
	16120–16127	1:8 000
	15563–15585	1:8 000
	15545–15546	1:12 000
	15488–15510	1:8 000
	15470–15482	1:8 000
	15383–15439	1:8 000
	15303–15463	1:8 000
	14566–14568	1:8 000
	14218–14226	1:8 000
	13170–13180	1:8 000
	13156–13162	1:8 000
	13052–13107	1:8 000
	13044–13046	1:8 000
	13002–13036	1:8 000
	12983–12992	1:8 000
	12963–12974	1:8 000
	12817–12937	1:8 000
	12752–12793	1:8 000
	12706–12730	1:8 000
	12668–12696	1:8 000
	12580–12659	1:8 000
	12355–12344	1:12 000
1975	11291–11305	1:8 000
1974	10449–10451	1:8 000
	10187–10193	1:8 000
	9359– 9362	1:8 000
	9267– 9270	1:12 000
	8287– 8291	1:11 000
1973	7058– 7099	1:8 000
	5313– 5333	1:12 000
	5304– 5309	1:10 000
	5272– 5273	1:10 000

Table C2 Selection of Aerial Photographs *(Continued)*

Year	Photograph Serial Number	Photograph Scale (Approx.)
1967	5248– 5251	1:10 000
	5037– 5039	1:10 000
	5651– 5679	1:12 500
	5629– 5642	1:12 500
	5604– 5620	1:12 500
	5594– 5597	1:12 500
	5568– 5576	1:12 500
	5511– 5521	1:12 500
	5489– 5501	1:12 500
	5461– 5467	1:12 500
	5445– 5451	1:12 500
1964	2609– 2603	1:25 000
	2544– 2539	1:25 000
	2464– 2456	1:25 000
	2492– 2498	1:25 000
	2522– 2526	1:25 000
	5423– 5418	1:14 000
	5439– 5448	1:7 400
1963	2610– 2603	1:25 000
	2544– 2539	1:25 000
	2465– 2456	1:25 000
	2492– 2498	1:25 000
	2522– 2527	1:25 000
	2609– 2603	1:25 000
	2544– 2539	1:25 000
	2464– 2456	1:25 000
	2492– 2498	1:25 000
	2522– 2526	1:25 000
	5948– 5976	1:5 400
	5058– 5092	1:5 400
	5916– 5931	1:5 400
	4802– 4821	1:5 400
	4926– 4942	1:5 400
	5129– 5142	1:5 400
	5200– 5213	1:5 400
	5125– 5113	1:5 400
	5187– 5178	1:5 400
	5190– 5198	1:5 400
	5868– 5884	1:5 400
	5892– 5908	1:5 400
	6054– 6042	1:5 400
	6076– 6064	1:5 400
	5214– 5224	1:5 400
	5849– 5859	1:5 400
	6090– 6082	1:5 400
	5240– 5244	1:5 400
	6098– 6091	1:5 400
	7153– 7164	1:5 400
	7198– 7240	1:5 400
	7298– 7317	1:5 400
	7380– 7393	1:5 400
	7487– 7438	1:5 400
	7029– 7088	1:5 400
	7296– 7242	1:5 400
	7378– 7319	1:5 400
	7027– 6966	1:5 400
	6823– 6886	1:5 400
	4029– 4104	1:5 400
	6566– 6625	1:5 400
	6716– 6767	1:5 400
	7491– 7540	1:5 400
	6814– 6769	1:5 400
	7641– 7631	1:5 400
	6654– 6625	1:5 400
	6564– 6533	1:5 400
	7553– 7542	1:5 400
	6683– 6672	1:5 400
	7618– 7623	1:5 400
	7595– 7585	1:5 400
	7571– 7581	1:5 400
	7612– 7602	1:5 400
	7629– 7624	1:5 400
	9527– 9539	1:7 400
	7951– 7971	1:7 400
	7973– 7997	1:7 400
	7999– 8041	1:7 400
	8082– 8043	1:7 400
	8084– 8108	1:7 400
	9527– 9539	1:7 400
1961	0076–0095 (F44/81A)	1:10 000 approx
	0077–0097 (F43/81A)	1:10 000 approx

Table C2 Selection of Aerial Photographs *(Continued)*

Year	Photograph Serial Number	Photograph Scale (Approx.)
1961	0080–0091 (F42/81A)	1:10 000 approx
	0077–0080 (F41/81A)	1:10 000 approx
	0117–0138 (F44/81A)	1:10 000 approx
	0116–0136 (F42/81A)	1:10 000 approx
	0116–0133 (F41/81A)	1:10 000 approx
	0153–0156 (F44/81A)	1:10 000 approx
	0153–0155 (F43/81A)	1:10 000 approx
	0159–0163 (F43/81A)	1:10 000 approx
	0159–0161 (F42/81A)	1:10 000 approx
1959	0290–0291 (F63/58A/RAF775)	1:13 320
	0286–0287 (F63/58A/RAF775)	1:13 320
	0287–0293 (F64/58A/RAF775)	1:13 320
	0287–0296 (F65/58A/RAF775)	1:13 320
1956	0022–0030 (F21/81A/RAF554)	1:10 000
	0024–0030 (F22/81A/RAF554)	1:10 000
1954	0105–0111 (V81A/RAF/552)	1:25 000
	0001–0024 (V81A/RAF/548)	1:25 000
1949	6001–6028 (81A/133)	1:4 800
	6001–6012 (81A/144)	1:4 800
	6144–6181 (81A/127)	1:4 800
	6182–6217 (81A/127)	1:4 800
	6029–6043 (81A/133)	1:4 800
	6209–6229 (81A/117)	1:4 800
	6220–6226 (81A/127)	1:4 800
	6044–6094 (81A/133)	1:4 800
	6074–6094 (81A/133)	1:4 800
	6095–6101 (81A/133)	1:4 800
	6102–6107 (81A/133)	1:4 800
	6112–6115 (81A/133)	1:4 800
	6037–6050 (81A/117)	1:4 800
	6156–6164 (81A/117)	1:4 800
	6023–6036 (81A/117)	1:4 800
	6010–6022 (81A/117)	1:4 800
	6001–6009 (81A/117)	1:4 800
	6166–6208 (81A/177)	1:4 800
	6068–6079 (81A/177)	1:4 800
	6044–6051 (81A/177)	1:4 800
	6155–6160 (81A/133)	1:4 800
	6146–6151 (81A/133)	1:4 800
	6129–6135 (81A/133)	1:4 800
	6137–6145 (81A/133)	1:4 800
	6118–6128 (81A/133)	1:4 800
	6001–6013 (81A/128)	1:4 800
	6045–6052 (81A/128)	1:4 800
	6035–6038 (81A/128)	1:4 800
	6014–6034 (81A/128)	1:4 800
	6060–6095 (81A/128)	1:4 800
	6097–6137 (81A/128)	1:4 800
	6054–6098 (81A/127)	1:4 800
	6099–6143 (81A/127)	1:4 800
	6013–6027 (81A/144)	1:4 800
	6028–6038 (81A/144)	1:5 100
	6025–6043 (81A/130)	1:4 800
	6052–6067 (81A/130)	1:4 800
	6001–6024 (81A/130)	1:4 800
	6111–6132 (81A/117)	1:4 800
	6133–6155 (81A/117)	1:4 800
	6051–6073 (81A/117)	1:4 800
	6074–6103 (81A/117)	1:4 800
1945	4109–4118 (681/)1	1:12 000
	4145–4158 (681/5)	1:12 000
	3020–3033 (681/6)	1:12 000
	4025–4037 (681/6)	1:12 000
	4059–4075 (681/6)	1:12 000
	3055–3069 (681/6)	1:12 000
	3122–3133 (681/6)	1:12 000
	4131–4140 (681/6)	1:12 000
	4146–4149 (681/6)	1:12 000
1924	2–16 (H19)	1:14 000
	10–19 (H25)	1:14 000
	14–16 (H12)	1:14 000
	27–35 (H26)	1:14 000

APPENDIX D

INFLUENCE OF ROCK MASS AND TERRAIN CHARACTERISTICS ON PLANNING AND ENGINEERING IN HONG KONG

List of Figures

APPENDIX D

INFLUENCE OF ROCK MASS AND TERRAIN CHARACTERISTICS ON PLANNING AND ENGINEERING IN HONG KONG

D.1 Introduction

The descriptions of the material characteristics and properties which are contained in this Appendix are intended to give planners and engineers a background understanding of the components of Hong Kong's terrain and materials. These components are described in the context of natural landform evolution. Consideration of the significance of natural landform evolution will allow interpretation of the terrain as it relates to engineering properties and behaviour and their influence on development. The information contained in this Appendix is presented as background to Section 3.

D.2 Rock Mass Characteristics

These sections outline the principal reasons for the differing rock mass characteristics and their influence on the development and behaviour of weathered rock and soil, both in the evolution of natural terrain and in their relevance to engineering. In this context, they are relevant at the planning stage of a project as they are capable of influencing the engineering feasibility of a particular form of project through construction cost, ancillary works and long-term maintenance. Particular problems, if anticipated at the earliest stages, can be avoided or accommodated with the minimum disruption, delay or expense. The main discussion on the planning and engineering significance of geotechnical problems is given in Sections 3 and 4.

The portion of Figure D1 devoted to Rock Mass Characteristics, and reproduced in Figure D2, shows in sequence the factors which contribute to rock properties and which, through mass strength and structure, permeability and chemical stability, contribute to the control of landforming processes and engineering performance. The succeeding sections explain in general terms how the variations in rock mass characteristics arise. They are not intended to be thorough from the geological point of view. Detailed geological descriptions of the particular rock types are given in Appendix C.1. The engineering properties such as strength or permeability are not specified in quantitative terms. Significant differences in the engineering properties of the individual rock types may occur, and these are indicated in Section 3.1 and in Table 3.1. However, the principal rock types exposed in the study area, the granites and volcanics, exhibit characteristic trends of mass behaviour. It is the qualitative differences in performance and characteristic terrain which can be interpreted at the planning stage to improve the quality of any planning decision.

D.2.1 *Mode of Generation and Texture*

It is the mode of generation of the rock which is often the major factor which controls the subsequent development of mass characteristics.

The mode of generation influences the grain or crystal size and texture and, hence, the intact strength, physical stability and intact porosity. Weathering is in part a direct function of porosity combined with chemical stability, which is related to mineralogy and mode of generation.

The tectonic history is related to the mode of generation of the rock, and on this depends the development of mass structure over a broad range of scale. Joints and faults are the result of the release of stresses built up during cooling, burial, intrusion, tectonic movement and unloading.

D.2.2 *Joints*

Joints are small fractures involving minimal movement which generally occur at close spacings in the volcanics and wider spacings in the granites. Differences between volcanic and granite jointing occur and these enable the nature of potential stability problems to be anticipated. Jointing directly influences mass transport through mass strength and structural control, and indirectly through permeability and groundwater flow. In this latter respect, it directly influences weathering development and the form of the weathered profile.

Volcanic rock is subject to a variety and range of tectonic stresses, which generally result in intense jointing of the rock. The volcanic joints, at 0.2 to 1 m spacing, are often not laterally extensive (of the order of 5 m), and their orientations appear to be fairly random. This generally has the effect of allowing fairly uniform permeation of groundwater through the rock mass, although groundwater flow may be locally restricted.

By contrast to the volcanics, joints in granitic rock are often spaced from 2 to 10 m and are laterally extensive. Their wide spacing and open nature tend to concentrate groundwater flow in the joints. Extensive 'sheeting joints', parallel to the ground surface, are characteristic. Being tension cracks, the granite sheeting joints are rough and thus usually have a high apparent angle of friction.

The more randomly oriented, smoother, volcanic joints will influence the stability of cut faces although this may only result in surface 'unravelling'. Granite joints by contrast are less likely to bring about failure in rock unless steeply inclined, due to their high roughness or vertical orientation. Note, however, that weathering on joint planes effectively reduces their roughness, thereby decreasing stability.

D.2.3 *Porosity and Permeability*

Neither the porosity nor the permeability of the rock or soil mass have a significant bearing on large-scale planning decisions. However, the groundwater regime can adversely influence stability if changes of permeability occur, for instance in the construction of piled foundation or basements. Lumb (1964, 1972) discussed building settlements within the Territory.

Porosity relates to the capacity of rock or soil to hold liquid, and is thus an important factor in determining the rate of weathering. Permeability controls the rate of throughflow, which influences weathering and also stability through water pressure. Mass permeability is influenced by jointing in granites, since flow tends to be concentrated in the open joints, whilst in volcanics, water permeation is more uniform. Hence, both porosity and permeability are important factors in weathering decomposition and in the nature of the weathered profile.

D.2.4 *Weathering and the Weathered Profile*

The weathering process and its products exert a significant influence on the performance of the materials and on their response to transport processes. At the planning stage, therefore, consideration of the weathering process and its effects will help to produce feasible layouts for projects, so that they are less influenced by geotechnical threat and, hence, less costly to construct and maintain.

The nature of weathering and its problems may often be inferred from the shape of the terrain, its geology and evidence of existing landforming processes, factors which are all discussed or presented in this Report. The factors shown in Figure D3, some of which are discussed above, all exert varying influences on the weathering process. The rate of weathering breakdown is usually a function of rock porosity and permeability in conjunction with active and fluctuating groundwater flow. The differing chemical stability of various minerals comprising the rock results in non-uniform breakdown of the rock.

The weathered product of granitic rock is a loose, granular quartz soil because feldspars are broken down during weathering. The proportion of clay in the weathered soil depends on the balance between eluviation and deposition, which is related to the terrain. The texture of weathered granite makes it particularly susceptible to erosion on ridgecrests and other situations where natural vegetation is removed. By contrast, the weathered volcanic rocks have a higher proportion of silt size particles and, due to their clay content, to some extent are more resistant to erosion.

Weathering progresses as a function of porosity and permeability. Mass permeability is important in determining the nature of the weathered profile. Table A3 in Appendix A shows schematically the constituents of a complete weathering profile in granitic rock. Water flowing through the joints initiates breakdown of the intact rock away from the joints and leaves core boulders of relatively unweathered material in a matrix of weathered soil. This particular problem is associated with boulders in granite and granitic colluvium. As weathering progresses, the depth of completely weathered material increases (Zone A) until, in an old profile, Zones B and C may be almost completely absent. The depth of Zone D is thought to be related to the lowest depth of active groundwater flow, although weathering by other processes, whilst not likely to be active at present in Hong Kong, may operate below this depth. The depth of the weathered profile in granite may exceed 90 m, which is considerably greater than that established in volcanic rock.

In volcanic rock, where the joint spacing is close and mass permeability is therefore more uniform than in granite, weathering appears to progress more uniformly, so that corestones are not often evident. The reasons for the generally thinner depth of the weathered mantle and for the rapid change from unweathered to completely weathered rock in volcanics are uncertain and are not widely considered in the literature. They may be due to topographic and hydrological factors prevailing during earlier climatic periods as well as to material properties.

Time, climatic change and the landform type combine with the physical characteristics outlined above to influence the processes and the present condition of the terrain. These are important variables, since they may introduce apparent anomalies into the weathered profile. Weathering profiles and landform patterns form over considerable periods of time and are balanced between the processes of weathering and erosion. Hence, rejuvenation or abandonment of an established weathering profile, removal of portions of a weathered mantle, or deposition and subsequent weathering of a colluvial blanket may result in a change in this balance. These changes often result from altered hydrological conditions. Although certain inferences may be made from the shape of the terrain as to trends in depth of the weathered profile (Ruxton & Berry, 1957, Ruxton, 1960), the current terrain may be the result of more recent transport processes, as described in Appendix D.3.

NATURAL AND MAN-MADE INFLUENCES ON LANDFORM EVOLUTION IN HONG KONG ; THE ENGINEERING CHARACTERISTICS AND PROCESSES WHICH INFLUENCE LAND USE POTENTIAL , AND THEIR EVALUATION WITHIN THE GAS PROGRAMME.

NATURAL LANDFORMING INFLUENCES :
SUBSURFACE & SURFACE VARIABLES.

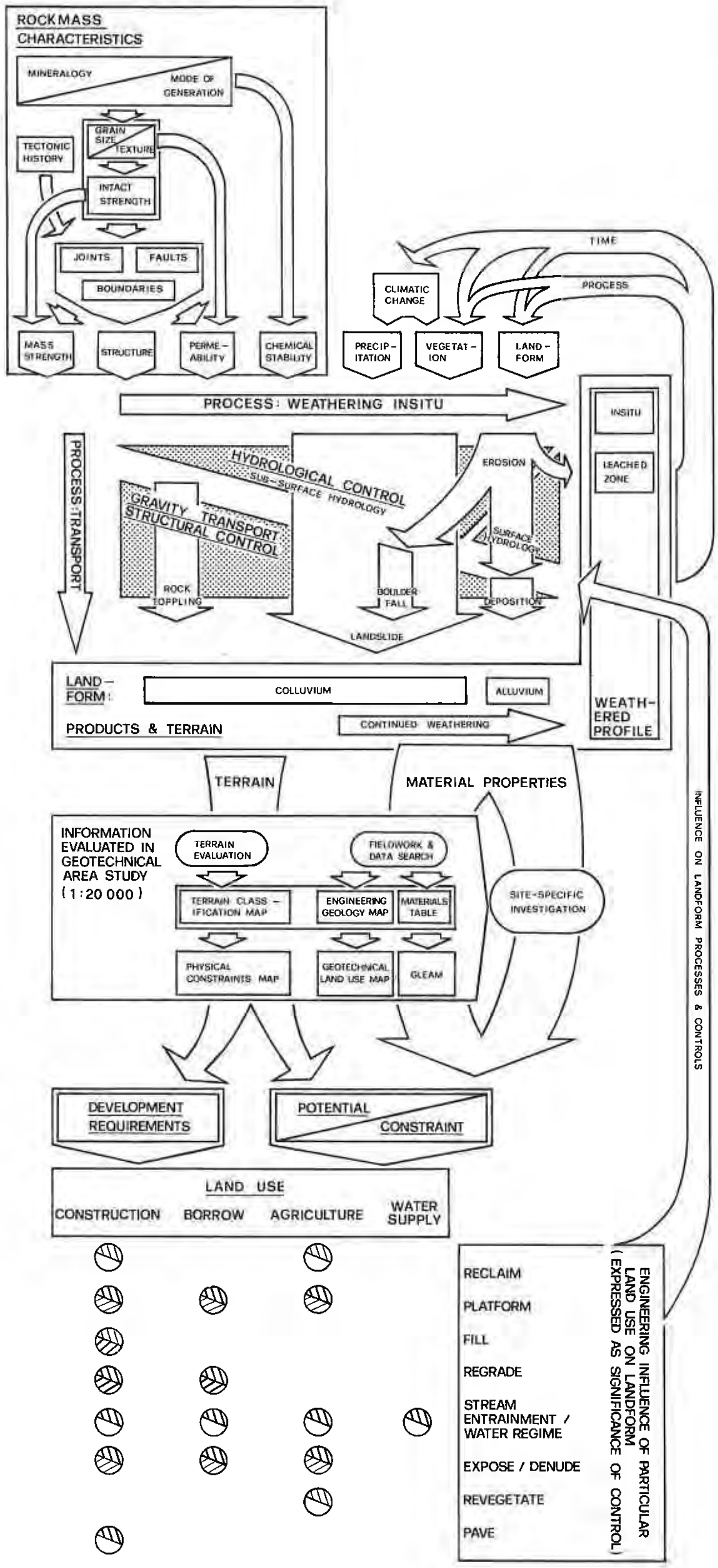
LANDFORMING PROCESSES :
RELATIVE INFLUENCE OF HYDROLOGY, STRUCTURE & WEATHERING ON TYPES OF TRANSPORT PROCESS. (BACKGROUND TRIANGLES SHOW PROPORTION OF INFLUENCE OF CONTROL).

LANDFORM :
INDICATED AS PRODUCTS OF VARIOUS LANDFORMING PROCESSES.

GEOTECHNICAL AREA STUDIES :
CLASSIFICATION OF TERRAIN & ENGINEERING MATERIALS, INTERPRETATION OF LANDFORM IN TERMS OF GEOTECHNICAL POTENTIAL & CONSTRAINT FOR STRATEGIC PLANNING & ENGINEERING FEASABILITY STUDIES. G A S PROVIDES PRELUDE TO SITE SPECIFIC INVESTIGATION.

INFLUENCES ON LAND USE :
POTENTIAL, CONSTRAINT, DEVELOPMENT REQUIREMENTS.

LAND USE CHART :
INTENSITY OF SHADING INDICATES ENGINEERING INFLUENCE OF PARTICULAR LAND USE ON
HYDROLOGICAL CONTROL
STRUCTURAL CONTROL THROUGH
MODIFICATION OF LANDFORM :
SLIGHT
MODERATE
SIGNIFICANT



LEGEND :

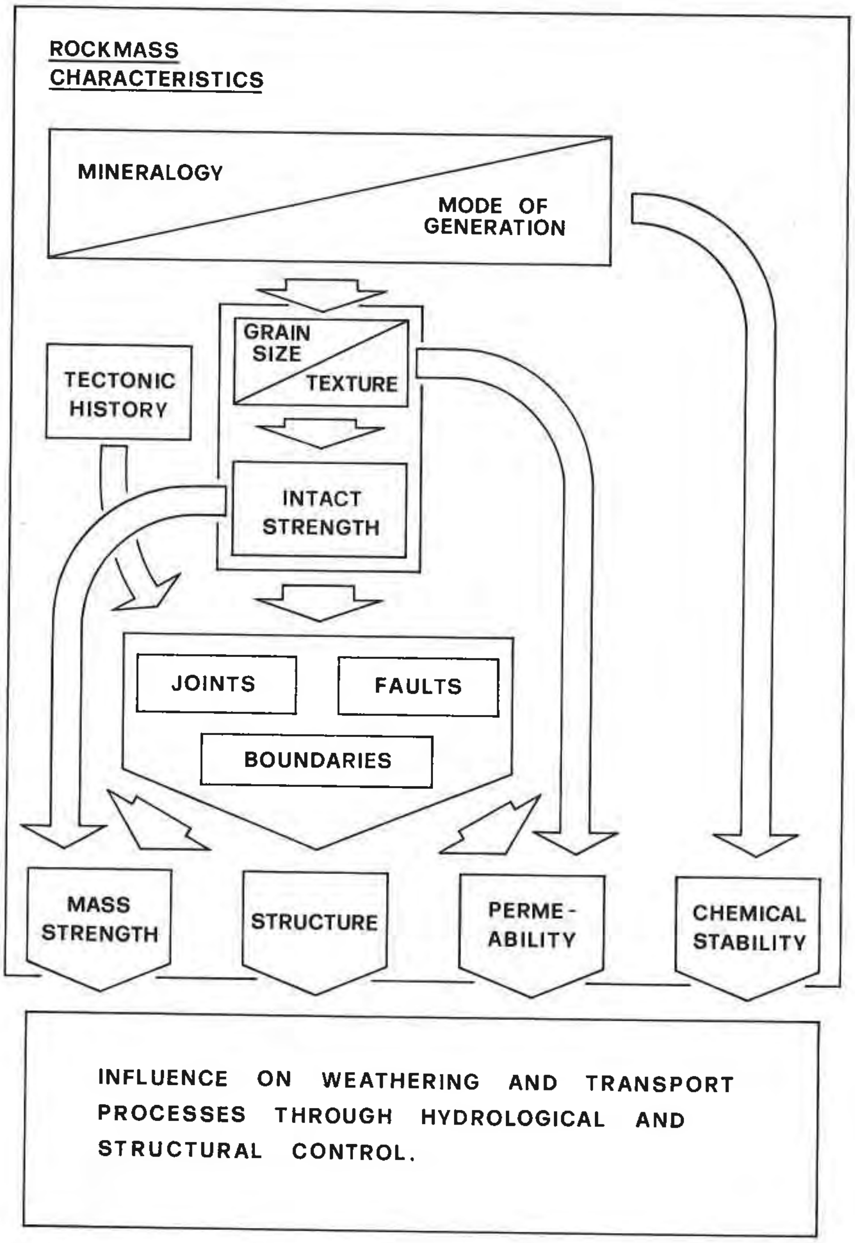
BOXES INDICATE : CAUSE OR PRODUCT

ARROWS INDICATE : INFLUENCE, PROCESS, OR MECHANISM

CIRCLES INDICATE : HUMAN INVOLVEMENT

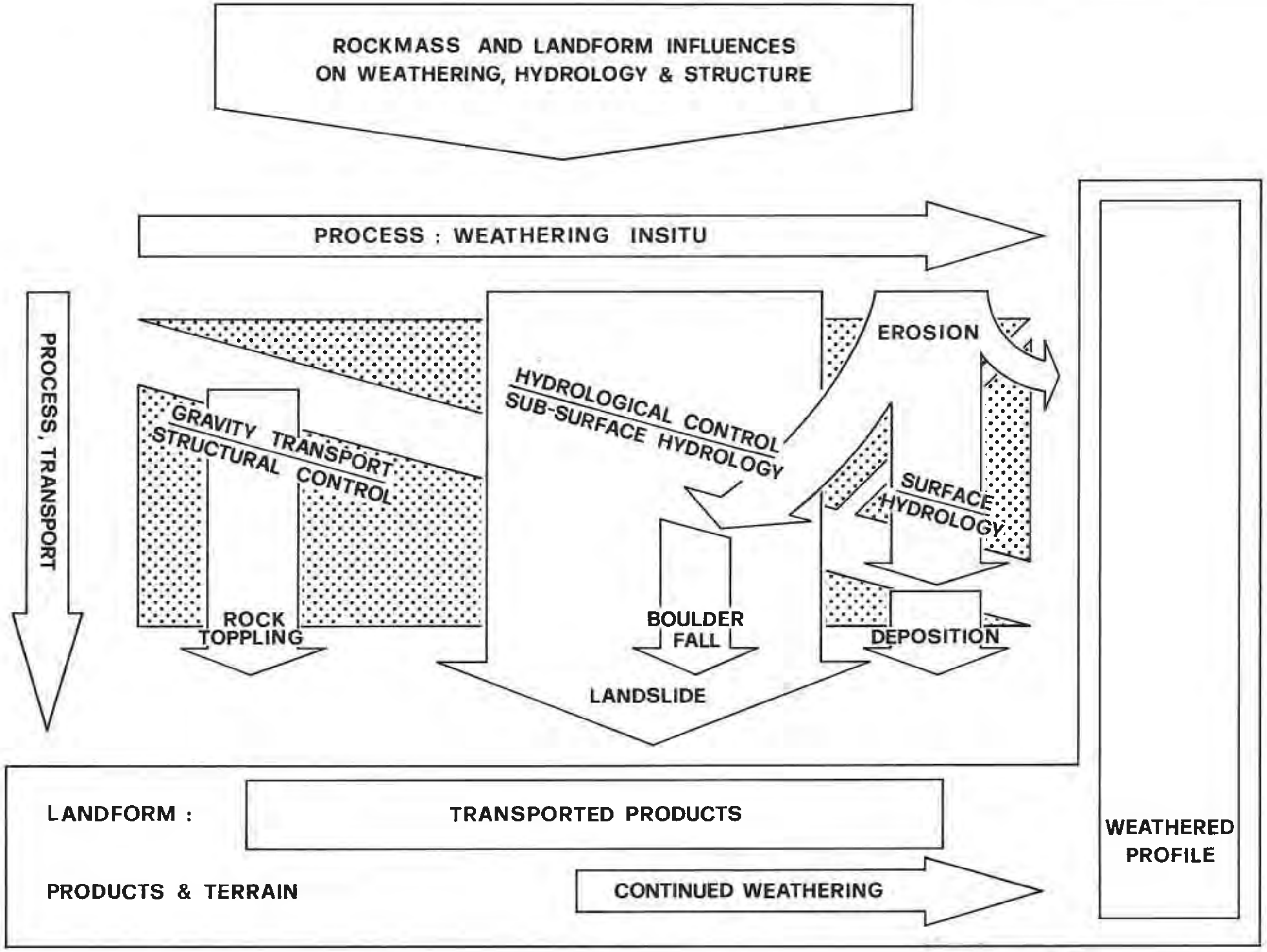
Influence of Landforming Processes

Fig. D1



SUMMARY OF ROCKMASS CHARACTERISTICS WHICH ARE SIGNIFICANT IN INFLUENCING NATURAL LANDFORM AND ENGINEERING WORKS IN HONG KONG. (EXTRACT FROM FIG.D1)

Rock Mass Characteristics	Fig. D2



SUMMARY OF LANDFORMING PROCESSES IN TERMS OF THE RELATIVE IMPORTANCE OF WEATHERING HYDROLOGY AND STRUCTURE. (EXTRACT FROM FIG. D1)

(BACKGROUND TRIANGLES SHOW PROPORTION OF INFLUENCE OF HYDROLOGY AND STRUCTURE)

Landforming Processes

Fig. D3

D.2.5 *Faults*

A fault is a fracture in rock along which there is an observable amount of displacement. Faults rarely occur in isolation, and more extensive faults or fault zones often display associated local shattering of the rock. Hence they may cause concentration of groundwater flow which permits deeper weathering to occur. If so, they often become observable in surface reconnaissance and from aerial photograph interpretation as photogeological lineaments.

D.2.6 *Boundaries*

Geological boundaries are often reflected geomorphologically and are sometimes enhanced by changes in vegetation. They commonly control the local hydrological regime and this, together with the local variations in structure and rock properties, is of significance in engineering work. Many geological boundaries in Hong Kong are also faulted.

D.3 Engineering Considerations for Development Planning

D.3.1 *General*

Geotechnical problems will be minimised if development takes place in a manner which reflects the basic suitability of the terrain for a particular use. The following sections discuss the engineering significance of the major terrain-related factors which influence the suitability of land for development. The discussion relates to those features which are particularly important for planning and engineering feasibility.

In Hong Kong, the relief of the terrain is dramatic, and the pressures for development are very high. A considerable portion of the currently developed terrain and natural terrain with potential for development is subject to high to extreme geotechnical limitations. These limitations are often associated with, or are related to, either natural or man-made features. For example, Vail & Beattie (1985) discuss the failure and stabilization of earthworks in the Territory. Further development within the study area will necessitate the utilisation of natural or man-made terrain which has geotechnical limitations. Some of these features continually recur across the landscape and have similar engineering problems. This section seeks to identify the major constraints associated with a number of engineering geological factors.

D.3.2 *Geotechnical Constraints to Development*

Within the study area, slope instability is a major geotechnical constraint to development. Instability may be associated with moderate to steeply sloping insitu or colluvial terrain or with land which has been disturbed by man. Landslips and other forms of slope instability are common occurrences on both natural and man-made terrain in Hong Kong. A number of serious landslip disasters have resulted in considerable loss of life and extensive property damage.

Rock toppling, rock slides and boulder falls are essentially structure controlled, although movement, which is usually sudden and without warning, may be initiated by groundwater pressure. Structural control is also affected by man's influence, because construction exposes release joints along which sliding may occur. Boulder falls usually require the erosion of weathered material or decomposition along planes of weakness through hydrological influence.

Landslips in weathered material pose a considerable hazard, but they are often preceded by signs of distress. Although largely controlled by relict jointing in moderately weathered material, natural failure is often precipitated by the subsurface water regime in conjunction with landslip-prone topography. Leach (1982) and Leach & Herbert (1982) studied the question of groundwater flows on Hong Kong Island.

Whilst erosion alone does not pose as great a hazard as slope instability, it can cause severe problems for engineering work. In addition, changes to the terrain and hydrology through construction or earthworks may cause erosion which may create conditions conducive to mass movement. The loose structure of weathered granites make these more susceptible to erosion than the volcanics when vegetation is removed. Evidence of this occurs in the denuded, eroded and bouldery upper sideslopes of the granitic terrain, where landslips are common at the heads of drainage lines. The debris from such landslips may travel at high velocity for considerable distances, blocking drains and resulting in surface water infiltration.

Deep weathering may be present, particularly where it is accelerated by shattered rock structure or active subsurface groundwater. Although weathering is not a severe constraint, it may pose considerable difficulties during construction, especially if very localised. Localised problems associated with geological photolineaments are discussed in Section D.3.4.

The following sections outline a number of specific problem areas which are important for planning and engineering feasibility.

D.3.3 *Fill and Reclamation*

Fill is soil or rock which has been used to provide site formation above the level of the natural terrain. The nature of the fill depends on the source material, the natural terrain, and the quality and control of construction. These factors, together with the history of filling, influence the engineering characteristics of the material.

The locations of fill and reclamation are shown on the Engineering Geology Map and the Physical Contraints Map. Large areas of fill are associated with the Government Housing Estates which occur around the Kowloon footslopes. Areas of Sau Mau Ping and Tsz Wan Shan are located on fill.

The nature and the engineering problems associated with fill can be categorised into the following:

(i) *Cut and Fill Platforms on Steep Terrain*

This technique is used in Hong Kong to provide level building platforms on otherwise steep terrain. A typical example is the Mid-levels district, where numerous cut slopes, platforms, fill slopes or retaining walls mask the natural slope profile. Plate 10 shows the extensive development in this area, much of it on slopes approaching 30° in gradient.

Since the disastrous fill slope failures at Sau Mau Ping in 1972 and 1976, fill has been recognized as a potentially hazardous engineering material. Consequently, recent fill platforms and slopes are designed and constructed to stringent requirements. Common problems in older fills on steep terrain are due to the fact that many were 'end tipped'. This results in:

(*a*) Poor compaction – a generally loose structure makes the fills susceptible to liquification resulting from infiltration of rainwater, movement of groundwater, through flow or from fractured water mains. This leads to sudden loss of strength and failure of the slopes. Loose fill is also liable to settlement and possible lateral movement on loading.

(*b*) Stratification parallel to the natural slope – this enables the infiltration of water from the level platform into the fill and also creates inclined planes of potential weakness liable to preferential failure.

Old fill has often been tipped into unprepared natural drainage lines, and the natural groundwater regime may persist beneath the fill, leading to infiltration and instability. The material behaviour is also subject to the variability of the source material. Completely weathered rock would result in a fairly uniform fill, whilst fill of less weathered rock may contain boulders and voids.

It is unlikely that new construction would occur on most old fill slopes, and even on old fill platforms, major reconstruction would probably have to comply with current practice.

Large areas of fill platform are used on the Kowloon footslopes for industrial and high density housing areas. Although they are generally located on more gently sloping terrain than those discussed above, they are very extensive in nature and obliterate the natural drainage pattern. Most of these areas are designed for their current land use.

(ii) *Fill on Low Lying Terrain*

The Kowloon Peninsula formerly consisted of isolated hills separated by alluvial areas. Most of these have long since been drained or raised to prevent flooding. Few engineering problems are envisaged in these areas, with the exception of settlement. Large buildings are generally piled. Deep excavations may experience difficulties due to high groundwater tables in underlying alluvium.

(iii) *Land Reclaimed from the Sea*

Almost all of the coastal areas on the mainland are modified by reclamation. Considerable recent and proposed development is based on these areas. On Hong Kong Island, reclamation has gradually extended the coastal plain northwards from Queen's Road. Almost all the residential, light industrial and commercial districts of Central, Wanchai, Causeway Bay and North Point are built on reclamation of varying age.

The historial development of reclamation is recorded on the Engineering Geology Map and is illustrated in Plates 18 and 19. At present, reclamation forms 12.7% of the study area.

Although most areas of reclamation are subject to current or proposed development, it is relevant to note that older reclamation materials may be very variable in quality. The following engineering problems should be anticipated during development in areas of reclamation:

(*a*) Lateral variability of materials—the extension of reclamation areas over a long time may result in material of differing sources and quality being present. Borehole samples should be examined and interpreted with this in mind.

(*b*) Variability of materials with depth—reclamation materials may vary with depth and cause local artificial aquifers and dense or loose zones. These should be anticipated in the choice of construction method and evaluated during site investigation. Boulders, timbers and other extraneous materials may be present in older areas. These may require localised measures during construction, such as hand-dug excavations. Better quality, more uniform material may allow driven piles for low structures such as warehouses, or larger diameter mechanically excavated sleeved caissons for heavier structures.

(*c*) Presence of old structures—within area of reclamation, features such as old foundations and sea walls may occur. Consultation of archive sources may help avoid local difficulties or anticipate setbacks during the critical foundation construction period.

(*d*) Dewatering problems—the reclamation material, in its loose, permeable, saturated stage, is likely to have water problems which may cause heaving in deep excavations. Grouting or dewatering may therefore be necessary. Dewatering may cause settlement problems in adjacent slabs and unpiled structures. Permanent or temporary impermeable barriers to water flow, such as continuous walling, may also cause problems to adjacent buildings by interrupting groundwater flow and raising water levels.

(*e*) Basements—these require tanking or water resistant design. External drainage may be necessary to prevent increase in water levels if drainage paths are blocked.

(*f*) Settlement—unpiled structures are subject to settlement and should be designed to redistribute loads or else to be flexible. Foundation stresses are subject to variation from fluctuating water levels in response to the tide. Piled structures may require design for negative friction in recent or deep reclamation.

(*g*) Underlying materials—the problems of construction on reclamation may be aggravated by considerable depths of marine or alluvial deposits and weathered bedrock. The depth of these will vary depending on the original ground profile. The general depth of underlying materials may be determined from site investigation, whilst local variation may be identifiable in the features of the old coastline and the onshore terrain.

(iv) *Sanitary Landfill*
Sanitary landfills are used for the disposal of domestic refuse. These are located within the study area at Ngau Chi Wan, Sai Tso Wan, Ma Yau Tong and Jordan Valley. Typical engineering problems associated with the development of sanitary landfills include:

(*a*) Heterogeneous materials which are difficult to remove.

(*b*) Unpredictability of stability of landfill slopes and embankments.

(*c*) Unpredictable, large settlements.

(*d*) Fire hazard from methane gas emission.

(*e*) Erratic water flows within landfill.

(*f*) Noxious leachates, posing pollution problems and chemical attack of concrete and steel.

For these reasons, recently completed sanitary landfills and adjacent platforms are probably unsuitable for development other than as open space or recreation areas.

D.3.4 *Geological Photolineaments*

Major geological photolineaments are shown on the Engineering Geology Map for the study area. These features and some more minor lineaments are also shown on the GLEAM if they are significant in the engineering feasibility of potential development areas.

Lineaments are the surface expression of subsurface structural features and, hence should be carefully examined during planning and engineering feasibility. Differences in rock type, structure or strength are amplified by the landforming processes to produce contrasts in erosion or vegetation, or linear patterns in relief or drainage. Such contrasts are readily identified using API and are often apparent during site reconnaissance. It should be noted that structural features causing lineaments will probably continue beneath superficial deposits such as alluvium, colluvium or fill and their influence should be anticipated in foundation works through these materials.

In general terms, contrasts in the terrain are a reflection of the resistance or susceptibility of the underlying material to erosion. Surface features are often good indicators of local engineering characteristics.

Lineaments tend to be localised and therefore they may often be avoided during the layout and design stages of an engineering project.

Engineering factors which are often associated with lineaments may be classified into the following:

(i) *Deep Weathering*
Shatter and shear zones in the rock tend to concentrate water flow and result in deep weathering. Localised rock shattering may be due to faulting and is likely to appear as a major lineament. Through Chai Wan, a band approximately 20 m wide of shattered rock was encountered during caisson excavation where volcanic rock (elsewhere not deeply weathered) was completely decomposed to a depth in excess of 40 m. The extent of the problem was apparent in both the terrain (major valleys extend on each side of the ridgeline) and in the site investigation results (a corresponding sharp dip in bedrock levels was indicated by boreholes). The influence of this lineament on weathering depths is very localised and, although the lineament is not extensive compared with others in the study area, the same may be true for more major structural features. The fault adjacent to Tai Tam Road at Red Hill Peninsula shows similar very localised deep weathering.

Other larger lineaments are present in the study area. For example, major features traverse Wan Chai Gap to Aberdeen, between Ma Yau Tong and Kwun Tong, and from Repulse Bay to Chai Wan. North of Tai Tam Tuk, the latter feature intersects with one trending northwest to southeast through Mount Butler Quarry near the contact between volcanic and granite rock. The GLEAM shows the influence of structure on drainage in this area; foundation difficulties may occur due to rapidly changing ground conditions.

Many of the lineaments are major features which are continuous across the study area.

(ii) *Slickensiding*
Slickensiding is evidence of larger scale movements in rock and soil. Smoothing and striation on a fault plane render it more susceptible to failure if a cut slope were to intercept and release a slickensided joint. Whilst this problem may not be obvious prior to excavation, it should be anticipated where fault lineaments are indicated.

(iii) *Changes in Rock Mass Structure and Properties*
Smaller scale lineaments are often identified from preferential drainage caused by a weakness or adjacent strength of the rock mass. This may be due to variation in the rock itself or in its structure. Where the lineament is evidence of a structural weakness, problems may be encountered in the founding of caissons and in the construction of rock cut slopes.

Small scale, as well as major, lineaments may be associated with anomalies in the general pattern of weathering depth which may cause differential settlements of raft foundations.

Regular patterns of lineaments, such as appear on the west coast of D'Aguilar Peninsula parallel to the regional lineaments, are evidence of the regional pattern of structure present at smaller scale. Engineering works in the area may experience instability problems on cut slopes at particular orientations.

In areas of active coastal erosion, the local rock structure is often apparent from the pattern of erosion and instability. This is shown on the GLEAM and, for example, confirms the pattern of lineaments and the local structure for the area around Cape Collinson.

Boundaries between rock types may or may not form lineaments, partly depending on whether they are faulted or not. Identified rock boundaries are shown on the Engineering Geology Map and the GLEAM. Changes in structure are likely at granite/volcanic boundaries due to cooling stresses, and in strength and weathering due to contact metamorphism.

(iv) *Preferential Groundwater Flow*
The preceding engineering features of lineaments are usually associated with preferential groundwater flow, both at and below the surface. This should be a consideration in the construction of fills in valleys where the subsurface hydrology may be largely unaffected inspite of surface water entrainment.

(v) *Seismic Influence*
Some lineaments are identified on the Engineering Geology Map (after Allen & Stephens, 1971) as faults, and other major lineaments may also have been caused by ground movements.

D.3.5 *Colluvial Deposits*

Colluvium is a transported material, whose nature and engineering characteristics depend on the origin of the material, the conditions of its deposition and its subsequent history. Various types of colluvium exist within the study area, and their location, nature and material properties are discussed in Sections 2.3, 2.4 and 3.1.2. The extent of colluvium as identified by terrain classification is shown on the Engineering Geology Map.

Colluvium need not necessarily be regarded as a constraint for engineering. Relict colluvium in a completely weathered state as it occurs on the Kowloon footslopes may be strengthened by overconsolidation and be virtually indistinguishable in material behaviour from its weathered parent. However, colluvium is inherently variable and, as demonstrated by the Po Shan Road disaster in 1972, when a portion of a large colluvial slope failed, it is usually an extremely difficult material to assess in engineering terms. Plate 9 shows the extent of the remedial works at Po Shan Road.

Engineering factors which are often associated with colluvium may be classified into the following:

(i) *Physical Properties*
Colluvium is subject to local variations of structure, density, strength and water content, both horizontally and vertically. In particular, concentrations of subsurface water flow may result in voids and pipes caused by the removal of fines, and in local piezometric variation. Stratification of these deposits may cause perched water tables and variations in the strength profile. Settlements under load may be unpredictable. Hence, heavily loaded structures should be founded on caissons through to bedrock. In situations were loading of the colluvium could cause instability, measures should be taken to ensure that loads are not transferred to the colluvium. The variable nature of colluvium will usually require the use of hand dug caissons. As discussed for boulder colluvium in Section 3.1.2, measures should be taken to avoid any adverse influence on the groundwater regime.

(ii) *Water Conditions*
The potential for localised flows and perched water tables should be anticipated if piezometers are to be installed. A single piezometer within the profile is seldom adequate to determine the groundwater regime, and the location of piezometers should be based on the observations of the site investigation. In particular, the water pressures should be monitored and interpreted, if significant to design, with respect to strata within the profile. Pressures in underlying weathered material, which in parts of the Mid-levels district is more permeable than the colluvium, are also important.

(iii) *Stability*
The stability of cut slopes is very susceptible to local variations in strength and water pressure. Since it may not be possible to define these fully from the site investigation, the progress of excavations should be closely monitored to accommodate local variation.

Particular attention should be paid to material boundaries, voids and seepage zones. These may render modelled design conditions doubtful. Many of the cuts in colluvium in the Kowloon footslopes show zones of water seepage. Local instability in natural oversteepened colluvial slopes results from emerging groundwater. In cuts in colluvium such conditions may lead to progressive collapse of a loose soil structure upslope with considerable debris flow.

(iv) *Site Investigation*
In heterogeneous deposits such as extensive recent colluvium and boulders, site investigation alone cannot reveal a comprehensive model of the ground, nor can appropriate strength values be accurately assessed. Carefully monitored trial caissons are often justified in colluvial deposits. Attention should be paid to variations in bedrock and its level in boreholes to ensure that foundations do not rest on boulders.

D.3.6 *Boulders and Rockfalls*

Boulder and rockfalls are a feature of the wet season in Hong Kong and have on occasion resulted in loss of life and considerable property damage.

Boulders are large blocks of rock which often result from wide joint spacing. They occur often in granitic rocks as the unweathered remnant corestones between completely weathered joints. If exposed on steep hillsides or in drainage lines, they may be liable to movement.

Adverse jointing and exposed location may result in potential rockfalls in both granitic and volcanic terrain. In this case, weathering, except as a local weakening of the joints, is not a major contributing factor. An example is the large zone of volcanic outcrop above the Mid-levels. In granitic rock, the presence of extensive sheeting joints also contributes to the rockfall potential.

Boulders, joint blocks and wedges may also be present in, or as exposed remnants of, both granitic and volcanic colluvium. Large colluvial granite boulders rest on the colluvial blanket above Tsz Wan Shan and on the slopes of Beacon Hill in Kowloon. The colluvium is very bouldery in nature and presumably results from the steep granite faces of Lion Rock.

In July 1926, a boulder, possibly of colluvial origin, reportedly caused a number of fatalities at Elliot Pumping Station on Pok Fu Lam Road.

Boulders may also exist in drainage lines where they are likely to be restrained and interlocked. However, high flows caused by torrential rain is liable to increase the likelihood of movement. Boulders in drainage lines may also trap detritus and torrential flows may cause mud or debris flows.

In areas with potential for development, boulders and rock outcrops are indicated on the GLEAM where they are obvious in aerial photographs. In many situations, boulders are hidden from view by dense vegetation.

Engineering solutions to the boulder and rockfall problem depend largely on the local situation, but may consist of one or a combination of the following:

(*a*) Removal—Isolated boulders may be removed from the slope if the situation permits. This could be achieved by blasting or excavation.

(*b*) Restraint—it may be possible to restrain or support isolated boulders and rock wedges by buttressing, anchoring, or cable support.

(*c*) Protection—in areas with long slopes and many potentially unstable boulders or blocks of small to moderate size, identification and removal of critical boulders may not be warranted or may detrimentally affect stability. In such cases, general protection measures may be more appropriate, such as sterile zones, trap ditches or bunds, catch fences, protection nets or deflection barriers.

D.3.7 *Boulders below Ground*

In the granites and colluvium of the study area, boulders are often present within the weathered matrix. Site investigation and construction of load bearing foundations should examine these features. For deep foundations, hand excavation may be required. Blasting of boulders in caissons or cuttings may cause loosening or collapse of the surrounding matrix. Variations in the bedrock level and in the bedrock material may also indicate the presence of boulders.

In bouldery colluvium, voids are likely beneath boulders as a result of the nature of deposition or due to washing out of the matrix in underground drainage lines. This poses particular problems for the construction of deep foundations through these materials.

Problems of this nature in colluvium should be anticipated on the south and southwest facing Kowloon footslopes where boulders in excess of 10 m diameter occur.

D.3.8 *Marine Deposits*

Marine deposits are not considered in detail from an engineering point of view in this Report, except in relation to reclamation. Their geological characteristics are discussed in Appendix C.

D.3.9 *Cut Slopes*

Cut slopes and/or slope support structures are an aspect of most large-scale developments in Hong Kong. Different considerations govern the use and design of slopes depending on the geological material, its state and structure. Hence, the overall form of a development should also relate to the engineering opportunities of the terrain.

The height and angle of a cut slope is a matter for design based on a model of the rock or soil strength and structure as determined by site investigation. Preliminary assessment of the size and form of slopes and retaining structures may be made on the basis of the engineering properties of the local rock type, as indicated on the Engineering Geology Map and in the Materials Table (Table 3.1). At the planning stage, flexibility of layout should be retained, especially where large cuts are involved, so that local variations in strength and structure can be accommodated in design. Lineaments and structural control are indicated on the GLEAM. Structural control may indicate shallow bedrock, and the structure will influence the stability of cuts in rock. Lineaments indicate a local structural feature which may influence the final slope design, probably requiring a shallower angle cut on the weaker rock zone.

In large developments on steep terrain, a more geotechnically economical use of the site can be made by providing a stepped site formation which follows the terrain, rather than a large level formation with very large cuts. The benefits of this approach occur in different ways, for each of the major geological materials occurring on steep terrain:

(i) *Volcanic Terrain*
Weathering depths of less than 15 m are generally noted for steep volcanic terrain in the study area, with rapid transition from weathered to fresh rock. In such terrain, structures can economically be founded at shallow depths and large fresh rock cuts avoided. Where fresh rock cuts are formed, the jointing of the rock may cause some surface unravelling, and net protection or a safety zone may be required to maximize slope angles. Locally persistent or unstable joints may require shallower angled cuts or support measures.

(ii) *Granite Terrain*
Considerable depths of various grades of weathering are encountered in the granitic areas of Hong Kong and Kowloon. Large structures founded in this terrain will generally require caisson foundations to bedrock. If large flat site formations are to be created in steep granitic terrain, major cuttings and retaining structures should be provided through a range of weathered rock. The only advantage of this is that shallower caissons can be used, and that extensive flat areas can be created.

The design of cut slopes in less weathered granite (less than Grade III) may require empirical approximations to model the strengthening influence of boulders. In cuts in fresh rock, sheeting joints are likely to be encountered, such as those on Wong Nai Chung Gap Road, which require additional support or the draining of water. These local measures enable steep cuts to be made in fresh granite, but the particular form of additional support cannot be determined in advance.

(iii) *Colluvial Terrain*
The creation of extensive cuts in colluvium should be avoided. Aspects of the material affecting stability are noted in Section 3.1.2. Colluvium overlies the insitu rocks in almost all the potential development areas outlined in this Report. Colluvium has been associated with a number of serious slope failures in the Territory, and there are many instances where local failure has occurred on cuts formed for development platforms on steeper terrain.

D.3.10 *Maintenance of Natural Drainage*

In colluvial areas and in the vicinity of man-made fills, where stability of excavations and slopes is particularly sensitive to water pressure and localised erosion, the pattern of natural drainage should be maintained as far as is practicable.

Diversion of natural drainage, if poorly maintained or of inadequate capacity, may cause overtopping of channels with consequent erosion and infiltration on slopes during heavy rains when stability is most vulnerable. Many streams in the study area carry large amounts of silt from surface wash, which is often deposited on bends or flatter sections of entrainment schemes. This is particularly the case in eroded granitic areas such as North Point. The abandoned reservoirs above Quarry Bay are heavily silted, and some are soon to be developed.

The pattern of subsurface flow beneath any superficial or partly weathered material is unlikely to be affected by most surface water entrainment schemes. Subsurface flows may enter fill in valleys from beneath, even though surface drainage reduces infiltration. It is possible that the fill slope failures at Sau Mau Ping were the result of such subsurface flows.

Even in situations where the natural drainage pattern is not significantly altered, an impermeable surface cover such as a large paved area can considerably increase the quantity of surface runoff and reduce the time of concentration. This has been observed during heavy rain at Pok Fu Lam and Chai Wan cemeteries. Flooding and consequent infiltration of slopes may become a problem even though, in the natural terrain, it is not the case. Old nullahs located in developing areas are often subject to overtopping in intense rain for this reason.

The natural and post-development hydrology requires careful investigation and design due to their influence on slope stability.

D.3.11 *Site Investigation*

A 'desk study' is a necessary preliminary to any site investigation. The GASP report summarises, interprets and presents much of the information which would be reviewed in a desk study and, in addition, is reinforced by field reconnaissance.

The 1:20 000 GASP Report is designed for use at a strategic planning and engineering feasibility study stage. The GLUM indicates the general level of site investigation envisaged for each class of map unit and is summarised in Table A2. Information on the engineering geological characteristics, the local geological and terrain constraints, and the general suitability of an area are shown on the EGM, PCM and GLEAM. Only in determining the engineering feasibility of a large uninvestigated area should a preliminary site investigation be based only on a 1:20 000 GASP Report.

When interpreting the GLUM with regard to site investigation, the following points should be considered:

(*a*) In the study area, extensive site investigation for a range of engineering projects is available. Some of the reports are accessible in the GCO's Geotechnical Information Unit (GIU), and many provide a great deal of the background geotechnical information necessary for a new project. Figure C2 gives an indication of the distribution and intensity of site investigation records held in the GIU.

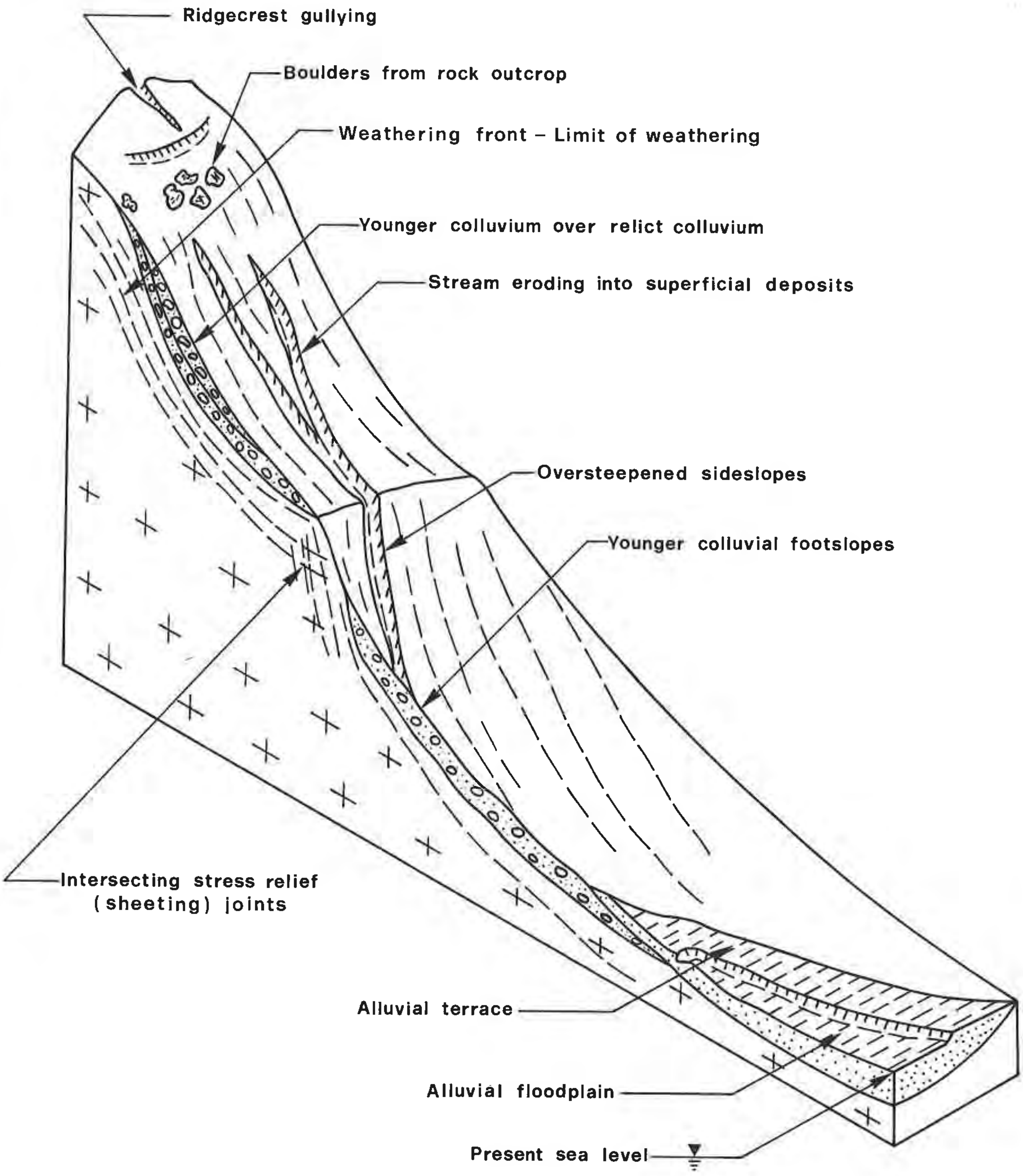
(*b*) A field reconnaissance of the site and the surrounding area is a necessary preliminary to planning a site investigation. On undisturbed sites, much can be inferred with regard to the strength of underlying materials, the pattern of superficial deposits, and local weaknesses in rock from site observations of the contrasts in landform and the pattern of drainage on and around the site.

(*c*) The site investigation should be designed to highlight the scope of any available information, the anticipated material, its nature and variability, and the type and form of the engineering project.

(*d*) Approximately 1 650 ha of the study area has been evaluated at a scale of 1:2 500 within the GASP District Stage 1 Study Programme. The EGM and Engineering Data Sheet (EDS) produced for each of the seven studies should be used to aid the design of site investigation.

D.4 Landform Model of the Terrain in Hong Kong

Landforms are the product of the local balance between weathering, erosion and deposition and are continually evolving. The mechanics of the system and its various components are shown in Figure D1 and described in Appendix D.3.1 (Hansen, 1984 a & b). This section discusses the significance of the sequence of landform evolution to the engineering properties of the materials within the study area. This is achieved in terms of their distribution and thickness. Many of the geomorphological processes act at rates that engineers consider insignificant. However an understanding of the evolutionary system will aid an engineering appreciation of the terrain, because the consequences of slope processes affect the materials with which an engineer constantly deals. Figure D4 provides a simplified hillslope model and relates to the following text.



Hillslope Model

Fig. D4

Slopes that are too steep for the weathered material to remain stable are subject to periodic failure. The magnitude of failure may be isolated and small or catastrophic in nature. Therefore, the recognition of slope process is important in order to highlight the landslip hazard. The origin of many of the oversteepened inland slopes in Hong Kong lies in the consequences of the fall in sea level that resulted from the growth of the ice sheets during the Pleistocence. During this period, the sea level fluctuated dramatically; there is evidence in southern China that stream incision occurred and produced oversteepened slopes adjacent to the channels. Gradually, the incision progressed inland, taking advantage of structural weaknesses in the underlying geology, with the result that many valleys are narrow with steep sides. The increased rate of erosion removed much of the weathered mantle adjacent to the streams. This, in part, explains the occurrence of shallow weathering depths and slightly weathered bedrock along the floors of many incised valleys in the Territory.

Drainage courses are the main axes of erosion within a valley. The density of drainage pattern responds to and is influenced by the materials and structural control. Incision and removal of material creates over-steepened sideslopes adjacent to the drainage lines by erosion and slope failure. This process continues to induce oversteepening of the terrain, which causes lateral recession of the hillsides. Oversteepening progresses upslope through erosion by instability, as the depth of weathered mantle increases to a limiting value. The terrain on either side of the oversteepened slope section contains different associations of landforms (as shown in Figure D4) as each part of the slope is reacting to a different set of denudational conditions. Below the oversteepened sideslopes, the landforms are comparatively young. Boulders in the colluvium, deposited as a result of landslips and slopewash from the oversteepened slope, are generally unweathered. The oversteepened sideslopes contain many landslip scars, often as recent and relict features, as well as rock outcrops protruding through the thin soils. Above the level of slope oversteepening, the landforms are generally much older. Thus, the spurlines are more deeply weathered and may possess a relict colluvial cover with boulders that are decomposed insitu. In some situations in the study area, younger colluvium overlies older relict deposits. Stream incision occurs at a faster rate than the upslope migration of the oversteepened slopes. This promotes instability adjacent to the stream channels through undercutting. Erosion may result in the exhumation of corestones or boulders which are either distributed across the terrain or are concentrated within drainage lines.

Irregularities in slope profile can also be the result of variations in the resistance to erosion of the underlying rock types. The existence of dykes, faults or more resistant strata are examples. However, these features usually result in a different spatial distribution of landforms and may can be distinguished through the careful use of aerial photograph interpretation and field mapping.

Provided that the debris resulting from the erosion of the oversteepened slope is continually transported away from the slope, instability will continue regardless of changes to the denudational system downslope. If the debris is not removed as fast as it is being deposited, colluvial fans form. If sediment supply decreases or base level is lowered, then incision of the fans results. A number of examples of colluvial fans with this type of geomorphological history exist in the Mid-levels district and along the footslopes of the Kowloon hills.

With the retreat of the ice sheets at the end of the Pleistocene, the sea level gradually rose. The deepened valleys became sediment traps for the material that was eroded from the sideslopes. Great thicknesses of alluvium (mainly sands and silts with occasional gravel lenses) accumulated, particularly in the lower reaches of the valleys in which there was an abundant sediment supply. Alluvium at the sides of these valleys is interlayered with colluvium deposited by landslips. As both alluvium and colluvium were deposited during the period of lower sea level, they may both exist beneath, as well as intercalating with marine sediments.

APPENDIX E

GLOSSARY OF TERMS

ALLUVIUM

Sediment transported and deposited by a river or stream.

ALLUVIAL FAN

Mass of sediments deposited at a point along a river or drainage line where there is a decrease in gradient. The fan is thickest at its point of origin and thins rapidly in a downstream direction.

AERIAL PHOTOGRAPH INTERPRETATION

Technique of interpreting data from aerial photographs which are viewed stereoscopically. This method enables the evaluation of the terrain in three-dimensions.

AGGLOMERATE

Pyroclastic rock consisting mainly of fragments greater than 60 mm in diameter; rounded pyroclastics predominate.

ASPECT

Direction in which a slope faces.

AREA INSTABILITY INDEX

Proportion of a particular area of land which is affected by instability.

BATHOLITH

Large intrusive igneous rockmass.

BEDROCK (=SOLID GEOLOGY)

Insitu rock exposed at the surface or underlying any superficial material such as topsoil, residual soil, alluvium or colluvium.

BLOCKS

Solid pyroclastic fragments greater than 60 mm ejected from volcanoes by volcanic action.

BOMBS

Partially or wholly molten pyroclastic fragments greater than 60 mm ejected from volcanoes by volcanic action. These fragments often acquire distinctive shapes or surface textures during ejection and subsequent transport.

BRECCIA

Rock consisting of coarse grained (>60 mm) angular fragments implying minimal transport of material. Breccias are poorly sorted and commonly contain rock fragments derived from a restricted source. Also see FAULT BRECCIA.

CATCHMENT AREA

Area from which a river or stream collects surface runoff. Often used synonymously with DRAINAGE BASIN.

CHLORITISATION

Replacement by, conversion into, or introduction of chlorite into the rock substance.

CHUNAM

Cement-lime stabilised soil used as a plaster to protect the surfaces of excavations from erosion and infiltration. The recommended mix for chunam plaster, the proportions being measured by weight, is one part Portland cement, three parts hydrated lime and 20 parts clayey decomposed granite or volcanic soil.

COASTAL PLAIN

Terrain component defined as flat terrain lying between the littoral zone and mountain footslopes.

COLLUVIUM

Heterogeneous deposit of rock fragments and soil material transported downslope through the influence of gravity, including creep and local slopewash.

COUNTRY ROCK (=HOST ROCK)

General term applied to rocks penetrated by and surrounding an igneous intrusion.

CUT SLOPE AND CUT PLATFORM

Surface which remains after volume of soil and/or rock has been excavated. Within the terrain classification system, such units with gradients in excess of 5° are cut slopes, while those with gradients less than 5° are cut platforms.

DETRITAL

Term applied to any particles of minerals or, more commonly, rocks which are derived from pre-existing rocks by processes of weathering and/or erosion.

DIP (or TRUE DIP)

Angle of a plane to the horizontal, measured in a direction perpendicular to the strike of the plane.

DIP DIRECTION

Direction or azimuth of dip.

DISCONTINUITY

Interruption, usually of a planar nature, to the homogeneity of a rockmass (i.e. joints, faults). The description and classification of discontinuities is given in the 'Geotechnical Manual for Slopes' produced by the Geotechnical Control Office. (1984).

DISTURBED TERRAIN

Terrain component, defined as land permanently altered from its original state by man. Cut and fill slopes are usually designated as 'disturbed terrain'.

DRAINAGE PLAIN

Terrain component, defined as an area subject to periodic overland flow of water, and within the GASP it is defined as colluvial in nature. It may be an area of spring activity. In some situations, drainage plains may include deeply incised drainage channels.

DURICRUST (=HARD PAN)

Near surface cemented layer occurring in soils or weathered rocks as a result of groundwater action. The cementing agent may be siliceous, calcareous, ferruginous or aluminous.

DYKE

Wall-like body of igneous rock which is discordant, i.e. cuts across bedding or structural planes of the host rock. Usually near vertical. A set of dykes in a parallel or radial pattern constitutes a DYKE SWARM.

EPHEMERAL STREAM

Stream which only flows for short periods of the year.

EROSION

Natural process which involves the wearing away and/or removal of the land surface by the action of a transporting medium or its entrained debris. The agents of transportation can be water, wind or gravity.

FABRIC

Overall appearance of a rock or soil exposure or hand specimen resulting from the combined features of texture and structure.

FAULT

Fracture in rock along which there has been an observable amount of displacement.

FAULT BRECCIA

Assembly of broken fragments formed by crushing or grinding along a fault plane.

FILL SLOPE AND FILL PLATFORM

Surface which is artificially constructed from soil or rubble transported by man. Within the terrain classification system, such units with gradients in excess of 5° are fill slopes, while those with gradients less than 5° are fill platforms.

FLOODPLAIN

Terrain component, defined as a flat area in alluvial terrain which is subject to periodic inundation.

FOOTSLOPE

Terrain component, which is essentially a zone of deposition and which usually occupies a basal position in the terrain. Within the Regional GASP, footslopes are defined as being colluvial in nature.

GENERAL INSTABILITY

Terrain attribute defined for use in 1:20 000 scale GASP mapping to describe areas where large numbers of small landslips or other instability occur.

GEOTECHNICAL AREA STUDY PROGRAMME (GASP)

Geotechnical study of a specific area by the GCO on the basis of systematic terrain classification using aerial photograph interpretation, fieldwork and engineering assessment.

GEOTECHNICAL LAND USE MAP (GLUM)

Map which delineates the general geotechnical limitations of the terrain for planning purposes.

GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP (GLEAM)

Map which delineates areas with potential for development and highlights the associated engineering constraints.

GULLY EROSION

Terrain attribute, characterised by incised drainage channels formed by the removal of soil or decomposed rock by the surface flow of water.

HILLCREST

Terrain component, which is convex in shape. The terrain surrounding this component falls away in all directions.

HYDROGRAPH

Graph showing the volume of stream (or channel) discharge against time. A 'flashy' hydrograph has a steep rising limb and indicates a very rapid increase of discharge following rainfall.

IGNIMBRITES (=WELDED TUFFS)

Chiefly a fine-grained rhyolitic tuff formed mainly of glass particles (shards), in which crystals of quartz, feldspar and sometimes other minerals are embedded. The glass shards are welded or bent around the crystals, having been viscous when deposited. The glass shards are often devitrified.

INDURATION

Process by which a soft soil or rock material becomes hard. Generally includes hardening by baking, pressure or cementation.

INSITU MATERIAL

Material in original position of formation as opposed to loose, disconnected, transported or derived material.

INTRUSION

Body of igneous rock which has forced itself into pre-existing rocks, either along some definite structural feature or by deformation and cross-cutting of the invaded rock.

LAND CAPABILITY

Capacity or potential of a parcel of land to sustain a particular use.

LANDFORM

General shape and characteristic morphology of the land surface.

LANDSLIP (=LANDSLIDE)

General name for downhill movements of soil or rock involving shear failure. Term is generally restricted to failures in soils. Rock failures are more commonly termed ROCKSLIDES or ROCKFALLS.

LAPILLI

Pyroclastic fragments measuring between 2 and 60 mm ejected from volcanoes by volcanic action.

LENTICULAR COLLUVIUM

Colluvial deposit which is essentially confined by valley sideslopes or is marginal to a natural drainage line. These deposits are usually ribbon shaped features.

LITHOLOGY

General physical character of a rock, including mineral constituents, texture and structure.

LITHOSTRATIGRAPHY

Stratigraphy based only on the physical and petrographic features of rocks (as opposed to a biological or age basis).

LITTORAL ZONE

Terrain component, defined as the area between the highest and lowest levels of spring tides, i.e. beach.

MANTLE (=REGOLITH)

Weathered rock material overlying fresh rock.

MASS WASTING

General term for the dislodgement and downslope movement of soil and rock material.

MATRIX

Finer grained fraction within a soil or rock containing large particles.

MAXIMUM DRY DENSITY

Density obtained using a specific amount of compaction at the optimum moisture content (British Standard Test: BS 1377).

NATURAL SLOPE

Area of sloping ground substantially unaltered by man.

OUTCROP

Part of a geological formation or rock that appears at the ground surface. The exposure of bedrock or strata projecting through the overlying cover of detritus or soil.

PEGMATITE

Igneous rocks of very coarse texture found usually as dykes or veins associated with a large mass of plutonic rock of finer grain size (e.g. granite).

PERENNIAL STREAM

Stream that flows throughout the year.

PHYSICAL LAND RESOURCES

Physical characteristics of land.

POLYGENETIC

Many cycles of development.

PYROCLASTIC ROCK

Volcanic rock composed of rock fragments (including molten material and fragments of country rock) explosively ejected from a volcano. TUFF is a general name for consolidated pyroclastic ash.

RECLAMATION

Area of land reclaimed from the sea.

RELICT

Term used to describe remnants of earlier landscapes or surface deposits. Also used to describe traces of lithological features in residual soil.

RESIDUAL SOIL

Soil resulting from the weathering of rock insitu.

RILL EROSION

Terrain attribute characterised by subparallel sets of small narrow channels formed by the concentration of surface runoff.

ROCK EXPOSURE (=ROCK OUTCROP as defined for Terrain Classification)

Discrete area of rock exposed at surface.

ROOF PENDANT

Mass of older country rock forming the roof of a major igneous intrusion (e.g. a granite batholith). On a map, a roof pendant is completely surrounded by the rock of the batholith.

SCREE (=TALUS)

Debris resulting from the mechanical weathering of rock which accumulates at the foot of a cliff or a steep slope.

SESQUIOXIDES

Oxides of iron and aluminium (e.g. Fe_2O_3 & $Al(OH)_3$) which are generally mobilized as ions in solution by groundwater and which, upon precipitation, often act as the cementing agent in the formation of duricrust.

SHEET EROSION

Terrain attribute, characterised by the removal of the surface layers of soil by wind or water.

SHEETING JOINT

Discontinuity produced by pressure release or exfoliation. Sheeting joints may separate large rock masses, e.g. of granite into tabular bodies or lenses, roughly parallel with the rock surface. Often persistent for large distances and generally following the shape of the landform.

SIDESLOPE

Terrain component, used to describe the terrain between footslope and hillcrest. This terrain unit is usually erosional.

STRIKE

Azimuth of a horizontal line drawn on a bedding plane. Strike is at right angles to the direction of true dip.

STRUCTURE

Relationship between different features (and their causes) in a rock mass or soil, e.g. bedding, jointing, cleavage, faulting, contacts between different lithologies and, in a regional context, the geographical distribution of these features.

TECTONIC

Relating to a period of deformation or mountain building e.g. granite emplacement. Post-tectonic refers to events occurring after a particular deformation period. Syntectonic implies an event taking place coextensively with a definite period of deformation, intrusion, etc.

TERRAIN ATTRIBUTE

Characteristic of the terrain as defined within the terrain classification system. (Refer to Table A1).

TERRAIN COMPONENT

Geomorphological unit, e.g. hillcrest, floodplain. One of the attributes by which terrain is classified.

TERRAIN EVALUATION

Assessment of an area of ground for engineering or other purposes. The technique of aerial photograph interpretation is used to assess the landscape features.

TEXTURE

Relationship between the grains of minerals forming a rock, mainly in terms of size, shape and arrangement.

TOR

Landform characterised by an elevated pile of rock slabs or loose boulders formed by weathering and erosion of insitu materials.

TUFF

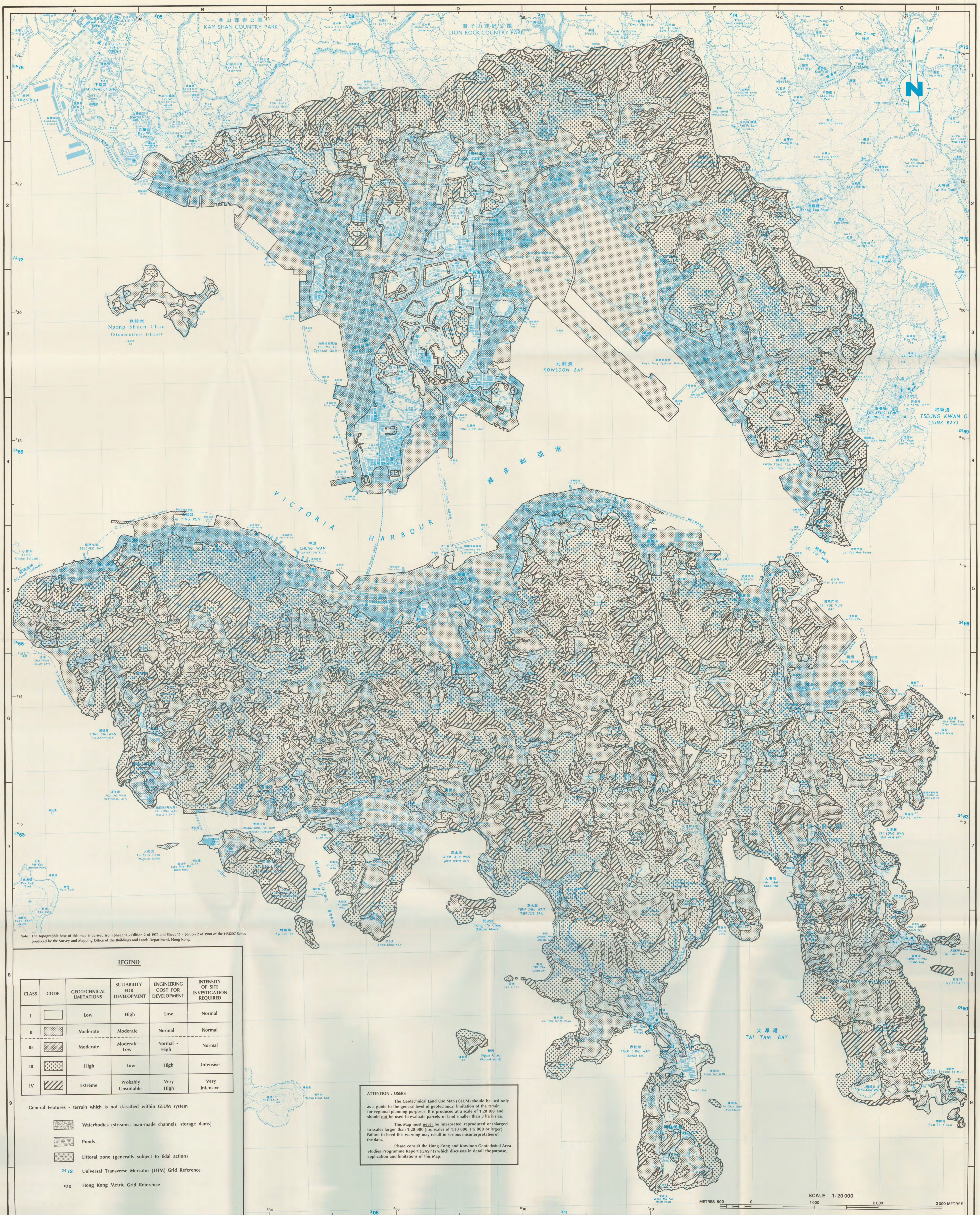
General rock name given to consolidated pyroclastic ash. Tuffs are classified as being essentially vitric (>50% glassy fragments), lithic (>50% rock fragments) or crystal (>50% crystal fragments) in composition, and fine (<0.06 mm), coarse 0.06–2 mm), lapilli (2–60 mm) and breccia (>60 mm) in size.

VOLCANICLASTIC

Clastic rock containing volcanic material in any proportion without regard to its origin or environment.

HK$240 (US$40 including surface postage)
P591509/1
ISBN 962-02-0005-5

Printed and Published by the Government Printer, Hong Kong 134563—18L—5/87



Note : The topographic base of this map is derived from Sheet 11 - Edition 2 of 1979 and Sheet 15 - Edition 2 of 1980 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.

LEGEND

CLASS	CODE	GEOTECHNICAL LIMITATIONS	SUITABILITY FOR DEVELOPMENT	ENGINEERING COST FOR DEVELOPMENT	INTENSITY OF SITE INVESTIGATION REQUIRED
I		Low	High	Low	Normal
II		Moderate	Moderate	Normal	Normal
IIs		Moderate	Moderate - Low	Normal - High	Normal
III		High	Low	High	Intensive
IV		Extreme	Probably Unsuitable	Very High	Very Intensive

General Features - terrain which is not classified within GLUM system

Waterbodies (streams, man-made channels, storage dams)

Ponds

Littoral zone (generally subject to tidal action)

24 72 Universal Transverse Mercator (UTM) Grid Reference

8 20 Hong Kong Metric Grid Reference

ATTENTION : USERS

The Geotechnical Land Use Map (GLUM) should be used only as a guide to the general level of geotechnical limitation of the terrain for regional planning purposes. It is produced at a scale of 1:20 000 and should not be used to evaluate parcels of land smaller than 3 ha in size.

This Map must never be interpreted, reproduced or enlarged to scales larger than 1:20 000 (i.e. scales of 1:10 000, 1:5 000 or larger). Failure to heed this warning may result in serious misinterpretation of the data.

Please consult the Hong Kong and Kowloon Geotechnical Area Studies Programme Report (GASP I) which discusses in detail the purpose, application and limitations of this Map.

Geotechnical Control Office

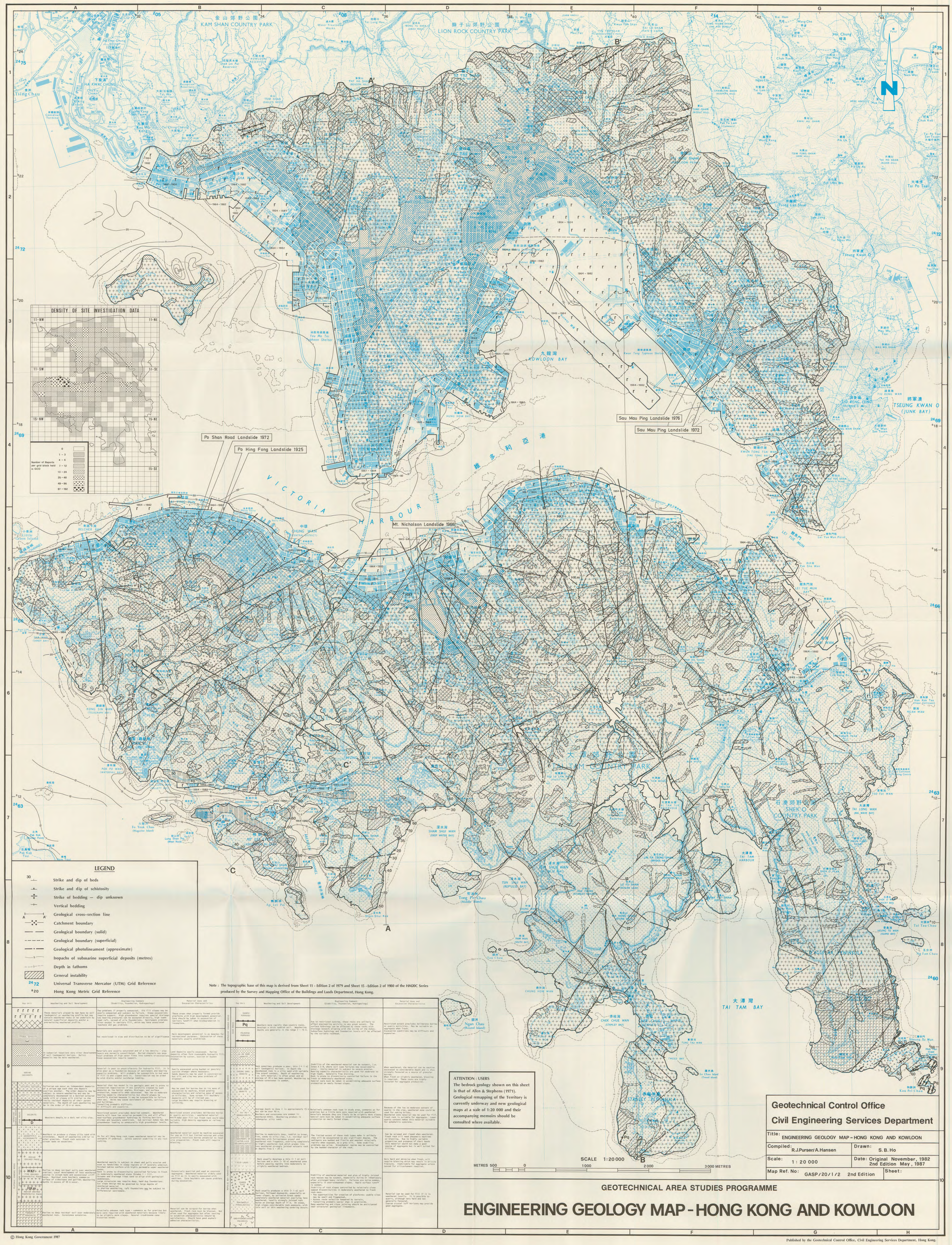
Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

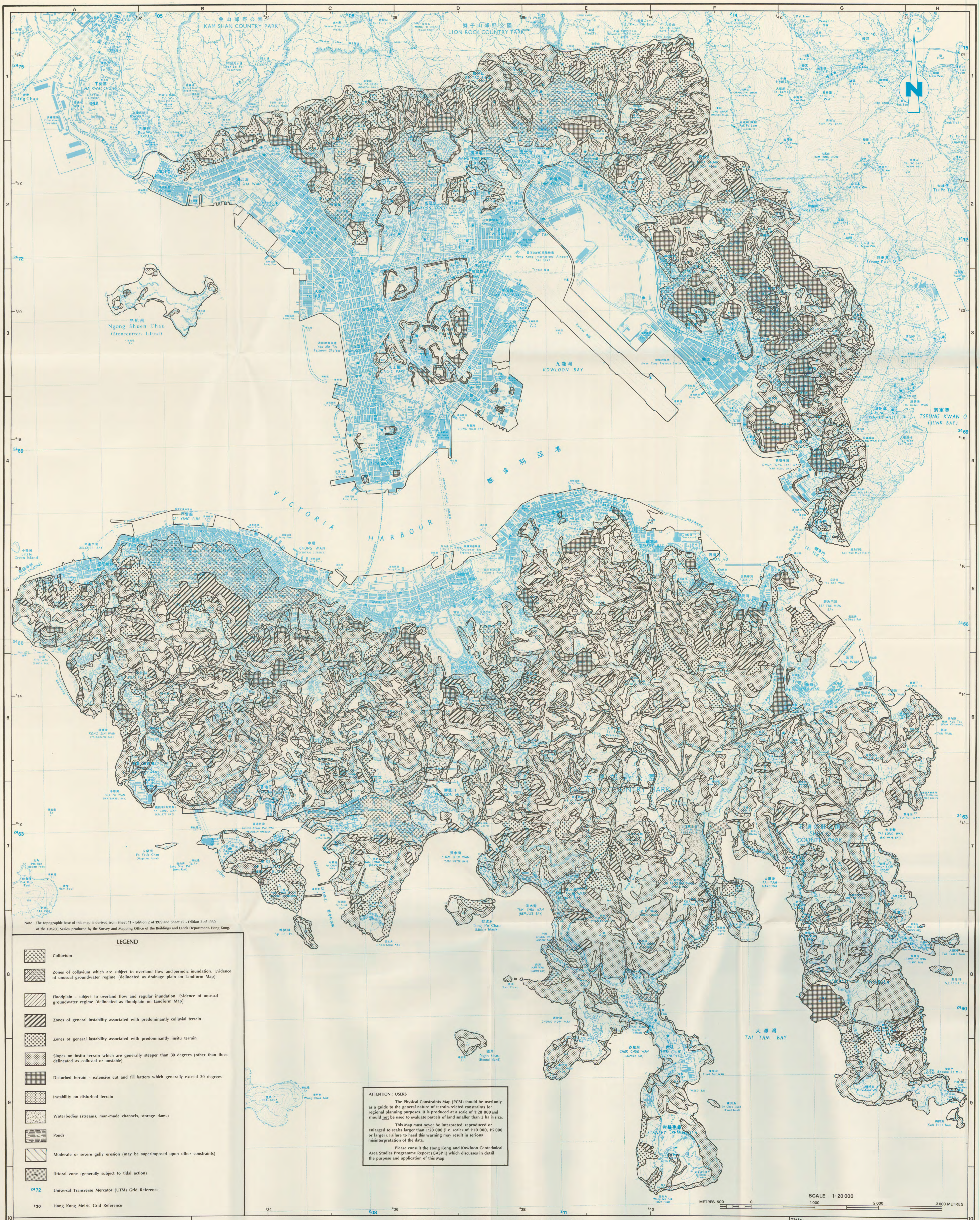
GEOTECHNICAL LAND USE MAP - HONG KONG AND KOWLOON

Title: GEOTECHNICAL LAND USE MAP-HONG KONG AND KOWLOON	
Compiled: A.Hansen/K.A.Styles/K.Emery	Drawn: S.B.Ho/ S.W.Lam
Scale: 1 : 20 000	Date: Original October, 1982 2nd Edition May, 1987
Map Ref. No: GASP/20/I/1 2nd Edition	Sheet:

Published by the Geotechnical Control Office, Civil Engineering Services Department, Hong Kong.



Published by the Geotechnical Control Office, Civil Engineering Services Department, Hong Kong.



Note : The topographic base of this map is derived from Sheet 11 - Edition 2 of 1979 and Sheet 15 - Edition 2 of 1980 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.

LEGEND

- Colluvium
- Zones of colluvium which are subject to overland flow and periodic inundation. Evidence of unusual groundwater regime (delineated as drainage plain on Landform Map)
- Floodplain - subject to overland flow and regular inundation. Evidence of unusual groundwater regime (delineated as floodplain on Landform Map)
- Zones of general instability associated with predominantly colluvial terrain
- Zones of general instability associated with predominantly insitu terrain
- Slopes on insitu terrain which are generally steeper than 30 degrees (other than those delineated as colluvial or unstable)
- Disturbed terrain - extensive cut and fill batters which generally exceed 30 degrees
- Instability on disturbed terrain
- Waterbodies (streams, man-made channels, storage dams)
- Ponds
- Moderate or severe gully erosion (may be superimposed upon other constraints)
- Littoral zone (generally subject to tidal action)
- 2472 Universal Transverse Mercator (UTM) Grid Reference
- 830 Hong Kong Metric Grid Reference

ATTENTION : USERS

The Physical Constraints Map (PCM) should be used only as a guide to the general nature of terrain-related constraints for regional planning purposes. It is produced at a scale of 1:20 000 and should not be used to evaluate parcels of land smaller than 3 ha in size.

This Map must never be interpreted, reproduced or enlarged to scales larger than 1:20 000 (i.e. scales of 1:10 000, 1:5 000 or larger). Failure to heed this warning may result in serious misinterpretation of the data.

Please consult the Hong Kong and Kowloon Geotechnical Area Studies Programme Report (GASP I) which discusses in detail the purpose and application of this Map.

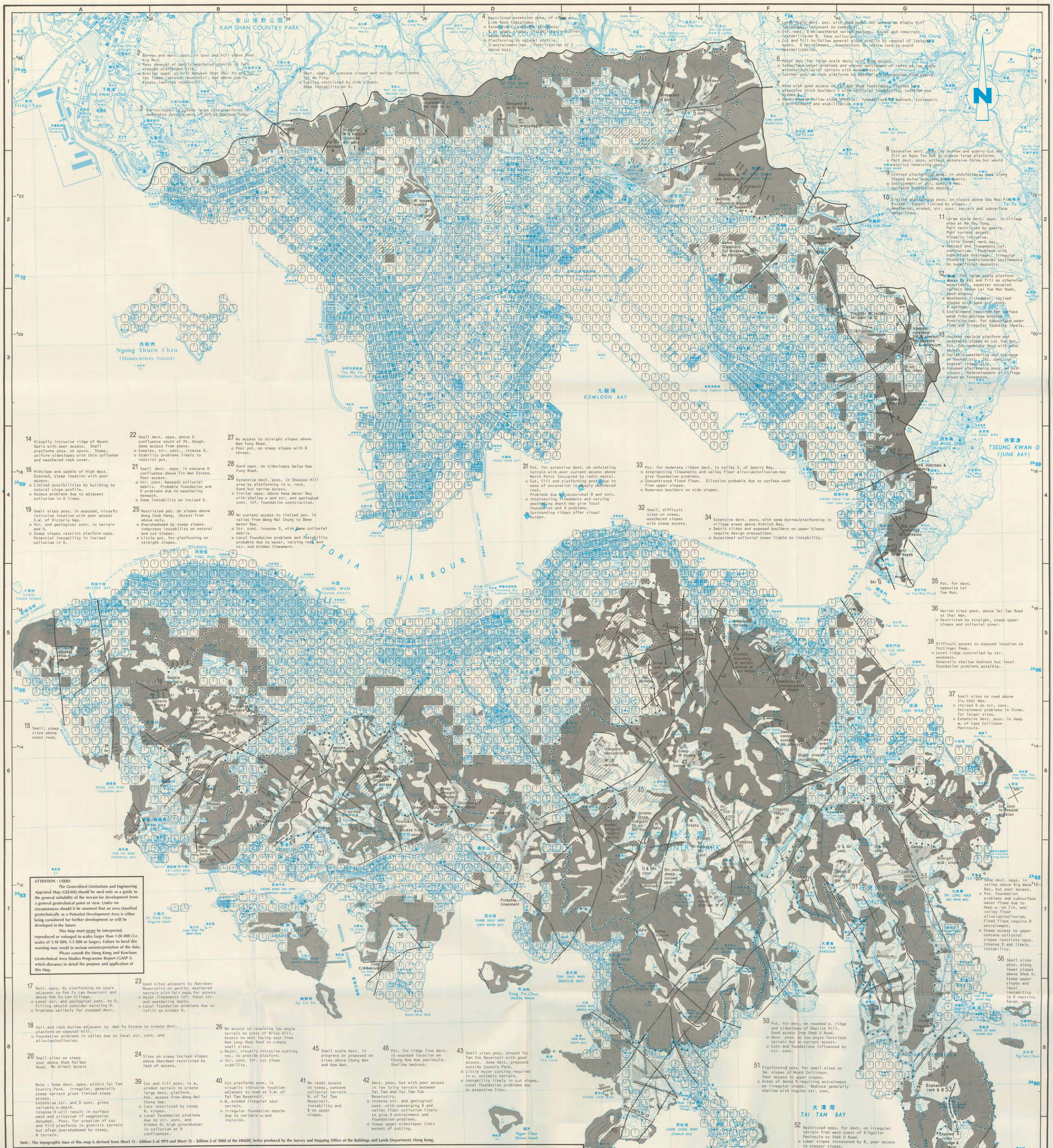
Geotechnical Control Office
Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

PHYSICAL CONSTRAINTS MAP – HONG KONG AND KOWLOON

Title: PHYSICAL CONSTRAINTS MAP – HONG KONG AND KOWLOON	
Compiled: A.Hansen/K.A.Styles	Drawn: S.B.Ho
Scale: 1 : 20 000	Date: Original October, 1982; 2nd Edition May, 1987
Map Ref. No: GASP/20/I/6 2nd Edition	Sheet:

Published by the Geotechnical Control Office, Civil Engineering Services Department, Hong Kong.



ATTENTION : USERS

The Generalised Limitations and Engineering Appraisal Map (GLEAM) should be used only as a guide to the general suitability of the terrain for development from a general geotechnical point of view. Under no circumstances should it be assumed that an area classified geotechnically as a Potential Development Area is either being considered for further development or will be developed in the future.

This Map must never be interpreted, reproduced or enlarged to scales larger than 1:20 000 (i.e. scales of 1:10 000, 1:5 000 or larger). Failure to heed this warning may result in serious misinterpretation of the data.

Please consult the Hong Kong and Kowloon Geotechnical Area Studies Programme Report (GASP I) which discusses in detail the purpose and application of this Map.

17 Devt. opps. by platforming on spurs adjacent to Pok Fu Lam Reservoir and above Pok Fu Lam Village.
- o Local str. and geological cont. to D. Filling should consider existing D.
- o Problems unlikely for stepped devt.

18 Soil and rock borrow adjacent to Wah Fu Estate to create devt. platform on coastal hill.
- o Foundation problems in valley due to local str. cont. and alluvium/colluvium.

Note : Some devt. opps. within Tai Tam Country Park. Irregular, generally steep terrain gives limited steep access. Extensive str. and D cont. gives variable w.depth. Intense D will result in surface wash and siltation if vegetation denuded. Poss. for creation of cut and fill platforms in granitic terrain but often overshadowed by steep, B terrain.

39 Cut and fill poss. in W, eroded terrain to create large devt. platform. Pot. access from Wong Nai Chung Gap.
- o Cuts restricted by steep B. slopes.
- o Local foundation problems due to str. cont. and hidden D; high groundwater in colluvium at D confluences.

40 Cut platforms poss. in visually intrusive location adjacent to road at S.W. of Tai Tam Reservoir.
- o W, eroded irregular spur terrain.
- o Irregular foundation depths due to variable w. and incision.

41 No ready access to steep, concave colluvial terrain N. of Tai Tam Reservoir. Instability and B on upper slopes.

42 Devt. poss. but with poor access in low lying terrain between Tai Tam and Tai Tam Tuk Reservoirs.
- o Intense str. and geological cont. with converging D and valley floor colluvium likely to give D entrainment and foundation problems.
- o Steep upper sideslopes limit extent of cutting.

Note : The topographic base of this map is derived from Sheet 11 - Edition 2 of 1979 and Sheet 15 - Edition 2 of 1980 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.

LEGEND

DEVELOPMENT PLANNING ZONES :

- Zone of potential for development (assessed in geotechnical terms)
- Zone of local geotechnical constraints (identified on PCM) within general PDA
- Zone of constraints for development (assessed principally in geotechnical terms)
- Zone of existing development, (based on principal use of GEOTECS 2 hectare unit)
- Country Park boundary
- Catchwater

NOTE Numerals on map refer to relevant general planning/engineering notes

24 72 Universal Transverse Mercator (UTM) Grid Reference

8 20 Hong Kong Metric Grid Reference

FEATURES OF ENGINEERING SIGNIFICANCE :

- Geological photolineament
- R Ridgeline
- D Di Drainage, incised drainage
- C Colluvium (also in 'zone of local constraints', and PCM)
- Str Structure
- W Weathering
- B Boulders
- Steeper slopes influencing area (orientation of symbols indicates downslope direction)
- Instability influencing area
- Potential for borrow or extensive cut and fill : opportunity to create site formation in 'constrained' area, or larger site formation in 'potential' area

NOTE

i) Features are generally indicated only where of significance to identified potential development areas

ii) For explanation of significance of identified features, see Report Appendix A , Table A6, and Section 4.2

iii) Geological boundaries and photolineaments are shown in full on the EGM. Those lineaments indicated represent the surface expression of obvious structural discontinuities which affect the PDA's

Abbreviations :

cont.	control
devt.	development
formn.	site formation
inf.	influence/influencing
nec.	necessary
opps.	opportunity
poss.	possible/possibilities
pot.	potential
N, S, NE, etc.	North, South, Northeast, etc.
PDA	Potential development area

SCALE 1:20 000

METRES 500 0 1000 2000 3000 METRES

Geotechnical Control Office

Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP HONG KONG AND KOWLOON

Title: GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP HONG KONG AND KOWLOON	
Compiled: J.N. Fowler	Drawn: S.B. Ho/N.L. Yuen
Scale: 1 : 20 000	Date: Original June, 1983 2nd Edition May, 1987
Map Ref. No: GASP/20/I/15 2nd Edition	Sheet:

Published by the Geotechnical Control Office, Civil Engineering Services Department, Hong Kong.