GASP Report XII

Geotechnical Area Studies Programme

Territory of Hong Kong

Geotechnical Control Office
Civil Engineering Services Department
Hong Kong

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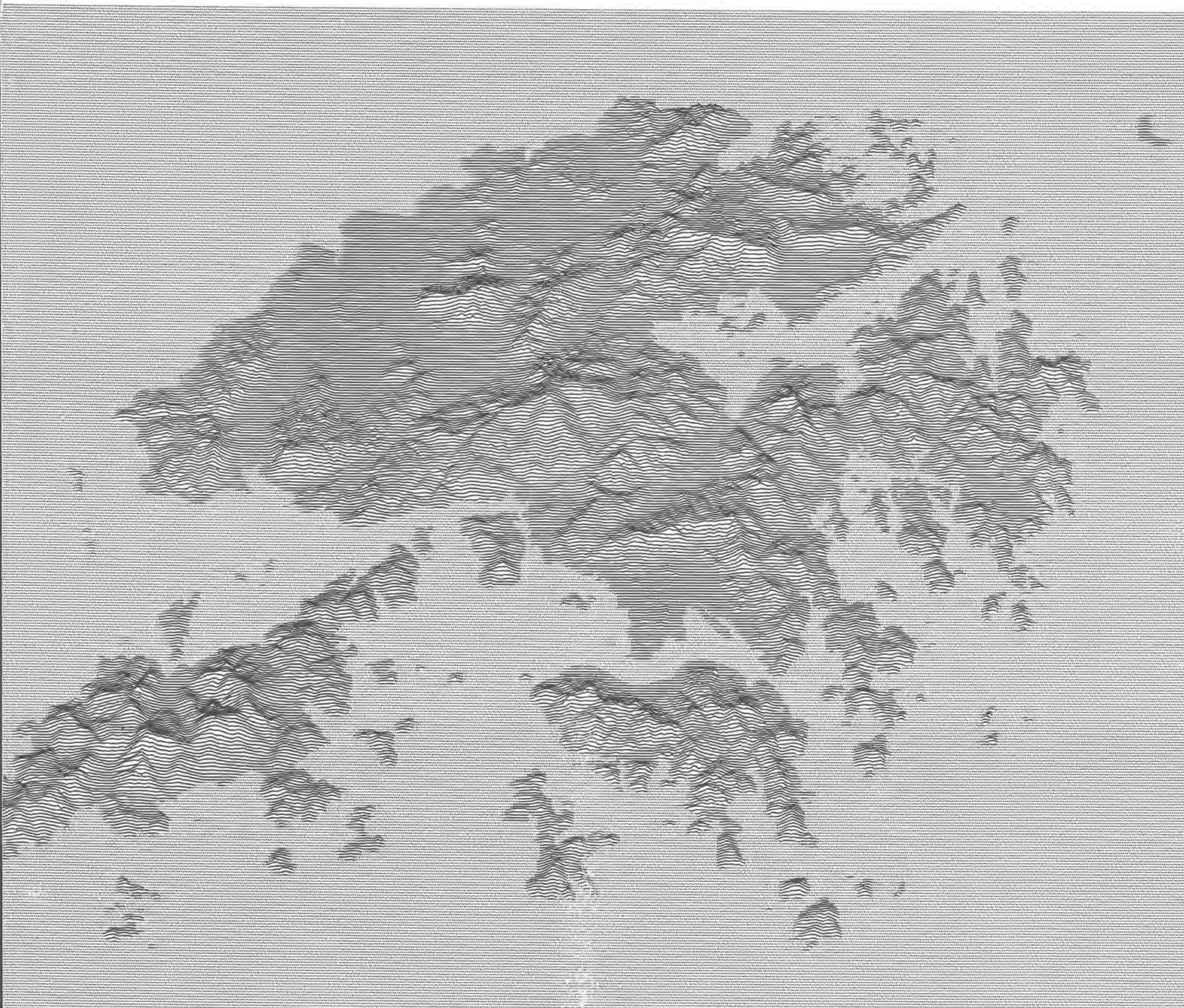
Cover Graphics: A computer-generated Digital Terrain Model (DTM) of the Territory of Hong Kong compiled from information contained within the GEOTECS database. This DTM was constructed by offsetting relief in a northerly direction, onto a base which is planimetrically correct at sea-level. The GEOTECS System is operated by the Geotechnical Control Office for regional and strategic planning purposes. The image was generated using in-house software written with initial assistance from Dr. M. J. McCullagh of the University of Nottingham.

Geotechnical Area Studies Programme

GASP Report XII

Territory of Hong Kong



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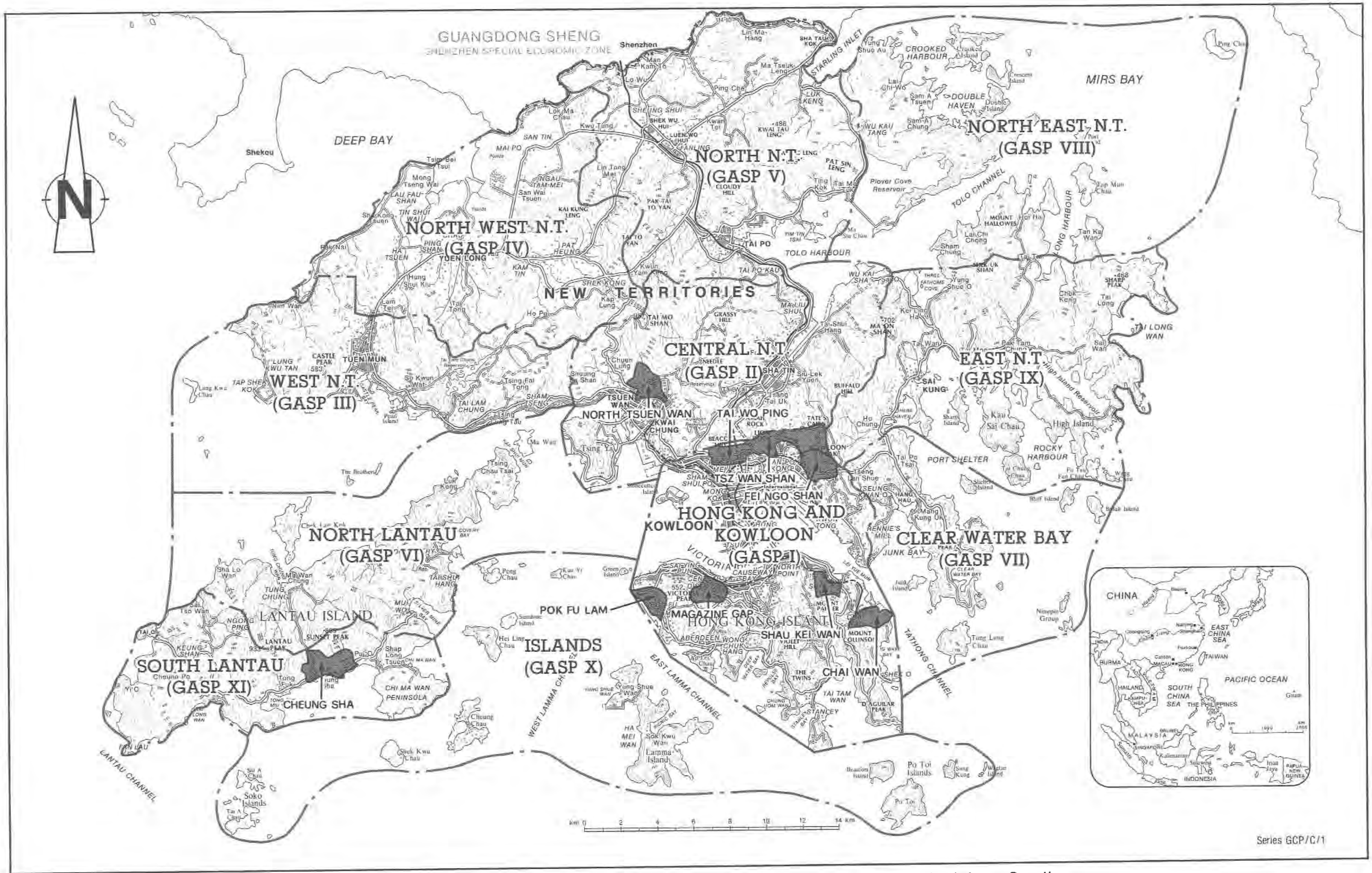

Map of the Territory of Hong Kong Showing the Locations of the Geotechnical Area Studies.
(Boundaries of the Regional Studies are shown by dashed lines and locations of District Studies are indicated by dark screens)

FOREWORD

This is the last in the series of twelve reports published as a result of the Territory-wide Geotechnical Area Studies Programme (GASP) carried out by the Geotechnical Control Office between 1979 and 1985. It fulfils the role of summarising the land resources information contained in the other eleven GASP Reports, each of which covers a specific area of the Territory. In compiling the report, the authors have taken the opportunity to provide additional historical information on the development of Hong Kong, largely through the medium of annotated photographs, so that the report represents an important historical document in its own right.

The series of GASP Reports is the culmination of by far the most detailed study ever undertaken of the land resources of Hong Kong. For the first time, the Territory now has a comprehensive land resources inventory for the purposes or strategic planning, land management and resource appraisal. Land development planning had proceeded satisfactorily for many years without the benefit of an overall broad physical evaluation of the Territory's terrain. Soon after the creation of the Geotechnical Control Office in July 1977, however, it became clear that a systematic geotechnical evaluation was necessary to provide adequate input for future land use management and development planning purposes. To this end, the Geotechnical Area Studies Programme was initiated by the GCO in 1979. The Regional Studies at a scale of 1:20 000 were complemented by a limited number of more detailed 1:2 500 District Studies undertaken on relatively small areas which were thought to be geotechnically difficult. Initially, the results of all these studies were made available only within Government, but the decision was taken in 1986 that the results of the Regional Studies should be made available to the public. Consequently, the whole series has been released in published form since the release of the Report for Hong Kong and Kowloon in July 1987.

A great deal of effort has gone into the GASP Studies over almost a decade. The terrain of the whole Territory has been mapped seven times from aerial photographs, with the production of more than 175 maps of many different types. In the course of the Studies, a vast amount of detailed information was assembled, much of which could not be included in the published reports. This collection of data is mainly housed in the GCO's Geotechnical information Unit, which is readily accessible by members of the public. In addition, much of the detailed information has been stored in the computerized GEOTECS system, from which computer maps depicting combinations of terrain attributes can be readily obtained.

When the Geotechnical Area Studies Programme was largely complete, the GCO embarked upon the separate exercise of producing 1 20 000 scale *geological* maps of the Territory, which hitherto had not existed. A total of fifteen new geological maps will be published, together with six explanatory memoirs. To-date, only a few of these are available, but all are planned to be published by 1991. These will naturally provide more up-to-date geological information than was available at the time the GASP work was undertaken. Readers of GASP reports would therefore do well to make reference to the Hong Kong Geological Survey maps and memoirs as they become available.

The Geotechnical Area Studies Programme was undertaken in the Planning Division of the Geotechnical Control Office under the overall direction of its Chief Geotechnical Engineer, Dr A. D. Burnett. The authors of this report, however, bore the brunt of the work on the whole Programme. In particular, Mr K. A. Styles established and ran the Terrain Evaluation Section throughout the period over which the GASP studies were carried out, and he was ably assisted by Mr A. Hansen. Mention must also be made of the contributions of Messrs D. C. Cox, M. J. Dale, S. R. Hencher, D. J. Howells, N. F. Johnson, H. O. Jones, N. P. Koirala, C. H. Leung, J. M. Nash, R. J. Purser and the late Mr J. N. Fowler, all of whom spent a period in the Terrain Evaluation Section engaged on GASP. Finally, acknowledgements are due to the Commissioner of the Soil Conservation Service of New South Wales, Australia, who made available Messrs G. Atkinson, K. A. Emery, P. D. Houghton and R. D. Morse for short periods to participate in the GASP project.

The physical production of the series of GASP reports has been a substantial task, and acknowledgements are due to a number of individuals who made noteworthy contributions to this effort. Mr P. G. D. Whiteside of the Planning Division acted as editor and production manager for GASP Reports II to XII. A small but dedicated cartographic team, under the leadership of Mr K. T. Chow, prepared the maps for all the GASP reports, in addition to producing the many associated maps which do not form part of the published series. The 55 maps contained in the twelve published reports were prepared by Mr S. P. Poon, Ms Jennie Tang and Ms Susanna Ho. Finally, the Geotechnical Control Office acknowledges the important roles played in the production process by staff of the Information Services Department and the Printing Department.

E. W. Brand
Director of Civil Engineering Services
September 1989

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1. INTRODUCTION

1.1 The Geotechnical Study of the Territory of Hong Kong

The Report presents a general geotechnical assessment of the Territory and summarises the results of the eleven Reports published as part of the regional Geotechnical Area Studies Programme (GASP Reports I to XI) (Geotechnical Control Office, 1987a, c & d, 1988 c–j). The information collected during the Studies also forms an inventory of the land resources of the Territory.

The Geotechnical Area Studies Programme was initiated by the Geotechnical Control Office in September 1979, with the aim of providing systematic geotechnical input for planning and land management within the Territory.

The GASP Studies were based primarily on:

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

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

(*c*) Field reconnaissance.

The Programme encompassed the entire land area of the Territory at a scale of 1:20 000, and a number of selected areas at 1:2 500 scale. The GASP areas were selected so that the results of each Study could be used for the assessment of engineering feasibility and for development planning.

The Geotechnical Area Studies were completed in 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 and other 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.

Eleven Regional Studies between them cover the whole Territory, and this Report, the twelfth, is the final in the current series to be published. Nine District Studies: Stage 1 have been completed and, although they are for use only within Government, some information in map form is available on request (see Sections 1.6 & 1.7). Background information on the reasons for the use of terrain classification methods in the Geotechnical Control Office are presented in Section A.1.2 in Appendix A.

In 1985, the decision was made to publish, in a slightly modified form, the Regional Geotechnical Area Studies Reports which had originally been prepared for Government use. The work on the original studies was carried out between December 1979 and December 1985, with the first Report (GASP I: Hong Kong and Kowloon) being released to the public in July 1987.

Nine terrain-related land resource factors were assessed in the Regional Studies, namely: slope gradient, geological materials, terrain component, erosion and instability, slope aspect, relief, vegetation, land use and rainfall. These factors are important in the assessment of geotechnical constraints associated with the terrain for general planning purposes and for the evaluation of broadscale engineering feasibility.

The superficial deposits were mapped during the terrain classification phase of the Regional Studies, and geological information on bedrock was based on the 1:50 000 scale Geological Map produced by Allen & Stephens (1971).

Currently, the Geotechnical Control Office is remapping the geology of the Territory to produce a new series of maps at a scale of 1:20 000, together with accompanying Memoirs. These will eventually supersede both the bedrock geology and the mapping of superficial deposits presented in GASP Reports I to XII. Although the 1:20 000 scale geological remapping is due for completion in 1991, new Geological Maps are currently available for Sha Tin, Hong Kong Island and Kowloon, Hong Kong South and Lamma Island, Castle Peak, and Yuen Long (Geotechnical Control Office, 1986a, b, 1988a, b & 1989). Memoirs accompany the 1:20 000 scale Geological Map Sheets (Addison 1986; Strange & Shaw, 1986; Langford et al, 1989). General information on the new Geological Survey is presented in Section C.1.1 in Appendix C.

1.2 Organisation of the Report

The main text of this Report, which is contained in Sections 1 to 4, provides a summary of the information collected in the eleven Regional Studies. Section 1 introduces the Report and provides background on GASP, including the nature and purpose of the maps. Section 2 describes the topography, geology, geomorphology, hydrology, vegetation, erosion, instability and land use of the Territory.

Section 3 provides an evaluation of the material characteristics of the major geological units. Section 4 presents a general geotechnical assessment for planning and discusses the suitability for development of various parts of the Territory from an engineering point of view.

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

A number of figures are included. These are designed to illustrate various aspects of the study and the system used for compiling the maps. Figures are used in the body of the Report in Section 7 but also occur in the Appendices. Figures 5, A1 & A7 illustrate the system used in GASP, and Figures 6–19 are extracts from the GEOTECS Computer Maps which are located in the accompanying Map Folder. Examples of the conventional line maps produced for the eleven Regional GASP Studies are presented in Appendix A in Figures A8 to A14. A chart illustrating the system of Regional terrain classification used in these studies is located in the Map Folder.

A large selection of photographs, including stereopairs and reproductions of old maps, follows the Figures. These are presented in Section 8 as Plates 1 to 223. The Plates form an important element of the Report because they highlight many of the geotechnical problems associated with the terrain, and they reflect the intensity and general nature of development within the Territory. They include a large number of aerial and conventional photographs which illustrate many of the more recent landslip disasters. A number of plates deal with major landslips during the last twenty years, including those at Mt Nicholson (1966), Po Shan (Kotewall) Road (1972) and Sau Mau Ping (1972 & 1976). In addition, some old photographs and maps are included which present an insight into the history of land development since the 1860's.

Appendix A provides details of the techniques, procedures and maps used in the terrain evaluation system designed for the Regional and District Stage 1 Geotechnical Area Studies. It also includes data on the terrain classification mapping methods employed during the study programme. Appendix B tabulates the data for the Territory. Appendix C contains information on the geological remapping programme, aerial photographs and rainfall data. Appendix D discusses landform evolution and its relationship to engineering. A Glossary of Terms used in GASP is presented as Appendix E.

Full-size conventional line maps do not accompany this Report. The Geotechnical Land Use Map (GLUM), Physical Constraints Map (PCM), Engineering Geology Map (EGM), and Generalised Limitations and Engineering Appraisal Map (GLEAM), which are normally presented in the Regional Studies at a scale of 1:20 000, are replaced in this Report by fourteen 1:100 000 scale GEOTECS computer-generated maps of the Territory. These computer maps are contained in the Map Folder. Information on the preparation and limitations of the computer maps and conventional line maps is presented in Sections 1.3 & 1.4 and in Appendix A. In addition, a large 'Chart' which illustrates the different types of maps produced in the GASP is located in the Map Folder.

1.3 Maps Produced for the Regional Studies

1.3.1 *General*

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

In GASP Reports I to XI, small-scale computer maps are used to highlight various features of the study area, and are presented in the Reports as Figures at reduced scales, without topographic bases. These maps are termed GEOTECS Plots, and are derived from the Geotechnical Terrain Classification System (GEOTECS) operated by the Geotechnical Control Office. The GEOTECS Plots are totally machine-generated, whereas the conventional line maps, including the Geotechnical Land Use Map (GLUM), Physical Constraints Map (PCM), and Engineering Geology Map (EGM), are produced by standard cartographic processes.

The 1:20 000 scale conventional line maps which accompany GASP Reports I to XI are either completely or partially derived from the information on the Terrain Classification Map. Although most of the fourteen GEOTECS Maps which accompany this Report are derived, at least in part, from information shown on the eleven conventional Terrain Classification Maps of the Territory, some information has been extracted from other sources. These include the geological map of Allen & Stephens (1971), rainfall data from the Royal Observatory, topographic data from maps issued by the Survey & Mapping Office of the Buildings & Lands Department, and in-house aerial photographic interpretative studies of vegetation and land use.

The GEOTECS Maps presented in this Report summarise the information contained in the 1:20 000 scale conventional line maps produced for each of the Regional Studies. The computer format allows an extremely flexible approach to map production. Computer-generated single- or multi-attribute features relating to the terrain can be combined with a topographic base. However, this process results in a considerable increase in the level of generality of the information. The 1:100 000 scale GEOTECS Maps consist of data extracted from the 1:20 000 scale conventional line maps, and as such are very general in nature. It is considered that the reduction in scale, from 1:20 000 to 1:50 000, approximately corresponds to the level of information loss during transfer.

The GEOTECS Maps provide a very convenient form for presentation of the Territory-wide data collected during the regional GASP studies. These maps are reviewed in Section 1.4. The 1:20 000 scale conventional line maps should be consulted in situations when more precise information is required. There are normally seven conventional line maps produced for each Regional Study area. The broad characteristics and purposes of these maps are discussed in this section, and examples of the maps, general rules for usage and method of production are presented in Appendix A.

1.3.2 *Terrain Classification Map (TCM)*

This map records the general nature of the geological material (insitu, colluvial, alluvial), 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 A8.

1.3.3 *Landform Map (LM)*

This map is totally derived from the Terrain Classification Map, and 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 A13.

1.3.4 *Erosion Map (EM)*

This map is totally derived from the Terrain Classification Map, and 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 A14.

1.3.5 *Geotechnical Land Use Map (GLUM)*

This map is totally derived from the Terrain Classification Map, and 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 A9.

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.

1.3.6 *Physical Constraints Map (PCM)*

This map is totally derived from the Terrain Classification Map, and 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 A10 and is discussed in detail in Appendix A.6.

1.3.7 *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 A11 and is discussed in detail in Appendix A.8.

1.3.8 *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 A12, and a detailed discussion is provided in Section 4.2 and in Appendix A.9.

1.3.9 *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 base management system which is referenced, through a grid cell, 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 smaller than 1:50 000 for strategic planning and resource inventory purposes.

A number of computer-generated maps and plots are presented within this Report. Fourteen, 1:100 000 scale GEOTECS Maps of the Territory are included in the Map Folder. Examples of these maps and plots are shown in Figures 6 to 22.

1.4 GEOTECS Maps of the Territory

1.4.1 *General*

A number of computer-generated Maps and plots are presented within this Report. Fourteen 1:100 000 scale GEOTECS Maps of the Territory are included in the Map Folder. Each map consists of data relating to some 53 400 sample points within the land mass of the Territory. The general nature of these maps is discussed below, and examples are presented at Figures 6 to 22. These GEOTECS Maps and Plots demonstrate the flexibility and multifunctional application of GEOTECS as a tool for resource evaluation and regional planning.

1.4.2 *Slope Gradient Map*

This map presents the general distribution of slope gradient within the Territory at a scale of 1:100 000. It is derived from the 1:20 000 scale regional Terrain Classification Maps. This Map is discussed in Section 2, and an extract is shown in Figure 6.

1.4.3 *Geology Map*

This map presents the geology of the Territory in a simplified form at a scale of 1:100 000. The information on superficial deposits is derived from the regional Terrain Classification Maps, and the bedrock geology is based on Allen & Stephens (1971). This Map is discussed in Section 2, and an extract is shown in Figure 7.

1.4.4 *Relief Map*

This map presents the general elevation of the terrain on a Territory-wide basis at a scale of 1:100 000. The data was extracted from the 1:50 000 Topographic Map (Edition 6, 1984) prepared by the Survey and Mapping Office of the Buildings & Lands Department. An extract of this map is shown in Figure 8.

1.4.5 *Rainfall Map*

This map presents the general pattern of annual rainfall distribution within the Territory at a scale of 1:100 000. It shows that some 50% of the Territory receives 2 100–2 400 mm of precipitation per annum, and only about 830 ha (<1%) is subject to the highest annual rainfall of 2 900–3 000 mm. The information was extracted from the Mean Annual Rainfall Chart 1952–1976 prepared by the Royal Observatory. An extract of the map is shown in Figure 9.

1.4.6 *Landform Map*

This map summarises the broad landform features of the Territory at a scale of 1:100 000. It is based on the slope gradient and terrain component information shown on the 1:20 000 scale regional Terrain Classification Maps. This Map is discussed in Section 2, and an extract is shown in Figure 10.

1.4.7 *Slope Instability Map*

This map indicates the general distribution of slope instability within the Territory at a scale of 1:100 000. It is derived from the regional Terrain Classification Maps. This Map is discussed in Sections 2 & 3, and an extract is shown in Figure 11.

1.4.8 *Erosion Map*

This map indicates the broad pattern of erosion and instability within the Territory at a scale of 1:100 000. The map is derived from the regional Terrain Classification Maps. This Map is discussed in Sections 2 & 3, and an extract is shown in Figure 12.

1.4.9 *Vegetation Map*

This map presents the general pattern of vegetation within the Territory at a scale of 1:100 000. This information was prepared from aerial photographic interpretation for each of the regional GASP studies. This Map is discussed in Section 2, and an extract is shown in Figure 13.

1.4.10 *Land Use Map*

This map describes the general pattern of existing land use within the Territory at a scale of 1:100 000. This information was prepared from aerial photographic interpretation for each of the regional GASP studies. This Map is discussed in Section 2, and an extract is shown in Figure 14.

1.4.11 *Geotechnical Land Use Map*

This map presents the broad pattern of geotechnical limitations associated with the terrain within the Territory at a scale of 1:100 000. It is essentially a summary of the 1:20 000 scale regional Geotechnical Land Use Maps. The GLUM maps are derived from the regional Terrain Classification Maps. This Map is discussed in Section 4, and an extract is shown in Figure 15.

1.4.12 *Map of Colluvium on Undeveloped Terrain*

This map illustrates the broad pattern of colluvium in relation, both to existing development and to undeveloped terrain within the Territory. The purpose is to highlight colluvial areas marginal to existing development. This Map is discussed in Section 4.2.3, and an extract is shown in Figure 16.

1.4.13 *Map of Generalised Depth of Weathering on Undeveloped Terrain*

This map illustrates the generalised depth of weathering on generally undeveloped terrain within the Territory. The information is conceptual in nature, and is based on an assessment of the general weathering characteristics of the major rock units. The purpose is to demonstrate the combination of different forms of interpretative information for general resource assessment. This Map is discussed in Section 4.2.3, and an extract is shown in Figure 17.

1.4.14 *Map of Existing Development, Reclamation, Undeveloped Terrain and Country Park*

The map summarises the broad pattern of development within the Territory at a scale of 1:100 000. Areas of existing development formed by reclamation are highlighted. This Map is discussed in Section 2, and an extract is shown in Figure 18.

1.4.15 *Map of Geotechnical Limitations associated with Undeveloped Terrain outside Country Park*

This map highlights areas of undeveloped terrain which occur outside Country Park, and which have low to moderate geotechnical limitations. It is a non-technical map designed specifically for strategic planning. This Map is discussed in Section 4.2.2, and an extract is shown in Figure 19.

1.5 Suitability of the Maps for Technical and Non-technical Use

The maps accompanying the Regional GASP Reports 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 illustrates the potential of the maps for different requirements. A four-class user recommendation (Fundamental, Useful, Background and Variable) indicates the relative value of each map to users. The GEOTECS Maps presented in this Report are designed to illustrate generalised features of the terrain in a simplified form and to highlight specific user-defined attributes. Therefore, the term 'variable' is used in Table 1.2 to describe the value, in general terms, of the GEOTECS Maps to users.

Table 1.2 Value of the Maps Produced in the Regional GASP Reports

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	Variable	Variable	Variable	Variable	Variable

1.6 GASP District Studies

Nine GASP District Studies: Stage 1 have been undertaken at a scale of 1:2 500. The areas covered by these are shown in Figure 3. Approximately 2 160 ha of the geotechnically problematical terrain within the Territory 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, more than 1 000 landslips were identified during the District studies.

The average number of landslips per hectare (Landslip Propensity) of terrain with high to extreme geotechnical limitations, is 0.71 for the District Stage 1 Studies. This figure is derived from the 1 030 landslips mapped in the detailed terrain classification at a scale of 1:2 500, and indicates that a landslip occurs on average for every 1.41 ha of terrain classified as having high to extreme geotechnical limitations.

On the basis of Landslip Propensity, it may be possible to broadly estimate the number of landslips in the Territory, based on the 2 160 ha sample provided by the GASP District Stage 1 Studies. In the Regional Studies, some 52 000 ha of terrain with high to extreme geotechnical limitations has been mapped at a scale of 1:20 000. If the Landslip Propensity calculated for the District Studies were to be applied to the area of high to extreme geotechnical limitations identified in the regional studies, then an estimate could be produced of the number of landslips affecting the Territory. Using this approach it is possible to estimate that in the order of 37 000 landslips affected the terrain at the time of mapping.

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

1.7 Access to GASP Data

Much of the data used in preparation of this Report is 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 on request.

Table 1.3 GLUM Classes and Landslips within the GASP District Studies

Study Area	District Stage 1 GASP Report No.	Geotechnical Limitation (GLUM Class—ha)				No. of Landslips	Total Area Class III & IV	Total Area (ha)	Landslip Propensity No. per ha
		Low I	Moderate II	High III	Extreme IV				
Pok Fu Lam	1	14.0	84.0	70.0	50.0	102	120.0	218.0	0.47 (0.85)*
Tsz Wan Shan	2	8.0	76.0	261.0	117.0	255	378.0	462.0	0.55 (0.68)
Cheung Sha	4	24.6	69.3	117.4	62.1	49	179.5	273.4	0.18 (0.27)
Fei Ngo Shan	5	7.0	24.5	99.3	115.2	167	214.5	246.0	0.68 (0.78)
Shau Kei Wan	6	23.7	29.8	64.9	13.3	64	78.2	131.7	0.49 (0.82)
Chai Wan	8	17.2	81.3	83.0	8.4	36	91.4	189.9	0.19 (0.39)
Tai Wo Ping	9	33.0	44.8	76.9	28.7	29	105.6	183.4	0.16 (0.28)
North Tsuen Wan	11	45.8	76.2	96.1	24.8	163	120.9	242.9	0.67 (1.35)
Magazine Gap	12	7.8	36.8	155.9	10.9	163	166.8	211.4	0.77 (0.98)
Total		181.1	522.7	1 024.5	430.4	1 030	1 454.9	2 158.7	0.48 (0.71)

Note: *The Landslip Propensity shown in brackets (–), in the final column, indicates the number of landslips per ha of terrain with high to extreme geotechnical limitations.

2. DESCRIPTION OF THE TERRITORY OF HONG KONG

2.1 Geographical Location

The Territory of Hong Kong consists of a large, irregularly-shaped peninsula extending from the southeastern coast of Guangdong Province of the People's Republic of China, into the South China Sea. Large marine embayments exist on either side of the Territory, with the Pearl (Zhujiang) River estuary to the west, and Mirs Bay to the east (Figure 1). Each of these creates significantly different natural environmental conditions. Within the mainland area of the Territory, several smaller peninsulas occur, separated by narrow, moderately deep inlets, e.g. the Sai Kung Peninsula, split from the northeastern parts of the Territory by Tolo Channel. Many of the approximately 230 offshore islands represent extensions of the hill ranges of the mainland, with the largest being Lantau and Hong Kong Islands. The area traditionally known as 'Hong Kong' is centred on the magnificent natural harbour, and comprises the undulating hills of the Kowloon Peninsula and the northern shore of Hong Kong Island. Plates 1 to 8 provide a general impression of the nature of the terrain and intensity of development within the Territory. The Kowloon and Hong Kong Island areas are shown in high level oblique aerial photographs in Plates 1 and 2.

GASP XII covers the entire land area of the Territory. The boundary of the area follows the border eastward along the Shum Chun River from Deep Bay, continuing along the Sha Tau Kok River, to Sha Tau Kok Hoi (Starling Inlet) in the east. Ping Chau, in the eastern part of Mirs Bay, is included within this study. The methods of investigation employed during the Geotechnical Area Studies Programme have concentrated on land resources; the offshore areas are being studied as part of the geological remapping programme (Appendix C.1).

Table 2.1 lists the areas of the mainland and the islands greater than 50 ha in size. The mainland includes approximately 2 500 ha of artificial channels and reservoirs, e.g. the Shing Mun River at Sha Tin, and the Plover Cove and High Island Reservoirs. The latter is linked to the mainland by coffer dams and reservoir-retaining dams.

Table 2.1 Main Areas of the Territory

Area	% of Total Area	Area (ha)
Mainland	72.32	78 845
Tai Yue Shan (Lantau Island)	13.28	14 480
Hong Kong Island	7.17	7 818
Lamma Island	1.33	1 453
Tsing Yi	0.80	873
Kau Sai Chau	0.62	678
Po Toi Island	0.37	398
Chek Lap Kok	0.29	318
Cheung Chau	0.25	278
Tung Lung Chau	0.23	251
Kat O Chau (Crooked Island)	0.22	237
Wong Wan Chau (Double Island)	0.20	214
Hei Ling Chau	0.19	204
Tiu Chung Chau	0.18	194
Tap Mun Chau (Grass Island)	0.15	167
Tai A Chau	0.13	139
Lo Chau (Beaufort Island)	0.12	135
Shek Kwu Chau	0.12	135
Ap Lei Chau	0.11	127
Kiu Tsui Chau (Sharp Island)	0.11	122
Ping Chau	0.11	120
Peng Chau	0.11	116
Ma Wan	0.09	96
Ngo Mei Chau (Crescent Island)	0.09	94
Fo Shek Chau (Basalt Island)	0.08	92
Siu A Chau	0.08	86
Tai O	0.07	78
Sha Tong Hau Chau (Bluff Island)	0.07	76
Ngong Shuen Chau (Stonecutters Island)	0.07	74
Fu Tau Fan Chau	0.06	65
Chau Kung Island (Sunshine Island)	0.06	63
Ngau Mei Chau (Shelter Island)	0.06	61
Tai Tau Chau (Urn Island)	0.06	61
Fat Tong Chau (Junk Island)	0.05	59
Sung Kong	0.05	59
Ma Shi Chau	0.05	55
Other Islands	0.65	708
Total	100.00	109 029

Note: All area calculations are based on the GEOTECS System and may vary from data published elsewhere.

2.2 Topography

Physiographically, the Territory is an extension of the South China coastal massif and includes many large hill masses. Table 2.2 lists the highest peaks, and the GEOTECS Map of Relief in the accompanying Map Folder highlights the elevation of the terrain. It shows that some 53% of the Territory has an average elevation of less than 100 m above Principal Datum, and that only 12.4% of the terrain is higher than 300 m in elevation. An extract is presented in Figure 8. This map should be compared with the GEOTECS Map of Slope Gradient, which emphasizes the areas of steep slopes by the concentration of dense symbols, and areas of low slope gradient by groups of less dense symbols.

The GEOTECS Map of Relief highlights the elongate shape of the majority of hill masses, and illustrates the dominant northeast to southwest trend of many of the ridges and valleys. A subordinate northwest to southeast trend is also apparent in some areas; in the east and southeast, this trend becomes dominant. A brief summary of the major topographic features of the various parts of the Territory is given below.

Table 2.2 Elevation of Major Summits

Name of Summit	Area	Height (m)
1. Tai Mo Shan	Central N.T.	957
2. Fung Wong Shan (Lantau Peak)	Lantau Island	934
3. Tai Tung Shan (Sunset Peak)	Lantau Island	869
4. Sheung Tung Au	Lantau Island	766
5. Nei Lak Shan (Ngong Ping)	Lantau Island	751
6. Ma On Shan	East Central N.T.	702
7. Ngau Ngak Shan (The Hunch Backs)	East Central N.T.	680
8. Tso Shan (Grassy Hill)	Central N.T.	645
9. Wong Leng	Northeast N.T.	639
10. Fei Ngo Shan (Kowloon Peak)	South Central N.T.	602
11. Tsing Shan (Castle Peak)	West N.T.	583
12. Pak Shek Kiu	Central N.T.	578
13. Tai Lo Shan (Tate's Cairn)	South Central N.T.	577
14. Pok To Yan	Lantau Island	576
15. Shui Ngau Shan (Buffalo Hill)	East N.T.	575
16. Kai Kung Leng	Northwest N.T.	572
17. Tai To Yan	North N.T.	565
18. Victoria Peak	Hong Kong Island	554
19. Kwun Yam Shan	Central N.T.	546
20. Pak Ka Shan (Mt. Parker)	Hong Kong Island	531
21. Unnamed Peak (816250N 813250E)	Lantau Island	529
22. Pat Sin Leng (Pat Sin Range)	Northeast N.T.	511
23. So Kwun Wat Shan	West N.T.	511
24. Sz Tsz Shan (Lion Rock)	South Central N.T.	495
25. High West	Hong Kong Island	493
26. Hung Fa Shan (Robin's Nest)	North N.T.	492
27. Unnamed Peak (809280N 804200E)	Lantau Island	490
28. Kwai Tau Leng	Northeast N.T.	486
29. Shek Uk Shan	East N.T.	481
30. Pak Tai To Yan	North N.T.	480

Note: Data on elevation extracted from Sheets 1 & 2 of the 1:50 000 Scale Topographic Map of the Territory (Edition 6, 1984).

The northwest New Territories contains a large proportion of the Territory's lowlands, but these often lie adjacent to steep slopes (Plate 8). In particular, a significant topographic boundary to this area is created by the northern slopes of the Tai Lam Chung massif and the hills which surround the Shek Kong plain. These include Tai To Yan (565 m), Kai Kung Leng (572 m), and the northwestern slopes of Tai Mo Shan (957 m).

Apart from the northeasterly trending ridge from Tai To Yan to Pak Tai To Yan (480 m), and Hung Fa Leng (Robin's Nest, 492 m), many of the hill masses in the northern New Territories are of only low to moderate relief. Numerous small valleys which separate the hills, also reflect the northeasterly trend. The Lam Tsuen Valley is an example.

The dominant feature of the area to the northeast of Tai Po is the ribbon of steep terrain that forms the southern slopes of the Pat Sin Range, which rises to over 500 m, and Wong Leng further east (Plate 6). Elsewhere in this area, the slopes are generally of moderate gradient.

Chek Mun Hoi Hap (Tolo Channel) lies along a strong linear depression. Further south, in the Sai Kung Peninsula, the terrain is very uneven, with many small steep slopes and narrow, linear valleys. The dominant peaks are Shek Uk Shan (481 m) and Nam She Shan (Sharp Peak, 468 m), and the lowland areas are small and scattered.

The Sai Kung Peninsula is separated from the major northeast trending lowlands of the Sha Tin Valley by the massive Ma On Shan (702 m) to Fei Ngo Shan (602 m) ridge (Plate 7). This ridge provides a strong physical boundary of long, steep slopes, on the southeastern side of the Sha Tin Valley. This valley is also separated from the Kowloon Peninsula by the Tate's Cairn, Sz Tsz Shan (Lion Rock) and Pak Ka Shan (Beacon Hill, 452 m) ridge and is also constrained to the northwest by the steeply sloping, northeast-trending Cham Shan (Needle Hill) ridge (Plate 3).

The southeastern part of the Territory, in an area extending from Leung Shuen Wan Chau (High Island) to Lamma Island, contains several northwest to southeast trending ridges, including Leung Shuen Wan Chau, Ma Lam Wat, Tin Yue Yung (High Junk Peak, 344 m), Pak Ka Shan (Mt Parker, 531 m), and Hok Tsui Shan (D'Aguilar Peak, 325 m). Other ridges form the backbone of the islands in this area, including Kau Sai Chau and Ngau Mei Chau (Shelter Island).

The largest island, Tai Yue Shan (Lantau), contains two northwest trending ridges one on either side of Tung Chung. However, this island is dominated by northeast trending ridges, including the Fung Wong Shan (Lantau Peak, 933 m) to Tai Tung Shan (Sunset Peak, 869 m) ridge, which is mostly surrounded by steep slopes and the lower, more gentle gradient ridge extending northeastward from Lo Fu Tau. The southwestern part of the island contains a northeast trending dissected plateau extending from Tai Hom Sham, through Keung Shan to Nei Lak Shan (Plate 4).

Table 2.3 summarises the distribution of slope gradients in the Territory. The land area of the Territory is just over 103 600 ha when the 5 390 ha occupied by waterbodies (i.e. artificial channels, reservoirs and ponds) is excluded. Of this figure, slightly over one-third is less than 15° in slope gradient, and nearly one-third is steeper than 30° in slope gradient.

Table 2.3 Slope Gradients

Slope Gradient	% of Total Area	Area (ha)	Cumulative %	Cumulative Area	Area Excluding Waterbodies		
					% of Area	Cumulative %	Cumulative Area (ha)
Waterbodies	4.9	5 390	4.9	5 390			
0 – 5°	19.9	21 673	24.8	27 063	20.9	20.9	21 673
5 – 15°	12.4	13 498	37.2	40 561	13.0	33.9	35 171
15 – 30°	33.5	36 557	70.7	77 118	35.3	69.2	71 728
30 – 40°	26.0	28 335	96.7	105 453	27.3	96.5	100 063
40 – 60°	3.0	3 214	99.7	108 667	3.1	99.6	103 277
>60°	0.3	362	100.0	109 029	0.4	100.0	103 639

Note: Waterbodies include artificial channels, reservoirs and ponds.

2.3 Geology

2.3.1 *General*

According to Allen & Stephens (1971), the regional geology consists of a sequence of folded, faulted and mildly metamorphosed volcanic and volcaniclastic rocks that overlie older metamorphosed sediments. These older metasediments include quartzites, metasandstones, shales, schists and phyllites of the Tolo Harbour, Tolo Channel, Lok Ma Chau and Tai O Formations. The volcanic and metasedimentary rocks have been intruded by various large acid intrusive igneous bodies, and in some locations they now only remain as roof pendants above the intrusion. In addition, the occurrence of marble has been confirmed in the northwest New Territories.

The igneous intrusives include fine-grained, medium-grained, coarse-grained and porphyritic granites, granodiorites and occasional basic rocks.

Later episodes of sedimentation deposited sequences of conglomerates, sandstones, siltstones and shales of the Port Island and Kat O Formations.

Formation of new and reworked deposits is continuing on land with colluviation and alluviation; offshore deposition is also occurring.

The geology of the Territory has been the subject of several mapping exercises, and these are described in Appendix C.1. The geological nomenclature for the bedrock used in GASP is based on Allen & Stephens (1971). The boundaries of the superficial deposits were drawn from the Terrain Classification Maps, produced by aerial photograph interpretation, fieldwork, and a review of borehole information for each of the Regional GASP studies (Styles, 1983). Data from these sources were used to compile the geological components of the GEOTECS database.

The Geotechnical Control Office is currently preparing a new series of geological maps at a scale of 1:20 000, This will result in a more precise definition of the distribution and nature of the geological units within the Territory. A considerable proportion of the Territory has been remapped already, and a list of map sheets and accompanying memoirs is given in Appendix C.1. As a precursor to the geological remapping programme, Bennett (1984a, b, c) reviewed the superficial deposits, weathering, stratigraphy, tectonic history and metamorphism of the Territory. Further general geological information is presented by Atherton & Burnett (1986) and Brand (1988). From an historical viewpoint, Davis (1952) remains of considerable interest.

The GEOTECS Map of Geology in the accompanying Map Folder shows the general distribution of major rock types in the Territory. An extract of this map is presented in Figure 7. The stratigraphic units used by Allen & Stephens are shown in a simplified form in this map. The main groups are metasedimentary rocks, volcanic and volcaniclastic rocks, intrusive igneous rocks, sedimentary rocks, colluvium and other superficial units. Table B6 in Appendix B summarises the distribution of the rock types as defined by Allen & Stephens (1971), while in Tables B8 and B11, geology is cross-tabulated with GLUM class and erosion respectively. In Table B10, geology is cross-tabulated with a combination of slope gradient, aspect, erosion and instability.

Table 2.4 summarises the distribution of the major geological groups present in the Territory. Volcanics and volcaniclastics are the commonest rock types, forming nearly 40% of the terrain. Superficial deposits, which include colluvium, alluvium, littoral deposits, fill and reclamation, occur on over 35% of the land. Colluvial deposits occur on some 15 700 ha (14%) of the terrain. Intrusive igneous rock types occur on just over 20% of the Territory. Metasedimentary and sedimentary rocks occur on less than 4% of the land.

Table 2.4 Geology

Material	% of Total Area	Area (ha)
Colluvium	14.4	15 718
Other superficial deposits	20.7	22 497
Sedimentary rocks	1.9	2 045
Volcanic and volcaniclastic rocks	39.3	42 855
Metasedimentary rocks	1.9	2 071
Intrusive igneous rocks	21.8	23 812
Unknown bedrock	$<$ 0.1	31
Total	100.0	109 029

Generally, the bedrock materials have 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 geological structure.

The nature of the individual rock types is summarised below. Their general engineering behaviour and planning significance are discussed in Section 3.1 and are summarised in Table 3.1. Examples of the geology of the Territory are given in the Plates described in Section 8.2.9.

2.3.2 *Metasedimentary Units*

In the north of the Territory there are sequences of folded and metamorphosed sediments, probably of Carboniferous age. In the northeastern part of the New Territories, sequences of conglomerates, quartzites, sandstones, mudstones, siltstones and shales, probably of marine origin, form the Tolo Harbour Formation (Allen & Stephens, 1971). On northwest Lantau Island, siltstones and quartzite are overlain by mudstones and sandstones, all of which are referred to as the Tai O Formation.

Small outcrops of metamorphosed marine sediments, represented by the Tolo Channel Formation, occur on both the northern and southern sides of Tolo Channel (Addison, 1986). Of greater extent, and probably resting unconformably on the Tolo Channel Formation, is the Bluff Head Formation which outcrops over much of the northern side of Tolo Channel (Plate 5). This latter sequence may be more than 1 000 m thick; current-bedded sandstones, quartzites, siltstones and shales, are probably of freshwater origin (Allen & Stephens, 1971).

Extending from the footslopes of Tsing Shan (Castle Peak) to the border at Lo Wu, a wide belt of folded, metamorphosed sediments crops out in generally low-lying terrain. The sequence includes phyllites, schists, quartzites and some metamorphosed limestones (marble).

Strata of the Tolo Channel, Bluff Head, Lok Ma Chau, and possibly the Tai O Formations, have been ascribed to the Jurassic Period. Although in places these underlie the Jurassic volcanic and volcaniclastic rocks of the Repulse Bay Formation, the possibility exists that at least some of these strata are sedimentary intercalations within the volcanic sequence.

Recent mapping for the revised Geological Survey of the Territory has confirmed the occurrence of marble within the Lok Ma Chau Formation (as defined by Allen & Stephens, 1971). The marble is fine to coarse-grained and is partly dolomitic or tremolitic. The marble sequence, which may be up to 300 m thick (Lai & Mui, 1985), is treated in greater detail in Geological Memoir No. 3 (Langford et al, 1989) and on the accompanying geological maps (Geotechnical Control Office, 1988a & b and 1989). Detailed geological mapping of parts of the Yuen Long district will result in the publication of a number of 1:5 000 scale geological maps. In the Yuen Long area marble has been reported by Siu & Kwan (1982), and Siu & Wong (1984a, b).

Metamorphosed sedimentary rocks crop out over approximately 2 071 ha, or 1.9% of the Territory.

2.3.3 *Volcanic and Volcaniclastic Units*

A large proportion of the Territory is underlain by volcanic and volcaniclastic rocks. The rock types represented include tuffs (often in massive units), agglomerates, rhyodacitic lavas and some sedimentary and volcaniclastic horizons. Allen & Stephens (1971) subdivided these rocks on the basis of major lithotypes. Detailed mapping during the present geological remapping programme has resulted in the compilation of a revised stratigraphy (Addison, 1986; Strange & Shaw, 1987). Recent work in the Sai Kung area by the Geological Survey, indicates that multiple volcanic centres may be present, resulting in the deposition of independent successions.

Principal constituents of the tuff range from fine to coarse ash, lapilli and volcanic bombs. Some of the tuffs show eutaxitic (welded) textures. In the northwestern New Territories, the tuffs are partially metamorphosed.

The volcanic succession outcrops over 42 855 ha or 39.3% of the Territory. Tables B6, B8 and B11 in Appendix B present data on the distribution of the rock units of Allen & Stephens (1971).

2.3.4 *Intrusive Igneous Rocks*

The intrusive igneous rocks of the Territory fall into two broad classes, plutonic and hypabyssal. These groups reflect the general grain size characteristics. The plutonic intrusions are usually large and were emplaced deep within the earth's crust. Granitic, granodioritic and quartz monzonitic (or syenitic—Strange & Shaw, 1987; Strange, 1987) intrusions of this form are fine-to coarse-grained and sometimes porphyritic in nature. Hypabyssal intrusions are closer to the surface and form dykes or sills, which are generally fine-grained or aphanitic and include rhyolite, quartz monzonite, granodiorite and porphyries. A few basic dykes have been recognised during geological survey.

Intrusive igneous rocks outcrop over 23 812 ha or 21.8% of the Territory. They occur in most areas except the northeast.

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. The grain size and intrusive relationships used by Allen & Stephens to distinguish between the various plutons, have been revised during recent mapping (Addison, 1986). The current geological remapping classifies the intrusive rocks on the basis of grain-size alone (Strange, 1985).

2.3.5 *Sedimentary Units*

In the northeastern part of the New Territories, a terrestrial sedimentary sequence of conglomerates, sandstones and shales, known as the Port Island Formation, forms the prominent escarpment of the Pat Sin Range, and outcrop across the northern dip slope of this range. These strata also occur on some of the neighbouring islands.

Small outcrops of red breccias and coarse grits are exposed at Kat O Chau and Lau Fau Shan. These are referred to as the Kat O Formation (Allen & Stephens, 1971).

Sedimentary rocks of the Port Island and Kat O Formations outcrop over 2 045 ha or 1.9% of the Territory. These Formations may be of Cretaceous and Tertiary ages respectively.

2.3.6 *Superficial Units*

In addition to the bedrock geology, both natural and man-made deposits cover some 35% (38 215 ha) of the land surface. These superficial deposits are classified as follows:

(i) *Colluvium*

Colluvial materials occur over 15 718 ha, or 15% of the Territory. These deposits are formed by gravity transport of rock and soil debris downslope. They occur as recent or relict deposits, and are highly variable in their physical characteristics, ranging from a mixture of clay, silt, sand and gravel, to large boulder fans containing units several metres in thickness.

The colluvial deposits are classified on the basis of their parent rock type:

(*a*) Volcanic colluvium (Cv)—This material occupies 9 157 ha (8.4%) of the Territory. It occurs predominantly as bouldery deposits in drainage channels, or as large fan-shaped deposits on footslope terrain. The detrital materials range from fresh boulders to completely weathered granular soil that may be highly permeable. In many locations, this material displays evidence of instability.

(*b*) Granitic colluvium (Cg)—The largest deposits of this material occur on the Kowloon footslopes, and on the northeast side of Hong Kong Island. Elsewhere in the Territory, broad colluvial fans are common below areas of deeply weathered and eroded granite. Boulders within the colluvium are often deeply or completely weathered, particularly in the relict deposits. They occur on some 3 651 ha (3.3%) of the Territory.

(*c*) Sedimentary and metasedimentary colluvium (Cs, Cms)—These deposits are generally sandy with occasional gravels, and occur downslope of sedimentary and metasedimentary rocks. They occur on 1 124 ha (1.0%) of the Territory.

(*d*) Mixed colluvium (Cm)—Derived from catchments with a variety of source rocks, these deposits are very variable in nature. They occur on 1 786 ha (1.6%) of the Territory.

(ii) *Alluvium*
Large areas of alluvium are present in the northwest and northern New Territories. Small areas also occur as valley floors. Alluvial deposits constitute approximately 14 800 ha (13.6%) of the Territory; of this, some 5 200 ha is covered by water bodies (streams, artificial channels and ponds) and was encoded as alluvium in the GEOTECS database. The material ranges from silts to sandy gravels.

(iii) *Littoral Deposits*
Deposits of medium dense sands and gravels may be found in bays around many of the coastal areas. They are mapped on 1.3% of the Territory.

(iv) *Marine Deposits*
Deposits of shelly sand and marine muds may be found on the seabed and beneath areas of reclamation.

(v) *Reclamation*
Approximately 3 700 ha (3.4%) of reclamation exists in the Territory at the time of mapping. The materials used are highly variable and may include rockfill, decomposed soils and waste products. Old masonry sea walls may also be present.

(vi) *Fill*
During site formation, areas of fill have often been created to form level platforms for development. These areas now total approximately 2 000 ha (2.0%) of the Territory. The engineering behaviour of these materials depends upon the constituent materials, degree and method of compaction, and any subsequent densification resulting from settlement.

2.3.7 *Structural Geology*

Two main regional structural trends are identified by Allen & Stephens (1971). Burnett & Lai (1985) discuss possible correlations of the major structural elements with those identified in the South China region.

(i) *Northeasterly Trending Fault Zone.*
It is possible that the trace of the southwest continuation of the Wuhua—Shenzhen fault zone passes to the north of Lantau Island. A number of parallel faults exist, of which the Starling Inlet—South Lantau fault zone may include the Tung Chung—Shek Pik and Yam O Wan—Pui O Wan faults. Within the mainland area of the Territory, these fault zones possess steeply-dipping, intensive crush zones (Burnett & Lai, 1985). Although crush zones are not always recognised, the faults provide strong control to the orientation of valleys and drainage lines, and indicate a considerable degree of rock fracturing.

(ii) *Northwest to North Northwesterly Trending Faults.*
This set of faults was identified in the area between Ngong Ping and Fan Lau by Allen & Stephens (1971). Burnett & Lai (1985) record additional faults aligned from Tung Chung to Cheung Sha, Sham Wat to Shek Pik, and Tai O to Tai Long Wan. Faults with this orientation are noted by Burnett & Lai to possess steeply dipping, narrow crush zones. The traces of many of these faults are identifiable as linear depressions on aerial photographs.

Numerous geological photolineaments are evident on aerial photographs and some are identified as faults. Most of the photolineaments are probably normal faults, although some may be tear faults. Major jointing may also produce some of the photolineaments. The distribution of geological photolineaments and faults is shown on the eleven, regional Engineering Geology Maps (EGM) which accompany GASP Reports I to XI.

A description of the geology of the Territory is available in the Report of the Geological Survey of Hong Kong (Allen & Stephens, 1971). This work is being updated by the programme of new geological mapping.

2.4 Geomorphology

2.4.1 *General*

The geomorphology of the terrain within the Territory reflects a complex Quaternary history of erosional and depositional responses to climatic change and eustatic sea level 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.

The landforms reflect a pattern of prominent ridges separated by well-developed valleys which have been drowned since their formation during periods of low sea-level. Sea-level is now probably at an intermediate level with respect to the overall relief. Consequently, many coastal slopes extend below sea-level and are subject to high rates of erosion as a result of wave action. Some examples of the geomorphology of the Territory are presented in the Plates contained in Section 8.

Tables B5 and B10 in Appendix B present data on the distribution of the major landform units. This information is summarised in Table 2.5. The distribution of slope gradient and landforms are illustrated in the GEOTECS Map of Landform contained in the Map Folder. An extract of this Map is shown in Figure 10.

The characteristics of the terrain are described in relation to geological materials. The volcanic terrain, which covers nearly 40% of the Territory, is subdivided by relief into areas of mountainous and of undulating terrain. Other terrain types relate to intrusive igneous terrain, sedimentary and metasedimentary terrain, colluvial terrain and alluvial terrain.

Table 2.5 Landform

Landform		% of Total Area	Area (ha)
Terrain	Slope Gradient		
Hillcrest		3.5	3 841
Sideslope :	0 – 5°	3.9	4 281
,, :	15 – 30°	27.0	29 402
,, :	> 30°	25.0	27 301
Cliff/Rock outcrop		2.1	2 325
Footslope (colluvium) :	0 – 15°	4.1	4 469
,, :	15 – 30°	2.3	2 518
,, :	> 30°	0.8	859
Drainage plain (colluvium) :	0 – 5°	4.3	4 639
,, :	15 – 30°	2.2	2 424
,, :	> 30°	0.5	502
Floodplain (alluvium)		5.0	5 435
Alluvial plain		3.5	3 804
Littoral zone		1.3	1 404
Wave cut platform		0.1	100
Disturbed terrain : cut		3.6	3 872
,, : fill		1.6	1 711
General disturbed terrain		0.6	680
Reclamation		3.4	3 698
Natural stream		0.3	373
Man-made channel		0.2	182
Water storage		2.1	2 331
Pond		2.6	2 878
Total		100.0	109 029

2.4.2 *Mountainous Volcanic Terrain*

The dominant terrain type in the Territory consists of moderate to steep, slightly concave sideslopes with narrow ridge convexities. Generally, soils are thin, overlying a shallow zone of weathered volcanic bedrock.

Evidence of both recent and relict landslip activity occurs on many slopes. Soil creep and slope wash also contribute to erosion, particularly where the slopes are steeper.

The terrain is typically irregular in shape, with large rock exposures on ridgelines such as that from Fei Ngo Shan to Beacon Hill, or on High Junk Peak, and on the extensive wave-cut coastline. The surface may be covered by a thin veneer of boulder scree deposits and clayey soil with a high percentage of rock fragments. Large boulders may be scattered over the upper slopes.

Most of the islands have steep coastal cliffs, where the slopes are undercut by wave action. Inland, the slopes are usually of moderate gradient and the soils are thin.

2.4.3 *Undulating Volcanic Terrain*

In areas where the relative relief between local hillcrests and valley floors is generally less than 70 m, soils and weathering depths on the volcanic rocks are generally deeper than on the steeper slopes, erosion rates are much lower and there is considerably less instability. These areas are of significance because they may possess potential for development. This type of undulating topography may be found around Hong Kong Island, on the Clear Water Bay Peninsula, Lamma Island and southern Lantau, and at the margins of some of the upland areas.

2.4.4 *Granitic Terrain*

Granitic terrain occupies approximately 21.8% (23 812 ha) of the Territory. Major areas occur in the western New Territories, the Tsuen Wan to Sha Tin area, 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) is preserved in parts of this terrain because of the lack of erosional energy due to the relatively low relief. Lowland terrain would probably have consisted either of alluvial or fine colluvial material or eroded granitic 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. The extensive formation of cut slopes and platforms is also evident.

Much of the undisturbed granitic 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 from the undermining of the granular soils. Although rock outcrops occur sporadically across the terrain, more continuous outcrops are evident along drainage lines and as cliffs on the steeper slopes.

The granitic terrain in the northern portion of Hong Kong Island and in the western New Territories, consists of a dissected plateau which is severely eroded in part. Slopes around the plateau are quite steep, yet still possess characteristically rounded morphology. On narrow peninsulas such as on Lamma Island or at the southern extremity of Hong Kong Island, the slopes extend from sea cliffs with long, essentially straight profiles, up to the narrow convexities of the ridgecrests. Shallower weathering depths are likely because of the more active basal removal of material by the sea.

2.4.5 *Sedimentary and Metasedimentary Terrain*

In general, the sedimentary sequences of rocks are less resistant to erosion than either the volcanic or intrusive igneous terrains, although locally, beds of quartzite or conglomerate may form prominent topographic features.

The Port Island Formation outcrops on the dip slope of the Pat Sin Range, and to the northeast of Tai Po, where it forms undulating terrain. Further east, this Formation outcrops at the summit of the escarpment at Wong Leng.

Many of the low hills in the area which extends from Tuen Mun north and northeastward to the border at Lo Wu, are formed of sedimentary and metasedimentary rocks. These strata occur beneath most of the alluvial and colluvial terrain in this area.

2.4.6 *Colluvial Terrain*

Colluvial deposits exist over 15% of the terrain in the Territory. Deposits have been delineated in the GASP if they are of significance to regional planning and engineering studies at a scale of 1:20 000 (Styles, 1983). The distribution is summarised on GEOTECS Maps of Geology and Landform in the accompanying Map Folder. Extracts of these maps are shown in Figures 7 & 10 respectively. A breakdown of the colluvial terrain according to slope gradient, is summarised in Table 2.5, and is given in full in Table B5 in Appendix B. Approximately 9 100 ha is less than 15° in slope gradient, and 1 360 ha is steeper than 30°. There are about 4 940 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 concentration of surface flow and possible groundwater flow.

Colluvial deposits exist over much of the footslope terrain. They form extensive blankets over the Kowloon footslopes, in the Mid-levels area, and on the footslopes of many of the Territory's mountainous regions. Large deposits are also evident to the east of Tsing Shan (Castle Peak), on Lantau Island, and around Tai Mo Shan. 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 southeastern side of Beacon Hill, the colluvial apron is only slightly dissected because the drainage path to the sea is quite long. On the southwestern side of this hill however, the drainage path into Cheung Sha Wan is much shorter and the stream profile steeper, and therefore the erosion is considerably greater. This has resulted in the removal of most of the colluvium from the southwestern side of Beacon 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.

2.4.7 *Alluvial Terrain*

Major alluvial deposits exist in the northwestern and northern parts of the Territory. Smaller areas exist in many of the valley floors scattered throughout the Territory. These are shown on the GEOTECS Map of Geology. The area of the major deposits is approximately 9 600 ha. Some alluvium is obscured by disturbed terrain and waterbodies and these features are not reflected in the area calculations given in Table 2.5. A more complete breakdown of the distribution of disturbed terrain is presented in Table B5 in Appendix B. The terrain in alluvial areas is usually flat or gently sloping, but may have a veneer of fill. Colluvial lenses or more extensive detrital bodies may also exist within the alluvial sequence, and both deposits may occur below the marine deposits.

The alluvial and colluvial deposits probably commenced 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 extends below present sea level, to a depth up to 80 m. The actual depth is dependent on the degree of sea level depression and on how much incision occurred before the onset of rising sea level.

Sea level has also been higher than at present, leaving small raised beach and raised alluvial terrace features in various parts of the lowland terrain. There is evidence of higher sea levels reflected in the terrain on Lantau Island and in the northwest New Territories. This possibility should be considered during interpretation of site investigation data.

2.5 Hydrology

2.5.1 *Surface Hydrology*

Much of the natural drainage pattern in the Territory is disrupted by development. The eleven Engineering Geology Maps produced in the regional studies show the location of the major catchments outside of the urban areas. 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.8.2. As it is not possible to map the drainage hierarchy within areas of urban development with reliability, the exact locations of the major catchment boundaries in the developed areas are uncertain.

Within the extensive built up areas, the principal changes caused by urban development are channelisation, coupled with possible realignment of drainage paths, together with the formation of an impervious surface to the ground. The climate in the Territory 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 extremely high volumes of runoff. Runoff is 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. Also, the expansion of areas of reclamation causes a reduction in overall gradient of a drainage channel or nullah, thus possibly necessitating regrading to maintain efficient discharge. Alternatively, an increase in channel cross-section may be required in the lower reaches to accommodate large flows. Many of the channels and drainage nullahs are covered, and their routes are not necessarily apparent from a visual inspection of an area. The drainage pattern is not shown within the urban area on maps produced at a scale of 1:20 000, except in the case of some of the major open nullahs.

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 of the unstable or geotechnically problematical slopes.

2.5.2 *Groundwater Hydrology*

With the exception of some of the alluvial deposits, the rocks and soils occurring within the Territory do not generally constitute well-defined aquifers.

Groundwater flow through the majority of lithotypes is normally by some form of conduit flow. The permeability characteristics of any of the rock or soil masses is thus a function of jointing, fissuring or piping rather than solely intergranular flow. Consequently, zones of groundwater flow and velocities are difficult to predict. This is particularly true within the Karstified marble bedrock in the Yuen Long area.

Groundwater flow in the solid rocks will depend to a large extent on the degree of jointing and fissuring, and flow will almost certainly be concentrated where these features are most prominent. Fault shatter zones may also act as water transmitting conduits, and groundwater flow can be expected to concentrate in areas most affected by faulting. Sheeting joints also tend to concentrate groundwater flow.

The superficial deposits exhibit groundwater flow of a similar nature to the solid rocks, but flow within the majority of these deposits is often due to piping which develops possibly as a result of tunnel erosion. Intergranular flow occurs to a limited extent.

The coarse-grained, loosely compacted soils are most susceptible to piping. This type of groundwater flow is difficult to predict because it may be sporadic and very complex. Pipes and voids may develop and collapse quickly in response to heavy rainfall. This phenomenon, of course, has major implications for the construction of earthworks and general slope stability.

Surface flow over bedrock frequently disappears underground on reaching superficial deposits, or indeed bedrock of different, usually softer lithology. This is well illustrated by the common occurrence of tunnel erosion in the superficial deposits and the rocks associated with the Repulse Bay Formation.

2.6 Vegetation

In the Regional Studies, a nine class system is used to classify the vegetation. The spatial distribution of these groups is illustrated in the GEOTECS Map of Vegetation which accompanies this Report, whilst the Pie Chart in Figure 4 shows their relative proportions. Over 20% of the area is devoid of vegetation, due principally to man's disturbance through urban development, and to a much lesser extent, surface erosion. An extract of this Map is presented in Figure 13.

The vegetation classes are:

(i) *Grassland*
This class generally consists of indigenous or introduced grass species which can colonise the ground after the clearing of shrubland or woodland. Grassland occupies 24 539 ha (22.5%) of the study area and occurs throughout the undeveloped terrain.

(ii) *Cultivation*
This group occupies 7.7% (8 459 ha) of the area. Urbanisation and abandonment of agricultural terraces during the last decade, has resulted in the alienation of substantial areas agricultural land in the Territory.

(iii) *Mixed Broadleaf Woodland*
This group contains a wide range of indigenous and exotic species. The largest areas of woodland occur in the Tai Lam Country Park and in the adjacent foothills. This group occupies 20.3% (22 112 ha) of the Territory and may be characteristic of the indigenous vegetation of the South China coast.

(iv) *Shrubland (Less than 50% Ground Cover)*
Shrubland occurs as regrowth on areas of disturbed terrain or develops on grasslands protected from hill fires. This group forms 11.2% (12 182 ha) of the area.

(v) *Shrubland (Greater than 50% Ground Cover)*
Similar to (iv) but has a denser vegetation cover. This class covers 12.4% (13 563 ha) of the Territory and occupies large areas of the upland terrain.

(vi) *No Vegetation on Natural Terrain*
Predominantly bare soil which is, or has been in the past, affected by soil erosion. This class occupies 2.2% of the Territory, and occurs mainly on ridgecrests and spurs of granitic terrain.

(vii) *No Vegetation due to Man's Disturbance*
Urban development, rural villages, and associated development are included in this class which occupies 16.2% (17 702 ha) of the Territory.

(viii) *Rock Outcrop*
Areas of general rock outcrop may contain sparse intermittent grass and shrub vegetation but the surface is predominantly rock. This class occupies 2.2% (2 353 ha) of the area.

(ix) *Waterbodies*
Natural streams, man-made channels and reservoirs occupy approximately 5.3% (5 764 ha) of the area.

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 likelihood 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 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 exists 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.

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 eleven regional Physical Constraints Maps and the latter also on the Engineering Geology Maps. A summary of the distribution of erosion and instability is given in the pie charts in Figure 4, are tabulated in Tables 2.6 and 2.7, and are illustrated in the GEOTECS Maps of Slope Instability and Erosion. Extracts of these maps are shown in Figures 11 and 12.

Erosion and instability affect 45.1% (49 217 ha) of the Territory. However, approximately 22% of the Territory is currently developed, with erosion occurring on some of the unprotected platforms and slopes.

Table 2.6 Erosion and Instability

Erosion		% of Total Area	Area (ha)
Instability			
	—well-defined landslips	0.1	102
	—coastal instability	1.1	1 233
	—general instability: recent	14.4	15 708
	: relict	6.0	6 480
Appreciable Erosion	Sheet erosion: minor	9.6	10 437
	: moderate to severe	5.7	6 269
	Rill erosion: minor	0.3	372
	: moderate to severe	0.7	712
	Gully erosion: minor	5.5	6 029
	: moderate to severe	1.7	1 875
No Appreciable Erosion		54.9	59 812
		100.0	109 029

2.7.2 *Weathering*

Within the regional context, it is important to appreciate the influence of local features on determining the actual depth of weathering at specific locations. For example, granite ridgecrests and sideslopes are often weathered to a depth of at least 20 m, but rock exposures may still be found within areas of otherwise deep weathering. This may be due either to erosion of the overlying soil, or to the existence of locally more resistant bedrock which is present because of changes in lithology or jointing.

For any given rock type, the depth of weathering is largely controlled by the mineralogy, discontinuity spacing and the 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 weathered profile. Major streams, if not filled with colluvium, generally have fresh rock exposed in their beds. In general, weathering is thickest beneath ridgecrests, reducing in depth on sideslopes and in eroding valley floors. Many rock exposures occur along stream channels. Beneath thick valley floor sediments, the weathering depths may increase due to interaction with groundwater.

In the Territory, weathering is largely a chemical process that transforms hard rock to soft soil, and therefore the engineering character of any site is affected by its local weathering characteristics. On a broader, 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 A4 in Appendix A.

2.7.3 *Erosion*

(i) *Sheet Erosion*

This form of erosion produces extensive areas of bare ground devoid of vegetation. Within the Territory, sheet erosion is most severe on the granitic terrain, particularly in the western New Territories. A total of 15.3% (16 706 ha) of the area is affected by sheet erosion.

(ii) *Rill Erosion*

This form of erosion is often associated with cut and fill batters, but also occurs on natural terrain. It is characterised by numerous subparallel drainage rivulets, which produce a striated appearance and result in significant soil loss. Rill erosion affects 1.0% (1 084 ha) of the Territory.

(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 7.2% (7 904 ha) of the Territory.

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.

Geology, vegetation and microclimatic variations all contribute to the degree of erosion. There is significant variation in the extent of the various rock units within the Territory, and consequently the sample size of some rock types is too small for a generalised comment on erosional characteristics.

Table 2.7 Geology, Erosion and Instability

<table>
<tr><th rowspan="3">Material</th><th rowspan="3">No Appreci-able Erosion ha (%)</th><th colspan="3">Appreciable Erosion</th><th colspan="4">Instability</th><th rowspan="3">Total Area ha (%)</th><th rowspan="3" colspan="2">Area Instability Index</th></tr>
<tr><th rowspan="2">Sheet ha (%)</th><th rowspan="2">Rill ha (%)</th><th rowspan="2">Gully ha (%)</th><th rowspan="2">WDL ha (%)</th><th rowspan="2">CI ha (%)</th><th colspan="2">General Instability</th></tr>
<tr><th>Recent ha (%)</th><th>Relict ha (%)</th></tr>
<tr><td>Colluvium</td><td>8 866 (56.4)</td><td>1 063 (6.8)</td><td>33 (0.2)</td><td>3 175 (20.2)</td><td>19 (0.1)</td><td>0 (0.0)</td><td>2 018 (12.8)</td><td>544 (3.5)</td><td>15 718 (100.0)</td><td>0.16</td><td rowspan="2">0.07</td></tr>
<tr><td>Other superficial deposits</td><td>20 798 (92.4)</td><td>1 226 (5.5)</td><td>88 (0.4)</td><td>369 (1.6)</td><td>6 (<0.1)</td><td>0 (0.0)</td><td>10 (<0.1)</td><td>0 (0.0)</td><td>22 497 (100.0)</td><td><0.01</td></tr>
<tr><td>Sedimentary rocks</td><td>624 (30.5)</td><td>676 (33.0)</td><td>0 (0.0)</td><td>188 (9.2)</td><td>0 (0.0)</td><td>32 (1.6)</td><td>345 (16.9)</td><td>180 (8.8)</td><td>2 045 (100.0)</td><td>0.27</td><td rowspan="5">0.30</td></tr>
<tr><td>Volcanic and volcaniclastic rocks</td><td>19 256 (45.0)</td><td>7 518 (17.6)</td><td>92 (0.2)</td><td>1 427 (3.3)</td><td>59 (0.1)</td><td>661 (1.5)</td><td>9 203 (21.5)</td><td>4 639 (10.8)</td><td>42 855 (100.0)</td><td>0.34</td></tr>
<tr><td>Metasedimentary rocks</td><td>1 173 (56.6)</td><td>322 (15.5)</td><td>2 (0.1)</td><td>120 (5.8)</td><td>16 (0.8)</td><td>78 (3.8)</td><td>163 (7.9)</td><td>197 (9.5)</td><td>2 071 (100.0)</td><td>0.22</td></tr>
<tr><td>Intrusive igneous rocks</td><td>9 081 (38.1)</td><td>5 901 (24.8)</td><td>869 (3.6)</td><td>2 625 (11.0)</td><td>2 (<0.1)</td><td>445 (1.9)</td><td>3 969 (16.7)</td><td>920 (3.9)</td><td>23 812 (100.0)</td><td>0.22</td></tr>
<tr><td>Unknown bedrock</td><td>14 (45.2)</td><td>0 (0.0)</td><td>0 (0.0)</td><td>0 (0.0)</td><td>0 (0.0)</td><td>17 (54.8)</td><td>0 (0.0)</td><td>0 (0.0)</td><td>31 (100.0)</td><td>0.55</td></tr>
<tr><td rowspan="2">Total</td><td rowspan="2">59 812</td><td rowspan="2">16 706</td><td rowspan="2">1 084</td><td rowspan="2">7 904</td><td>102</td><td>1 233</td><td>15 708</td><td>6 480</td><td rowspan="2">109 029</td><td rowspan="2" colspan="2">0.22</td></tr>
<tr><td colspan="4">23 523</td></tr>
</table>

Note: WDL=Well-defined landslips CI=Coastal instability

Table 2.7 summarises the distribution of the major forms of erosion associated with the main groups of surface materials. Within the various categories, it is significant that approximately 40% of the granitic terrain is affected by some form of erosion. Erosion is also prevalent on terrain underlain by sedimentary rocks, with some 42% affected. However, the area is less than 10% of that of the granitic terrain.

The volcanic and volcaniclastic rocks, together with the metasedimentary rocks, are comparatively free of severe erosion except on the northern slopes of Tai Mo Shan and the eastern parts of the New Territories. In parts of the Sai Kung Peninsula, the volcanic rocks are weathered to a much greater degree than elsewhere, rendering the surface materials more prone to erosion. On Tai Mo Shan, the north and northwest-facing slopes are generally subject to rapid downcutting on the oversteepened slopes. Minor sheet erosion also occurs on the volcanic terrain, in particular on convex slopes with only a thin vegetation cover.

The high incidence of gully erosion on colluvial terrain (20%) can partly be attributed to the mapping of incised drainage lines as 'gullys' during the terrain classification phase of this Programme.

Lam (1977, 1978) carried out a study of mechnical and chemical denudation rates in three catchments in the western New Territories. He reported that rates of ground retreat for granitic badlands were very variable, but averaged some 2.17 cm over a 15-month period, which included almost two complete wet-seasons (summers), and a typhoon during the early part of the study. Calculated rates for mechnical denudation were up to 865 $m^3/km^2/yr$ for a catchment containing some 40% of the area as badlands (about 280 tonnes/ha), as compared to only 36 $m^3/km^2/yr$ for a forested catchment. Rates for chemical denudation ranged from 8.2 $m^3/km^2/yr$ for the badland-dominated catchment, to 13.9 $m^3/km^2/yr$ for the forested catchment.

2.7.4 *Instability*

The term 'instability' used in the regional GASP studies refers to 'well-defined landslips' and terrain over which there is 'general instability'. This classification provides an indication of the inherent susceptibility of the terrain to slope failure and/or the occurrence of unfavourable groundwater conditions. Expensive slope stabilisation works may be required to permit development of unstable areas on natural terrain.

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 less than 0.5 ha in size within a terrain classification system designed for use at 1:20 000 scale. This is because these features are too small in comparison to the size of the basic terrain 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 Territory. Some 23 523 ha of the terrain displays some form of instability, and this represents 21.6% of the Territory. Section 8 contains in excess of 220 photographic plates, more than 150 of these are directly related to slope failure and instability.

(i) *Well-defined Landslips*
Within the Territory, 'well-defined landslips' occupy only 1 335 ha (1.2%) of the land surface and, of this, some 1 233 ha consists of coastal instability. Nonetheless, a number of large landslips have resulted in considerable loss of life and property. The most significant of these landslips occurred in the urban areas at Po Hing Fong in 1925 (Plate 31), Tsui Ping Road in 1964 (Plates 52 to 56), Mt Nicholson in 1966 (Plates 81 to 85), Po Shan Road in 1972 (Plates 94 to 106), and at Sau Mau Ping in 1972 and 1976 (Plates 107 to 115) (Government of Hong Kong, 1972 a & b, 1977; Vail, 1984; Vail & Beattie, 1985). In addition, large landslips have also been associated with construction and borrow areas.

(ii) *General Instability—Recent*
This form of instability affects some 14.4% (15 708 ha) of the Territory and relates to colluvial and insitu terrain where many failures and other evidence of instability occur. It is not possible, however, to delineate each small feature as a separate terrain map unit at a scale of 1:20 000.

(iii) *General Instability—Relict*
This form of instability occupies 6.0% (6 480 ha) of the area. This class is no less important in terms of geotechnical constraints upon development than general instability-recent, as areas may be reactivated by construction or earthworks.

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

Well-defined landslips and coastal instability are too limited in extent for significant conclusions to be drawn from the data presented in Table 2.7. Of more importance are the figures referring to General Instability and to the Area Instability Index (AII). Volcanic terrain should be ascribed the highest incidence of instability, with an Area Instability Index of 0.34. The AII for sedimentary rocks is slightly lower at 0.27, while for both the granitic and metasedimentary rocks, the AII is 0.22. Colluvium has the highest AII for the superficial deposits, at 0.16, due to its nature of deposition and occurrence on generally steeper gradients than the other natural superficial deposits.

2.8 Land Use

2.8.1 *Existing Development*

Considerable pressure for urban development has existed since the Territory became established as a centre for regional trade. Commercial and trading facilities, with associated high density residential accommodation and localised commerce, have expanded along the harbour foreshores, on reclamation along coastal areas and on low-lying terrain. Supportive light industrial areas are intermixed with these. Residential accommodation has spread from the commercial and industrial centres, with lower density housing occurring on more elevated areas. Throughout the process of expansion, progress has been controlled by economic and social requirements balanced by the difficulties imposed by the terrain.

The general distribution of existing land use groups within the Territory is illustrated in the GEOTECS Land Use Map and the GEOTECS Map entitled 'Existing Development, Reclamation, Undeveloped Terrain and Country Park'. Both maps accompany this Report, and extracts are given in Figures 14 and 18 respectively. 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. In addition, a large number of photographic plates pictorially describe the history of development within the Territory. These plates are discussed in Section 8.

The data presented in this Report was collected during the eleven regional GASP studies, for which the general date of mapping and field-work is given in Table B15. The resource information has not been updated, although some modifications and corrections have been made to the conventional line maps and the GEOTECS data base.

A rapid increase in population during the last 30 years has created considerable pressure for the construction of public housing. Many public housing estates are located in the Hong Kong Island and Kowloon 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 the 1970's squatters have markedly increased in some districts, particularly the Lam Tin area of East Kowloon. Squatters currently occupy about 3% of the Territory.

Transport links have grown and become overloaded as the urban centre has expanded with population increase. Inspite of this, in the Hong Kong Island and Kowloon (GASP I) study area, major roads occupy in excess of 25% of the intensely developed zones.

In the course of urban expansion, agricultural land has been alienated, and now occupies only about 10% of the Territory. Agricultural and horticultural 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 Hong Kong and Kowloon (GASP I) study area is developed.

A large portion of the quarrying for borrow, and the aggregate requirements of the Territory, are supplied by Government and contract quarries. These are used for fill, aggregate, crushed rock 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 the Territory have been designated as catchment areas. These generally consist of steeper terrain of high relief and are often associated with Country Park. Within proclaimed catchment areas, the Water Supplies Department imposes strict controls on land use. Some 2 330 ha of the Territory is currently used for water storage and includes the reservoirs at High Island, Plover Cove, and Shek Pik on Lantau Island.

Country Parks occupy approximately 37% (40 143 ha) of the Territory. The GEOTECS Maps, extracts of which are given in Figures 14 and 18, show the distribution of the Country Park. A further 19% of the Territory consists of undeveloped natural terrain.

2.8.2 *GLUM Class and Existing Land Use*

Existing development and large scale construction projects currently occupy about 22% of the Territory. This represents some 29% of all the terrain with low to moderate geotechnical limitations (GLUM Classes I and II).

The distribution of GLUM classes is shown in the GEOTECS Geotechnical Land Use Map contained in the Map Folder. The general distribution pattern of the four classes is shown in the extract of the Map in Figure 15. 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 principal land uses.

(i) *Natural and Undeveloped Areas*
Some 85 500 ha or 78% of the Territory is not as yet intensively developed, and of this almost 24% is GLUM Class III and 18% is GLUM Class IV, whilst some 29% is GLUM II, and less than 3% is GLUM Class I. Excluding the areas designated as Country Park, the area available for intensive development is reduced to 45 271 ha (42%) of the Territory.

(ii) *Squatters*
Squatters are located on approximately 2 835 ha (3%) of the Territory. 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 within the urban area of Hong Kong and Kowloon is given in the extract of the GEOTECS Map in Figure 14. The distribution of squatters in the Territory is given on the GEOTECS Land use map in the Map Folder. Note that, on this Map, the distributions of squatters and single storey housing are combined; it is not always possible to distinguish squatters from low rise village type housing by aerial photograph interpretation. 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; refer to Table B13 in Appendix B.

(iii) *Residential*

Residential development occupies about 6.4% of the Territory and, as such, is the largest form of developed land use. More than 75% of residential development is situated on GLUM Classes I & II terrain. It is also quite significant that almost 20% of residential development occurs on GLUM Class III terrain. This indicates that in many parts of the Territory, 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 geotechnical constraints. However, it also highlights the fact that a large proportion of residential development occurs on geotechnically difficult terrain, and that careful land management and sound engineering practice are necessary to minimise the occurrence of slope failure.

Residential areas consist of about 13% of GLUM Class I, 64% of GLUM Class II and 20% of GLUM Class III terrain. Only about 3% of GLUM Class IV terrain is associated with this type of development, and most is associated with steep cut and fill slopes. These figures include residential intermixed with commercial or industrial uses.

(iv) *Commercial and Industrial*

Commercial and industrial areas occupy less than 1% of the Territory and occur almost entirely on GLUM Class II terrain. This probably reflects the need for accessibility and for large level sites, and is generally due to the use of reclamation and filling over low-lying alluvial terrain.

(v) *Recreational*

Sporting facilities and urban recreational areas occupy less than 1% of the Territory. They are generally located on terrain of low GLUM class. Parks and golf courses form the largest component of this group, and only these occur on any significant amounts of GLUM Class IV terrain.

(vi) *Community and Institutional*

Community facilities and institutions such as schools and hospitals occupy less than 1% of the terrain. 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 only a very small area. They generally involve only small scale disturbance to natural ground profiles but, because they usually are located in 'auspicious' situations (fung shui), they often utilise steeper terrain. Hence, they characteristically occur on GLUM Classes II & III terrain.

(viii) *Transportation*

Airport and seaports occupy about 1% of the Territory. 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 cells and are rarely mapped as discrete units.

(ix) *Service Facilities*

Of the community service facilities, service reservoirs and areas of water storage utilise the largest area (2 435 ha). In total, these facilities occupy less than 2% of the Territory. 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 occupy less than 3% of the Territory, utilising mostly GLUM Classes II & III terrain.

(xi) *Quarries*

These form less than about 1% of the Territory. Whilst a pattern of 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 about 12% of the terrain. Most of this is GLUM Class II terrain, with only construction sites having a significant proportion of GLUM Class III terrain.

2.8.3 *Trends in Development*

On 20 January 1841, the population of Hong Kong stood at about 7 450 persons, but within 5 years it had trebled to 21 835. By 1876, the population had increased by a factor of seven to about 140 000. With the exception of the period 1941–1945, the population has steadily increased. Table 2.8 presents some data for the period 1841 to 1986, mostly extracted from Chiu & So (1986). It is evident that in the 30 years since 1956, the population has increased by some 3 million, and consequently, provision of housing has been a major issue. Rapid development and construction have been necessary, in many instances on geotechnically difficult terrain. Early development is well documented by Tregear & Berry (1959), and a number of the old maps are reproduced in the GASP I Report (Geotechnical Control Office, 1987a). Pryor (1983) and Bristow (1984) provide further information on the history of development and housing within the Territory.

Table 2.8 Population Growth of the Territory

Year	Population	Year	Population
1841	7 450	1945	650 000
1846	21 835	1946	1 550 000
1876	139 144	1956	2 614 600
1901	300 660	1966	3 732 400
1921	625 166	1976	4 443 800
1941	1 639 337	1986	5 600 000

Note: Most of the figures are reproduced from Chiu & So (1986)

By March 1966, the urbanised area was considered to consist of parts of Hong Kong Island, Kowloon, New Kowloon and Tsuen Wan. These areas formed some 10 000 ha or about 10% of the Territory's total land area (Government of Hong Kong, 1968). Chiu & So (1986) report that by 1975 the total area of urbanisation was approximately 12 700 ha. The information collected during the GASP Studies indicates that during the period of some 20 years since 1966, the extent of generally developed terrain increased to approximately 22% (23 600 ha) of the Territory. This represents an increase of some 1 000 ha per annum for the decade following the mid-1970's, and indicates the intense pressure for urban expansion which has given rise to the need for development on geotechnically-problematical terrain.

It is interesting to compare the population densities based on the 1976 Census and Chui & So's estimate of the area of urbanisation for 1975, with the 1986 Census and the GEOTECS land use data presented in this study. In 1975, the population of the Territory was 4.4 million and the area of urbanisation was some 12 700 ha; by 1986, the population had risen to 5.6 million and the area of generally developed terrain to some 23 600 ha. The approximate population density in 1975 was about 35 000 per km^2, but by 1986 it had fallen to about 24 000 per km^2. It should be noted that these figures may not be strictly comparable, because the basis for Chui & So's estimate of the area of urbanisation is unknown. Nonetheless, at face value alone, it would seem that the period of rapid urban development during the 1970's and early 1980's gave rise to a significant decrease in population density by spreading the population away from the traditional areas of concentration in urban Kowloon and Hong Kong Island. This tended to counter the dramatic influx of people during the 1950's and 1960's (Table 2.8).

A summary of the projected population growth of the seven New Towns is presented in Table 2.9. The figures reflect the degree of New Town development in the New Territories since the mid-1970's.

Table 2.9 Population of New Towns

Area	1987	Mid-1990's
Tsuen Wan	700 000	800 000
Sha Tin	460 000	750 000
Tuen Mun	300 000	500 000
Tai Po	150 000	290 000
Fanling	110 000	220 000
Yuen Long	110 000	180 000
Junk Bay and Sai Kung	—	325 000

Source: Government of Hong Kong (1988)

2.8.4 *Future Development*

Development principles for the Territory are presented within the 'Hong Kong Planning Standards and Guidelines' (HKPSG). The future development of natural terrain and the upgrading of existing facilities 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 curtail development in Country Park and areas of designated 'Green Belt'. Water Supplies Department upland catchments are similarly protected. Natural and geotechnical constraints also have a restricting influence on the future development of some terrain.

Land use planning issues are reviewed by Pryor (1983), Bristow (1984), Lo & Ma (1986), and Ma (1987). Styles & Burnett (1985b) discuss the application of the regional GASP maps for land planning in the Territory.

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 Territory, and the nature and extent of their influence varies accordingly. The general properties of the rocks 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, volcanic rocks normally weather to depths of about 10 m but rock outcrops such as on Fei Ngo Shan or Ma On Shan are devoid of weathered material. Investigations for reclamation associated with the Ma On Shan New Town development have revealed evidence of weathering in excess of 90 m below Principal Datum. During the construction of water tunnels from Plover Cove to the Lower Shing Mun Reservoir, weathering was encountered 300 m below the ground surface.

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.

Another factor that may be important in the weathering process is the presence of hydrothermally altered material. Chemical changes in the rock caused by the infiltration of hot fluids at depth increase the susceptibility to weathering. In some cases, the products of the alteration closely resemble those of weathering.

Erosion removes the soft products of weathering and reduces the actual thickness of the weathered profile. Major stream courses, if not filled with colluvium or alluvium, generally have fresh or at most, moderately weathered rock exposed in their beds. This is due to erosion of the weathered profile. In areas of active coastal erosion, the weathering profile is usually absent but may be developed beneath the marine and/or offshore terrestrial deposits laid down during a period of lower sea level.

In the Territory, 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 A4 in Appendix A. (refer to Section A.8.5).

(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 the GEOTECS Map of Erosion and Rock Type, an extract of which is presented in Figure 22, and are tabulated in Tables 2.7, B10 and B11 in Appendix B. The Area Instability Index presented in these tables 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. Within the Territory, 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 geological materials, found in such variety in the Territory, 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. In Section 4.2.3, a method of identifying potential sources of rock is given in the GEOTECS Plots in Figures 20 and 21.

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 are broadly classified into six groups:

(*a*) Man-made deposits—fill and reclamation.

(*b*) Recent deposits—alluvium, littoral and marine deposits.

(*c*) Colluvium.

(*d*) Volcanic and volcaniclastic rocks.

(*e*) Intrusive igneous rocks.

(*f*) Sedimentary and Metasedimentary rocks.

3.1.2 *Characteristics of Fill and Reclamation*

The materials in this group have been placed by man and are therefore the youngest of all the materials in the Territory. Their nature is controlled not only by their source, but also by the method of placement and compaction.

The engineering standards applied to these materials have varied over the years, and the older fill deposits may be inadequately compacted and contain voids and/or large blocks of masonry. The material for land-based fill has usually been obtained from nearby site formation works, such as the current large-scale developments on Tsing Yi Island, and may consist in part, of the weathered local rock type together with construction debris. Areas of older reclamation may incorporate materials obtained from further afield. In the older areas of reclamation, lateral and vertical variability in material behaviour should be anticipated. The presence of old structures, such as foundations or old sea walls, should be checked by consulting archival data. Recently, fill for reclamation has been economically obtained from offshore sources by dredging (Whiteside & Wragge-Morley, 1988). In addition, some onshore landfill projects are likely to benefit from these methods.

Reclamation materials, in a loose, permeable and saturated state, may have water-related problems, and grouting or dewatering may be necessary in deep foundations. It should also be noted that dewatering may induce settlement in adjacent structures. Where water problems occur, basements may require 'tanking' or other water-resistant designs.

Some large areas of reclamation consist of sanitary landfill. This material, mixed with layers of natural borrow, may be subject to large and unpredictable settlements.

Fill is a natural material used to form site formation platforms above the general level of the terrain. The location of fill is shown on the GEOTECS Map of Geology contained in the Map Folder accompanying this Report. Common problems with old fill slopes are due to the practice of 'end-tipping'. Fill material was simply tipped downslope and allowed to accumulate at its angle of repose, in much the same way as natural colluvium is formed. The poor compaction and loose structure resulting from this practice has made old fill slopes susceptible to liquefaction through rainwater infiltration, blockage of pre-existing natural drainage channels or from fracture of water mains.

When carrying out site investigations in areas of fill, it is often useful to consult old aerial photographs in order to determine the age and extent of the deposit. Standard Penetration Tests may give a guide to material density, but undisturbed samples are required in order to test the shear strength parameters. Special note should be taken of the relative density of the material. Fill and reclamation are also discussed in Appendix D.3.3.

Table 2.7 contains a summary of the proportions of the main geological units affected by the various types of erosion and instability. Table B11 gives a more detailed breakdown by rock types. It is apparent from Table B11, that only some 14 ha of fill and 2 ha of reclamation are affected by instability. Sheet, rill and gully erosion are more common, occurring on respectively 1 167, 82 and 22 ha of fill and reclamation combined.

Much of the erosion on fill and reclamation occurs soon after placement, before establishment of an adequate surface protection cover. This cover may be in the form of either concrete or chunam on slopes, or development on platforms. The re-establishment of a protective vegetative cover, for example by hydro-seeding or planting, reduces erosion, and also adds to the amenity value.

In materials prone to erosion, severe rill and gully erosion may occur even on relatively flat terrain. Once initiated on an adjacent slope, rills and gullys may extend onto and across a flat platform. An example of this is evident in the Ma On Shan New Town, where reclamation platforms formed using fill from adjacent, severely eroded slopes, have also suffered from the affects of erosion.

3.1.3 *Characteristics of Alluvium, Littoral and Marine Deposits*

These natural materials occur as thin, flat-lying recent deposits that have a poorly developed or no weathering profile. They form complex coastal and submarine stratigraphies due to the fluctuations in sea level during the last 10 000 years. In geological terms, they are immature. There is a wide range in the particle size distribution in this group.

The alluvial material is predominantly a cobbly sand with poor stratification and is usually in a loose condition. The littoral deposits consist of well-sorted coarse sands that are usually well-compacted due to wave action, but are subject to marine erosion. Marine deposits in the Territory are variable, with some areas of sand that have been commercially extracted, and other areas of highly compressible marine mud. Many of the marine deposits have plasticity indices that plot above the 'A' line, with values in excess of 50% and are, therefore, highly plastic. No incidence of erosion is evident on the terrestrial deposits, but alluvium can be erodible if hydrological conditions are adversely altered by construction activity.

Recent investigations for offshore fill have revealed substantial quantities of buried alluvial sand and gravel beneath marine deposits. The geology of different types of offshore granular deposits is examined by Arthurton (1987), and the exploitation of these resources is discussed in Whiteside & Wragge-Morley (1988).

All steep-sided excavations require strutting, as these superficial materials have little or no cohesion. There is little natural instability in these materials, due mainly to their intrinsically low slope angle. These various deposits exhibit a wide range of shear strengths; the lowest values correspond to the marine muds and the highest values to alluvial horizons. Consolidation is rapid in the alluvium and littoral deposits, but may be very slow and of a high magnitude in the marine deposits. The absolute magnitude of settlement is largely dependent on the imposed load, local groundwater conditions and the local stratigraphy. Undisturbed samples are required for laboratory tests to determine the material strength characteristics applicable to individual sites. Site investigations in alluvium may be enhanced by the application of geophysical techniques such as resistivity or shallow seismic refraction. Offshore, marine seismic techniques are useful in obtaining profiles of marine sediments.

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 pile type most appropriate for high loads will be dependent on the overall stratigraphy, but nearly all members of this group are suited to driven piles. The materials in this group are easily excavated by machine methods. Marine deposits of sand, such as those south of Tsing Yi, in Deep Bay, or in Tide Cove, have been extracted or covered by reclamation. Marine silts and clays are generally unsuitable as hydraulic fill. The siting of villages and large-scale developments such as the Tin Shui Wai or Ma On Shan New Towns, on areas of alluvium, generally precludes the use of these areas as sources of fill.

From a planning point of view, this group of materials, although not free of problems, is generally suitable for development. The littoral deposits, which are subject to marine erosion, have significant amenity value as beaches.

Instability in these materials is rare, as indicated in Table B11, although local failures may be initiated by inadequate support during excavation, particularly when excavation proceeds below the groundwater table, or by river bank collapse caused by stream undercutting. The low incidence of erosion, less than 3% of the area of alluvial terrain, should be qualified. 'Gully' erosion is almost entirely due to the incision of stream courses, while elsewhere, low levels of erosion may occur on agricultural terrain. Generally, these were not identified during the terrain classification mapping because the general incidence was too low to be of engineering significance.

Table 3.1 Description and Evaluation of Geological Materials

Type	Age	Symbol	Map Unit	MATERIAL DESCRIPTION: General Lithological Description	Topographic Form	Weathering and Soil Development	EVALUATION OF MATERIAL: 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 and crushed quarry rock. Often a mixture of silt, sand, gravel and cobbles. Some building waste, mine waste or sanitary fill may also be included.	Extensive planar deposits adjacent to the 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 the 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. $\emptyset' \cong 25°–35°$. 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 or piled 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 intertidal zone, forming beaches and sandbars. Occasionally raised beaches may occur.	Nil	Generally sand-sized granular material, often uniformly graded and well rounded.	Materials are usually saturated and saline. Raised beaches may be leached by rainwater but may remain saline at depth. Groundwater extraction may induce incursion of saline water. Poor grading characteristics—low fines. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or piled foundations.	Main development potential of existing beaches is for recreational purposes. Excavation of these materials is usually prohibited.
SUPERFICIAL DEPOSITS	QUATERNARY – RECENT?	L(RB)	RAISED BEACH DEPOSITS						Raised beaches can provide local sources of partly-washed, rounded sand which are very easily excavated. Some have already been mostly sterilised by development.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	P	ALLUVIAL DEPOSITS – PONDS	Generally brownish-grey silty sand with subangular gravel. Occasionally contains cobble and boulder horizons.	Extensive area of small shallow (±5–6 m) constructed ponds separated by bunds or earth embankments, the material for which is usually won from the pond area.	In subaerial locations very minor development of soil horizon. Relict deposits may be more weathered. Very old deposits may contain completely weathered boulders.	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, $\emptyset' \cong 20–25°$.	Locally low-lying terrain may be subject to flooding. 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. Groundwater may be saline if adjacent to coast. Incursion of saline groundwater following abstraction of fresh groundwater may occur. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or piled foundations.	Land deposits easily excavated. Marine deposits often form reasonable hydraulic fill. Excavation by cutter, suction or bucket dredger.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	A	ALLUVIAL DEPOSITS – UNDIFFERENTIATED		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.				
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	Al	ALLUVIAL DEPOSITS – RAISED TERRACES						
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	M	MARINE SEDIMENTS	Usually dark grey silty sand or clay with traces of shell fragments, and some sand horizons, especially near shore. A mixed succession with alluvium and/or colluvium may be present.	Seabed sediments of variable thickness (0–10's of metres) below low tide mark.	Nil	Silt and silty clay layers are 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, $\emptyset' \cong 25°$. SPT < 10 but increases with depth. Sand deposits are typically 20 to 50% fines, with the granular component being a mixture of fine quartz and comminuted shells.	Material is poor to unsatisfactory for hydraulic fill. It is also poor as a foundation because of settlement and bearing capacity problems. Silty and silty clay materials will probably be susceptible to formation of mud waves 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; SEDIMENTARY AND METASEDIMENTARY 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, sandy silts and clays are to be found on the middle to lower sideslopes and footslopes. Coarse boulder colluvium exists in many stream channels.	Mainly occupies the lower sideslope and footslope terrain and may underlie much of the alluvial floodplain. Generally gently 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 medium gravel. Plasticity varies from PL 22–28%, LL 28–40%. Typical shear strength values are $c' \cong 0–5$ kPa, $\emptyset' \cong 29°–42°$. Standard compaction values: OMC $\cong$ 17–20%, MDD $\cong$ 1 630– 1 750 kg/m³. CBR $\cong$ 3–8%.	This material has moved in its geologic past and is prone to reactivation if not carefully treated by such measures as low batter angles, drainage, and surface protection, especially 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. Site investigation is 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 bouldery stream deposits will be of limited use. Large boulders may require blasting or splitting.

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	QUATERNARY PLEISTOCENE?	K	SEDIMENTARY ROCKS: KAT O FORMATION	Formation consists of beds of brecciated rocks which are pale grey-green when fresh. They contain angular fragments of volcanic rocks, commonly 100 mm long and include some larger blocks and coarse grit beds	Forms a small headland north of Sai O. Also forms the islands of Ap Chau and Sai Ap Chau.	Rock weathers to a weak red to red-brown poorly cemented breccia.	Very little data available. The degree of weathering would determine overall strength. Individual clasts may retain rock strength depending on original material even when the matrix is weathered.	Extremely minor distribution; very unlikely to be built upon.	Extremely hard and durable when fresh; blasting would be required. Possible local source of aggregate.
	LOWER CRETACEOUS MESOZOIC	PI	PORT ISLAND FORMATION	Interbedded conglomerate, pebbly sandstone and mudstone. Usually red or pink in colour. Rocks are moderately well cemented, very thickly bedded.	Outcrop essentially forms the gently northward dipping cuesta ranging from the Pat Sin Range to near Starling Inlet.	Rock generally decomposed to a reddish brown silty sand with pebble traces. Weathering depths are usually small, less than 7 m.	Very few results available. Properties vary depending on parent material.	Material has seldom been worked hence its characteristics are virtually unknown. The soil profile should be similar to the RBp. The rock profile stability aspects will be controlled by the existing discontinuities. No bearing capacity problems anticipated.	Material could be scraped for borrow when weathered. Fresh rock must be blasted. Not recommended for aggregate until further studied.
	LOWER AND MIDDLE JURASSIC	RBs	SEDIMENTARY, VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS: REPULSE BAY FORMATION: SEDIMENTARY AND WATER-LAID VOLCANICLASTIC ROCKS	Generally 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. Conglomerates also found.	Forms areas of moderate relief or (usually) prominent rises in the hillside profile resulting from the presence of locally resistant beds.	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 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. Scarn mineralisation with magnetite has been mined.
		RBv	ACID LAVAS	Dark green or bluish-grey, fine-grained with light phenocrysts, banded, strong rhyolite. The rock often displays closely spaced smooth joints.	Forms areas of moderate relief, rock outcrops common. Thin beds often forming prominent rises on hillsides.	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 closely 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.
		RBag	AGGLOMERATE	Tuff breccia, lapilli breccia and blocks of sediments in a coarse lapilli matrix. Volcanic bombs over 600 mm can be found. Jointing is closely spaced and smooth.					
		RBc	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 weathered mantle occurs.	The near surface completely decomposed material has a DD ≅ 1 500 kg/m³ 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: $c' \cong$ 0–10 kPa, $\phi' \cong$ 30–35° Fresh rock properties are approximately as follows; Unconfined compressive strength ≅ 150–250 MPa. Joint strength parameters are $c' \cong$ 0 kPa. $\phi' \cong$ 30° roughness angles 5–10° DD ≅ 2 500–2 700 kg/m³. Point Load Is(50) ≅ 6–14 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.
		RBp	DOMINANTLY PYROCLASTIC ROCKS	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.					
		RBvb	MAINLY BANDED ACID LAVAS SOME WELDED TUFFS	Amygdaloidal banded rhyolite, banded trachyandesite, spherulitic rhyolite and ignimbrite. Displays closely spaced smooth joints.					
		RB	UNDIFFERENTIATED VOLCANIC ROCKS	Rock types not mapped in detail by Allen & Stephens (1971), but probably similar to the above volcanic units.					
		T	SEDIMENTARY ROCKS: TAI O FORMATION	Lower beds are black silty shale, white orthoquartzite, black and white siltstones, purple sandy siltstones and some graphitic sandstone. Upper beds include massive white fine-grained orthoquartzite and very fine-grained micaceous sandstone interbedded with siltstone.	Occurs on footslope and sideslope terrain forming relatively dissected relief. Incision is evident along drainage lines. Terrain is essentially planar-convex in morphology, broad convex spurs are common.	Generally moderately deep (5–10 m) uniform or gradational, red to red-brown residual clayey soil, overlying completely to highly weathered sediments.	No test data available.	Fresh material is generally stable and has good bearing capacity characteristics. Weathered material subject to creep and some instability, especially when saturated. May break down to silt if weathered material is over compacted.	Restricted outcrop precludes extensive usage. Weathered horizon can be excavated by machine, fresh rock needs pneumatic tools or blasting. Possible use as borrow but fresh rock not suitable for aggregate.

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	MIDDLE AND LOWER JURASSIC	LMC	METAMORPHOSED SEDIMENTARY AND VOLCANIC ROCKS	LOK MA CHAU FORMATION	Metamorphosed sedimentary and volcanic rocks including schist, phyllite, quartzite, metasediments and marble.	Forms hills of moderate to low relief due to its low resistance to erosion. Occurs extensively beneath colluvial and alluvial cover. Local areas of surface boulders and occasional rock outcrops on sideslopes and in gullys.	Metasediments generally weather to produce moderately deep (1–2 m), uniform or gradational, red to red-brown clayey metasediments. Marble (metamorphosed limestone) weathers in two forms: (i) Complete solution, originating along discontinuities; to produce interconnecting cavities which may exceed 1 m in size; (ii) Intergranular solution which produces a weak granular layer at the marble surface.	The near surface completely weathered residual soil acts as a silt with void ratio of ≅ 0.25–0.33. Gradings show 5–15% clay, 40–60% silt, 20–30% fine sand. Plasticity varies from PL 25–35%, LL 34–40%. Typical shear strength values are c' ≅ 0–15kPa, Ø' ≅ 35°. completely to highly weathered materials generally have a DD in the range 1 600 to 1 800 kg/m^3. Fresh rock UCS ≅ 40–90 MPa. Discontinuity strength parameters are approximately c' ≅ 0–5 kPa, Ø' ≅ 25–30°.	Considerable care is required during investigation, design and formation in materials of the Lok Ma Chau Formation. Bearing capacity characteristics are reasonable for low and moderate loads. Stability of this rock in cutting is dependent on the very closely spaced discontinuities, the strengths of which are generally low-considerable care is thus required. Roughness friction values of 0°–5° may be added to Ø' values. Discontinuity surveys are essential in cutting design. Metasediments may be prone to instability, especially along discontinuities when weathered and saturated. Bearing capacities are reasonable for low to moderate loads on metasediments and marble without large cavities. Interconnecting cavities within the marble provide excellent hydraulic conductivity. Whilst this may be beneficial for water supply wells, rapid fluctuations of the groundwater table can lead to the formation of either collapse sinkholes or gradual settlement in the overlying superficial deposits if hydraulic continuity exists, as soil is washed into the void system.	Material can be used as a source of bulk fill but may break down to silt if overcompacted. Excavation by machine is relatively easy.
		BH	METASEDIMENTARY ROCKS	BLUFF HEAD FORMATION	Variably indurated pale coloured fine sandstones, orthoquartzites, siltstones and mudstones with occasional conglomerate horizons.	Rock type forms the larger portion of Bluff Head Peninsula and shows rounded form as a dissected ridgeline with perpendicular spurlines.	Only a thin (1–2 m) pedogenic horizon develops but the rocks are otherwise moderately weathered to great depths (5–25 m) as shown by the red colouration.	Very little data is available for these steeply dipping, folded strata of alternating mudstones, siltstones and sandstones.	Caution is advised regarding slope stability. Metasediments may be prone to instability, especially along discontinuities when weathered and saturated. Bearing capacities are reasonable for low to moderate loads on metasediments.	Could be used as very localized source of fill. May break down to silt upon overcompaction. Only the sandstone members will require blasting otherwise machine digging may be possible.
		TC		TOLO CHANNEL FORMATION	The sediments are steeply dipping or vertical thin quartzites and black shales containing abundant pyrite. They are commonly flexed, locally contorted and contain marine fossils. Closely spaced smooth joints are common, locally schistose.	Forms only a very restricted intertidal rock platform on the north shore of Tolo Channel. Submarine outcrop has been postulated.	No soil development due to intertidal location.	Not known due to limited extent and intertidal location of outcrop.	Very restricted occurrence and intertidal location preclude detailed comments.	All exposures would require blasting. Not suitable for aggregate or fill due to schistosity and sulphide content.
	PERMIAN	TH		TOLO HARBOUR FORMATION	The main rock types are black shales, thinly banded shale and mudstone. Low grade metamorphism has converted some rocks to quartzite. This unit is structurally complex with numerous closely spaced smooth tectonic joints. It is also folded and faulted.	Encountered beneath Tide Cove and also forms part of the southern tip of Centre Island.	Palaeosol developed beneath old alluvium. Weathering may be up to 40 m thick extending to −90 mPD.	Little information available. SPT ≅ 20–100.	If encountered in foundations the weathered material will be of low strength and contain sulphur. Acid attack on steel piles may occur.	Location precludes borrow activities. Excavation by machine digging with some blasting.
	UPPER JURASSIC	Mc	INTRUSIVE IGNEOUS ROCKS (PLUTONIC)	GRANOPHYRIC MICROGRANITE	Pink to grey fine-grained non-porphyritic rock. Pink and white feldspars and quartz with granophyric texture. Jointing similar to other granitic rocks.	Very small outcrops forming lower sideslopes and coastal slopes.	Weathers to produce a clayey silty sand with corestones. Depth of weathering similar to other granites. Fresh rock outcrops in stream beds on occasions. Outcrops on Green Island are subject to marine erosion along shoreline, soil development very limited, shallow weathering only.	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 can be machine excavated for use as fill. Limited outcrop and urban proximity restricts borrow potential to local site preparation. Fresh rock will require blasting.
		NH	NEEDLE HILL GRANITE	FINE-GRAINED PORPHYRITIC PHASE	Fine-grained, pink, with phenocrysts of quartz and potassium feldspar in varying proportions. Pyrite is a common accessary mineral. Jointing is similar to other granites.	Occurs as strongly dissected midslope benches and extensively eroded granite ridges and spurs. Narrow but rounded ridges and spurcrests. Moderate to steep planar sideslopes.	Shallow to deep residual soils over deeply weathered granite. Local occurrence of less weathered rock outcrop and/or massive boulders on upper sideslopes and incised gully floors.	The near surface decomposed material has a DD ≅ 1 350–1 400 kg/m^3, MC ≅ 17–32%. Permeability, K ≅ 24 – 0.1 × 10^{-6} m/s. c' ≅ 0–30 kPa, Ø' ≅ 34–44° Fresh rock properties similar to other granites.	Unstable areas result from deep weathering and joint controlled rock slopes. Extensive rill and sheet erosion affects the weathered mantle. Bearing capacity characteristics are generally favourable for moderate to high loads. Materials are generally free draining.	Used as a source of borrow and aggregate, the former requiring machine excavation and the latter blasting. Molybdenum mineralisation has been mined. 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.
		NHm		MEDIUM-GRAINED PORPHYRITIC PHASE	Medium-grained gradational with above with similiar mineralogy and jointing.					

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	HK	INTRUSIVE IGNEOUS ROCKS (PLUTONIC)	HONG KONG GRANITE		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.	Forms extensive areas of moderate to steep concave-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 occasional cliff faces. Residual core boulders common on surface of sideslopes and gullys. 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 c′ ≅ 0–25 kPa, Ø′ ≅ 31–43°; permeability ≅ 10^{-6}–10^{-8} m/s. DD ≅ 1 500 kg/m^3; MC ≅ 15% near surface, ≅ 30% at depth. Fresh rock has an unconfined compressive strength in the range 80–150 MPa. Rock mass strength essentially dependent on joint characteristics. Roughness angles for tectonic joints ≅ 5–10°, for sheet joints ≅ 10–15°. Basic friction angle ≅ 39°. Point Load Is(50) ≅ 4–10 MPa (fresh rock material)	Weathered mantle is subject to sheet and gully erosion and even to landslides in steep slopes or if severely undercut. Perched water tables conform with highly permeable upper weathered zones. Rock is prone to discontinuity-controlled failures in fresh to moderately weathered state (Grades I–III). Stream and drainage lines tend to align with geological weaknesses. Large structures may require deep foundations. Cut slope design may be governed by large depths of weathered material.	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.
		HKf		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.					
		HKm			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.					
		FL		FAN LAU PORPHYRITIC GRANITE		Pale pink, fine-grained groundmass with phenocrysts of feldspar and quartz making up about half of the rock. Euhedral feldspars commonly exceed 10 mm in length; quartz usually occurs as large pools of intergrown crystals.	Forms areas of moderate to steep relief with broad convex hillcrests.	Moderate to deep weathering on ridgecrests and slopes protected from erosion. Shallow weathering on rocks exposed to wave erosion. Soils contain large percentage of coarse quartz sand.	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°. Mass strength characteristics for 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) ≅ 6–11 MPa. Joint strength parameters are 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 occassionally occur. Insitu material is prone to severe erosion. Special care must be taken in establishing adequate surface protection on newly formed slopes. 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.	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.
		MS		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. Occurs as steep to precipitous terrain especially along coastlines exposed to wave action. Drainage is dendritic in nature although structural control may 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. At depth the decomposed rock is a silty sand with variable fine gravel content. Depth of weathering i.e. soft material, is often great and can exceed 10 m. Weathering to produce corestones is common. Upper weathered zone porous and permeable.			
		CC		CHEUNG CHAU 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.					
		SK		SUNG KONG 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.					
		G		UNDIFFERENTIATED GRANITIC ROCK		Nature of rock uncertain but similar to granitic rocks discussed above.					
		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 a 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.	Small outcrop on central Lamma Island forms moderate ridge with narrow crest convexity. Moderately steep sideslopes are prone to instability and erosion.	Weathering depth to Zone C can exceed 10 m. Boulders and corestones are common in weathered zones. Weathering product is subangular silty sand.	Little test data available for study areas but decomposed granodiorite has the following general properties: DD ≅ 1 300–1 700 kg/m^3, clay content 2–8%, silt content 30–55%, sand 40–60%, MC ≅ 15–35%. Plasticity varies from non-plastic to PL 27–37%, LL 40–50%, c′ ≅ 0–14 kPa; Ø′ ≅ 33–42°. Standard compaction values: OMC ≅ 16–22%, 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) ≅ 7–11 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 slopes.	Because of the low to moderate content of quartz in the clay, weathered zone may be suitable 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 asphaltic concrete.

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	LOWER CRETACEOUS	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.	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 loci for subsurface water concentration.	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 Ø' values. Intact rock strength will be very high, >100 MPa when fresh.	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.
	UPPER JURASSIC	Mo		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 with moderately broad ridgecrests.	Shallow to deep residual soil over moderately weathered rock. Corestones extensive.	Coarser grained fresh rock has an unconfined uniaxial 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 rquired with weathered materials because likely to be slightly more clayey. Several troublesome case histories noted.	Material can be scraped 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.
		La		DYKE ROCKS	FELDSPAR PORPHYRY	Grey to greenish-grey. Fine-grained groundmass with up to 20% large (8–10 mm) phenocrysts of 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 loci for subsurface water concentration.	Generally weathers faster than volcanic rocks but slower than granitic 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.	Surface hydrology can be affected by these rocks with drainage networks 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.
		Pq			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.					
		MG			PORPHYRITIC MICROGRANODIORITE	Very fine-grained groundmass with abundant basic xenoliths.			No data available but should be similar to Tai Po Granodiorite.		
		Dc			COMPOSITE DYKE	Dyke within dyke, mixed igneous lithologies.			Material properties of dyke components noted above.		
		—ka			DEEPLY WEATHERED PEGMATITE WITH KAOLINITE	Very coarse granite rock composed of quartz, feldspar and mica altered to kaolinite and sand.	Forms narrow local depressed lineaments and irregular depressions.	Deep to very deep weathering with kaolinite development.	Coarse sand in silty clay matrix, erodible.	May form a local deepening of weathered profile.	Kaolinite has been commercially mined.
		—q		VEINS	QUARTZ VEIN	White or translucent microcrystalline quartz rarely over 100 mm thick. Can be associated with narrow dykes of microgranite.	Too narrow to have any significant affect on topography.	Quartz veins undergo only mechanical disintegration as they are very resistant to decomposition. Coarse angular gravel is the product.	Generally too small to be discretely sampled and tested.	Generally too small to affect structure but contained sulphides may affect groundwater chemistry and react with concrete and steel in foundation.	Restricted extent precludes deliberate borrow activity for these rocks. Weathering results in mechanical break up only of quartz and decomposition of sulphides. Fresh rock not suitable for aggregate due to potential sulphide reaction with cement. Molybdenite has been commercially mined.
		$\frac{mo}{}_q$			QUARTZ VEIN WITH MOLYBDENITE	As above with molybdenum sulphide in veins					
		$\frac{Py}{}_q$			QUARTZ VEIN WITH PYRITE	As above with iron sulphide					

* 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/m³—kilograms per cubic metre
MDD —maximum dry density—kg/m³—kilograms per cubic metre
DD —dry density—kg/m³—kilograms per cubic metre
CBR —California Bearing Ratio—%—percent
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
≅ —about equal to

3.1.4 *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.

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

Relict colluvium, which may occur on hillcrests below adjacent large hill masses, may be considerably weathered, but recent colluvial deposits, especially those occurring in the beds of fast flowing streams, may contain very little weathered material. For example, relict colluvium, found in a lobe near Wu Kwai Sha and on the footslopes to the east of Fei Ngo Shan, is considerably weathered and has significantly different geotechnical properties compared with the fresh bouldery colluvium found in adjacent streambeds.

Colluvial materials may also occur offshore and beneath areas of reclamation; this indicates a response of the depositional environment to past changes in sea level. Colluvial deposits can be traced offshore in some investigation records, for example for the Sha Tin Area B reclamation, and a relict deposit of weathered colluvium occurs beneath the nearby Sha Tin Sewage Treatment Works.

From an examination of Table B10, in which the data is subdivided by slope angle, it appears that colluvium has a higher incidence of erosion compared to insitu materials. This may reflect the mode of origin of these materials and the fact that colluvial deposits frequently occur in drainage lines where they are subject to erosion by streams and a high water table. There does not appear to be a large difference in the susceptibility to erosion of granitic colluvium as compared with colluvium derived from volcanic rocks, because volcanic colluvium only has a slightly higher Area Instability Index. The higher indices for the various rock types given in Table 2.7 and B11 may result from their generally greater slope gradients when compared with the superficial deposits.

Erosion in colluvium may sometimes result in the undercutting of contained boulders which subsequently move downslope. 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 (Nash & Dale, 1983).

One of the engineering problems associated with colluvium in Hong Kong is instability. As this material consists mainly of the debris of past landslips, it accumulates at its angle of repose. Although these deposits may settle and become more dense with time, they are liable to subsequent movement if disturbed, whether by stream undercutting or by man.

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.

In general, colluvium is unsuitable as a founding material for large structures, and it is therefore 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 flow over bedrock frequently disappear beneath areas of colluvium.

The presence of tunnels or 'pipes' may severely disrupt the groundwater, and site investigations that involve the installation of piezometers in colluvium need to be carefully interpreted to avoid generating an inappropriate groundwater model.

An aid to anticipating the presence of 'pipes' is to observe the behaviour of streams that intercept the colluvial mass. If these streams disappear underground, such as the area north of Tsuen Wan, then there is a reasonable chance that subsurface pipes occur.

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. Areas north of Wu Kwai Sha and on the eastern footslopes of Castle Peak, have been worked extensively for borrow and reclamation. As stated earlier, these deposits usually occur at the base of steep slopes and are the result of the accumulation of landslip debris, and any excavation for borrow may destabilise the adjacent terrain. Older colluvial deposits may have suitable grading characteristics for use as fill, but the younger streambed deposits, generally lacking in matrix, are probably unsuitable. 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.

3.1.5 *Characteristics of the Volcanic and Volcaniclastic Rocks*

The location and type of volcanic and volcaniclastic rocks found in the Territory are discussed in Section 2.3.3. These rocks tend to have similar material characteristics, excluding the minor sedimentary member.

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 (Geotechnical Control Office, 1988k) commonly ranges from 'very closely-spaced' (20 to 60 mm) to 'medium-spaced' (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 closely-spaced 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. 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 and joint controlled failures are visible along many of the rock cut slopes in the Territory. Site investigations for projects involving rock cut slopes should be designed to identify and define the dominant joint sets prior to engineering design (Geotechnical Control Office, 1987d).

In these rocks, weathering tends to be relatively shallow, with average depths in the order of 8 to 10 m. The volcaniclastic 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, very close jointing may be encountered which locally depresses the weathering profile. This effect increases the erodibility of the material by streams. These streams tend to preferentially follow such lines of weakness and can be seen on aerial photographs as lineaments. Characteristics of other lineaments are revealed by tunnelling records, and many faults and crushed seams encountered in these excavations can be related to surface photogeological lineaments. In addition, within the Territory there are a number of hydrothermally altered zones of white clay (kaolinite) and green mica (chlorite). Although the hydrothermally altered zones are not the result of weathering but rather are related to the granite batholith emplacement into the volcanic country rock, the effect is to produce a zone of weak erodible material similar to a joint controlled weathering profile. Very little water inflow has been reported along these altered zones.

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 2.7 and B11 indicate that, except for the more deeply weathered coarse tuffs, the Repulse Bay Formation rocks show a general trend of relatively low incidence of erosion. In view of the large statistical sample and the relative lack of major urban development on these rocks, this is probably a good reflection of the erodibility of these materials. The incidence of instability, as measured by GEOTECS, is slightly above the average compared with the mean for the insitu terrain. 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. These rocks are difficult to crush and are not currently used for aggregate production because of their fine grain and relatively high strength. The narrow joint spacing and fracturing characteristics of 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. Recent developments on Tsing Yi Island have been carried out partly in coarse tuff, and shallow stripping depths have been encountered.

Site investigations in the volcanic 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 the 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.

3.1.6 *Characteristics of the Intrusive Igneous Rocks*

The intrusive igneous rocks that underlie much of the main urban area of the Territory are of similar origin, and consequently they 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. Usually they are not of great engineering significance except when they occur as a dyke swarm, as on Tsing Yi and Lantau Islands. In this case, rapid local variation in ground conditions may result in a complex piezometric surface.

The various granite intrusions 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 ground 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 with the volcanics, the intrusive igneous rocks of the Territory tend to weather to a greater extent and depth. This is primarily due to the higher porosity of the weathered material and joint-controlled 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 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. As a result of weathering, joints lose their effective roughness and this, 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 syenite, monzonite and Tai Po Granodiorite have higher concentrations of clay compared with other members of this group with the exception of dolerite. This is probably 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 Tables 2.7, B10 and B11 indicate relatively high levels of erosion within the intrusive igneous rocks when compared with the other rock types, although there appear to be significant differences between the individual intrusive rocks. When exposed during excavation, the Tai Po Granodiorite appears susceptible to erosion. This may be due to the dispersive properties of the clays and the grain size distribution of the weathered material.

Landslips on natural slopes in granitic terrain are generally smaller than those on volcanic or colluvial terrain; length to width ratios are usually in the range 1:1 to 2:1. Because of the generally wider discontinuity spacing in granitic rocks, landslips within the soil mantle are less frequently the result of the orientation of relict joints as planes of weakness, than in volcanic soils. However, the usually quoted fact that landslips are not as common on granitic terrain as on volcanic terrain, needs some clarification. Comparison of the Area Instability Indices for granitic and volcanic terrain in Table B10 in Appendix B, wherein the distribution of instability is subdivided by slope, aspect and material type, shows that for slopes steeper than 15°, instability is more common on volcanic than on granitic terrain. However, this may only be a result of the relative longevity of the identifiable landslip scars within these two types of terrain. Granitic soils are more sandy, and are therefore generally more easily eroded, especially when the protective surface vegetation cover is removed. Landslip scars on granitic soils therefore tend to lose their recognisable features more quickly than on volcanic terrain. The severe rainstorms of May 1982 did not reveal much difference between the susceptibility of the granitic and volcanic terrains to the incidence of landslips; the belt of highest landslip incidence could be traced from western Lantau to the Pat Sin Range in the northeast New Territories and beyond, crossing many different rock types. These landslips were probably the result of the passage of a small, though particularly intense, rain-cell. It may be possible to conclude from this that the susceptibility to landslips on the various rock types is not greatly different, at least under conditions of locally very intense rainfall. Many hollows on volcanic terrain can easily be recognised as resulting from past landslips, as they possess the typically sharp, arcuate upper boundary of a failure scar; margins of hollows on granitic terrain quickly become rounded. It is possible that many of the smooth hollows on granitic terrain, particularly within the concave upper sections of hillside depressions adjacent to the drainage lines, are relicts of ancient landslips.

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 granitic rocks should identify weathering grades, as well as the nature and orientation of joints (Geotechnical Control Office, 1987e). 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 alternating with 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. Unweathered granitic rocks are generally favoured as a source rock for aggregate production due to the relative ease of crushing and shape characteristics (Brand et al, 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 syenite, 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 could be considered for quarrying. The depth of weathered material is a major problem in determining suitable sources of roadstone or aggregate.

From a planning point of view, granitic rocks are generally favoured. They require more site formation compared with 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.

Feldspar porphyry and quartz porphyry dyke rocks form a minor unit within the suite of intrusive igneous rocks. These rocks are characterised by areas of slightly subdued relief, with weathered rock depths generally between 7 and 15 m. Few diagnostic properties are available, although weathering, jointing, discontinuity and material characteristics are probably similar to those of the granites. Depth to rockhead, permeability and strength properties are likely to be extremely variable within the dyke swarm due to the close proximity of different rock types, local variations in the degree of jointing, and grain size of individual lithologies.

3.1.7 *Characteristics of the Sedimentary and Metasedimentary Rocks*

Within the Territory, the following sedimentary and metasedimentary rocks occur:

(i) *Tolo Harbour Formation*
The outcrop of the Tolo Harbour Formation is of such a limited extent (Centre Island) that its material characteristics would have little influence on development of any scale. Black shales and mudstones form the major rock types; these are weak and fissile, and have closely spaced tectonic jointing. Resistant quartzites are also present in thin bands, and are structurally stronger than the shale and mudstone. A thin weathered zone may form, especially over siltstone and mudstone, and could be removed by machine methods. Fresh rock may require blasting, especially when quartzites are present.

(ii) *Tolo Channel Formation*

The outcrop of this Formation is restricted to a wave cut platform on the northern shore of Tolo Channel and, as such, is unlikely to form the founding material of any but the most minor structures. Lithologies and structure are similar to those of the Tolo Harbour Formation. However, no pedogenic zone has developed due to the erosive tidal action. Removal of material would require blasting, but ripping could suffice where weathering has occurred along joint planes.

(iii) *Bluff Head Formation*

The distribution of the Bluff Head Formation is restricted to the northern side of Tolo Channel. These sediments consist of conglomerates, sandstones, siltstones and shales which were laid down in cyclic sequences. Metamorphism has marginally altered these sediments, mainly by hardening. The extent of induration varies according to rock type, the fine-grained representatives being more thoroughly affected than the coarser-grained rocks. Very little testing data is available for these sediments. However, closely spaced jointing has been observed, and Standard Penetration Tests on conglomerates and sandstones have indicated N values increasing from N <30 in the weathered horizons, to N >150 in the fresher rock, at depth. Laminated siltstones reveal a range of N values between 15 and 100. Hematite and pyrite are present in the finer-grained rock types of the Bluff Head Formation. These materials may produce reactive groundwater charged with sulphides which could adversely affect reinforced concrete or other foundation materials. Weathering of the Bluff Head Formation may produce deeply weathered profiles up to 10 m in thickness especially in the finer-grained rock types. The bearing capacity of these rocks is reasonable for low to moderate loads, but stability depends on joint orientation, and discontinuities would have to be examined to determine stability characteristics.

When weathered, the finer-grained representatives may slake, and these may be machine excavated to considerable depth. Fresh rock, especially the coarser representatives, might provide a suitable fill material but is probably unsuitable as a roadstone or concrete aggregate.

(iv) *Tai O Formation*

Sedimentary rocks outcrop within the Tai O Formation on northwest Lantau and The Brothers islands. Lithologies present include sandstones, silty shales and occasional conglomerates. The Tai O Formation has undergone low grade metamorphism which has produced a slight hardening of the strata, particularly within the finer-grained materials.

Very little test data is available for these sediments. However, some general comments may be made regarding these materials. Moderate to steep natural slopes are likely to possess zones of rock outcrop amid areas of slightly deeper weathering. This occurs due to variations in the joint spacing and grain size of different layers within the sedimentary sequence. Where conditions are favourable for the evolution of a deeper weathered mantle, sediments may be partially weathered to depths in excess of 10 m. This could occur on low gradient slopes without local stream or marine undercutting.

The bearing capacity of these rocks is reasonable for low to moderate loads, except when weathered. Stability is strongly controlled by discontinuities such as joints and bedding planes. When weathered, the finer-grained representatives may slake, and these may be machine excavated to considerable depth. Fresh rock, especially the coarser-grained material, may be suitable as a source of fill but is unlikely to be suitable for use as roadstone or aggregate.

(v) *Lok Ma Chau Formation*

The Lok Ma Chau Formation includes metamorphosed sedimentary units and a marble-bearing stratum which may be up to 300 m in thickness (Lai & Mui, 1985).

The metamorphosed sedimentary units generally exhibit close, smooth jointing, often with some related cleavage. The rock mass is usually significantly weathered to depths in excess of 20 m. Although this facilitates easy excavation, the weathered rock mass is inherently weak, especially along joints and other discontinuities. Discontinuity surveys are essential for the safe design and construction of cut slopes and excavations. Bearing capacities are reasonable for low to moderate loads. Fresh material is usually stronger and is generally more stable. Where accessible, this material is suitable for low grade bulk fill but is not suitable for use as concrete aggregate or roadstone.

Marble has been encountered in boreholes and excavations through the alluvium of the Yuen Long plain. It occurs in isolated patches beneath an approximately 2 km wide strip of land between Lo Wu and just north of Tuen Mun, and is particularly prevalent in the Yuen Long area. Ha et al (1981) refer to the existence of cavities within the marble, while Siu & Kwan (1982) and Siu & Wong (1984a and b) describe problems encountered with the construction of building foundations on marble in Yuen Long.

Marble does not occur everywhere under the Yuen Long plain, and not all of the marble contains cavities. Care is required during site investigation to identify the existence of cavities within the marble if it occurs beneath a site.

Weathering of the marble has two effects. Solution along discontinuities creates interconnecting void systems; solution of marble adjacent to another rock or competent sediment can also create a void. Surface solution of marble leaves a clay-rich residual soil which may exist beneath the overlying alluvium. Many of the void surfaces also have a coating of this clay-rich material. Intergranular solution of the near-surface marble produces a weak granular layer up to several metres thick.

Interconnecting cavities within the marble provide excellent hydraulic conductivity. Whilst this may be beneficial for water supply wells, rapid fluctuations of the groundwater table can lead to the formation of collapse sinkholes in overlying superficial deposits with which there is hydraulic continuity. Collapse of cavities and in-washing of sediment into cavities can lead to settlement and other foundation problems.

(vi) *Port Island Formation*

Rocks of the Port Island Formation outcrop on the escarpment of the Pat Sin Range. The Formation consists of sequences of conglomerates and pebbly sandstones with shales. The conglomerates and pebbly sandstones form up-standing strike ridges, whilst the finer-grained members form lower relief. All beds in this formation are cleaved and locally sheared. Weathering profiles vary according to rock type, but the coarser beds weather up to 7 m in depth, forming a coarse sandy soil, often with numerous pebbles.

Little data is available on the engineering characteristics of these rocks. However, jointing and shearing characteristics probably determine rock slope configurations. The conglomerates and sandstones which form harder beds of the Formation should support moderate to high loads on bedrock. These rocks could be used as fill, but only the conglomerates should be considered as a potential source of aggregate. Weathered material could be removed by machine methods, and bedrock could be ripped because of the close jointing in some of the beds.

(vii) *Kat O Formation*

The limited and very remote occurrence of these rocks renders them of relatively minor engineering significance. The beds comprise a coarse-grained breccia with large angular fragments, and subordinate gritstones. The unweathered rock should support moderate loads. However, the rock weathers to a weak, poorly cemented clay, with the larger fragments remaining unaltered. Foundations on the weathered rock could only be of a minor nature unless excavated to bedrock. Machine excavation would normally be possible, although it is unlikely that these rocks would be sought as a source of borrow, unless for use in minor projects in the immediate locality.

An outcrop of coarse breccias forms a small headland some 700 m north of Lau Fau Shan (Allen & Stephens, 1971). The breccia consists of abundant angular fragments of volcanic rocks with very steeply dipping bedding. This material may be suitable as a source of fill but is of limited extent.

Overall, the Area Instability Index for both the sedimentary and metasedimentary rocks (Table 2.7) is slightly below the mean for all the bedrock terrain. The incidence of erosion is greater than that for the volcanic terrain, but is well below that of the granitic terrain.

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 level of geotechnical limitations associated with the terrain. These limitations in turn reflect the basic suitability of the land for development from a geotechnical point of view. The Geotechnical Land Use Map is described in detail in Appendix A7, and an example of the conventional line form GLUM, at the scale of 1:20 000 as produced for the eleven Regional Studies, is given in Figure A9. An extract of the 1:100 000 scale GEOTECS Map showing generalised geotechnical limitations is presented in Figure 15. A copy of this map is enclosed in the Map Folder which accompanies this Report.

The general distribution of the GLUM Classes for the Territory is summarised in the pie chart in Figure 4, and the data is presented in Tables 4.1 and B9.

For eight of the eleven GASP Regional Studies, the Generalised Limitations and Engineering Appraisal Maps (GLEAM) have been prepared at a scale of 1:20 000 in order to identify parcels of land with potential for development from a geotechnical point of view. In this study, which is a summary of the eleven Regional GASP Studies, a GEOTECS Map at a scale of 1:100 000 is used to highlight, from a strategic point of view, broad areas with low to moderate geotechnical limitations with potential for development. An extract of this GEOTECS Map is shown in Figure 19, and a copy is contained in the Map Folder.

The distribution of GLUM Classes for the eleven Regional Studies is summarised in Table B14.

4.1.2 *Land with Low to Moderate Geotechnical Limitations*

Within the Territory, there is only a relatively small area (5 849 ha) of terrain with low geotechnical limitations, whilst there is approximately 44 500 ha which is subject to moderate geotechnical limitations. Some 5 431 ha of the GLUM Class II terrain is associated with areas of floodplain. Together, GLUM Classes I & II occupy some 50 300 ha or 47% of the Territory. The distribution is shown schematically in the GEOTECS Map accompanying this Report. An extract of this Map is presented in Figure 15.

Land with a low degree of geotechnical limitation (GLUM Class I) 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, i.e. insitu terrain of moderate steepness or flat or gently sloping alluvial terrain. Areas of reclamation are also included in GLUM Class II.

GLUM Class I & II terrain is usually considered to have significant potential for development. A discussion of the development opportunities within the Territory is presented in Section 4.2.

Table 4.1 GLUM Class and Development

GLUM Class	Geotechnical Limitations	Area (ha)			% of Total Area
		Undeveloped Terrain	Developed Terrain	Total	
I	Low	3 545	2 304	5 849	5.4
II	Moderate	32 029	12 390	44 419	40.7
III	High	25 894	5 294	31 188	28.6
IV	Extreme	19 196	1 110	20 306	18.6
Unclassified		4 750	2 517	7 267	6.7
Total		85 414	23 615	109 029	100.0

4.1.3 *Land with High Geotechnical Limitations*

Approximately 29% (31 200 ha) of the Territory is subject to a high level of geotechnical limitation (GLUM Class III). The general pattern is shown in the GEOTECS Map which accompanies this Report. An extract is given in Figure 15. Some 17% of this terrain is 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 lower 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.

Small areas of GLUM Class III terrain may be included within areas of potential for development. These are shown on the Generalised Limitations and Engineering Appraisal Maps contained in most of the Regional GASP Reports, if they are unlikely to affect the overall suitability for development of the area.

4.1.4 *Land with Extreme Geotechnical Limitations*

Approximately 19% (20 300 ha) of the Territory is classified as terrain with extreme geotechnical limitations. This terrain should not be developed if alternatives exist. The general pattern is indicated in the GEOTECS Map which accompanies this Report. An extract is given in Figure 15. Some 5% of this terrain occurs within areas of current development.

Intensive site investigation on GLUM Class IV land 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 with 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.

Isolated areas of GLUM Class IV occur within the developed area associated with locally steep terrain, and other parcels may be associated with drainage across colluvium or the presence of instability. These features are also highlighted on the Physical Constraints Maps (PCM) which accompany all of the Regional GASP Reports.

4.2 Areas with Suitability for Development

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 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 is efficient construction important, but long-term serviceability and safety should be fundamental aims.

From a geotechnical viewpoint, land with potential for development should be generally free of constraints. Engineering design, if possible, should be unhindered by geotechnical limitations. Within the Territory, there are many areas still unused, but a significant proportion occur within designated Country Parks, Green Belt, military land and water supply catchments. Thus, it is essential that a cautious and integrated approach is adopted in order to optimise the use of the remaining areas.

In dealing with land which is as yet undeveloped, the regional Generalised Limitations and Engineering Appraisal Maps (GLEAM) are valuable at two levels. At the planning stage, they identify broad areas in which an integrated approach to large-scale development could be adopted. Subsequently, at the engineering feasibility stage, they enable possible problems to be anticipated for the design of site investigations, preliminary layout and other more detailed aspects of design. The use of the GLEAM as a tool for integrated planning and engineering feasibility in the Territory is outlined in Appendix A9.

In this study, the GEOTECS system is used to highlight in a more general way than the regional GLEAM Maps, the broad areas of terrain with suitability for development from a geotechnical point of view. Computer-generated maps derived from GLUM Class and existing land use, together with other factors, are used to delineate areas with general suitability for development.

4.2.2 *Undeveloped Areas with Low to Moderate Geotechnical Limitations*

Undeveloped terrain without high to extreme geotechnical limitations is generally considered to have a high suitability for development. These areas can be highlighted in map form using the GEOTECS system.

The GEOTECS system was used to generate a 1:100 000 scale map entitled "Geotechnical Limitations Associated with Undeveloped Terrain outside Country Park". A copy is contained in the Map Folder, and an extract of the Map is shown in Figure 19.

Within the Territory, there is approximately 22 550 ha of undeveloped terrain outside Country Park which is characterised by low to moderate geotechnical limitations. This represents some 21% of the land area of the Territory. In addition, if the area of GLUM Classes I & II within Country Park is included, then the area of suitability increases by 70% to 38 615 ha. Therefore, although some 24 000 ha (22%) of the Territory is already developed, many options remain available for future urban expansion on undeveloped terrain which is essentially unencumbered by geotechnical constraints.

4.2.3 *Assessment of Planning Strategies Using GEOTECS*

Any search for areas suitable for a proposed use normally 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 that fulfil any given strategy (Styles et al, 1986). Computer-generated maps and plots are used to illustrate various aspects of this Report. GEOTECS is discussed in Sections 1.3.9 & 1.4 and in Appendix A.11.

GEOTECS Maps and Plots can be prepared at scales from 1:20 000 to 1;100 000. For planning at a conceptual and/or strategic level, GEOTECS Maps or Plots at scales of 1:100 000 and 1:50 000 are recommended.

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. Four examples are provided to illustrate the application of GEOTECS for planning and engineering purposes. These are shown as the GEOTECS Maps in Figures 16 & 17 and as Plots in Figures 20, 21 & 22.

(i) *Sources of Rock*
The GEOTECS Plot in Figure 20 is an example of a map which delineates areas with potential as sources of rock, on the basis of a combination of several terrain attributes. The selection criterion excludes areas of existing development or Country Park. A combination of slope gradient, terrain and superficial geology is used to identify areas of potential. The selection criteria consist of ridgecrests and sideslopes without a cover of superficial deposits and with a slope gradient of less than 40°, together with terrain which has a superficial cover and is between 5 and 30° slope gradient.

Bedrock lithology is not used in the assessment of potential presented in Figure 20, although it is incorporated in the next stage of planning. The GEOTECS Plot in Figure 21 illustrates the areas of potential in relation to granitic rock types. The areas of potential shown in Figure 20 have been reduced by narrowing the range of options by the addition of rock type. For the combination of terrain types noted above (Figure 20), the total area of the Territory with potential is 39 994 ha. This reduces by 27 302 ha to 12 692 ha when only granitic rock types are considered.

(ii) *Geology, Erosion and Instability*
Figure 22 is a GEOTECS Plot showing the distribution of sheet, rill and gully erosion, and instability on the main geological units. This could be used for a preliminary assessment of the rate of reservoir sedimentation or to provide landscape managers with an indication of areas requiring monitoring or investigation to reduce soil loss.

(iii) *Colluvium on Undeveloped Terrain*
An example of the GEOTECS Map showing colluvium on undeveloped terrain, reclamation and other areas of existing development is presented in Figure 16. The 1:100 000 scale GEOTECS Map is located in the Map Folder. This Map highlights the locations of colluvial deposits on undeveloped terrain (13 735 ha) in relation to the distribution of reclamation (3 700 ha) and other forms of

existing development (10 820 ha). Colluvium that occurs on undeveloped terrain occupies some 12.6% of the Territory, and represents a considerable proportion of the total area of undeveloped land. If urban expansion continues in the future, then large areas of colluvial terrain, which may be subject to geotechnical constraints, will need to be developed. This contrasts with the use of reclamation as a means of land formation. At present, reclamation represents some 26% of the total area of existing development. Urban expansion has already occurred on the steeper terrain marginal to the developed areas, and also by reclamation into the harbour and coastal areas.

(iv) *Generalised Depth of Weathering on Undeveloped Terrain*
This map is conceptual in nature and highlights the general extent and degree of weathering of volcanic, granitic, metasedimentary and colluvial materials on generally undeveloped terrain. The degree of weathering for each rock type is derived from the assessment of material characteristics presented in Table 3.1. This map could be used to illustrate, in very general terms, areas of suitability for borrow. For example, some 20 000 ha of moderately to deeply weathered granitic terrain occur on undeveloped areas within the Territory. An extract of the Map is presented in Figure 17, and the Map at a scale of 1:100 000 is included in the Map Folder which accompanies this Report.

5. CONCLUSIONS

The information presented in this Report summarises the results of the eleven Regional GASP Studies of the Territory. These studies form an inventory of the physical land resources of Hong Kong. The data obtained from them are summarized in Tables B1 to B14.

During the study programme, a total of 41 maps were published at a scale of 1:20 000 to assist planning, land management and the assessment of engineering feasibility. Geotechnical Land Use Maps (GLUM), Physical Constraints Maps (PCM) and Engineering Geology Maps (EGM) have been published for the entire Territory, and Generalised Limitations and Engineering Appraisal Maps (GLEAM) have been published for some 70 000 ha. A further 33 regional Terrain Classification Maps, Erosion Maps and Landform Maps are available on request from the Geotechnical Control Office. In addition, a total of 45 maps at 1:2 500 scale, compiled for the District Stage 1 Studies, are also available on request. These include Terrain Classification Maps, Engineering Geology Maps, Vegetation Maps and Surface Hydrology Maps.

In this Report, fourteen GEOTECS Computer Maps are presented to assist in planning, land management and the assessment of engineering feasibility in the Territory. In addition, over 220 Plates are presented in Section 8 to illustrate various aspects of the terrain, urban development and geotechnical constraints. A large number of photographs of landslips are included, particularly those which occurred within the last 25 years. The photographs are accompanied by reproductions of some old maps dating back to 1845. The plates form an integral part of this GASP Report because they highlight many of the geotechnical problems associated with the terrain, and because they reflect the intensity and general nature of development within the Territory.

The major conclusions from the Regional Studies of the Territory 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

The conclusions relating to materials and land resource distribution are:

(*a*) Slope instability of some form or other is relatively common within the Territory. Approximately 23 520 ha of the terrain (22%) is associated with or affected by instability. Instability is associated with most of the geological materials. Slope failures in the colluvium and volcanics are generally characterised by small landslip scars with extensive debris trails. In the case of volcanic rocks, this is probably due to the relatively steep slopes on which failure occurs. Landslips on the intrusive igneous rocks are also common but tend to be relatively small rotational or joint-controlled failures, often associated with cut slopes. Slope failures in intrusive igneous rocks usually cause less impact on the terrain than failures in volcanic rock or colluvium.

(*b*) Some 46% of the terrain mapped as high to extreme geotechnical limitations is influenced by slope instability. In addition, it is estimated that in the order of 37 000 landslips affected the terrain in the Territory at the time of mapping. This figure is based on the Landslip Propensity Index for the 1 030 landslips recorded in the 1 455 ha mapped as GLUM Classes III & IV at a scale of 1:2 500, in the GASP District Stage 1 Studies (Table 1.3), and in the 52 000 ha of GLUM Classes III and IV terrain identified in the Regional Studies. Comparison of the Area Instability Indices (% of terrain affected by instability) on GLUM Classes III and IV terrain for the eleven Regional Studies, indicates a high of 70% for the East New Territories and a low of 23% for the Hong Kong Island and Kowloon area. The average figure for all the GLUM Classes III and IV terrain in the Territory is 47%.

(*c*) 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. There are numerous photolineaments present, many of which are likely to be faults, shear zones, major joint zones or dykes. The Territory is currently being remapped at a scale of 1:20 000 by the Geotechnical Control Office as part of the revised geological survey. At present, only map sheets covering Hong Kong Island, Kowloon and the Sha Tin areas and their accompanying Memoirs have been published, but 1:20 000 maps will be available for the whole Territory by 1991. Geological maps will also be published at a scale of 1:5 000 for the Yuen Long area, because cavernous marble underlies the alluvium in that area. Investigation, design and construction for heavy structures and for structures sensitive to differential settlement need to be carefully undertaken if marble is found to exist beneath a site.

(*d*) Instability affects some 22.4% (5 336 ha) of the granitic terrain, 33.9% (14 562 ha) of the volcanic terrain, 21.9% (454 ha) of the metasedimentary terrain, and 16.4% (2 581 ha) of the colluvial terrain.

(*e*) Surface erosion is more pronounced on granitic terrain than on volcanic terrain. Approximately 39.4% of the granitic terrain is affected by erosion, whilst only 21.2% of the volcanics is affected. Some 27.3% of the colluvial terrain is also eroded. Bedrock terrain with slope gradients in the range of 5 to 30° appears to be the most severely affected by sheet erosion, and that in the range of 15 to 40° is the most affected by gully erosion. In comparison, erosion affects only 2.7% (406 ha) of the alluvial terrain, with gully erosion being the most prevalent, generally resulting from stream incision.

(*f*) Erosion of the land surface, other than by slope failure, affects some 25 690 ha or 24.5% of the Territory. Sheet erosion constitutes the major form of soil loss, with 16 700 ha affected , whilst gully erosion influences an additional 7 900 ha. If the erosion figures from Table B11 are applied to the work on soil loss in the Territory by Lam (1977 & 1978), it is estimated that about 2.6 million tonnes per annum of soil material is eroded from the 9 400 ha of granitic terrain affected by sheet, rill and gully erosion within the Territory. This represents some 40% of the granitic terrain.

(*g*) Approximately 22.5% (24 539 ha) of the Territory is covered by grasslands, 20.3% (22 112 ha) by mixed broadleaf woodland, a further 20.6% (22 410 ha) is devoid of vegetation, and 33.6% (25 745 ha) is covered by shrubland.

(*h*) Granitic terrain is generally suitable as a source of borrow and aggregate. Usually, the expansion of existing quarries is not restricted by geological constraints but by urban development and areas of Country Park.

(*i*) Approximately 5% (5 435 ha) of the Territory is delineated as floodplain and is subject to periodic inundation and flooding. This represents some 60% of all the areas of alluvial plain.

(*j*) Approximately 15 710 ha of the natural footslope terrain is covered by extensive colluvial deposits: 16.4% of the colluvium is affected by instability. Significant geotechnical limitations should be anticipated on zones of runoff and surface drainage across the colluvium, which occupy some 50.3% (7 063 ha) of the generally low angle (<30°) colluvial footslope terrain.

(*k*) The granitic terrain has a marginally lower proportion of GLUM Classes I & II (47%) than the volcanics (48%). Of the 15 718 ha of colluvial terrain which occurs within the Territory, some 86.7% is subject to high to extreme geotechnical constraints (GLUM Classes III & IV).

(*l*) Approximately 27% of the Territory is characterised by slopes which have gradients between 0 and 15°. A further 59.5% of the terrain has slope gradients between 15 and 40°, and 3.3% is steeper than 40°.

(*m*) There is approximately 3 700 ha of reclamation (3.4%) within the Territory, and additional areas of reclamation are underway or planned. The siting of development on extensive reclamation that is underlain by thick compressible marine sediments may give rise to foundation problems, and differential settlement may cause disruption to services. In addition, reclamation represents some 26% of the total area of existing development within the Territory.

5.2 Land Management Associated with Planning and Engineering Feasibility

(*a*) During the last 25 years, a number of large landslips within the Territory have resulted in considerable loss of life and very substantial property damage (So, 1971; Lumb, 1975; Brand, 1984). Landslips have occurred in developed areas, construction sites, squatter villages and natural terrain (Chen, 1969, Government of Hong Kong, 1972 a & b, 1977). 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*) Approximately 22% of the Territory is currently developed in some form or other. Squatters occupy approximately 2 850 ha or 2.6% of this area. Some 37% is allocated to Country Park. The remaining 41% generally consists of undeveloped and undesignated natural terrain. The GASP studies would seem to support the view that there has been a considerable lowering of the population density of the urbanised/developed area, from 35 000 persons per km^2 in 1975, to 24 000 persons per km^2 in 1986. This results from a net increase of over 1 000 ha of developed area per year for the decade commencing 1975, giving an increase of 86% in the developed area (12 700 to 23 600 ha). The rise in population of 1.2 million during the same period represents an increase of only 27% over the 1975 figure (Chiu & So, 1986). It would seem reasonable to conclude that the cost of development has been offset against a relative increase in the standard of living as reflected by the population density.

(*c*) There is approximately 22 550 ha of undeveloped terrain with low to moderate geotechnical limitations outside of Country Park. This represents some 21% of the Territory, and can generally be considered suitable for development from a geotechnical point of view.

(*d*) Opportunities do exist for urban expansion in the Territory, but it is unrealistic to envisage that future development can avoid areas with geotechnical limitations. The Generalised Limitations and Engineering Appraisal Maps (GLEAM) prepared for eight of the Regional Study areas recognise this fact and delineate 177 areas which have overall potential for development from a geotechnical point of view. These represent a total of 14 100 ha or 13% of the terrain. 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.

(*e*) Squatters occur on approximately 2 835 ha within the Territory. This figure is only very general, since it is not possible to determine the precise location of squatters in the New Territories from the GEOTECS data base. This is because of limitations on interpretation of village-type land uses on aerial photographs. Nonetheless, for the Hong Kong Island and Kowloon area, where there is a more distinctive contrast between squatters and other forms of development, some 62% of the 660 ha occupied by squatters is affected by high to extreme geotechnical limitations.

(*f*) This study indicates that there is approximately 33 478 ha of currently undisturbed natural terrain outside of Country Park. Of this figure, GLUM Classes I & II occur on some 30% (12 627 ha) of the terrain, and 19 349 ha is associated with high to extreme geotechnical limitations (GLUM Classes III & IV). There is approximately 40 150 ha of Country Park and, of this figure, 16 065 ha is classified as either having low or moderate geotechnical limitations (GLUM Classes I & II).

(*g*) Physical land resources are basic input for planning, land use management and assessment of engineering feasibility. Socio-economic, political and other constraints for development should be assessed in sympathy with the physical land resource information.

6. REFERENCES

Addison, R. (1986). *Geology of Sha Tin*. Geotechnical Control Office, Hong Kong, 85 p. (Hong Kong Geological Survey Memoir no. 1).

Alderson, G. L. D. (1971). *History of Royal Air Force Kai Tak, 1927–1971.* Royal Air Force, Kai Tak, Hong Kong, 104 p.

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

Arthurton, R. S. (1987). Studies of Quaternary geology and the exploration for offshore fill in Hong Kong. Proceedings of the Symposium on the Role of Geology in Urban Development in Southeast Asia (Landplan III), Hong Kong. Published as *Geological Society of Hong Kong, Bulletin* no. 3, pp 229–238.

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).

Bowler, R. A. & Phillipson, H. B. (1982). Landslip preventive measures—a review of construction. *Hong Kong Engineer,* vol. 10, no. 10, pp 13–38.

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. (1988a). *Bibliography on the Geology and Geotechnical Engineering of Hong Kong to December 1987.* Geotechnical Control Office, Hong Kong, 147 p. (GCO Publication no. 1/88).

Brand, E. W. (1988b). Landslide risk assessment in Hong Kong. *Proceedings of the 5th International Symposium on Landslides,* Lausanne, Switzerland, vol. 2, pp 1059–1074.

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

Bristow, R. (1984). *Land-use Planning in Hong Kong: History, Policies and Procedures.* Oxford University Press, Hong Kong, 328 p.

Burnett, A. D. (1988). Geological and terrain mapping in Hong Kong. *Proceedings of the ESCAP Seminar on Geological Mapping in the Urban Environment,* Bangkok, Thailand, vol. 1, pp 85–97.

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, Japan, 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, India, vol. 1, pp 167–176.

Burnett, A. D. & Styles, K. A. (1986). Review of the reliability of an engineering geology mapping system used for the delineation of landslide prone terrain in Hong Kong. *Engineering Geology in Asia* (No. 1), Science Press, Beijing, China, pp 321–340.

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

Chen, T. Y. (1969). *The Severe Rainstorms in Hong Kong during June 1966. Supplement to Meteorological Results 1966.* Royal Observatory, Hong Kong, 82 p.

Chiu, T. N. & So, C. L. (1986). *A Geography of Hong Kong.* (Second edition). Oxford University Press, Hong Kong, 403p.

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

Davis, S. G. (1961). Mineralogy of the Ma On Shan Mine, Hong Kong. *Economic Geology,* vol. 56, pp 592–602.

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.

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

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

Geotechnical Control Office (1986a). *Sha Tin: solid and superficial geology. Hong Kong Geological Survey Map Series HGM20, sheet 7, 1:20 000.* Geotechnical Control Office, Hong Kong.

Geotechnical Control Office (1986b). *Hong Kong and Kowloon: solid and superficial geology. Hong Kong Geological Survey Map Series HGM20, sheet 11, 1:20 000.* Geotechnical Control Office, Hong Kong.

Geotechnical Control Office (1987a). *Geotechnical Area Studies Programme—Hong Kong and Kowloon.* Geotechnical Control Office, Hong Kong, GASP Report no. I, 170 p.

Geotechnical Control Office (1987b). *Hong Kong South and Lamma Island: Solid and superficial geology. Hong Kong Geological Survey Map Series HGM20, sheet 15, 1:20 000.* Geotechnical Control Office, Hong Kong.

Geotechnical Control Office (1987c). *Geotechnical Area Studies Programme—Central New Territories.* Geotechnical Control Office, Hong Kong, GASP Report no. II, 165 p. & 4 maps.

Geotechnical Control Office (1987d). *Geotechnical Area Studies Programme—West New Territories.* Geotechnical Control Office, Hong Kong, GASP Report no. III, 155 p. & 4 maps.

Geotechnical Control Office (1987e). *Guide to Site Investigation (Geoguide 2),* Geotechnical Control Office, 362 p.

Geotechnical Control Office (1988a). *Tsing Shan (Castle Peak): Solid and superficial geology. Hong Kong Geological Survey Map Series HGM20, sheet 5, 1:20 000.* Geotechnical Control Office, Hong Kong.

Geotechnical Control Office (1988b). *Yuen Long: Solid and superficial geology. Hong Kong Geological Survey Map Series HGM20, sheet 6, 1:20 000.* Geotechnical Control Office, Hong Kong.

Geotechnical Control Office (1988c). *Geotechnical Area Studies Programme—North West New Territories.* Geotechnical Control Office, Hong Kong, GASP Report no. IV, 120 p. & 3 maps.

Geotechnical Control Office (1988d). *Geotechnical Area Studies Programme—North New Territories.* Geotechnical Control Office, Hong Kong, GASP Report no. V, 134 p. & 3 maps.

Geotechnical Control Office (1988e). *Geotechnical Area Studies Programme—North Lantau.* Geotechnical Control Office, Hong Kong, GASP Report no. VI, 124 p. & 3 maps.

Geotechnical Control Office (1988f). *Geotechnical Area Studies Programme—Clear Water Bay.* Geotechnical Control Office, Hong Kong, GASP Report no. VII, 144 p. & 4 maps.

Geotechnical Control Office (1988g). *Geotechnical Area Studies Programme—North East New Territories.* Geotechnical Control Office, Hong Kong, GASP Report no. VIII, 144 p. & 4 maps.

Geotechnical Control Office (1988h). *Geotechnical Area Studies Programme—East New Territories.* Geotechnical Control Office, Hong Kong, GASP Report no. IX, 141 p. & 4 maps.

Geotechnical Control Office (1988i). *Geotechnical Area Studies Programme—Islands.* Geotechnical Control Office, Hong Kong, GASP Report no. X, 142 p. & 4 maps.

Geotechnical Control Office (1988j). *Geotechnical Area Studies Programme—South Lantau.* Geotechnical Control Office, Hong Kong, GASP Report no. XI, 148 p. & 4 maps.

Geotechnical Control Office (1988k). *Guide to Rock and Soil Descriptions (Geoguide 3),* Geotechnical Control Office, 189 p.

Geotechnical Control Office (1989). *San Tin: Solid and superficial geology. Hong Kong Geological Survey Map Series HGM20, sheet 2, 1:20 000.* Geotechnical Control Office, Hong Kong.

Government of Hong Kong (1968). *Land Utilization in Hong Kong.* Hong Kong Government Printer, 17 p. & 11 maps.

Government of Hong Kong (1972a). *Interim Report of the Commission of Inquiry into the Rainstorm Disasters, 1972.* Hong Kong Government Printer, 22 p.

Government of Hong Kong (1972b). *Final Report of the Commission of Inquiry into Rainstorm Disasters, 1972.* Hong Kong Government Printer, 94 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.

Government of Hong Kong (1988). *Hong Kong 1988—A review of 1987.* Hong Kong Government Printer, 380 p.

Ha, T. H. C., Ng, S. K. C. & Li, Q. W. (1981). Discovery of carbonate rocks in the Yuen Long Area, Hong Kong. *Hong Kong Baptist College Academic Journal,* vol. 8, pp 129–131.

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. (Published as *Geological Society of Hong Kong, Bulletin* no. 2).

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. & Mui, M. (1985). Lithostratigraphic comparison of the Lok Ma Chau Formation of Hong Kong with Carboniferous Strata of Shenzen and Guangzhou. *Geological Society of Hong Kong Newsletter,* vol. 3, no. 2, pp 4–7.

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.

Lam, K. C. (1977). Patterns and rates of slopewash on the badlands of Hong Kong. *Earth Surface Processes,* vol. 2, pp 319–332.

Lam, K. C. (1978). Soil erosion, suspended sediment and solute production in three Hong Kong catchments. *Journal of Tropical Geomorphology,* vol. 47, pp. 51–62.

Langford, R. L. (1986). Lecture on the new classification of the Repulse Bay Volcanic Group, May 8, 1986. (Report by D. R. Workman on a Geological Society of Hong Kong meeting, 8 May 1986). *Geological Society of Hong Kong Newsletter,* vol. 4, no. 2, pp 23–24.

Langford, R. L., Lai, K. W., Arthurton, R. S. & Shaw, R. (1989). *Geology of the Western New Territories.* Geotechnical Control Office, Hong Kong, (Hong Kong Geological Survey Memoir, No. 3).

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.

Lo, C. P. (1978). Landslide mapping with the CP1 Plotter. *Photogrammetric Record,* vol. 9 (51), pp 377–389.

Lo, C. W. & Ma, C. T. (1986). Urban Redevelopment in Hong Kong. *Planning and Development,* vol. 2, no. 1, pp 2–10.

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. *Géotechnique*, 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. *Géotechnique*, 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.

Ma, M. (1987). Planning in an utilitarian society—the case of Hong Kong. *Planning and Development,* vol. 3, no. 2, pp 72–75.

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. (Published as *Geological Society of Hong Kong, Bulletin*, no. 1).

Peterson, P. & Kwong, H. (1981). *A Design Rain Storm Profile For Hong Kong.* Royal Observatory, Hong Kong, Technical Note no. 58, 30 p.

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.

Pryor, E. G. (1983). *Housing in Hong Kong.* Oxford University Press, Hong Kong.

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 Institute of British Geographers*, no. 53, pp 55–65.

Shaw, R. (1986). Offshore Quaternary geology in Hong Kong. *Proceedings of the CCOP Symposium on Developments in Quaternary Geological Research in East and Southeast Asia during the Last Decade,* Bangkok, Thailand, pp 283–292.

Siu, K. L. & Kwan, S. H. (1982). Case history of a pile foundation in unusual ground in Hong Kong. *Proceedings of the Seventh Southeast Asian Geotechnical Conference,* Hong Kong. vol. 1, pp 423–438.

Siu, K. L. & Wong, K. M. (1984a). Marble and sub-surface karst at Yuen Long, New Territories. *Geological Society of Hong Kong Newsletter,* vol. 2, no. 5, pp 1–7.

Siu, K. L. & Wong, K. M. (1984b). Concealed marble features at Yuen Long. *Proceedings of the Conference on Geological Aspects of Site Investigation,* Hong Kong pp 423–428. (*Published as Geological Society of Hong Kong, Bulletin* no. 2).

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

Strange, P. J. (1986). Urban geological mapping—techniques used in Hong Kong. *Proceedings of the Symposium on the Role of Geology in Urban Development in Southeast Asia (Landplan III)*, Hong Kong, pp 181–190. (Published as *Geological Society of Hong Kong Bulletin* no. 3).

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. (Published as *Geological Society of Hong Kong Bulletin* no. 1).

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, Thailand, 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, Canada, 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, 79–100, 131–135, 168–169, 201–203, 289–293 and 321–323).

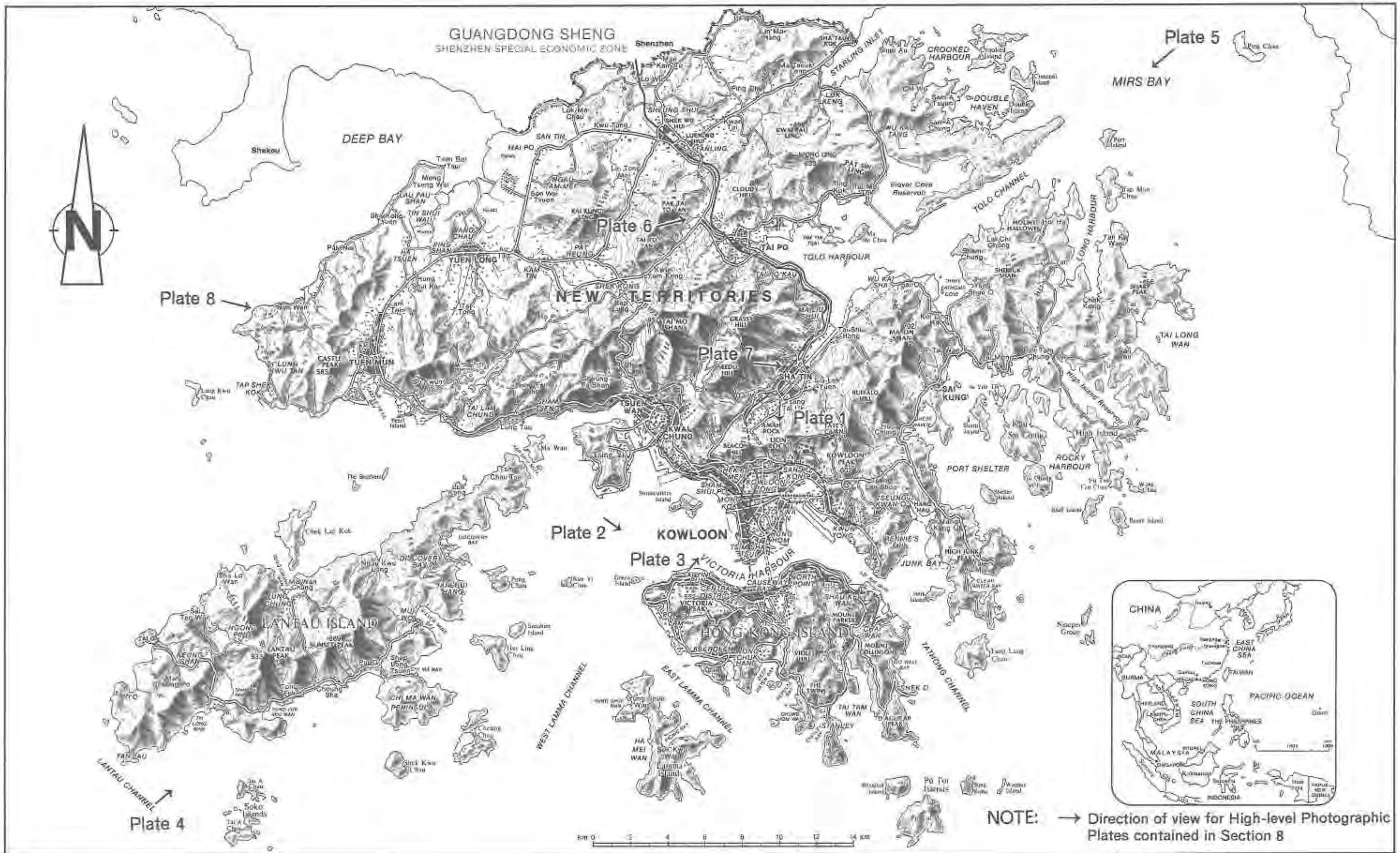
Vail, A. J. (1984). Two landslide disasters in Hong Kong. *Proceedings of the Fourth International Symposium on Landslides*, Toronto, Canada, vol. 1, pp 717–722.

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, UK, pp 15–28.

Whiteside, P. G. D. & Wragge-Morley, N. (Editors), (1988). *Marine Sand and Gravel Resources of Hong Kong.* (Proceedings of the Seminar on Marine Sources of Sand, Hong Kong, December 1987). Geological Society of Hong Kong, 222 p., Hong Kong.

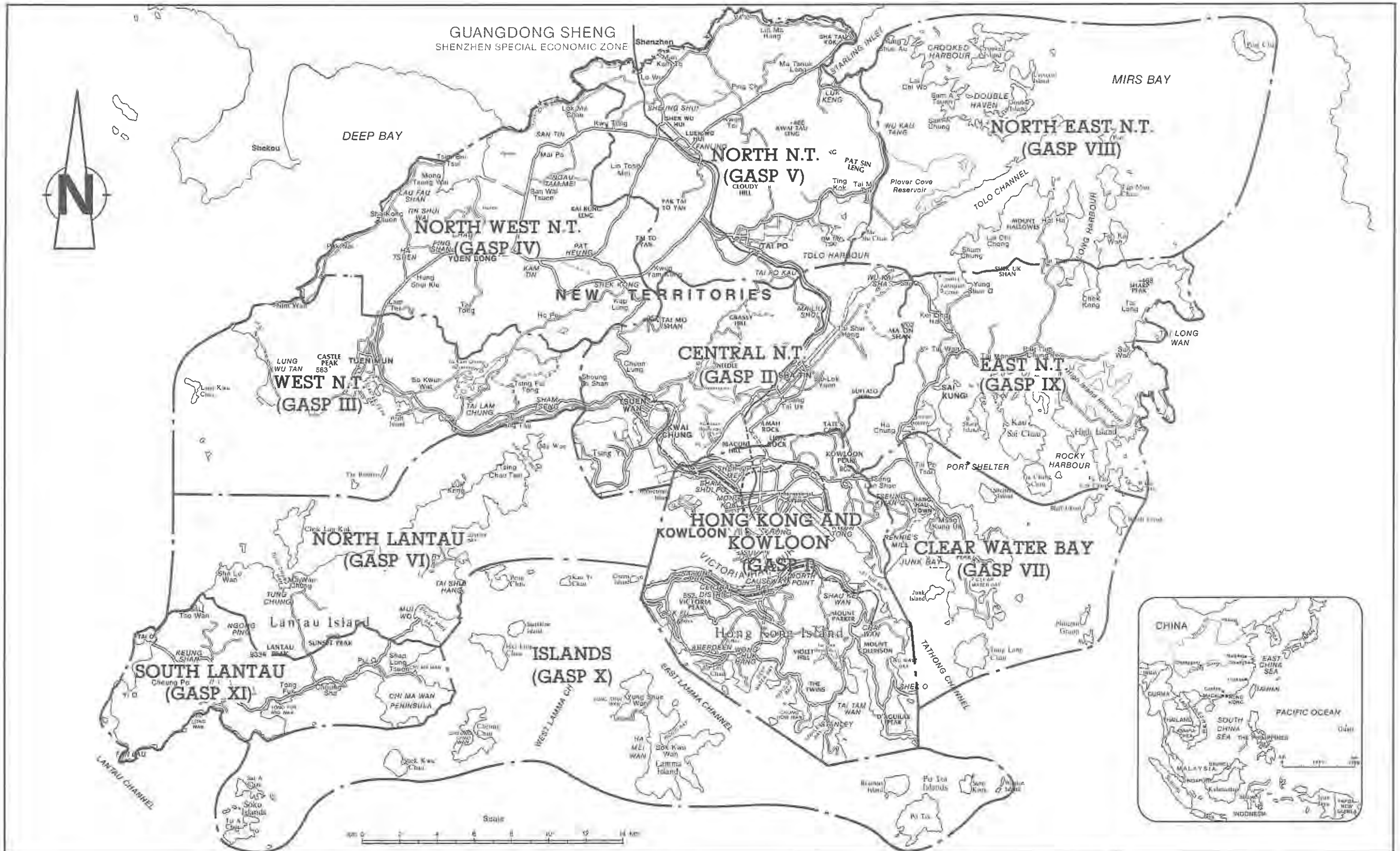
7. FIGURES

List of Figures

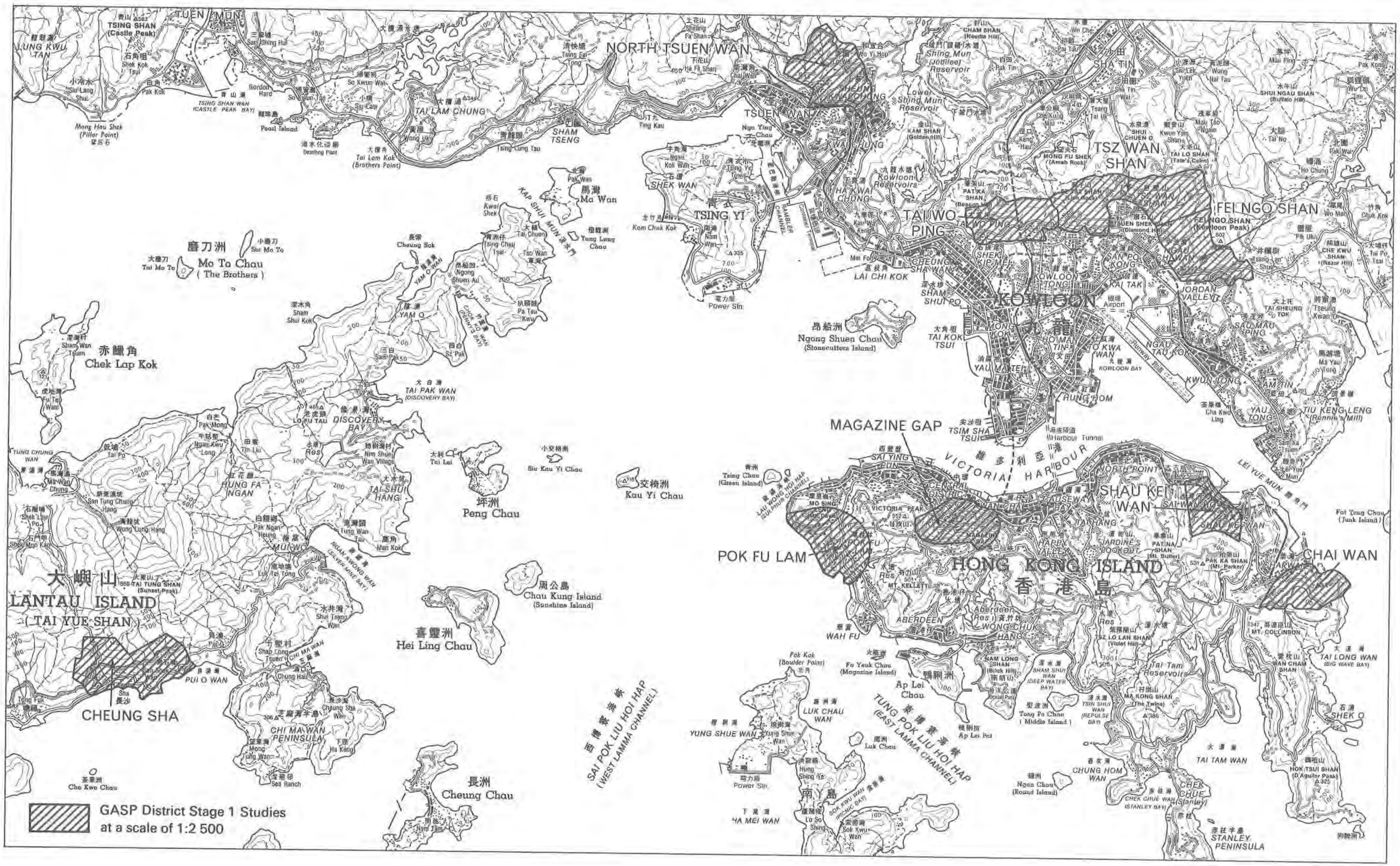


NOTE: → Direction of view for High-level Photographic Plates contained in Section 8

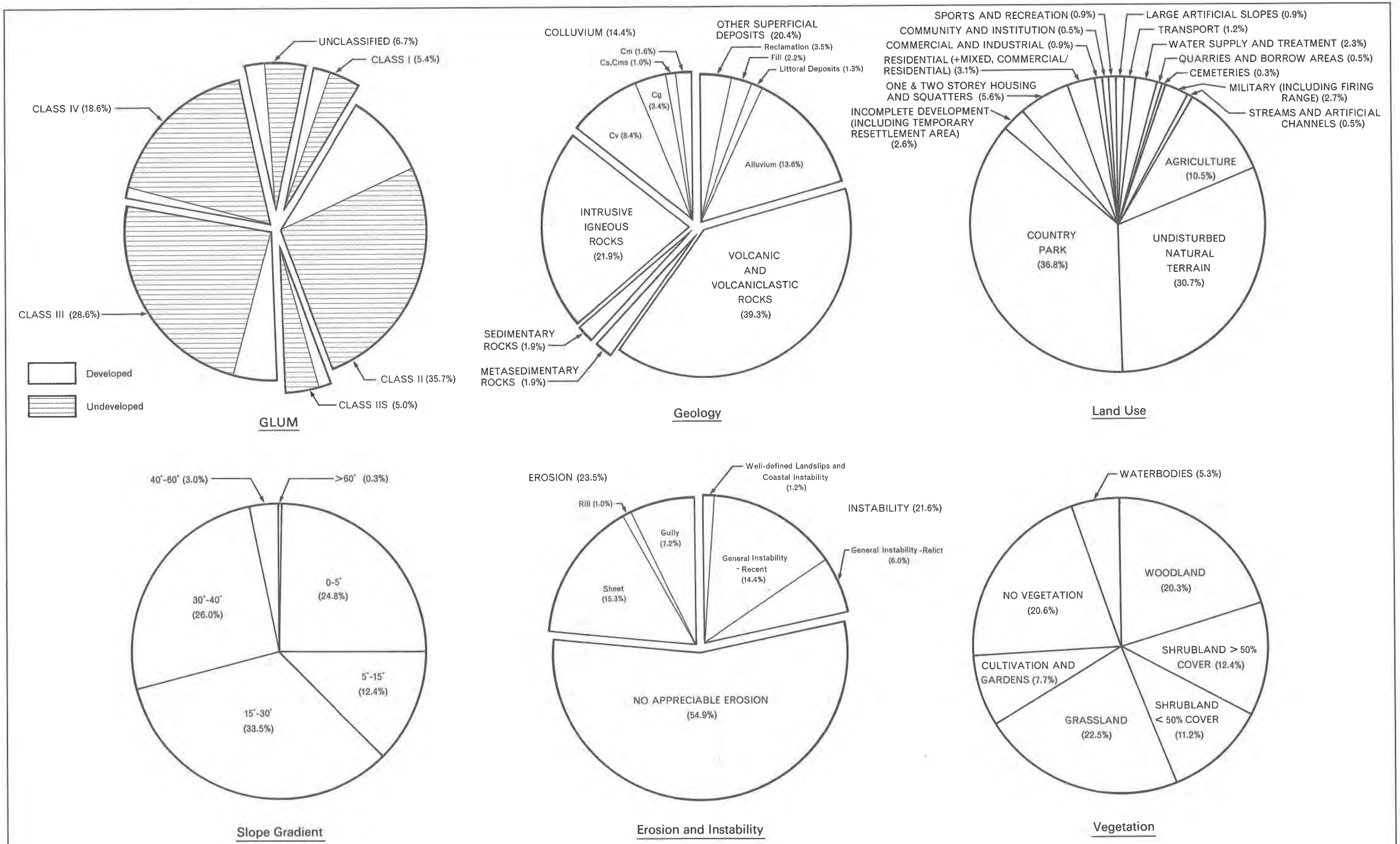
Scale 1:300 000	Territory of Hong Kong	Fig. 1



Scale 1:300 000	Location Map of the GASP Regional Studies	Fig. 2

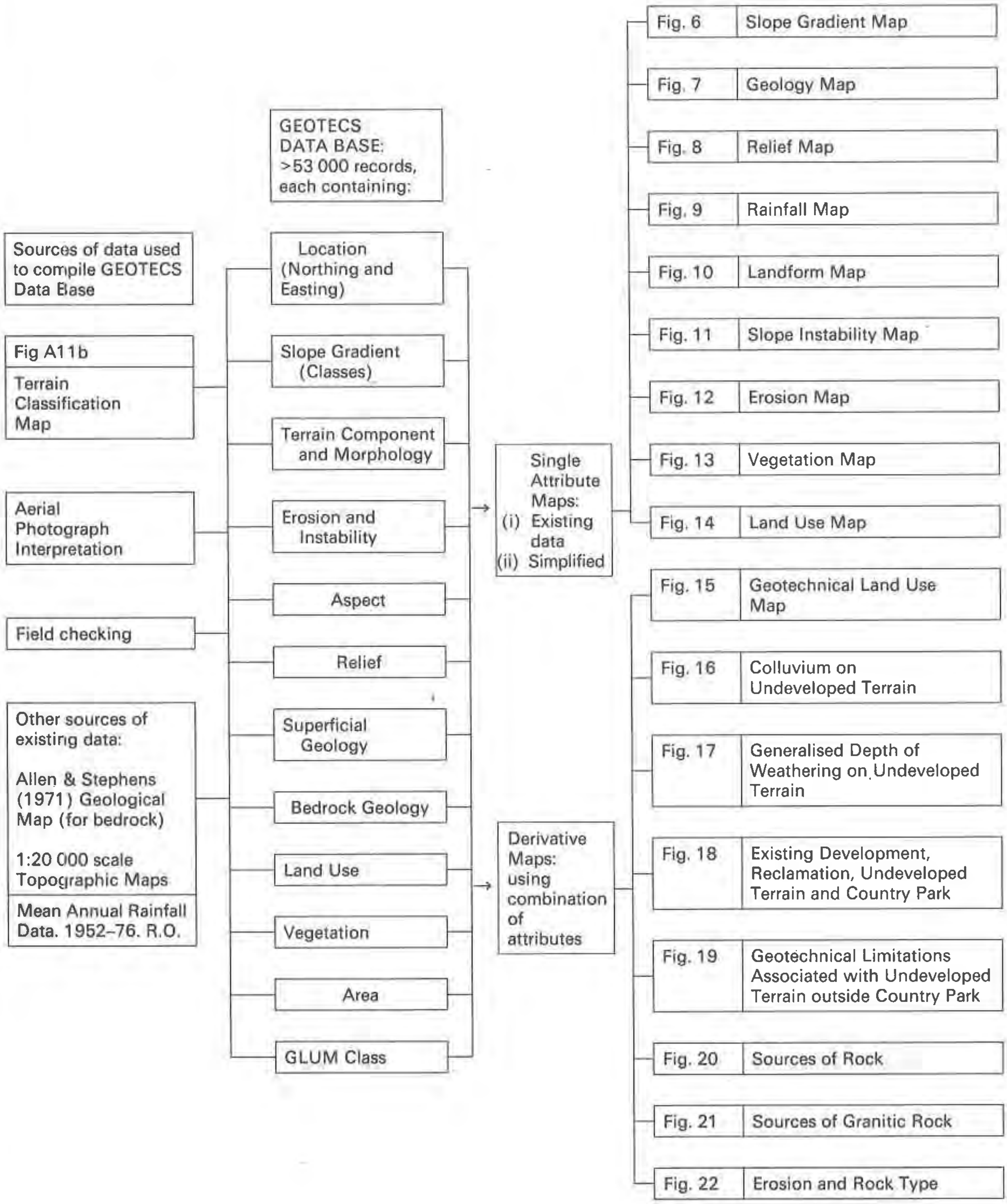


Scale 1:100 000	Location Map of the GASP District Stage 1 Studies	Fig. 3



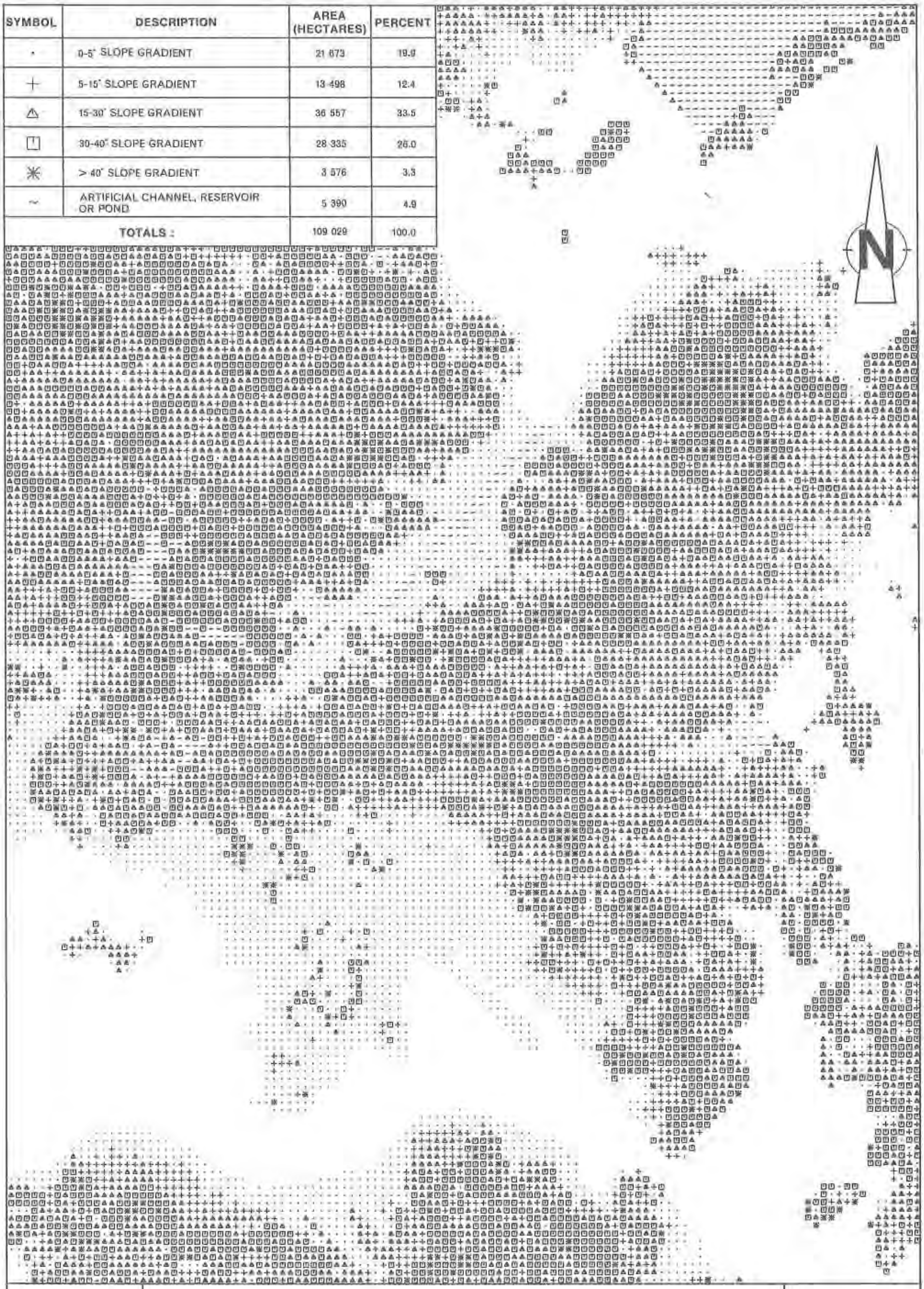
Pie Charts of Selected Attributes of the Territory

Fig. 4

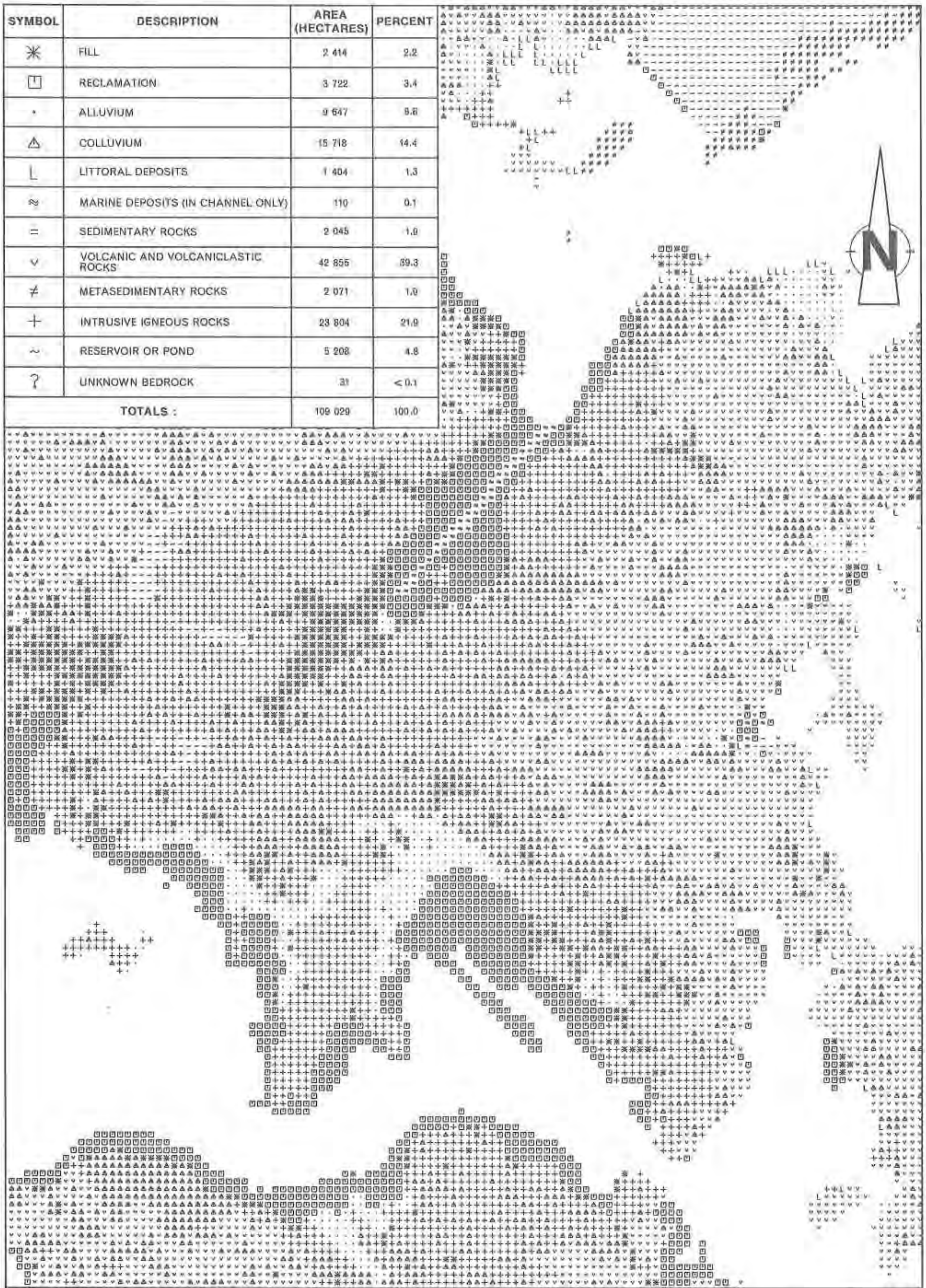


Presentation of the GEOTECS Computer Maps and Plots | Fig. 5

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
·	0-5° SLOPE GRADIENT	21 673	19.9
+	5-15° SLOPE GRADIENT	13 498	12.4
△	15-30° SLOPE GRADIENT	36 557	33.5
⊡	30-40° SLOPE GRADIENT	28 335	26.0
✳	> 40° SLOPE GRADIENT	3 576	3.3
~	ARTIFICIAL CHANNEL, RESERVOIR OR POND	5 390	4.9
	TOTALS :	109 029	100.0



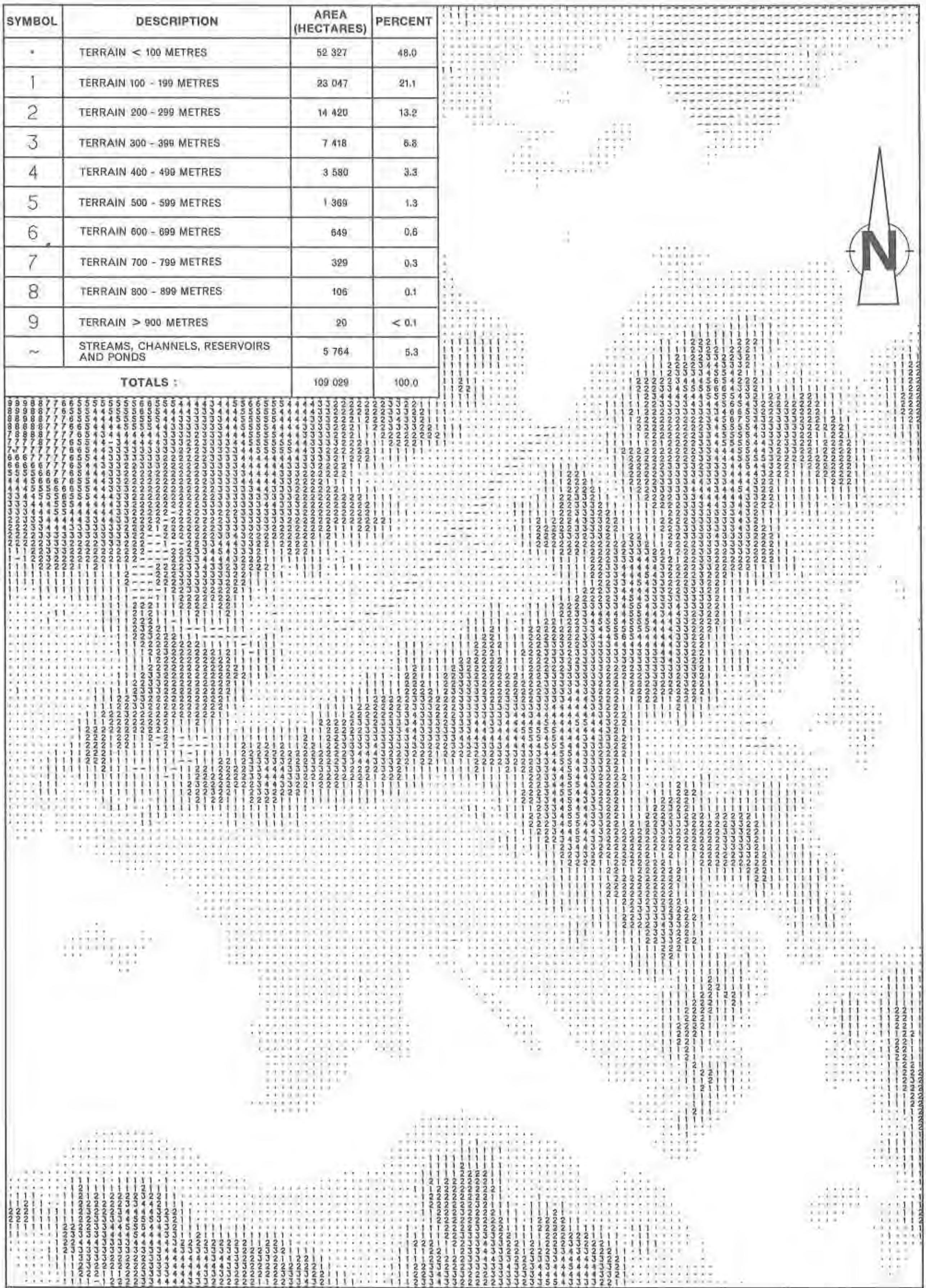
Scale 1:100 000	Example of the GEOTECS Slope Gradient Map	Fig. 6



SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
✳	FILL	2 414	2.2
⊓	RECLAMATION	3 722	3.4
•	ALLUVIUM	9 647	8.8
△	COLLUVIUM	15 718	14.4
L	LITTORAL DEPOSITS	1 404	1.3
≈	MARINE DEPOSITS (IN CHANNEL ONLY)	110	0.1
=	SEDIMENTARY ROCKS	2 045	1.9
v	VOLCANIC AND VOLCANICLASTIC ROCKS	42 855	39.3
≠	METASEDIMENTARY ROCKS	2 071	1.9
+	INTRUSIVE IGNEOUS ROCKS	23 804	21.9
~	RESERVOIR OR POND	5 208	4.8
?	UNKNOWN BEDROCK	31	< 0.1
TOTALS :		109 029	100.0

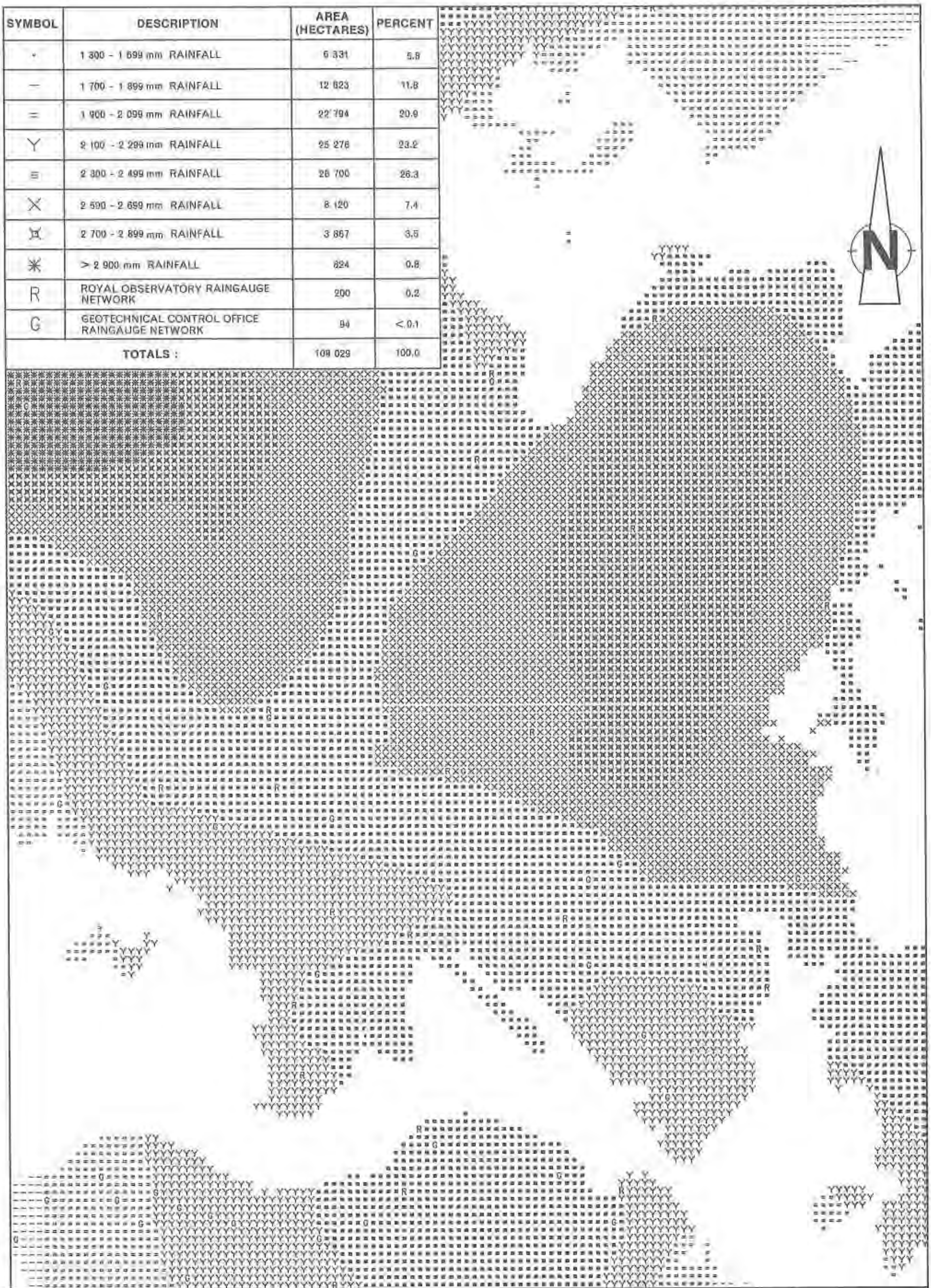
Scale 1:100 000	Example of the GEOTECS Geology Map	Fig. 7

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
·	TERRAIN < 100 METRES	52 327	48.0
1	TERRAIN 100 - 199 METRES	23 047	21.1
2	TERRAIN 200 - 299 METRES	14 420	13.2
3	TERRAIN 300 - 399 METRES	7 418	6.8
4	TERRAIN 400 - 499 METRES	3 580	3.3
5	TERRAIN 500 - 599 METRES	1 369	1.3
6	TERRAIN 600 - 699 METRES	649	0.6
7	TERRAIN 700 - 799 METRES	329	0.3
8	TERRAIN 800 - 899 METRES	106	0.1
9	TERRAIN > 900 METRES	20	< 0.1
~	STREAMS, CHANNELS, RESERVOIRS AND PONDS	5 764	5.3
TOTALS :		109 029	100.0

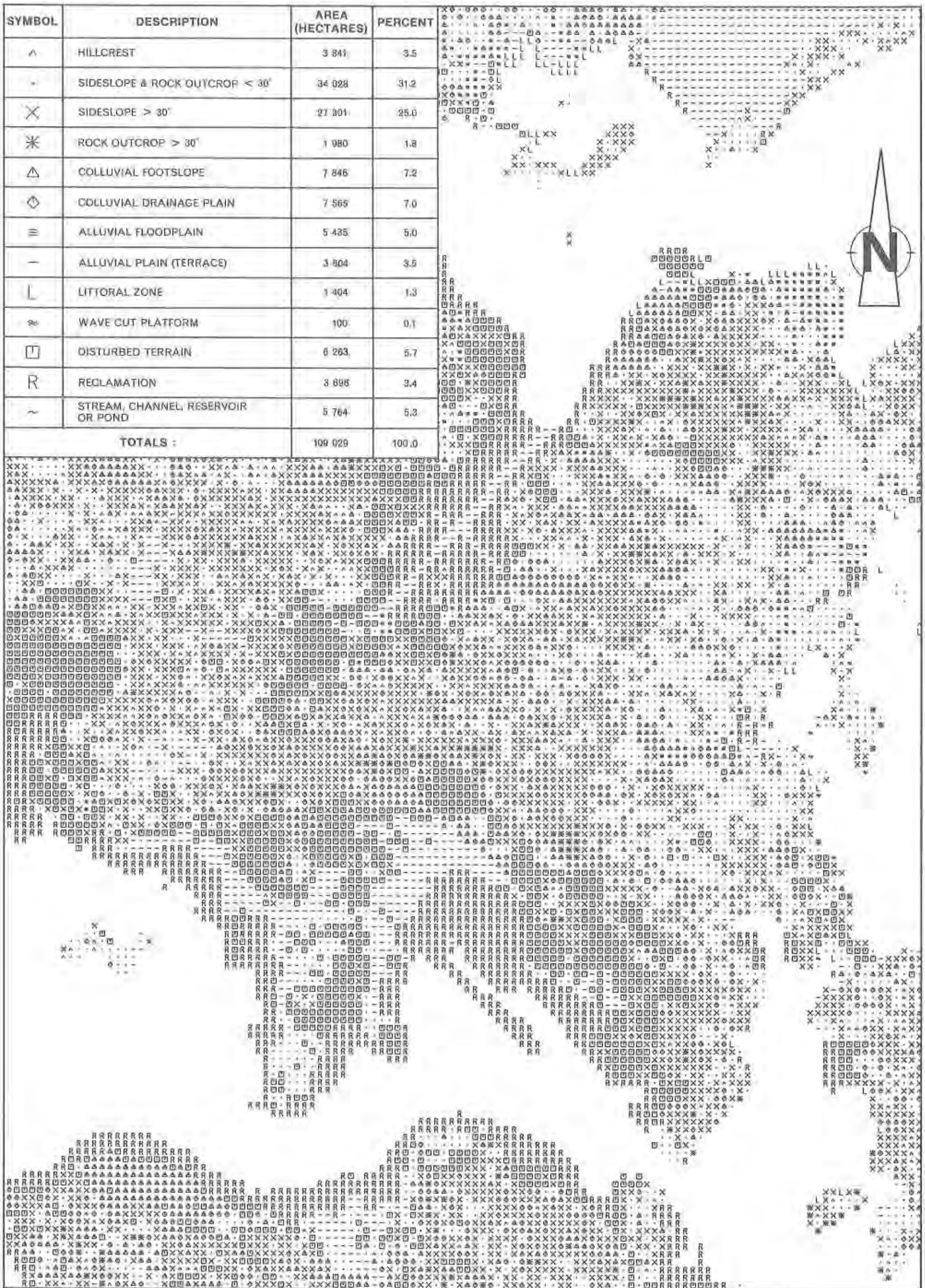


Scale 1:100 000	Example of the GEOTECS Relief Map	Fig. 8

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
·	1 300 - 1 699 mm RAINFALL	6 331	5.8
—	1 700 - 1 899 mm RAINFALL	12 823	11.8
=	1 900 - 2 099 mm RAINFALL	22 794	20.9
Y	2 100 - 2 299 mm RAINFALL	25 276	23.2
≡	2 300 - 2 499 mm RAINFALL	28 700	26.3
X	2 500 - 2 699 mm RAINFALL	8 120	7.4
⌧	2 700 - 2 899 mm RAINFALL	3 867	3.5
✳	> 2 900 mm RAINFALL	624	0.6
R	ROYAL OBSERVATORY RAINGAUGE NETWORK	200	0.2
G	GEOTECHNICAL CONTROL OFFICE RAINGAUGE NETWORK	94	< 0.1
TOTALS :		109 029	100.0



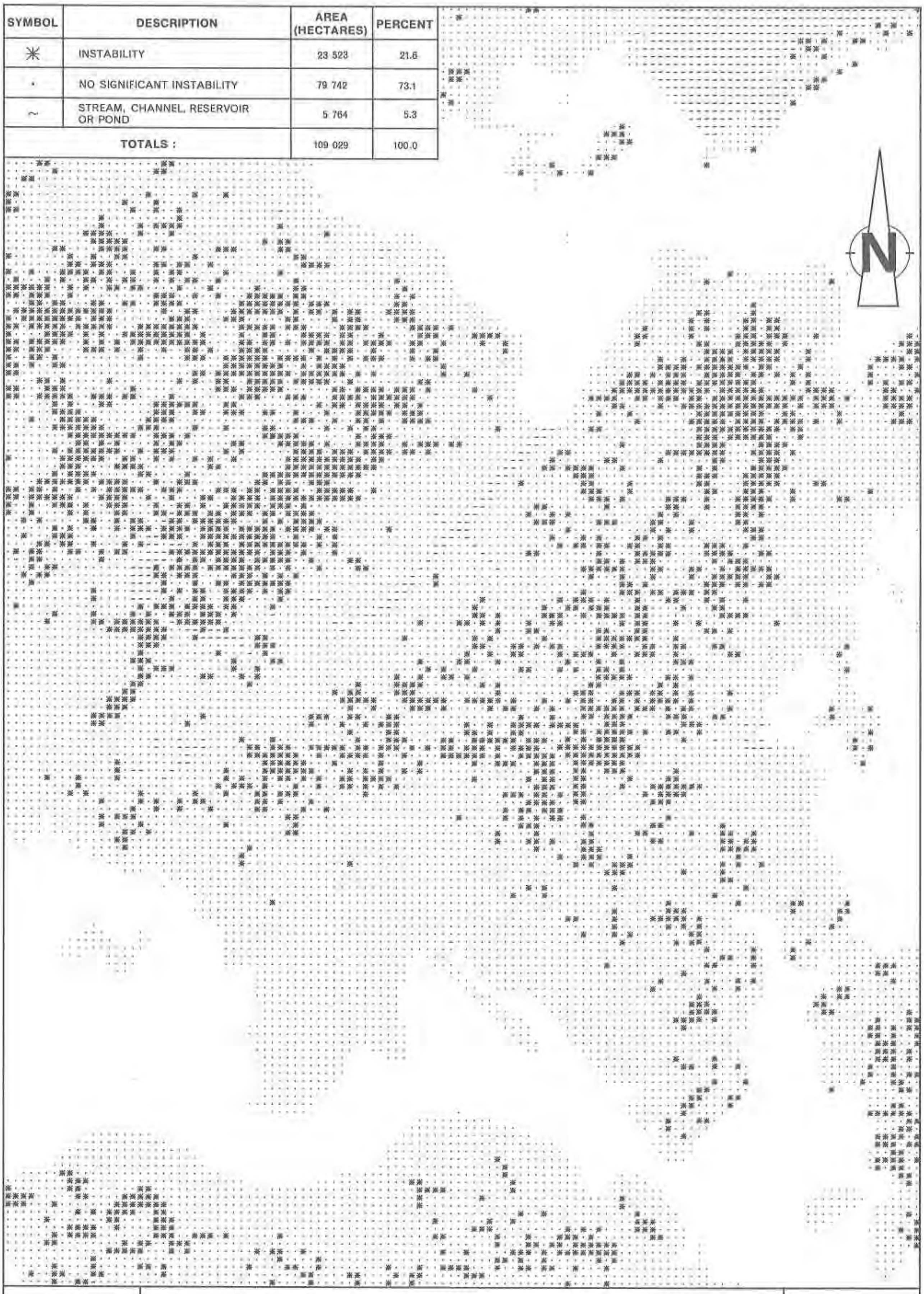
Scale 1:100 000	Example of the GEOTECS Rainfall Map	Fig. 9



SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
∧	HILLCREST	3 841	3.5
·	SIDESLOPE & ROCK OUTCROP < 30°	34 028	31.2
×	SIDESLOPE > 30°	27 301	25.0
✳	ROCK OUTCROP > 30°	1 980	1.8
△	COLLUVIAL FOOTSLOPE	7 846	7.2
◇	COLLUVIAL DRAINAGE PLAIN	7 565	7.0
≡	ALLUVIAL FLOODPLAIN	5 435	5.0
—	ALLUVIAL PLAIN (TERRACE)	3 804	3.5
L	LITTORAL ZONE	1 404	1.3
≈	WAVE CUT PLATFORM	100	0.1
⊡	DISTURBED TERRAIN	6 263	5.7
R	RECLAMATION	3 698	3.4
~	STREAM, CHANNEL, RESERVOIR OR POND	5 764	5.3
	TOTALS :	109 029	100.0

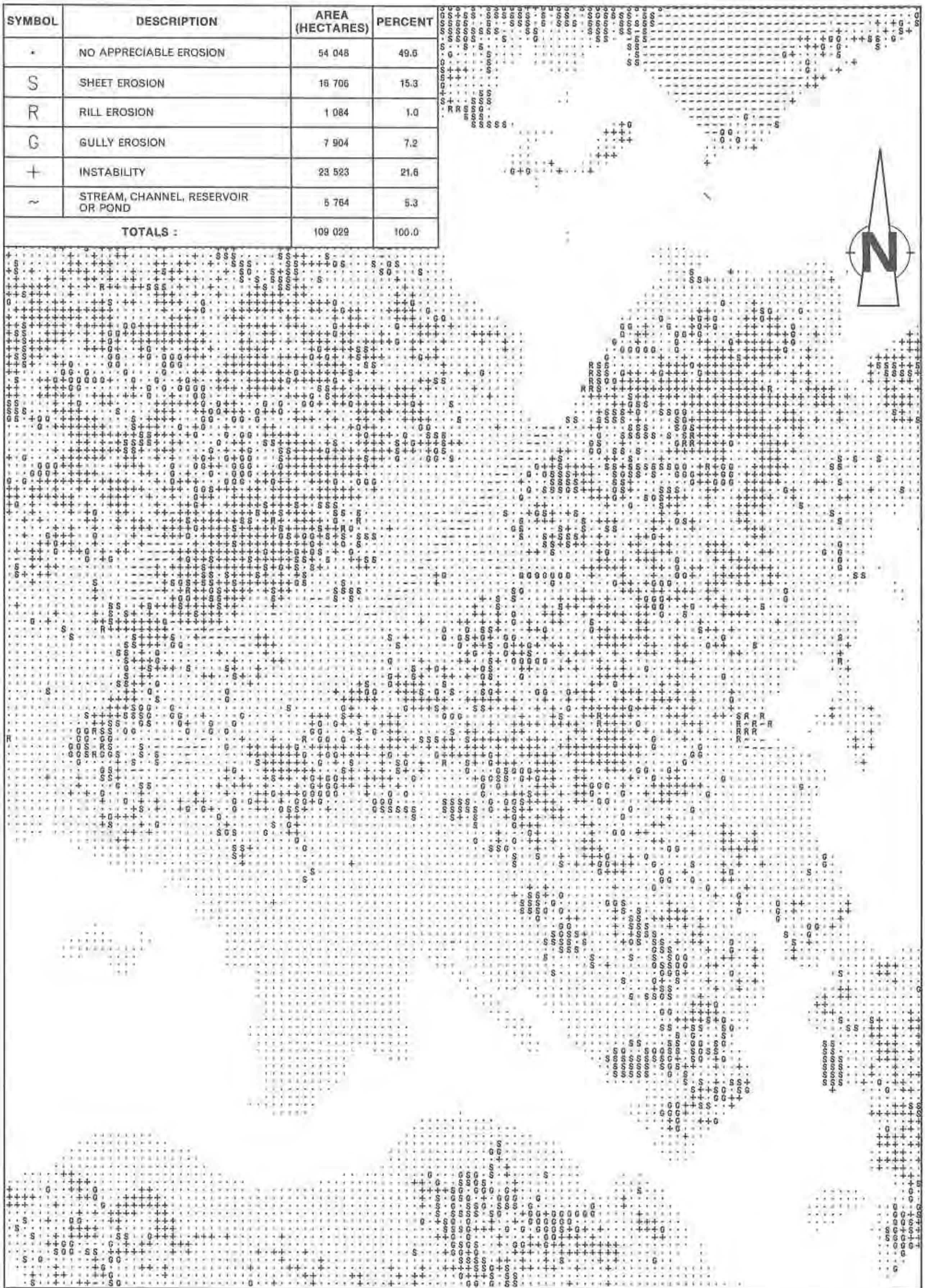
Scale 1:100 000	Example of the GEOTECS Landform Map	Fig. 10

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
✳	INSTABILITY	23 523	21.6
·	NO SIGNIFICANT INSTABILITY	79 742	73.1
~	STREAM, CHANNEL, RESERVOIR OR POND	5 764	5.3
TOTALS :		109 029	100.0

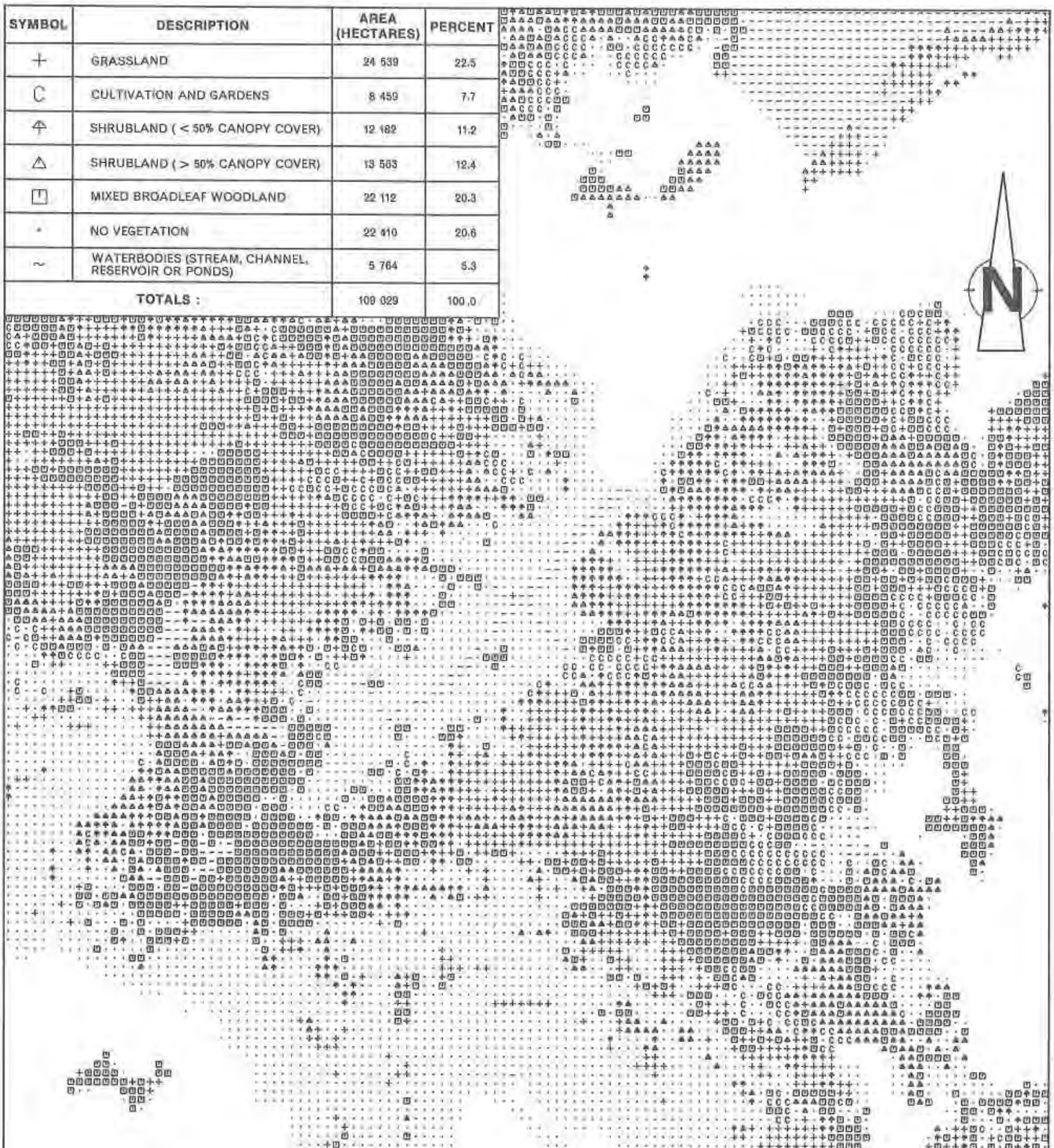


Scale 1:100 000	Example of the GEOTECS Slope Instability Map	Fig. 11

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
·	NO APPRECIABLE EROSION	54 048	49.6
S	SHEET EROSION	16 706	15.3
R	RILL EROSION	1 084	1.0
G	GULLY EROSION	7 904	7.2
+	INSTABILITY	23 523	21.6
~	STREAM, CHANNEL, RESERVOIR OR POND	5 764	5.3
TOTALS :		109 029	100.0



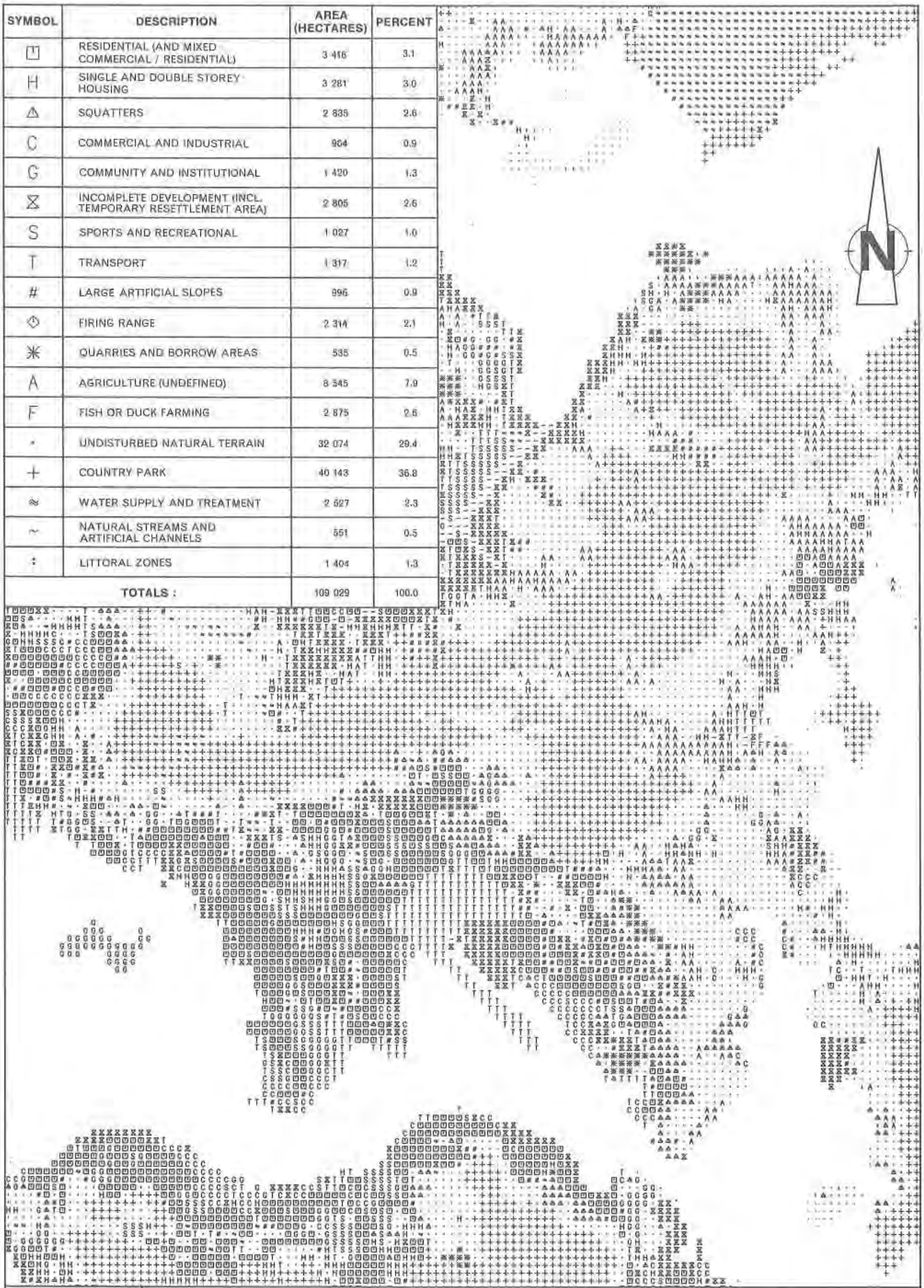
Scale 1:100 000	Example of the GEOTECS Erosion Map	Fig. 12



SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
+	GRASSLAND	24 539	22.5
C	CULTIVATION AND GARDENS	8 459	7.7
⯊	SHRUBLAND (< 50% CANOPY COVER)	12 182	11.2
△	SHRUBLAND (> 50% CANOPY COVER)	13 563	12.4
◻	MIXED BROADLEAF WOODLAND	22 112	20.3
·	NO VEGETATION	22 410	20.6
~	WATERBODIES (STREAM, CHANNEL, RESERVOIR OR PONDS)	5 764	5.3
TOTALS :		109 029	100.0

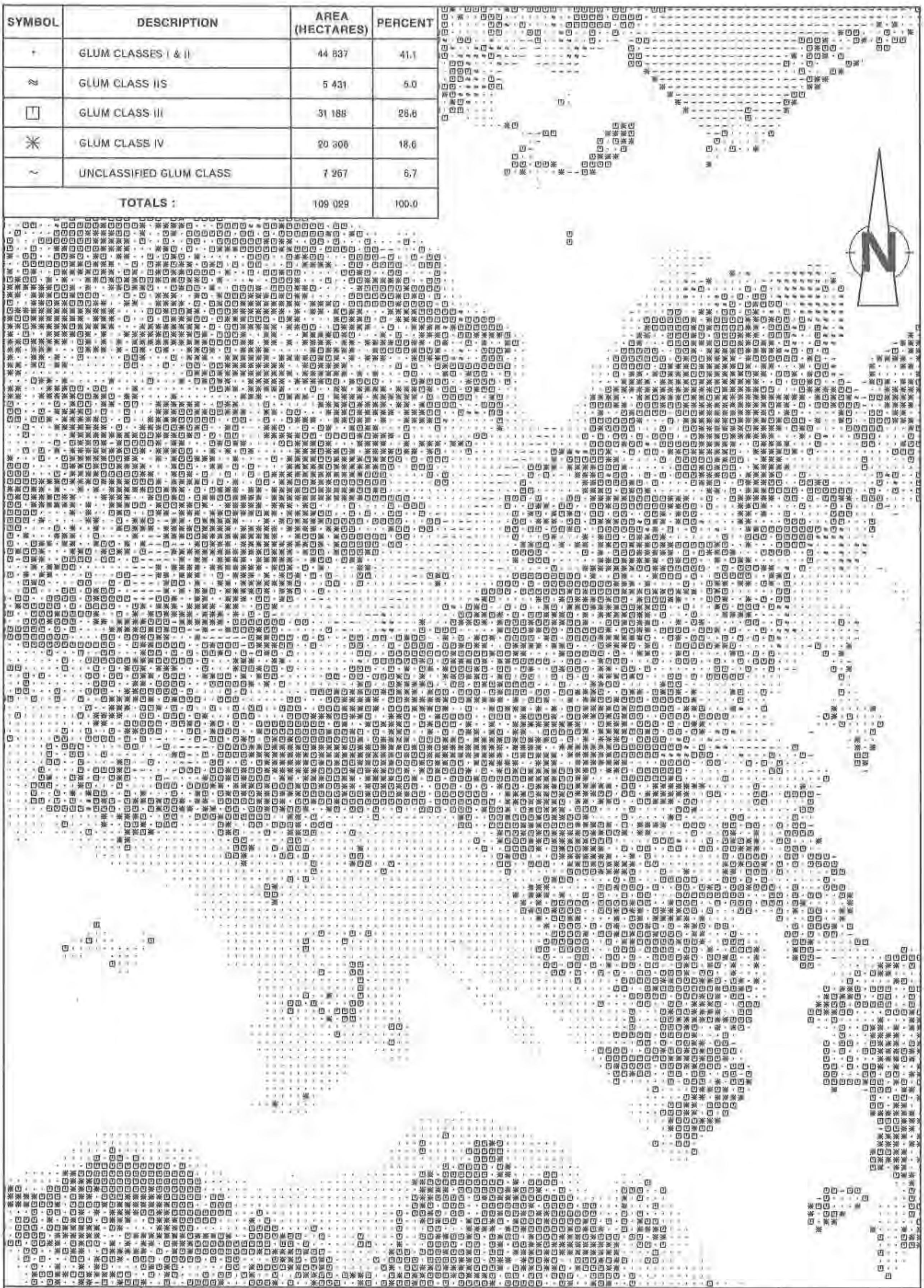
Scale 1:100 000	Example of the GEOTECS Vegetation Map	Fig. 13

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
⊡	RESIDENTIAL (AND MIXED COMMERCIAL / RESIDENTIAL)	3 416	3.1
H	SINGLE AND DOUBLE STOREY HOUSING	3 281	3.0
△	SQUATTERS	2 835	2.6
C	COMMERCIAL AND INDUSTRIAL	904	0.9
G	COMMUNITY AND INSTITUTIONAL	1 420	1.3
⧖	INCOMPLETE DEVELOPMENT (INCL. TEMPORARY RESETTLEMENT AREA)	2 805	2.6
S	SPORTS AND RECREATIONAL	1 027	1.0
T	TRANSPORT	1 317	1.2
#	LARGE ARTIFICIAL SLOPES	996	0.9
◇	FIRING RANGE	2 314	2.1
✳	QUARRIES AND BORROW AREAS	535	0.5
A	AGRICULTURE (UNDEFINED)	8 545	7.9
F	FISH OR DUCK FARMING	2 875	2.6
·	UNDISTURBED NATURAL TERRAIN	32 074	29.4
+	COUNTRY PARK	40 143	36.8
≈	WATER SUPPLY AND TREATMENT	2 527	2.3
~	NATURAL STREAMS AND ARTIFICIAL CHANNELS	551	0.5
⁝	LITTORAL ZONES	1 404	1.3
	TOTALS :	109 029	100.0



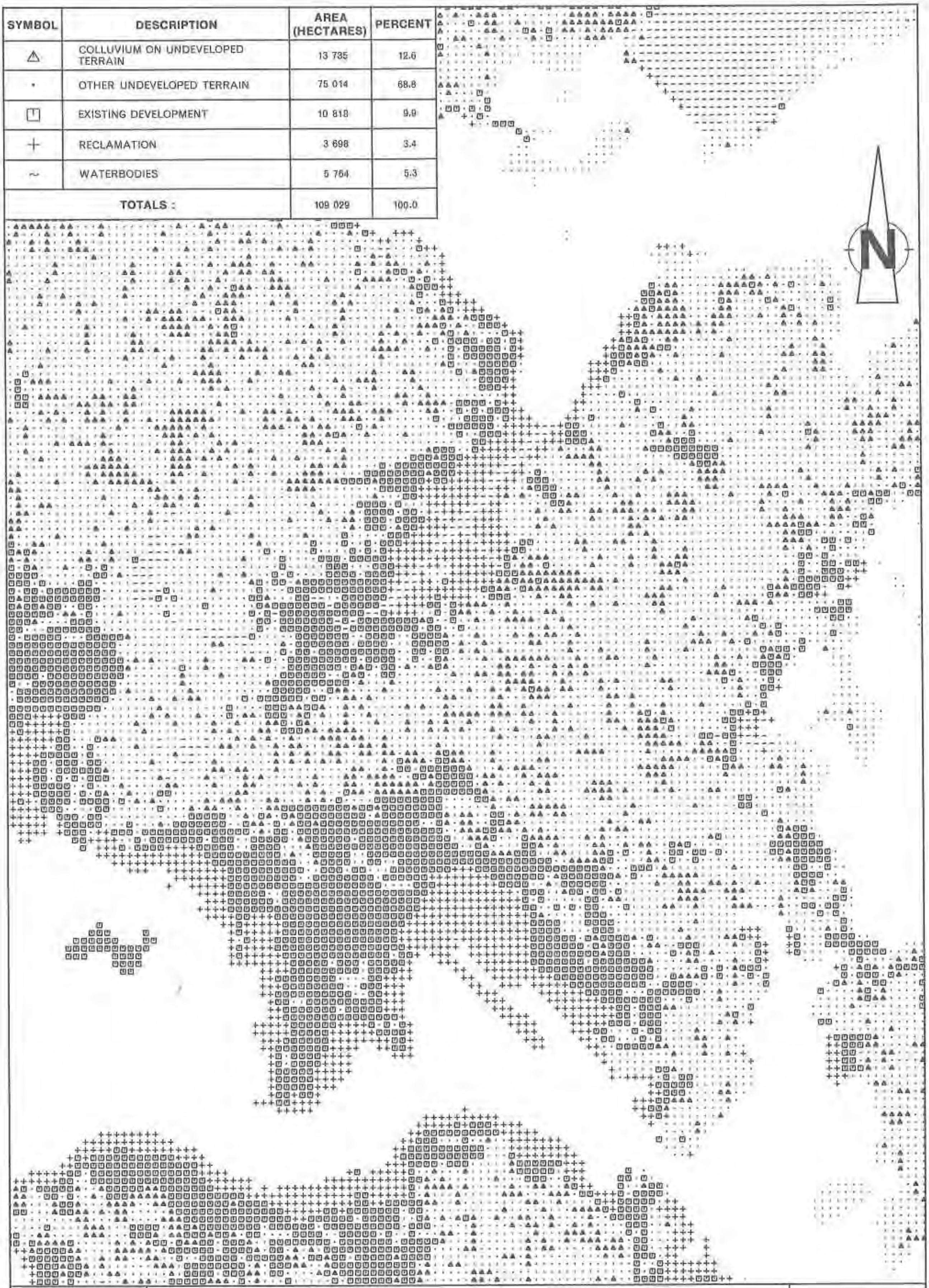
Scale 1:100 000	Example of the GEOTECS Land Use Map	Fig. 14

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
+	GLUM CLASSES I & II	44 837	41.1
≈	GLUM CLASS IIS	5 431	5.0
◫	GLUM CLASS III	31 188	28.6
✳	GLUM CLASS IV	20 306	18.6
~	UNCLASSIFIED GLUM CLASS	7 267	6.7
TOTALS :		109 029	100.0

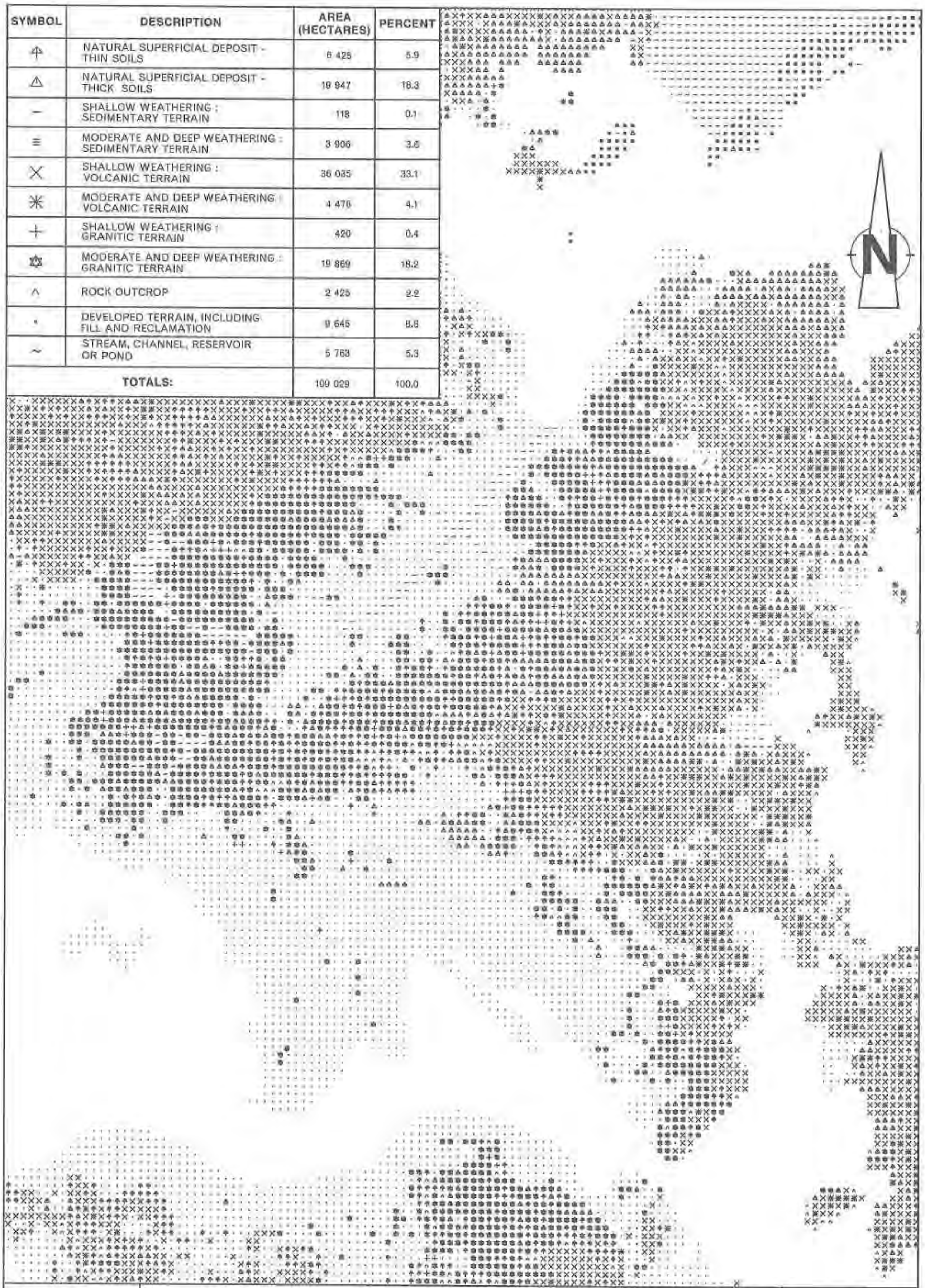


Scale 1:100 000	Example of the GEOTECS Geotechnical Land Use Map	Fig. 15

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
△	COLLUVIUM ON UNDEVELOPED TERRAIN	13 735	12.6
·	OTHER UNDEVELOPED TERRAIN	75 014	68.8
◫	EXISTING DEVELOPMENT	10 818	9.9
+	RECLAMATION	3 698	3.4
~	WATERBODIES	5 764	5.3
TOTALS :		109 029	100.0



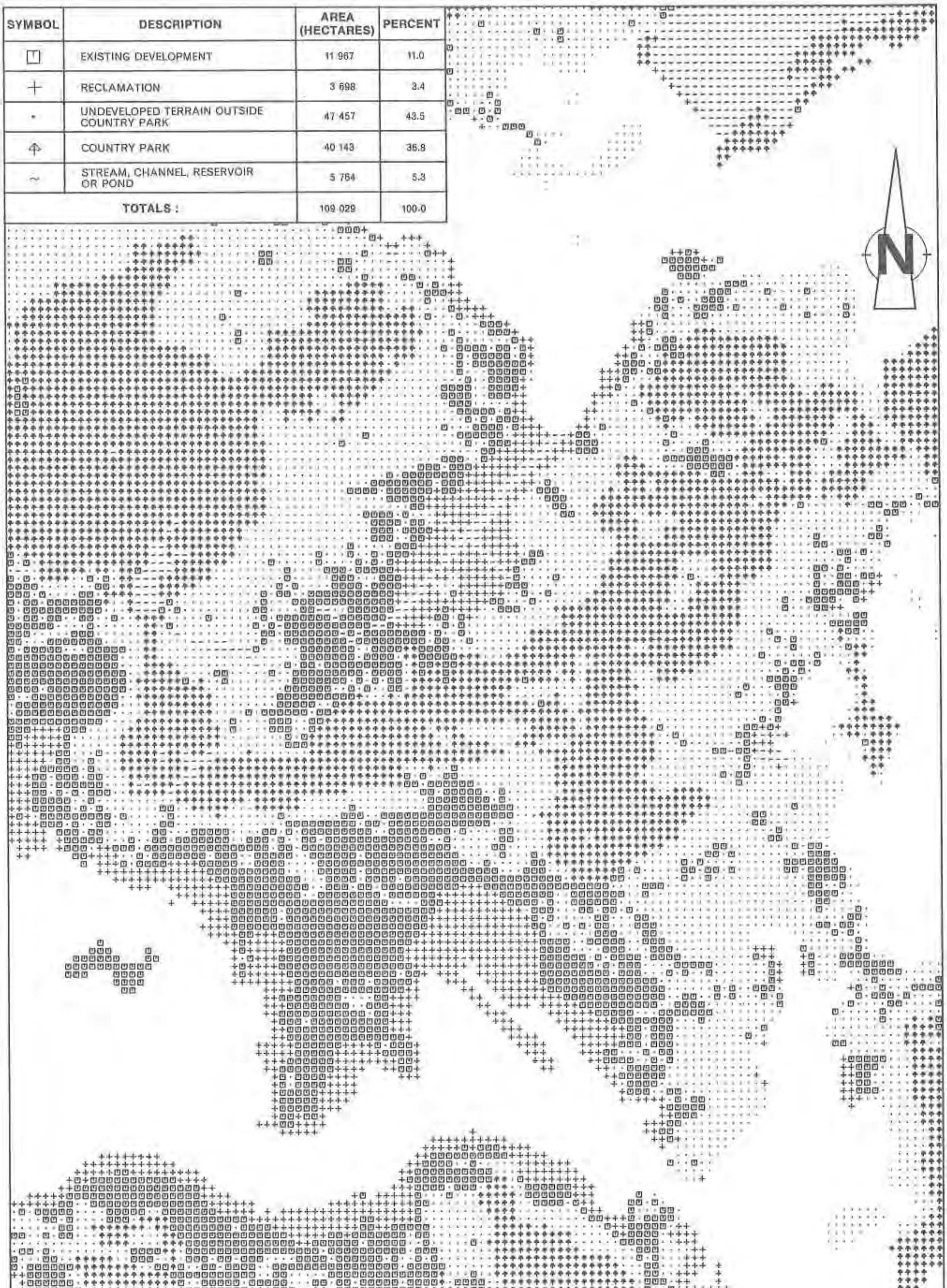
Scale 1:100 000	Example of the GEOTECS Map of Colluvium on Undeveloped Terrain	Fig. 16



SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
⁂	NATURAL SUPERFICIAL DEPOSIT - THIN SOILS	6 425	5.9
△	NATURAL SUPERFICIAL DEPOSIT - THICK SOILS	19 947	18.3
–	SHALLOW WEATHERING : SEDIMENTARY TERRAIN	118	0.1
≡	MODERATE AND DEEP WEATHERING : SEDIMENTARY TERRAIN	3 906	3.6
×	SHALLOW WEATHERING : VOLCANIC TERRAIN	36 035	33.1
✳	MODERATE AND DEEP WEATHERING : VOLCANIC TERRAIN	4 476	4.1
+	SHALLOW WEATHERING : GRANITIC TERRAIN	420	0.4
✡	MODERATE AND DEEP WEATHERING : GRANITIC TERRAIN	19 869	18.2
^	ROCK OUTCROP	2 425	2.2
·	DEVELOPED TERRAIN, INCLUDING FILL AND RECLAMATION	9 645	8.8
~	STREAM, CHANNEL, RESERVOIR OR POND	5 763	5.3
	TOTALS:	109 029	100.0

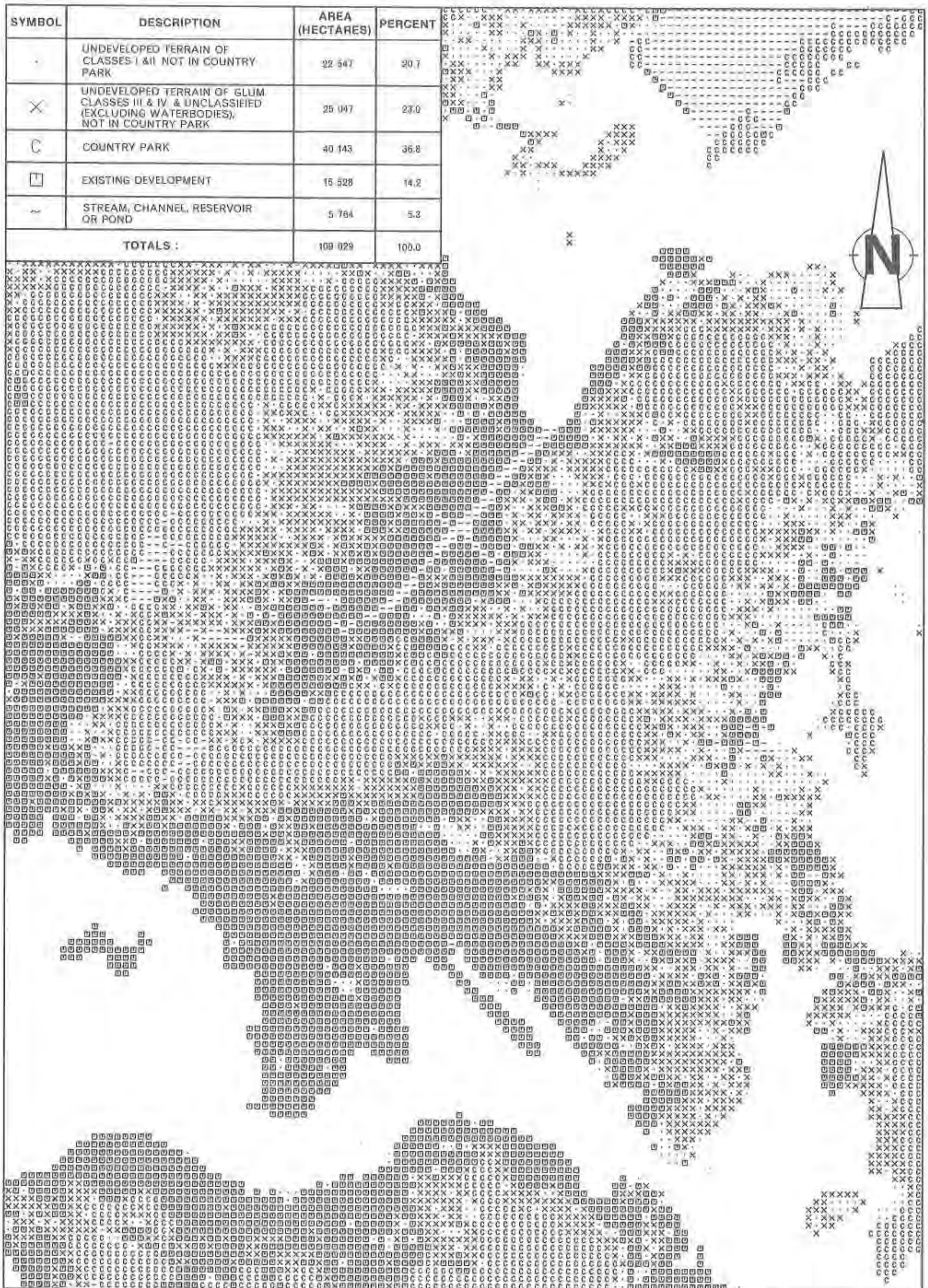
Scale 1:100 000	Example of the GEOTECS Map of Generalised Depth of Weathering on Undeveloped Terrain	Fig. 17

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
⊡	EXISTING DEVELOPMENT	11 967	11.0
+	RECLAMATION	3 698	3.4
·	UNDEVELOPED TERRAIN OUTSIDE COUNTRY PARK	47 457	43.5
⇞	COUNTRY PARK	40 143	36.8
~	STREAM, CHANNEL, RESERVOIR OR POND	5 764	5.3
TOTALS :		109 029	100.0



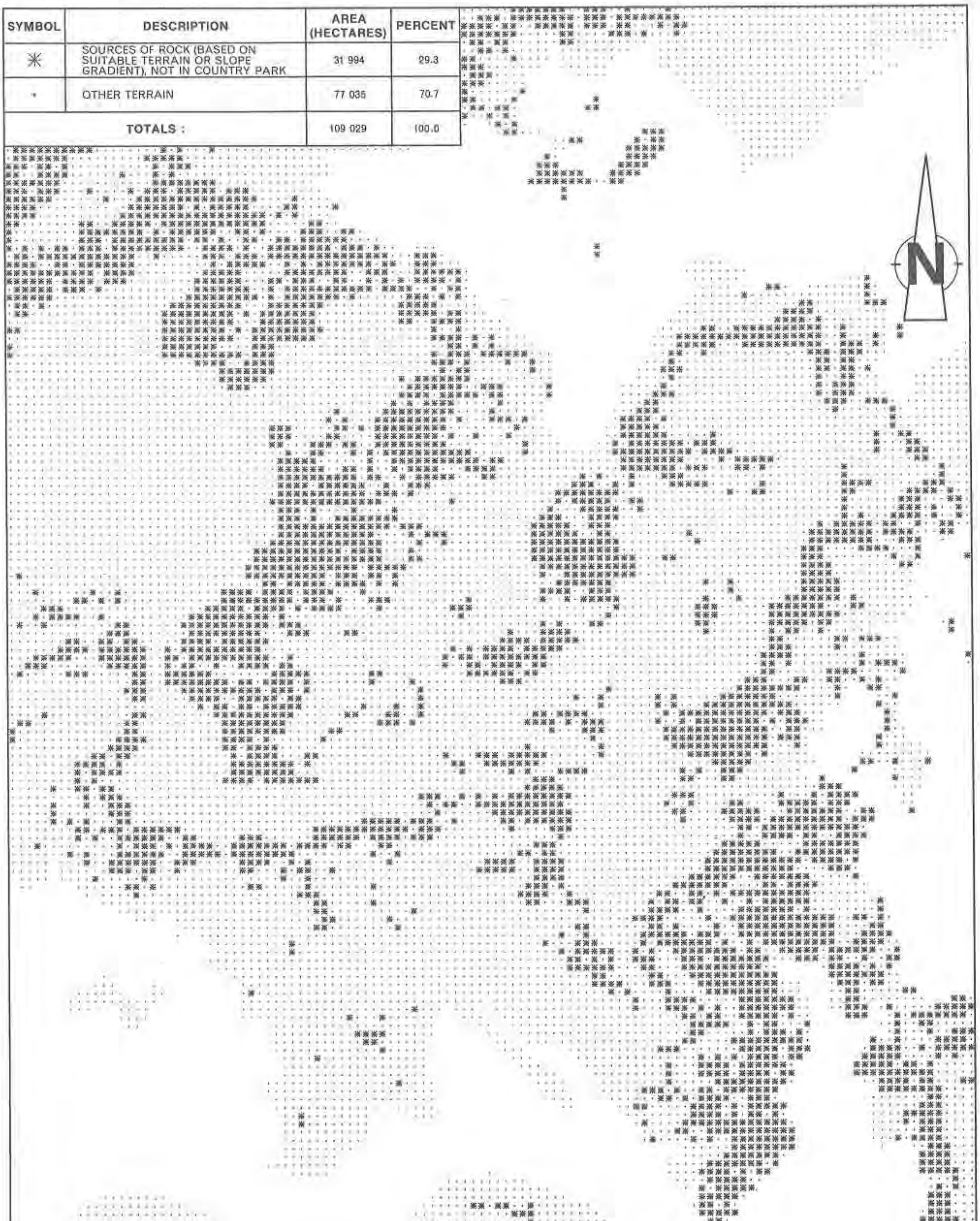
Scale 1:100 000	Example of the GEOTECS Map of Existing Development, Reclamation, Undeveloped Terrain and Country Park	Fig. 18

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
·	UNDEVELOPED TERRAIN OF CLASSES I &II NOT IN COUNTRY PARK	22 547	20.7
×	UNDEVELOPED TERRAIN OF GLUM CLASSES III & IV & UNCLASSIFIED (EXCLUDING WATERBODIES), NOT IN COUNTRY PARK	25 047	23.0
C	COUNTRY PARK	40 143	36.8
⊡	EXISTING DEVELOPMENT	15 528	14.2
~	STREAM, CHANNEL, RESERVOIR OR POND	5 764	5.3
TOTALS :		109 029	100.0



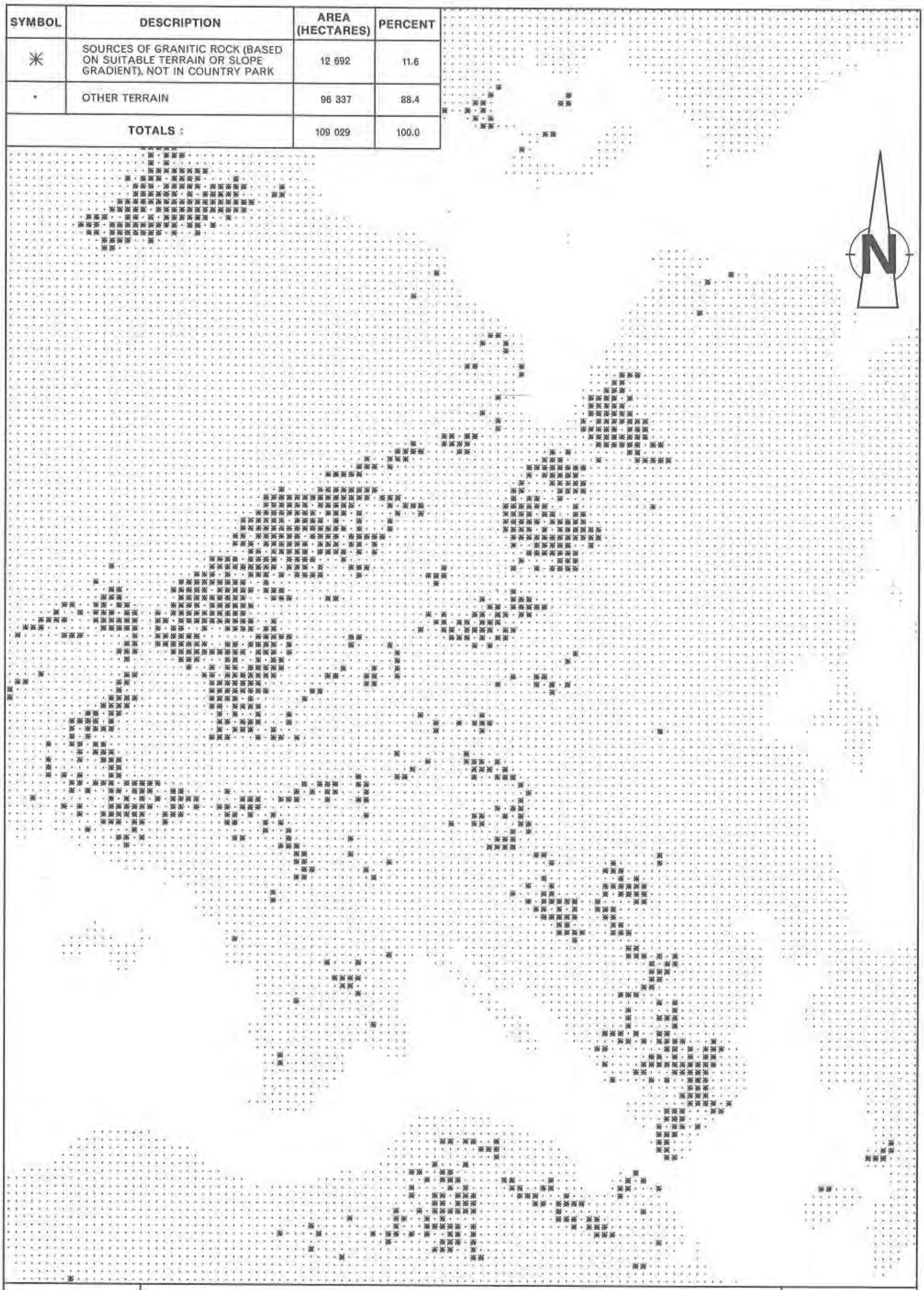
Scale 1:100 000	Example of the GEOTECS Map of Geotechnical Limitations Associated with Undeveloped Terrain outside Country Park	Fig. 19

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
✳	SOURCES OF ROCK (BASED ON SUITABLE TERRAIN OR SLOPE GRADIENT), NOT IN COUNTRY PARK	31 994	29.3
·	OTHER TERRAIN	77 035	70.7
TOTALS :		109 029	100.0



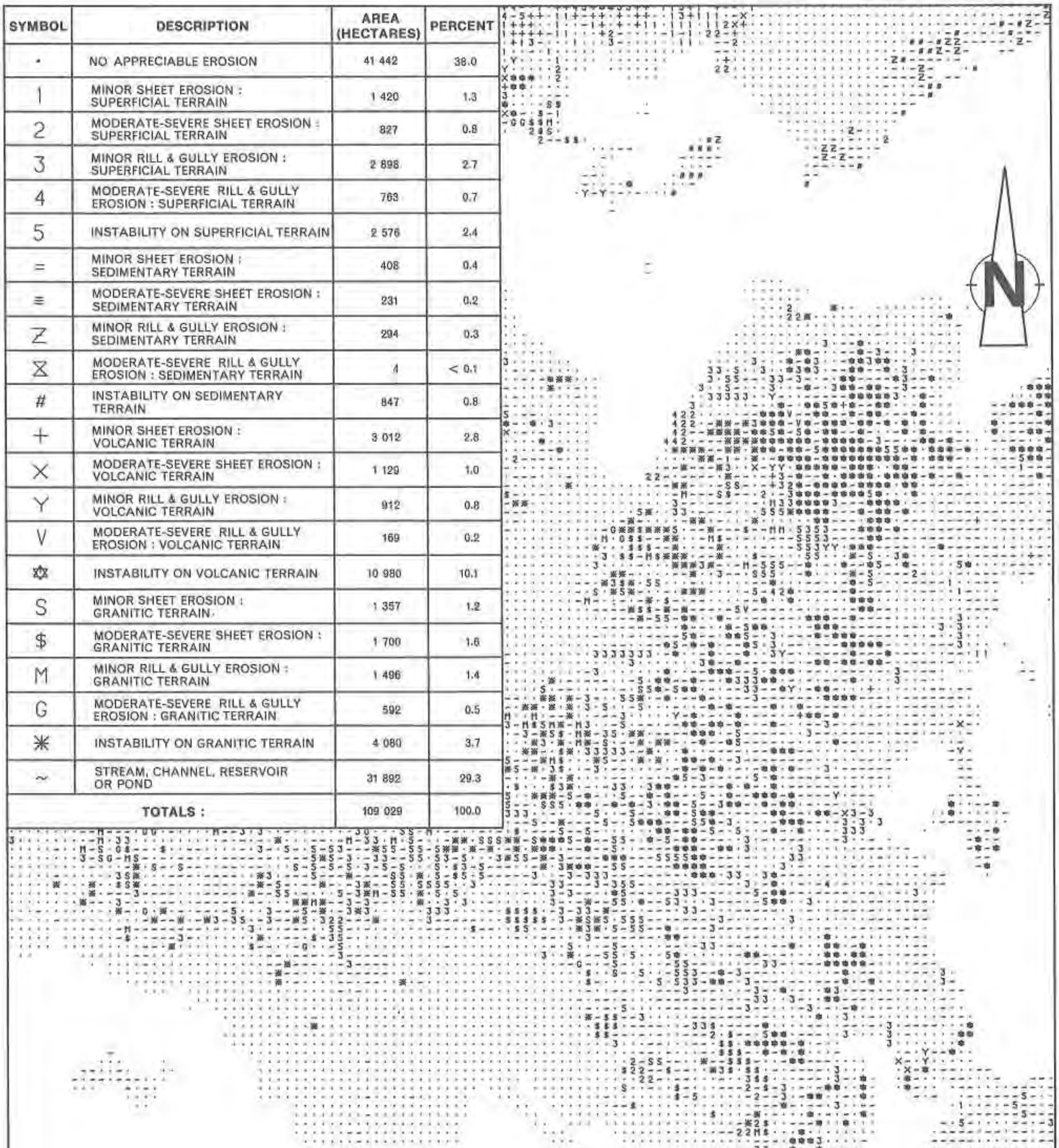
Scale 1:100 000	GEOTECS Plot-Sources of Rock	Fig. 20

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
✳	SOURCES OF GRANITIC ROCK (BASED ON SUITABLE TERRAIN OR SLOPE GRADIENT), NOT IN COUNTRY PARK	12 692	11.6
·	OTHER TERRAIN	96 337	88.4
TOTALS :		109 029	100.0



Scale 1:100 000	GEOTECS Plot-Sources of Granitic Rock	Fig. 21

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
·	NO APPRECIABLE EROSION	41 442	38.0
1	MINOR SHEET EROSION : SUPERFICIAL TERRAIN	1 420	1.3
2	MODERATE-SEVERE SHEET EROSION : SUPERFICIAL TERRAIN	827	0.8
3	MINOR RILL & GULLY EROSION : SUPERFICIAL TERRAIN	2 898	2.7
4	MODERATE-SEVERE RILL & GULLY EROSION : SUPERFICIAL TERRAIN	763	0.7
5	INSTABILITY ON SUPERFICIAL TERRAIN	2 576	2.4
=	MINOR SHEET EROSION : SEDIMENTARY TERRAIN	408	0.4
≡	MODERATE-SEVERE SHEET EROSION : SEDIMENTARY TERRAIN	231	0.2
Z	MINOR RILL & GULLY EROSION : SEDIMENTARY TERRAIN	294	0.3
Z̄	MODERATE-SEVERE RILL & GULLY EROSION : SEDIMENTARY TERRAIN	4	< 0.1
#	INSTABILITY ON SEDIMENTARY TERRAIN	847	0.8
+	MINOR SHEET EROSION : VOLCANIC TERRAIN	3 012	2.8
X	MODERATE-SEVERE SHEET EROSION : VOLCANIC TERRAIN	1 129	1.0
Y	MINOR RILL & GULLY EROSION : VOLCANIC TERRAIN	912	0.8
V	MODERATE-SEVERE RILL & GULLY EROSION : VOLCANIC TERRAIN	169	0.2
✡	INSTABILITY ON VOLCANIC TERRAIN	10 980	10.1
S	MINOR SHEET EROSION : GRANITIC TERRAIN	1 357	1.2
$	MODERATE-SEVERE SHEET EROSION : GRANITIC TERRAIN	1 700	1.6
M	MINOR RILL & GULLY EROSION : GRANITIC TERRAIN	1 496	1.4
G	MODERATE-SEVERE RILL & GULLY EROSION : GRANITIC TERRAIN	592	0.5
✳	INSTABILITY ON GRANITIC TERRAIN	4 080	3.7
~	STREAM, CHANNEL, RESERVOIR OR POND	31 892	29.3
	TOTALS :	109 029	100.0



Scale 1:100 000

GEOTECS Plot-Erosion and Rock Type

Fig. 22

8. PLATES

8.1 General Description

Photographs of various types form an important part of the Geotechnical Area Studies Programme, because they provide a visual impression and historical record of geotechnically-related features and events within the Territory. Throughout the history of Hong Kong, natural disasters have been a common occurrence of daily life. The effects of slope failure in particular has had a substantial impact on the community in terms of financial cost, disruption and, in many cases, tragic loss of life. With this in mind, the plates have been selected to highlight many of the geotechnical problems associated with the terrain and to reflect the intensity and general nature of development within the Territory.

The plates include a large number of both aerial (oblique and vertical) photographs and conventional photographs, which portray landslips and the impact of slope failure on differing types of development. The Hong Kong Government has an Aerial Survey Unit which has excellent facilities for aerial photography and photogrammetry. A very large number of vertical aerial photographs of the Territory exist, and copies are held in the Aerial Photograph Library of the Survey & Mapping Office. The library is located on the 14th Floor of Murray Building in the Buildings & Lands Department. Extensive coverage is available from 1963 onwards, with quite a number of vertical aerial photographs being available for the 1950's, for 1949 and 1945, with the oldest dating back to 1924. The 1924 aerial photographs were taken by a small team from the Fleet Air Arm attached to HMS Pegasus (Alderson, 1971). More than 150 frames have survived to the present day, and although only about twenty exist for the harbour area, they provide a unique insight of the Territory in the midst of the 'Roaring Twenties'. Some historical information about this early aerial photography is included in Section 8.2.4.

Vertical aerial photographs are important because they are the basis for aerial photograph interpretation and terrain classification. The Geotechnical Area Studies Programme was founded on the application of terrain classification techniques which utilise the stereoscopic interpretation of aerial photographs. Twelve stereopairs of aerial photographs demonstrate various aspects of the terrain and major geotechnical features.

In this selection of plates, particular attention is given to the disastrous landslips of the mid-1960's and early to mid-seventies, including: the Mt Nicholson landslip (1966), the Po Shan (Kotewall) Road (1972) failure and the Sau Mau Ping failures (1972 & 1976). The Sau Mau Ping failures in 1976 provided much of the impetus for the formation of the Geotechnical Control Office in 1977.

In addition to the plates illustrating slope stability and erosion on developed and natural terrain, a number of photographs describe some of the physiographic features of the Territory. A selection of old maps and photographs is included which presents an insight into the history of development since the mid-Nineteenth Century.

There are 223 plates in this Section. To assist in the location and identification of specific features and events or groups of photographs, the plates are classified according to general themes. Within each of the nine subsections, well known features or events are highlighted, and a list of all plates that fall within each theme is given in Section 8.2. Plates 1 to 8 are recent high level oblique aerial photographs which set the scene for the Report and form a recent backdrop against which the body of the plates are set. They provide a general impression of the nature of the terrain and degree of development within the Territory. Most of them were taken from an altitude of 20 000' with an RC10 aerial survey camera and present a quite unusual, and in some cases a disorienting, perspective. Each of these high level photographs covers an area of some 25 000 to 35 000 ha, and some provide rare views of the Territory. The first eight plates generally reflect the land resources of the Territory early in 1987; their orientations are shown in Figure 1. By way of contrast with the recent photographs, the reproduction of an old 1845 map at Plate 9 enables us to step back some 140 years to a time when the Territory was in its infancy. From Plate 9 onwards, the photographs are generally in chronological order, in an attempt to capture something of the impact of slope failure and the history of development in the Territory.

Each plate falls into one of the following descriptive themes:

(i) General aerial photographs that show the nature of the terrain and the intensity of recent development.

(ii) Reproductions of old maps for the period 1845 to 1911.

(iii) Terrestrial photographs dating from 1860 to 1954.

(iv) Aerial photographs dating from 1924 to 1949.

(v) Comparisons of the intensity of development between old and recent aerial photography.

(vi) Examples of landslips that affected natural terrain, squatters and areas associated with intensive development.

(vii) Comparisons of landslip sites and pre-failure terrain.

(viii) Examples of remedial works to landslip sites and other geotechnically-problematical slopes, carried out by the Geotechnical Control Office.

(ix) General photographs showing geomorphological, geological and physiographic features.

In addition, the plates are indexed according to locality and date of photography (Sections 8.3 & 8.4).

8.2 Theme Index of Plates

8.2.1 *General Nature of the Terrain and Intensity of Recent Development*

Plates—1, 2, 3, 4, 5, 6, 7, 8, 32, 33, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 117, 118, 125, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222 & 223.

8.2.2 *Maps: 1845 to 1911*

Plates—9, 11, 23 & 26.

8.2.3 *Terrestrial Photographs: 1860 to 1954*

Plates—10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 25, 27, 28, 29 & 30.

8.2.4 *Aerial Photographs: 1924 to 1949*

Plates—31, 34, 35, 36, 37, 64, 69 & 101.

Some interesting background on the 1924 aerial photographs is provided by Alderson (1971) in his account of the history of the RAF at Kai Tak. The initial aerial survey commenced when HMS Pegasus arrived in Singapore in May 1924. During the subsequent few months, photographic surveys were made of Singapore Island and southern Malaya. Apparently, the first aerial survey flight was made in the Territory on 4.11.24, a day after the arrival of the Pegasus from Singapore. The carrier had a small detachment from the newly created Fleet Air Arm and four Fairey IIID seaplanes.

The first series of missions was made from Hong Kong harbour, but the crowded conditions created by the water traffic made the operation of the float planes particularly hazardous. Consequently, the Pegasus moved to Tolo Harbour until its return to Singapore in January 1925. Although the main purpose was aerial photographic survey of the Territory, the Flight was also used, at the request of the Navy, for reconnaissance in Mirs and Bias Bay in an attempt to locate pirate hideoouts. In addition, the Flight also enabled the Governor, Sir Reginald Stubbs, to complete the first ever airborne gubernatorial progress around the Territory.

8.2.5 *Comparison of Intensity of Development on Aerial Photographs*

Plates—31, 34, 35, 36, 37, 38, 39, 40 & 41.

8.2.6 *Examples of Landslips, Erosion and Flooding Affecting Natural Terrain, Squatters and Areas Associated with Intensive Development*

(i) Tsui Ping Estate (1964)—Plates—52, 53, 54, 55 & 56.

(ii) Mt Nicholson (1966)—Plates—81, 82, 83, 84 & 85.

(iii) 1966 Rainstorms—Plates—58, 59, 60, 61, 62, 63, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 86 & 87.

(iv) Po Shan (Kotewall) Road (1972)—Plates— 94, 95, 96, 97, 98, 99, 100, 101,102, 103, 104, 105, 106 & 117.

(v) Sau Mau Ping (1972)—Plates—107, 108 & 109.

(vi) Sau Mau Ping (1976)—Plates—111, 112, 113, 114 & 115.

(vii) Caine Lane (1976)—Plate—116.

(viii) Tuen Mun Borrow Area 19—Plates—120, 121, 122, 123 & 124.

(ix) General Plates—57, 92, 93, 110, 119, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 162, 163, 164, 167, 169, 171, 172, 173, 174, 175, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199 & 200.

8.2.7 *Comparison of Landslip Sites and Pre-existing Terrain*

Plates—57, 58, 88, 89, 90, 91, 109, 192, 193, 194, 195 & 196.

8.2.8 *Examples of the Geotechnical Control Office's Remedial Treatment to Slopes*

Plates—149, 165, 166, 167, 168, 169, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188 & 189.

8.2.9 *General Geomorphological, Geological and Physiographic Features*

Plates—125, 128, 170, 200, 201, 202, 203, 204, 205, 206, 207, 209 & 213.

8.3 Locality Index of Plates

8.4 Year Index of Plates

The first eight Plates are recent high level oblique aerial photographs which provide an impression of the terrain and nature of development in the Territory. Plates 1 to 8 present different views and, in some cases, quite unique and unusual perspectives. Many of the prominent locations and features mentioned in the Report are highlighted. These photographs are part of a small collection taken at an altitude of 20 000 feet by the Air Survey Unit in aircraft of the Royal Hong Kong Auxiliary Air Force (RHKAAF). With Plate 9, we step back over 140 years to an old map produced in about 1845 showing the Territory in its infancy. The remaining 214 plates are generally in chronological sequence, and their content is described in the introduction to this Section.

Plate 1. *High Oblique Aerial Photograph Looking South across Kowloon towards Hong Kong Island in 1987.* This Plate shows the historical focus of development within the Territory. Hong Kong Island is shown at A, and the area generally referred to as Kowloon at B. Almost 70% of the Territory's population of 5.6 million (1985 Census) live within the Kowloon area and along the northern shore of Hong Kong Island. The rapid development of the seven New Towns has significantly increased the proportion of the population in the New Territories over the last decade. In 1987, approximately 1.83 million lived in the New Town areas (Government of Hong Kong, 1988). Traditionally however, the harbour foreshores have been the subject of reclamation to meet the demands for development. There is approximately 1 600 ha of reclamation fringing Victoria Harbour. The rate of reclamation has dramatically accelerated since the mid-1960's, and it is estimated that this now represents some 24% of the developed terrain within the Territory. Development has been forced to encroach on the Harbour because of severe limitations on the availability of undeveloped usable land. The developed areas are generally bounded on the landward side by steep, rugged terrain. In the Territory, some 70% of the terrain is steeper than 15° in slope gradient, 45% is affected by high to extreme geotechnical limitations and there is evidence of landslips and slope instability on 22% of the total landmass. Superimposed on this geotechnically-problematical terrain is an annual rainfall in the order of 2 250 mm, mostly occurring as intense rainstorms during the period May to September. As an example, in a single rainstorm during June 1983, some 263 landslips were reported in the Hong Kong Island and Kowloon areas alone. This storm produced the most intense 5hr rainfall (274.4 mm) since June 1966. Some of the disastrous effects of the 1966 rainstorms are depicted in Plates 58 to 87. It is within this context of steep terrain, high rainfall and intense demand for rapid expansion that development has occurred within the Territory. The approximate position of the camera when this photograph was taken is depicted on the map at Figure 1. Compare this Plate with Plate 51, taken from a similar position in 1979. (5.1.1987/A08547).

Plate 2. *High Oblique Aerial Photograph Looking Southeast across Hong Kong Island in 1985.* This Plate highlights the intensive development along the coastal areas of Hong Kong Island. The central core of the Island is composed of steep terrain, with Victoria Peak rising to an elevation of 554m (A). There are large tracts of undeveloped land which are allocated as Country Park and water storage catchment. Disastrous slope failures have occurred in a number of locations on Hong Kong Island. Probably the most significant are associated with the intensively developed Mid-levels District, where much of the terrain is in the 15–30° slope range. During the period 1979 to 1983, the Mid-levels area was the subject of intensive geotechnical investigation. The sites of the Po Shan (Kotewall) Road Landslip in 1972, and the Po Hing Fong Landslip in 1925, are shown at B and C respectively. The camera position for this photograph is shown on the map at Figure 1. (4.10.85/A02895).

Plate 3. *High Oblique Aerial Photograph Looking Northeast across the Kowloon Peninsula towards Sha Tin and Tolo Harbour in 1987.* This Plate highlights the intensive development of the low-lying Kowloon Peninsula. Many of the granitic hills on the peninsula were removed for reclamation during the early years of the Territory. Sha Tin (A) is one of seven New Town development areas and its population is estimated to rise from a 1987 level of 460 000 to 750 000 by 1995. Tolo Harbour and Tai Po New Town are shown at B and C respectively. The areas of intensive development in Sha Tin, Tsuen Wan (D) and Kowloon are constrained by the steep, mountainous terrain which forms the Kowloon Hills. Fei Ngo Shan (602m), Tate's Cairn (577 m), and Beacon Hill (452 m) are at E, F and G respectively. Large areas of the footslope terrain below the Kowloon Hills have been the subject of considerable geotechnical investigation as part of the public housing programme. Detailed terrain classification mapping has been completed on these areas within the GASP District Stage 1 Studies. Site formation for the Junk Bay New Town is evident at H, and large areas of undeveloped terrain are apparent around Port Shelter (I). The highest peak in the eastern part of the Territory is Ma On Shan (J) with an elevation of 702m. The camera position for this photograph is shown on the map at Figure 1. (5.1.1987/A08574).

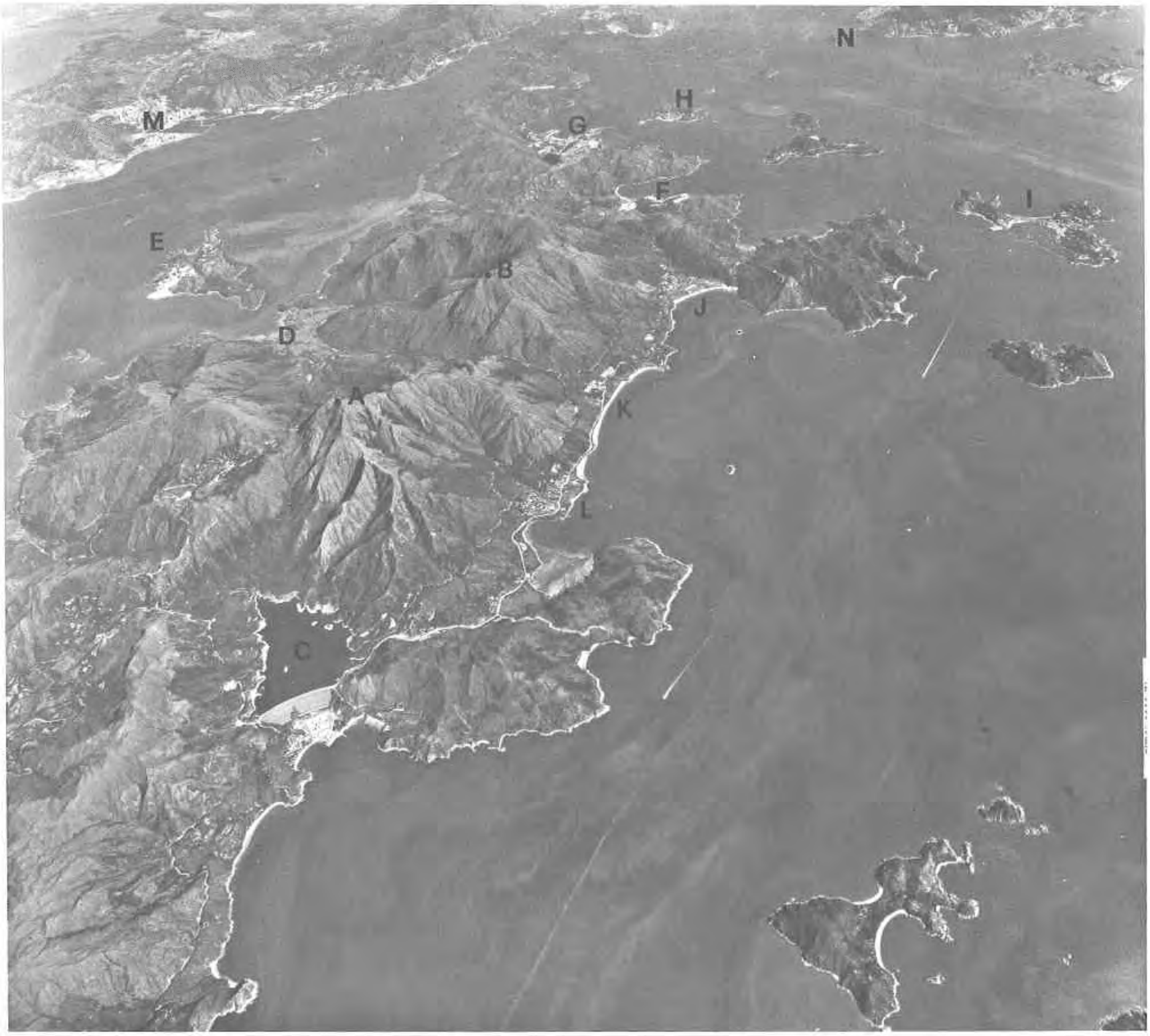


Plate 4. *High Oblique Aerial Photograph Looking Northeast along the Coast of South Lantau Island in 1987.* This Plate highlights the relatively undeveloped terrain of Lantau Island. Much of the rugged terrain in the southern half of the island is designated as Country Park. The central spine rises to elevations of 934 m at Lantau Peak (A) and 869 m at Sunset Peak (B). Shek Pik Reservoir is at C, Tung Chung at D, Chek Lap Kok at E, Silvermine Bay at F, the large residential development of Discovery Bay at G and the islands of Peng Chau and Cheung Chau at H and I respectively. Further development is planned along the southern coastline between Pui O (J), Cheung Sha (K) and Tong Fuk (L). Tuen Mun is approximately 20 km away at M, and the western side of Hong Kong (N) is some 25 km away. The camera position for this photograph is shown on the map at Figure 1. (5.1.1987/A08364).

Plate 5. *High Oblique Aerial Photograph Looking Southeast across the Plover Cove Reservoir and Tolo Channel towards Sha Tin and Tai Po in 1987.* This Plate provides a very unusual view of the Territory from the east. Plover Cove Reservoir is at A, Tolo Channel at B, Sha Tin at C and Tai Po at D. Much of the terrain in this sector is designated as Country Park and water catchment. Port Shelter is at E, the town of Sai Kung at F, and Tap Mun Chau and Port Island are at G and H respectively. The Fanling Sheung Shui New Town is at I, Yuen Long (J) is some 40 km away and Hong Kong Island (30 km distant) is at K. The camera position for this photograph is shown on the map at Figure 1. (5.1.1987/A08496).

Plate 6. *High Oblique Aerial Photograph Looking East across Tai Po towards the Plover Cove Reservoir and Tolo Harbour in 1987.* This Plate, viewed from the west of Tai Po (A), looks across Tolo Harbour (B) towards the Plover Cove Reservoir (C). A large area of the foreshore has been reclaimed for the construction of Tai Po New Town (Plates 49 & 50). The Chinese University of Hong Kong is located at D, with Ma On Shan (702 m) at E. Fanling is at F, Starling Inlet at G and Sha Tau Kok at H. The Pat Sin Range forms the east-west striking ridge at I, with a maximum elevation of 511 m. Robin's Nest (492 m) at J, is slightly lower. The camera position for this photograph is shown on the map at Figure 1. (5.1.1987/A08535).

Plate 7. *High Oblique Aerial Photograph Looking Northeast across Ma On Shan towards Sai Kung and Port Shelter in 1987.* This Plate, taken from above the Sha Tin valley, looks across the Ma On Shan Country Park toward Sai Kung (A) and Port Shelter (B). Ma On Shan (702 m) is at C, Hebe Haven at D, the Clear Water Bay Peninsula at E, and site formation works for the Junk Bay New Town at F. The largest area of slope failure in the Territory, associated with the old mine site at Ma On Shan, is at G (Plate 128). The camera position for this photograph is shown on the map at Figure 1. (5.1.1987/A08544).

Plate 8. High Oblique Aerial Photograph Looking East across the Tuen Mun and Yuen Long Districts towards Tsuen Wan and Kowloon in 1987. This Plate views the Territory from above Black Point in the far west. Tuen Mun is at A, Yuen Long at B, Tsuen Wan at C and Kowloon (30 km away) at D. The highest point in the Territory is some 25 km away at Tai Mo Shan (975 m, at E). Much of the hilly granitic terrain occurring in the west of the Territory is affected by erosion which is indicated by the bright tones on the hillcrests and ridgelines (e.g. at F). Major geotechnical problems arose during the development of the footslope terrain at G, below Castle Peak (583 m, at H) (Plates 120–124 & 126). Further geotechnical issues arose following confirmation of areas of cavernous marble beneath parts of the Yuen Long plain (I) during the remapping of the geology of the District. The camera position for this photograph is shown on the map at Figure 1. (5.1.1987/A08473).

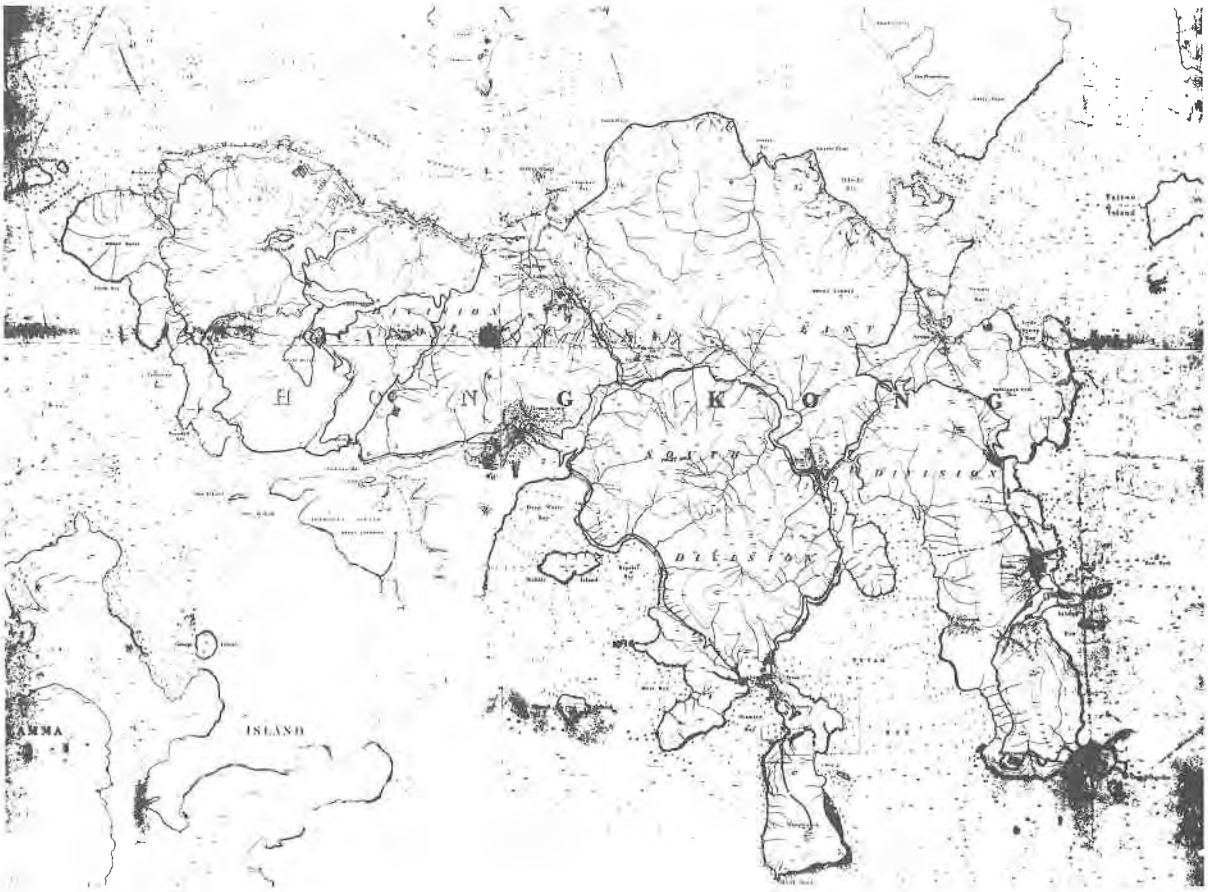


Plate 9. *Map of Hong Kong in 1845.* With this old map we step back over 140 years to a time when the Territory was in its infancy. This map shows the early stages of development and was produced by Lt. Collinson. The original is at a scale of 4 inches to 1 mile. (SMO/HE9/Neg. 318).

Plate 10. *Reclamation on the Northern Shore of Hong Kong Island in 1860.* From the earliest times in the Territory, reclamation was used to assist in the formation of level ground. The site of the Garrison Parade ground, near Murray Barracks, was also used for recreational activities. (PRO 1/14/378).

Plate 11. Plan of Victoria City in 1867. The original scale is 1 inch to 160 feet. (SMO/HM43/Neg. 374).

Plate 12. Victoria Waterfront Looking West towards the Central District, circa 1865. The barren, bouldery slopes below Victoria Peak are clearly evident. (PRO 1/5/128).

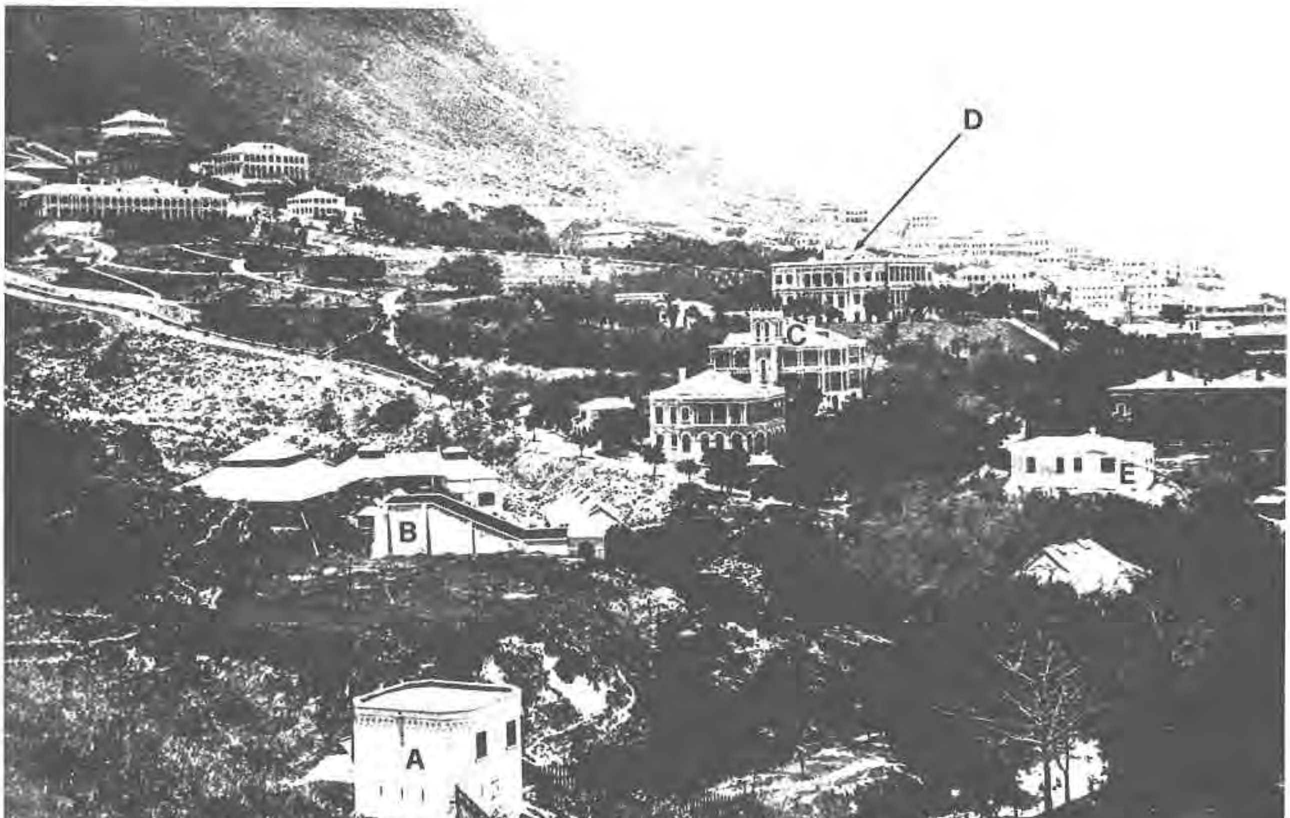


Plate 13. View of the Mid-levels District Looking West from Murray Barracks, circa 1868. In the foreground is the 'White Tower' (A) and Army racquet court (B). Across Garden Road is the residence of the Manager of the Hong Kong and Shanghai Banking Corporation (C), Government House (D), and the Drill Hall of the Volunteers (E). Eroded, barren slopes below Victoria Peak are evident in the background. (PRO/1/15/404).

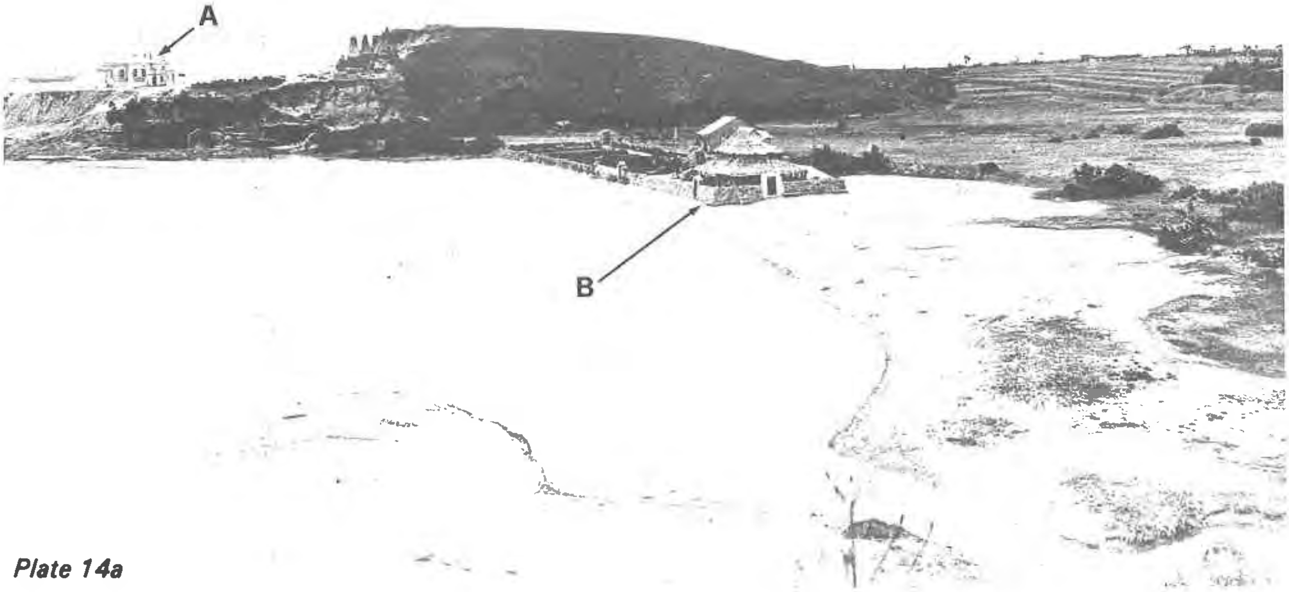


Plate 14a

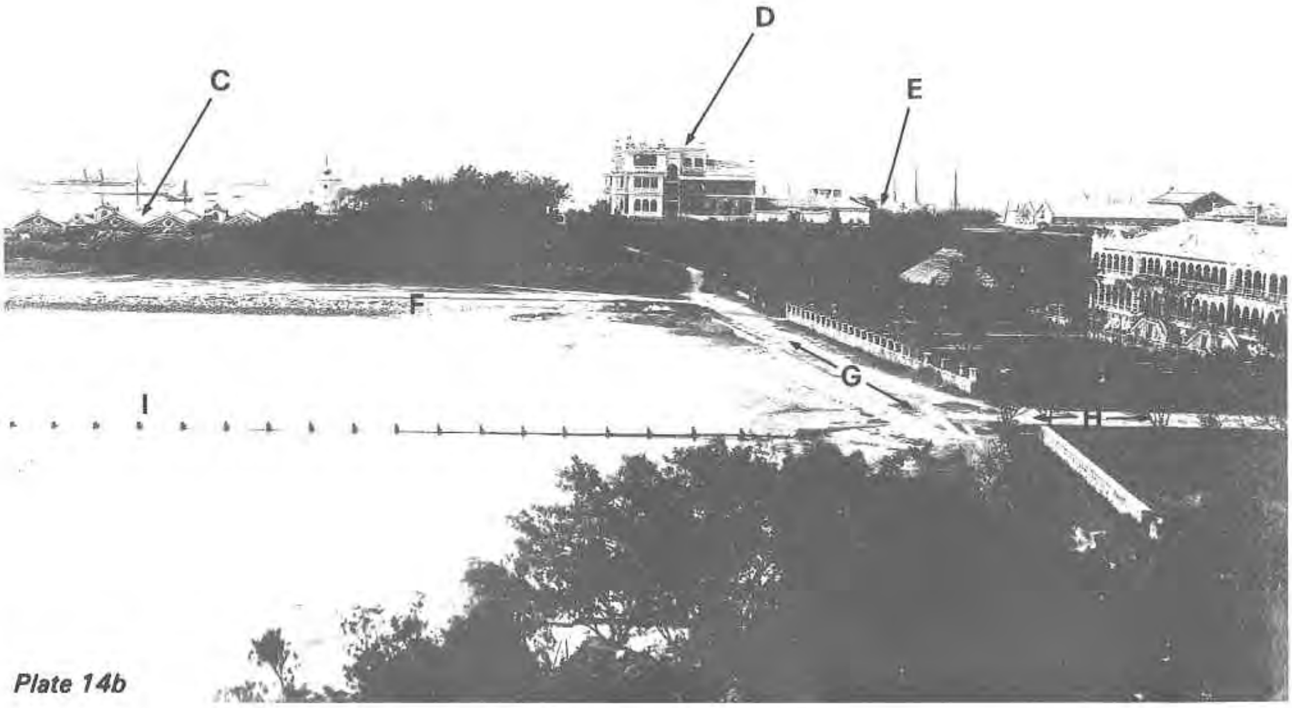


Plate 14b

Plate 14. *Southern Tip of the Kowloon Peninsula Looking West, circa 1868 and 1898.* In Plate 14a, the old Police Post (A) is on a quite severely eroded and deeply weathered cut platform. The matshed compound (B) is in the approximate position of Middle Road. Plate 14b is taken from a similar position about 30 years later (circa 1898). The roofs of the godowns located along the southern end of Canton Road are evident at C, the Marine Police Headquarter is at D, and the cut platform apparent in 1868 has been extended to the north (E). Considerable reclamation has occurred along the western side of the bay (F), and the general position of Middle Road is shown at G. The location of Nathan Road, then known as Robinson Road, is at H. The bay was further reclaimed to provide the present sites of the Peninsula Hotel (I). Compare this with Plates 32 & 33. (Plate 14a: PR03/2/25. Plate 14b is reproduced with the permission of the Museum of History, Urban Council: P72.1).

Plate 15. *Bowrington Canal and Leighton Hill from Morrison Hill, circa 1868.* The severely eroded granitic slopes of Leighton Hill (A) is probably associated with excavation for the nearby reclamation. At the time, this area was known as East Point. (PRO 1/8/211).

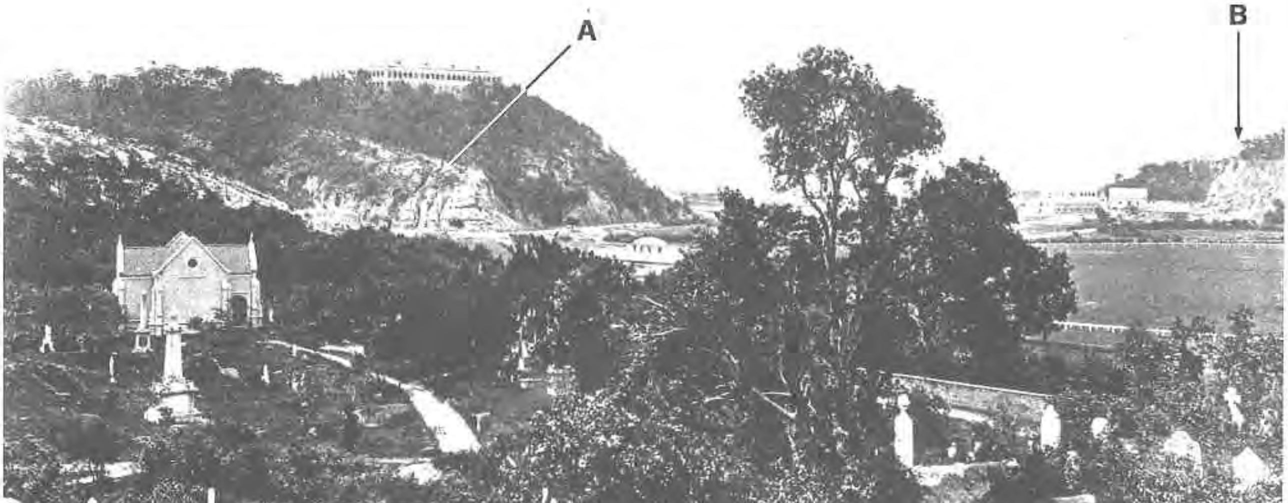


Plate 16. *Morrison Hill and East Point from the Cemetery in Happy Valley, circa 1868.* The severely eroded granitic slopes of Morrison Hill and Leighton Hill are apparent at A and B respectively. (PRO 1/8/210).

Plate 17. *View of Victoria from North Point, circa 1868.* The approximate alignment of King's Road is evident along the shore in the foreground (A) and Kellett Island is at B. (PRO 1/7/184).

Plate 18. *Botanical Gardens Looking South towards the Albany, circa 1868.* The steep mid-slopes and footslopes of Victoria Peak are bouldery, eroded and possess only a sporadic grassy vegetation cover. (PRO 1/7/189).

Plate 19. *Flood Damage and Debris in Pedder Street, circa 1879.* This view was taken looking north along Pedder Street towards the harbour following a severe rainstorm. The old Clock Tower evident at A was demolished in the early years of this century. This Plate is reproduced with the permission of the Museum of History, Urban Council (P68.31).

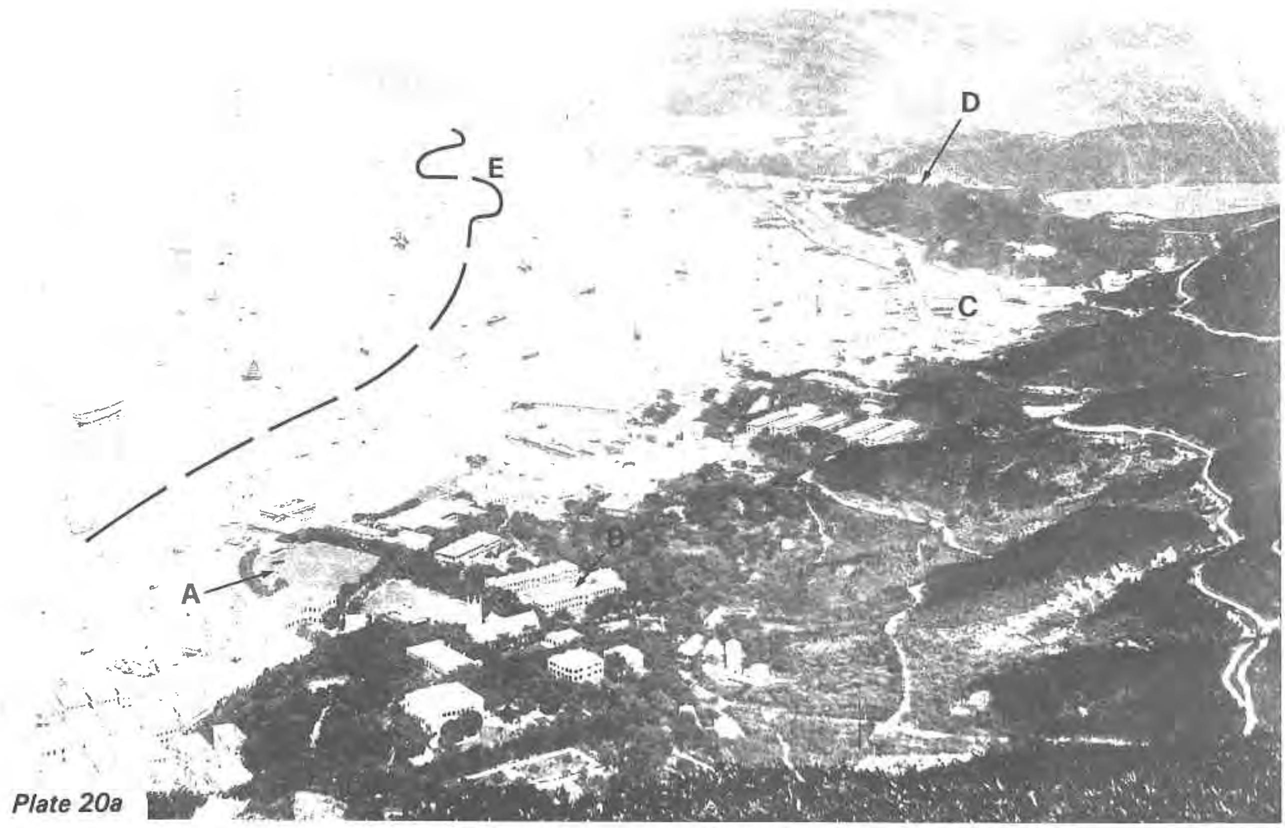


Plate 20a

Plate 20b

Plate 20. *Northern Shore of Hong Kong Island, circa 1880 and 1988.* Some 108 years span these photographs, taken from the northern side of Victoria Peak. In 1880, Plate 20a, note the area of reclamation (A) used as a military 'parade' and Cricket Ground, Murray Barracks (B), Wan Chai area (C) and Morrison Hill (D). Kellett Island, and the approximate line of current reclamation (1988) is shown at E. Plate 20b is taken from Mt Austin and provides a similar perspective in 1988. (PRO 1/5/108 & GCO/TP/91–8).

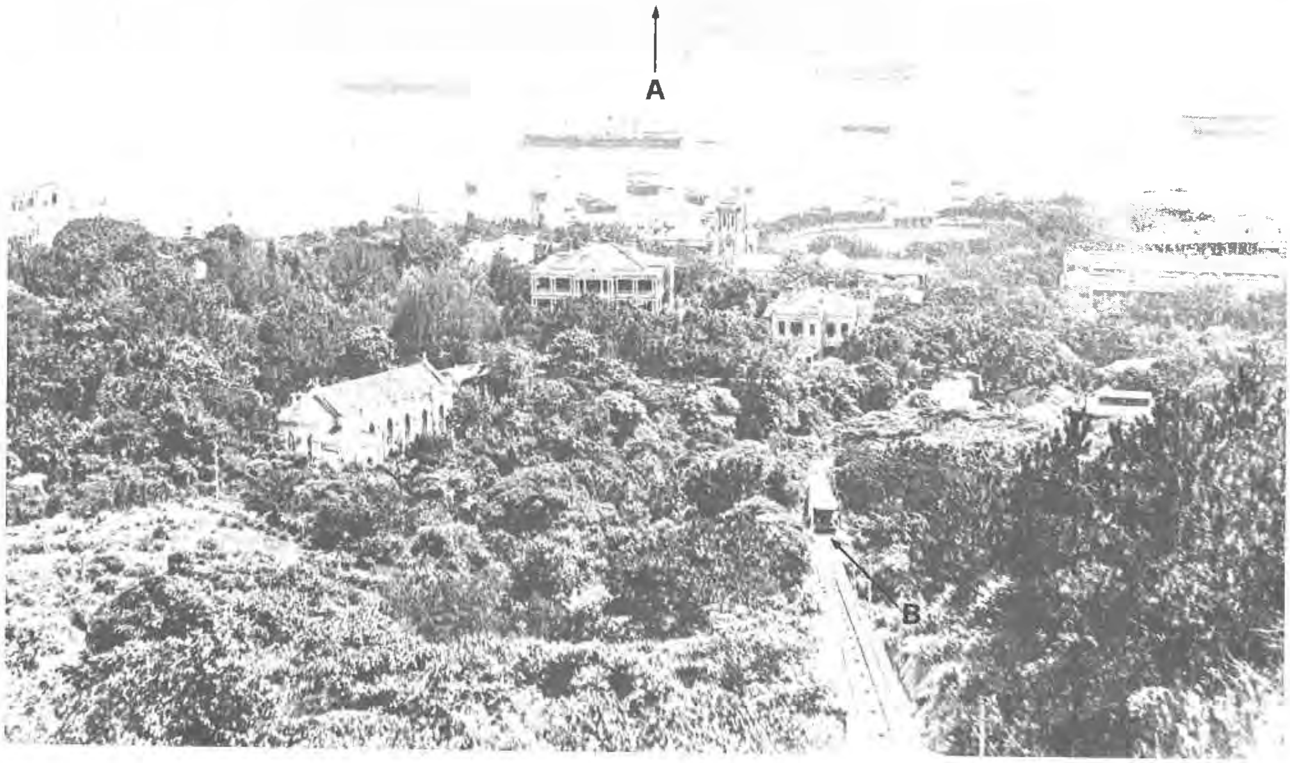


Plate 21. *Central District and the Harbour from the Mid-levels, circa 1890.* Note the eroded granite hills in the Kowloon area (A) and Peak Tram in the foreground (B). The Peak Tramway commenced operation in 1888. (PRO 1/14/390).

Plate 22. *Kowloon City from the Landing Pier, circa 1898.* The walls on the hillside (A) define the boundary of the Kowloon Walled City. Compare this with Plates 40 & 220. (PRO 3/3166).

Plate 23. *Ordnance Map of Hong Kong in 1896.* The original scale is 4 inches to 1 mile. The base map appear to be Collinson's 1845 edition which has been updated to 1896. Unfortunately, the dates in the title are misleading. (SMO/ HE11/Neg. 59).

Plate 24. *Victoria Waterfront near Sai Ying Pun, circa 1905.* (PRO 1/4/105).

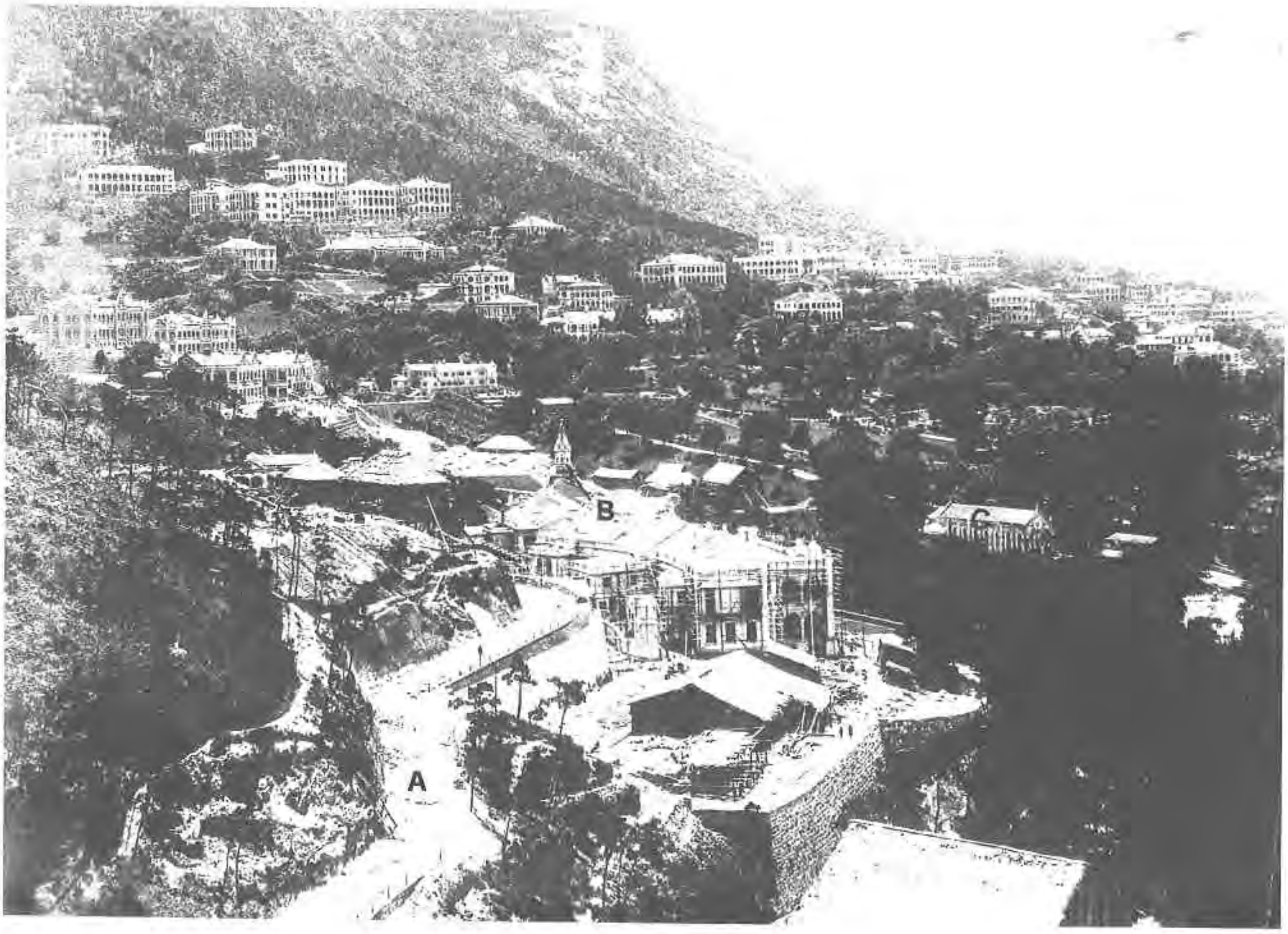


Plate 25. *View of the Mid-levels from above MacDonnell Road, circa 1905.* MacDonnell Road is under construction (A), the Union Church Spire (B), and St. Joseph's Church (C) are also evident. (PRO 1/3/65)

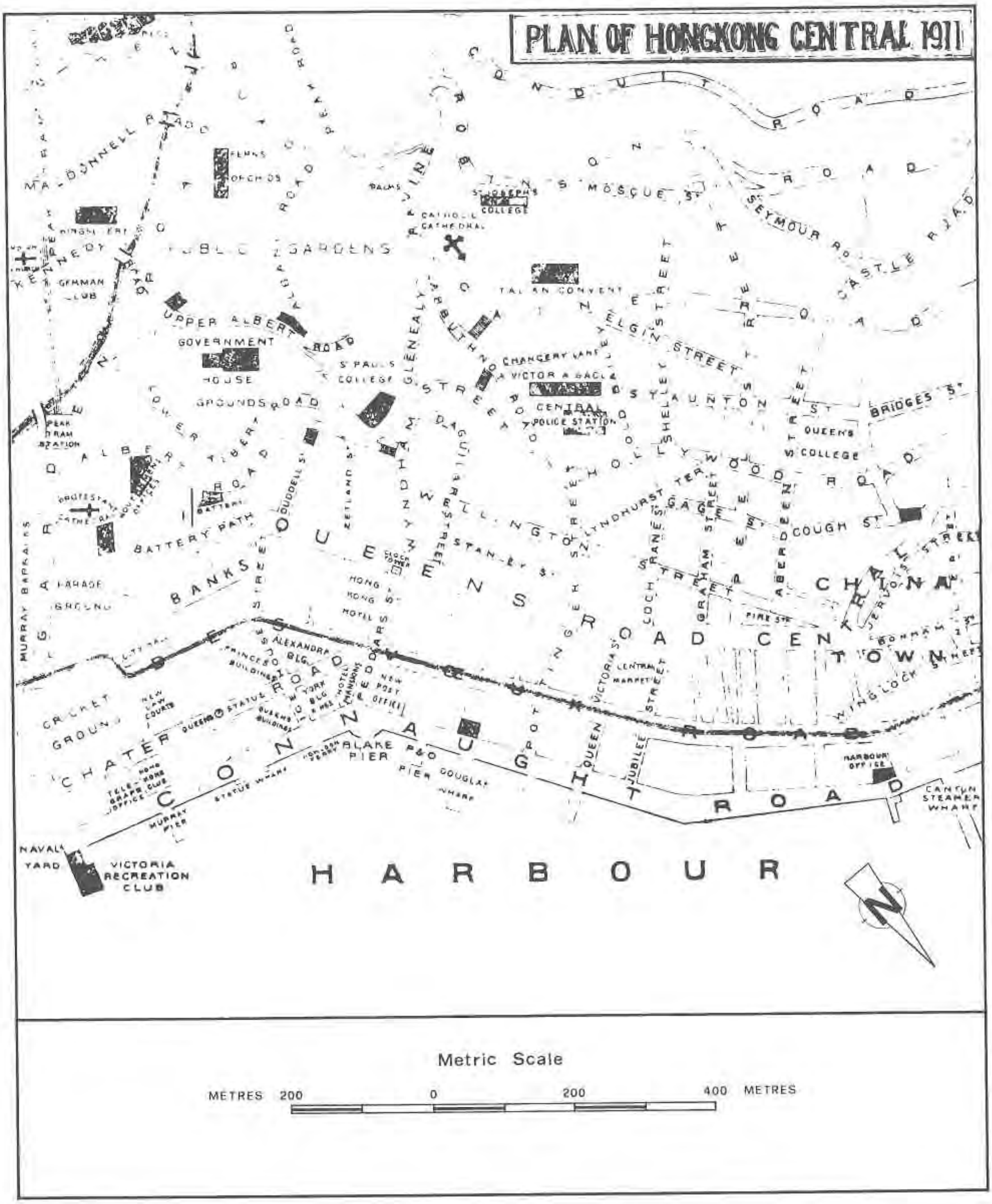


Plate 26. *Plan of the Central District of Hong Kong in 1911.* The original scale is 4 inches to 1 mile. (SMO/HM71/Neg. 58).

Plate 27. *Floodwaters on the Western Side of Happy Valley in 1923.* Rock and boulder debris has been washed downslope from the cemetery and the drainage nullah at A has overflowed. (PRO 1/4/94).

Plate 28. *Oblique Aerial Photograph Looking across the Northwestern Portion of Hong Kong Island, circa 1930.* In a rare early example of oblique aerial photography, this Plate shows the extent of development in the Central, Mid-levels and Western areas. The site of the Po Hing Fong landslip, which claimed in excess of 200 lives in 1925, is circled at A. The old City Hall is at B (partially demolished in 1932), the Hong Kong and Shanghai Bank Building is at C, and the Chater Road ground of the Hong Kong Cricket Club is at D. This Plate is reproduced with the permission of the Museum of History, Urban Council (P68.258).

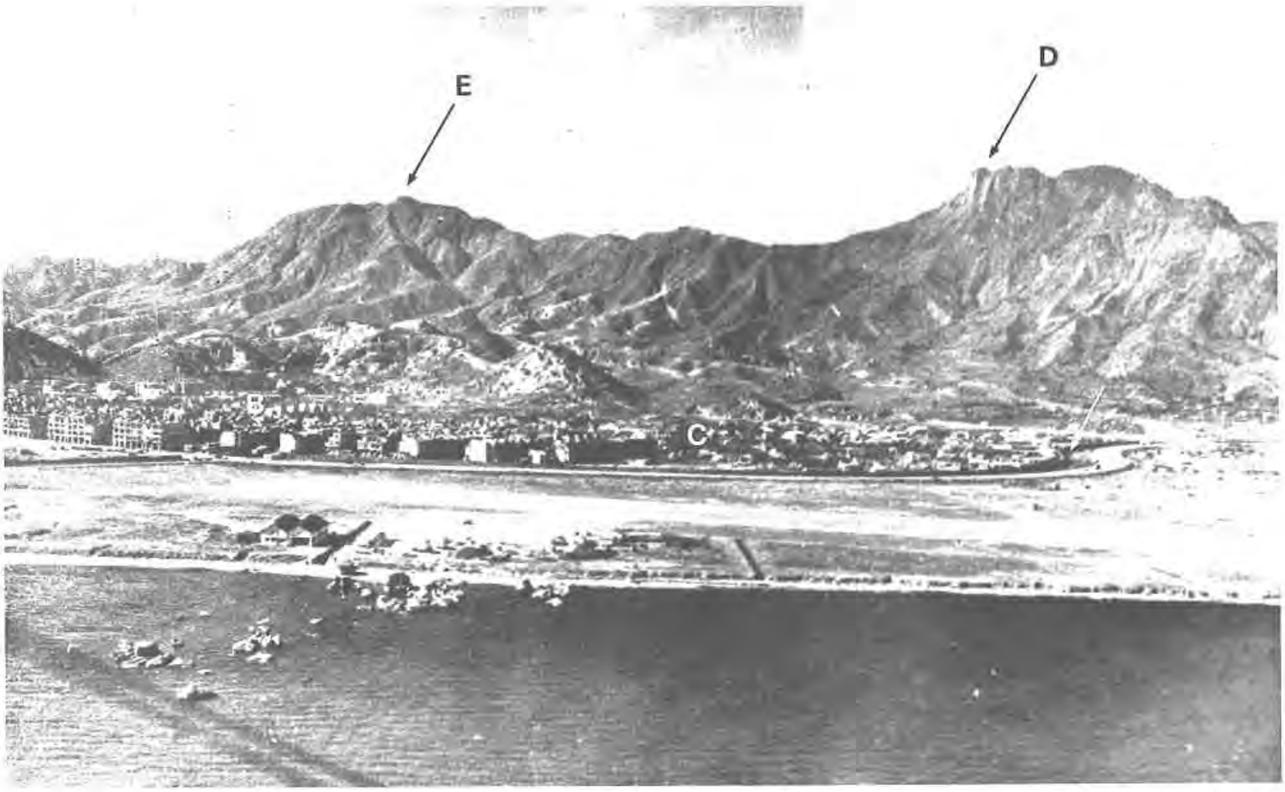


Plate 29. *Kai Tak Airfield in 1947.* The main runway is oriented in an east to west direction and a large nullah (A) drains the low-lying terrain to the north of the airfield. The Kowloon City area is at B and San Po Kong at C. Lion Rock (D) and Beacon Hill (E) are evident in the background. (PRO 3/1/14(f)).

Plate 30. *Waterfront of the Central District in 1954.* In this Plate, the shoreline is dominated by 5 to 7 storey buildings. Some 35 years later the harbourscape has changed dramatically, with an almost continuous belt of skyscrapers from Causeway Bay to Sai Ying Pun. Government House is evident at A and the Hong Kong and Shanghai Bank Building is at B. (PRO 1/2/372).

Plate 31a

Plate 31b

Plate 31. *Comparative Aerial Photographs of the Central and Mid-levels Area on Hong Kong Island in 1924 and 1958.* Plate 31a illustrates the intensity of development on 12.11.1924. The waterfront is approximately in the position of Connaught Road. There is evidence of fill slopes (A) on Po Shan Road in the area affected by the landslip in 1972 (cf Plate 101b). The aerial photographs taken in 1924 are the earliest known vertical aerial photographs of the Territory. They were taken by a small group from the Fleet Air Arm operating off HMS Pegasus, in Hong Kong waters from early November 1924 to January 1925. Further information on these old photographs is given in Section 8.2.4. Plate 31b illustrates the amount of reclamation in the intervening 60 years. The remedial works to the Po Shan Road landslip are indicated at D. A number of other major landslips have occurred in the area, in particular the failure at Po Hing Fong (B) at about 9.30 a.m. on 17.7.1925, and of the retaining wall at Caine Lane (C) in August 1976. Newspaper reports in 1925 estimated that in excess of 200 fatalities resulted from the Po Hing Fong landslip. The Po Hing Fong failure occurred during a period of heavy rainfall. Apparently three masonry retaining walls situated one above the other collapsed and demolished a row of seven 3-storey houses. This disaster, and the resulting Coroner's Inquiry, were widely reported in the Press at the time. The Caine Lane retaining wall failure on 25.8.1976 caused the evacuation of some 400 people (cf Plate 116). (12.11.1924/H19/9 and 4.10.1985/A02620).

Plate 32. Oblique Aerial Photograph of the Tsim Sha Tsui Area Looking Northwards along Nathan Road in 1978. The Planetarium (A), New World (C) and Regent (D) Hotels are under construction. The site of the Cultural Centre is at B. (24.1.1978/21042).

Plate 33. Oblique Aerial Photograph Looking Northeast across Tsim Sha Tsui in 1983. Compare this with the photograph circa 1868 at Plate 14. The approximate location of the Police Post in 1868 is shown at A, and the position of the 'Mat Shed Compound' at B. The Planetarium is taking shape at C. (4.5.1983/48513).

Plate 34. *Comparative Aerial Photographs of the Tsim Sha Tsui Area in 1945 and 1980.* The location of Nathan Road (A), Chatham Road (B), Gascoigne Road (C), Jordan Road (D) and the Kowloon-Canton Railway Terminal (E) are indicated on the 1945 photograph. Hilly, severely eroded granitic terrain is apparent in the vicinity of Wiley Road and the Ho Man Tin area in 1945 (F). By comparison, the area in 1980 has been extensively redeveloped, and a large area (G) to the east of Chatham Road has been reclaimed from the harbour. (11.11.1945/3025 and 28.11.1980/33441).

Plate 35. *Comparative Aerial Photographs of the Kwun Tong and Sai Tso Wan Area in 1945 and 1983.* Note the severe erosion on the granitic terrain, sediment plumes in the bay (A) and the line of the sea wall (B) in the 1945 photograph. By 1983, the bay has been reclaimed and intensively developed up to the line of reclamation evident in 1945 (C). The Sai Tso Wan Landfill is shown at D. (10.11.1945/681–5/4146 and 24.1.1983/47140).

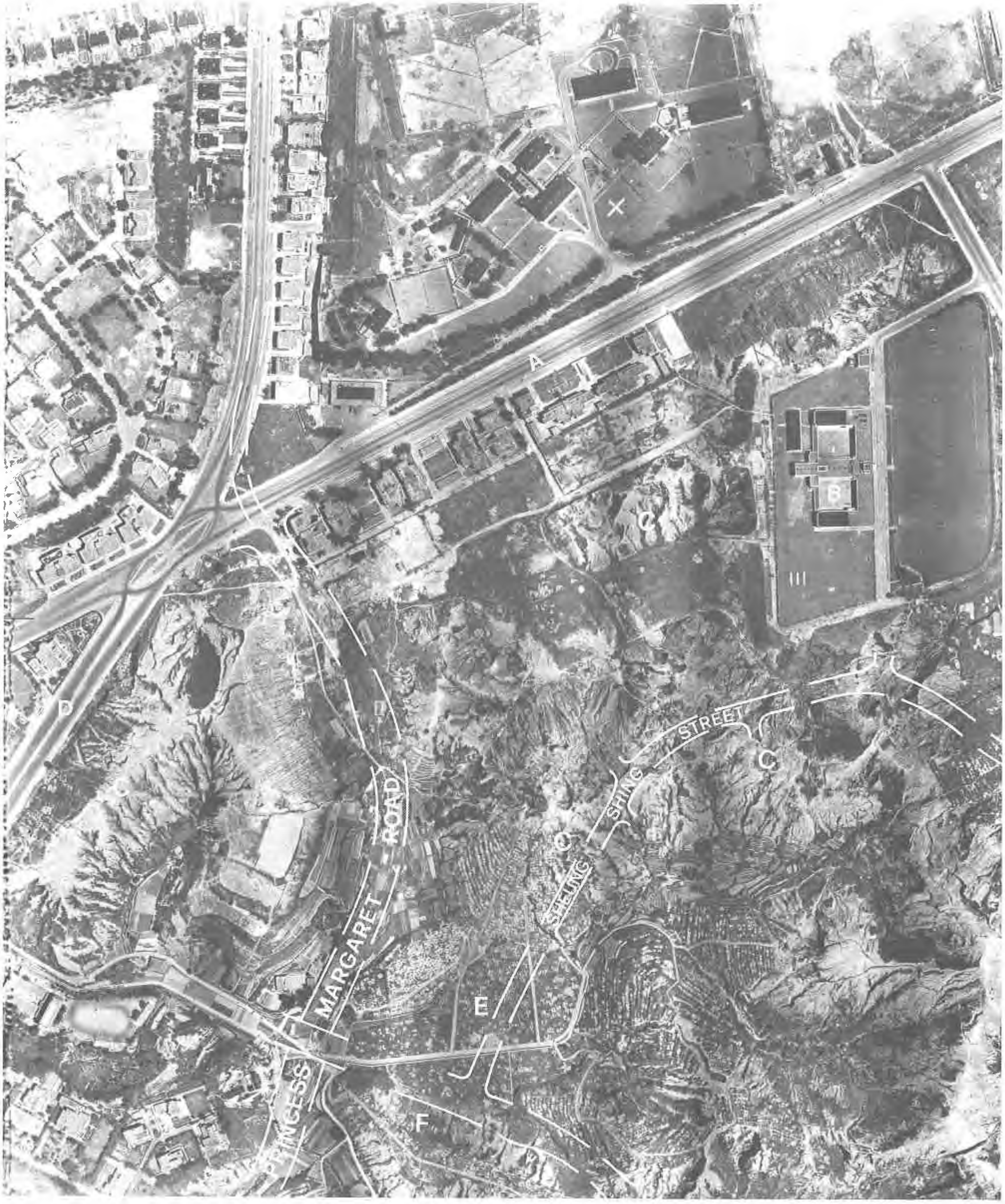


Plate 36. Aerial Photograph of the Ho Man Tin and Argyle Street Area in 1949. This plate illustrates the deeply weathered granitic terrain in the Ho Man Tin area. Argyle Street is shown at A, King George V School at B, severely weathered and eroded granitic terrain at C, and Waterloo Road at D. This frame shows the exhumation of grave sites in the Chinese Cemetery (E) and the approximate location of the old Smallpox Hospital (F). The general alignments of Princess Margaret Road and Shing Sheung Street are indicated as broken lines. (24.4.1949/81A/117/6146).

Plate 37. *North Point in 1949.* The extensive, orderly pattern of squatter development (A) on the granitic terrain on the eastern side of King's Road (B) is quite evident. (8.5.1949/81A/128/6027).

Plate 38. *Comparative Aerial Photographs of North Point, Causeway Bay, Happy Valley and Wan Chai in 1972 and 1985.* Plate 38a shows the state of development in 1972. The areas of reclamation associated with the Cross Harbour Tunnel entrance and development of Wan Chai are evident at A and B respectively. Major earthworks are in progress for the relocation of the Hong Kong Cricket Club from Chater Road to Wong Nai Chung Gap (C). Significant changes have occurred in the intervening 13 years as Plate 38b illustrates: multi-storey tower blocks on the Wan Chai reclamation (D); the completion of the Aberdeen Tunnel and associated infrastructure (E); construction of the Island Eastern Corridor (F); and extensive development along the Broadwood Road area (G). An oblique view of the area is presented in Plate 43. (3 10 1972/2305 and 4 10.1985/A02618).

Plate 39a

Plate 39b

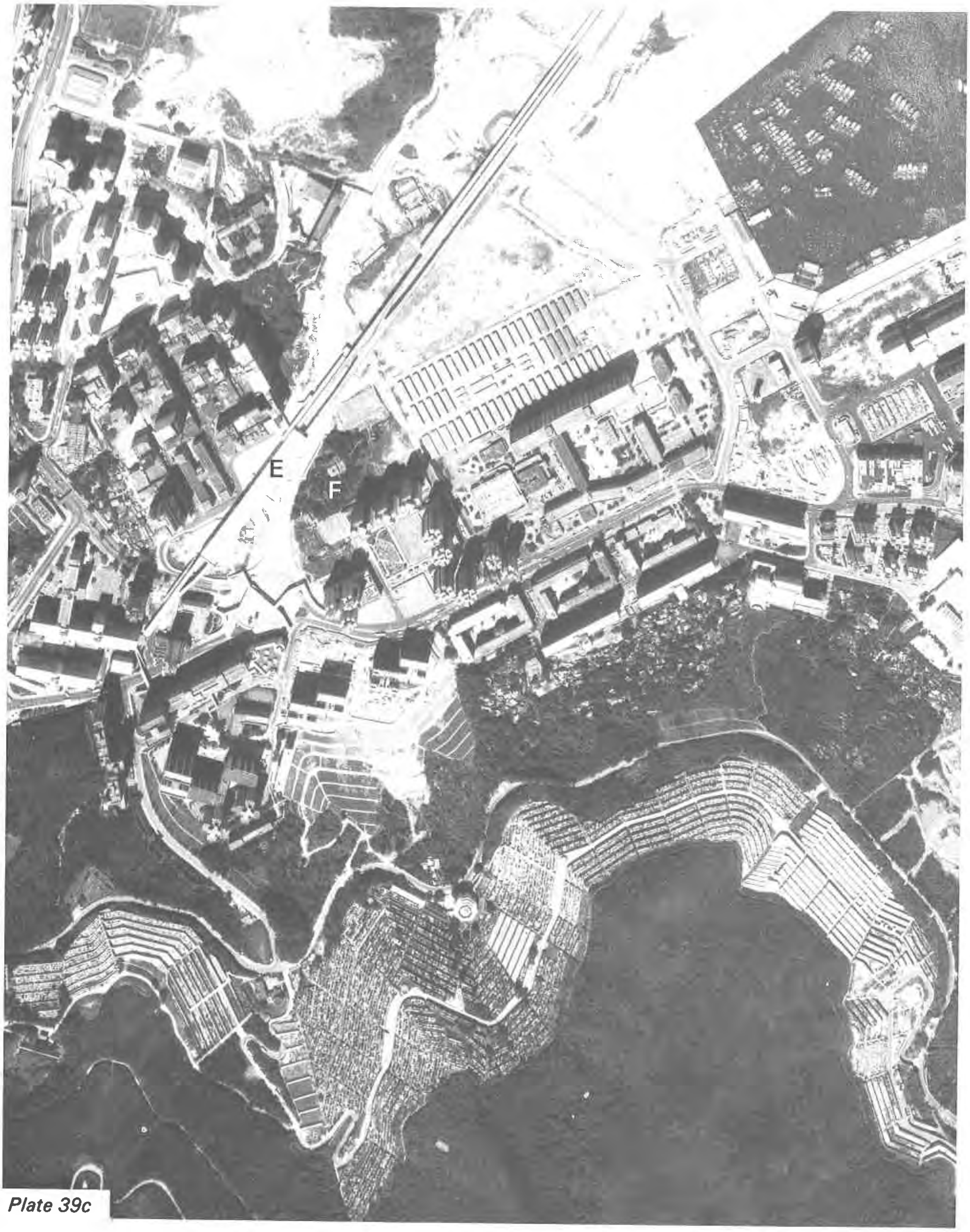


Plate 39. *Comparative Aerial Photographs of the Chai Wan Area in 1961, 1973 and 1985.* In 1961, the first housing estate blocks are being constructed and some reclamation is evident in the bay. The island is clearly evident at A, the War Cemetery at B, and the Licensed Areas at C. By 1973, extensive reclamation is apparent, although the island is still discernable at D. In 1985, there has been further reclamation, the infrastructure for the Mass Transit Railway (MTR) is in place (E) and only a small portion of the island remains (F). This area is featured in the Insets at Figures A8a to A14b in Appendix A, which are used to demonstrate the GASP terrain classification mapping system. (17.1.1961/F43-81A/0119, 24.10.1973/5460, 4.10.1985/A02615).

Plate 40a

Plate 40b

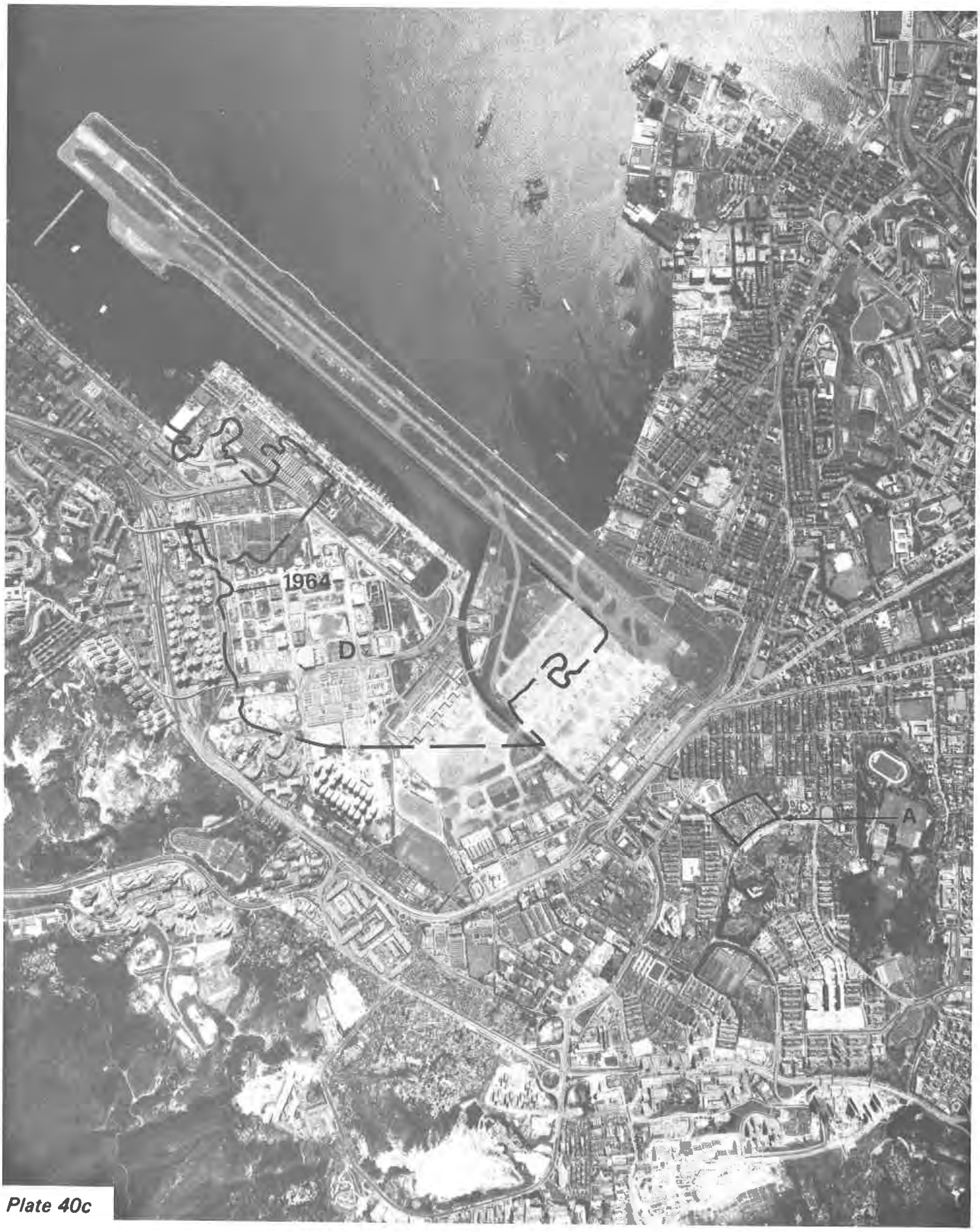


Plate 40c

Plate 40. ***Comparative Aerial Photographs of the Kai Tak Area in 1954, 1964 and 1985.*** **In 1954, the dual** runway system is evident on an area of general reclamation. The Kowloon 'Walled City' is highlighted at A on each photograph. By 1964, the old runway configuration has been superseded by the current '130–310' layout which extends some 2 500 m into the harbour. In addition, substantial reclamation has occurred in the Kowloon Bay (B) and To Kwa Wan areas (C), immediately to the east and west of the new runway respectively. The 'Walled City' has developed since 1954 into the multi-storied conglomeration of structures apparent in 1985. By 1985, further reclamation is evident to the east of the runway (D). (18.11.1954/18A/552/0108, 1964/2606, 4.10.1985/A02661).

Plate 41. *Comparative Aerial Photographs of the Lei Yue Mun Area in 1963 and 1986.* Extensive reclamation and site formation has occurred around the bay. (1963/6085 and 3.3.1986/A04261).

Plate 42. High Oblique Aerial Photograph Looking East across Hong Kong Island in 1983. This photograph offers a similar perspective to that in Plate 2, which was taken 2 years later. Large areas of reclamation are underway along the harbour foreshores (A) and at Sandy Bay (B). A number of features of geotechnical significance are evident. The location of the Po Shan Road Landslip is at C (Plates 94 to 106), the site of a large reconstructed fill slope on Pok Fu Lam Road at D (Plate 165), and the site of the landslip in Pok Fu Lam Cemetery is at E (Plate 136). Victoria Peak is at F and Mt Davis at G. (11.2.1983/48137).

Plate 43. Oblique Aerial Photograph of the Wan Chai, Happy Valley and North Point Areas in 1983. The Wan Chai, Happy Valley and North Point areas are at A, B and C respectively. Mt Butler Quarry is at D, Mt Nicholson is at E, the location of the 1966 landslip at Victoria Flats (Plates 81 to 85) is at F. Plate 38 compares the degree of development of this area between 1972 and 1985. (17.2.1983/48137).

Plate 44. ***High Oblique Aerial Photograph of the Eastern Kowloon and Junk Bay Areas in 1983.*** The public housing estates in eastern Kowloon and the general area of the Junk Bay redevelopment are highlighted at A and B respectively. Sai Kung is at C, Port Shelter at D and Hebe Haven at E. The High Island Reservoir is at F and Rennie's Mill is at G. The Junk Bay Tunnel exits at H, and the location of the Junk Bay landfill failure is at I (Plates 159 & 160). The Anderson Road Quarries are at J (Plates 211 & 217). Most of the undeveloped terrain in the area is Country Park. (16.5.1983/48777).

Plate 45. ***High Oblique Aerial Photograph Looking West across Port Shelter towards Sha Tin and Tolo Harbour in 1983.*** This photograph provides a southwesterly view across Port Shelter (A), Hebe Haven (B) and Sai Kung (C). Sha Tin New Town is at D and Tolo Harbour at E. Kai Tak runway is at F. (16.5.1983/48622).

Plate 46. ***High Oblique Aerial Photograph Looking Southeast across Tai Po towards Sha Tin in 1983.*** This photograph views Tai Po (A) and Sha Tin (B) from the north. Kowloon and Hong Kong Island are at C and D respectively. Ma On Shan (E) is the highest peak in the area, with an elevation of 702 m. The current population of Tai Po is about 150 000 and this is expected to increase to some 290 000 by the mid-1990's. In comparison, Sha Tin has absorbed approximately 460 000 people since development commenced some 15 years ago, and it's population is likely to reach 750 000 by 1995. Development is encroaching onto the steeper terrain along the valley footslopes. Compare this with Plates 49 & 50. (16.5.1983/48639).

Plate 47. ***High Oblique Aerial Photograph Looking Southwest towards Deep Bay in 1983.*** **Fanling is** evident at A, Sheung Shui at B, Sek Kong airfield at C and Yuen Long at D. The population of Fanling New Town is about 110 000 and is expected to double by 1995. Yuen Long New Town is expected to increase from it's current population of 111 000 to 180 000 during the same period. Deep Bay is at E, Tsim Bei Tsui at F and the Shum Chun River is at G. The peaks of Kai Keung Leng (572 m) and Tai To Yan (560 m) are at H and I respectively. (16.5.1983/48640).

Plate 48. ***Oblique Aerial Photograph Looking North across Tuen Mun towards Deep Bay in 1980.*** The population of the Tuen Mun area is about 300 000 and is expected to increase to 500 000 by 1995. The rapid expansion of the Tuen Mun New Town area has created considerable pressure for development on the steeper terrain flanking the valley. Many of the natural landforms in the area show evidence of previous slope instability; this is especially apparent on the footslopes. Geotechnical problems have occurred in a number of borrow areas. Tuen Mun Borrow Area 8 is evident at A; instability associated with this area is shown in Plate 126. (13.6.1980/30699).

Plate 49. ***High Oblique Aerial Photograph Looking Northwest across Tai Po in 1983.*** Compare the extent of reclamation with that of only 5 years earlier, shown in Plate 50. (16.5.1983/48631).

Plate 50. ***Oblique Aerial Photograph Looking Northwest across Tai Po in 1978.*** **Compare the extent of reclamation with that shown in Plate 49. (24.1.1978/21062).**

Plate 51. ***High Oblique Aerial Photograph Looking South across Kowloon towards Hong Kong Island in 1979.*** Compare this with Plate 1, which was taken in 1987. In the intervening 8 years, a considerable area of the harbour has been reclaimed (hatched). In addition, construction of the East Island Corridor along the southern shore of the harbour from Shau Kei Wan to North Point (A) has not commenced, and only vacant reclaimed land is evident in Tsim Sha Tsui East area (B). (4.7.1979/25851).

Plate 52. ***Oblique Aerial Photograph Looking Northeast towards the Landslip at Tsui Ping Road Estate in 1964.*** Hong Kong was badly hit by Typhoon Ida in August 1964. Two landslips occurred on a fill slope under construction on terrain upslope of Tsui Ping Road in the Kwun Tong area of Kowloon. The first landslip was early in the morning of 10.8.1964, after intense rainfall the previous day. Reports indicate that a mud avalanche flowed down the valley and deposited up to 3m of debris in an area approximately 90m by 70m in a resettlement estate. Surprisingly, only three people were listed missing, and no other injuries were reported. Six days later, at the same location during heavy rain on 16.8.1964, a second smaller landslip occurred shortly after 3.30 p.m. The Royal Observatory recorded a 24 hr rainfall of 2.86 inches (72.6 mm) for 16.8.1964. Five injuries were recorded, and hundreds were evacuated from their homes in the Kwun Tong Estate. In this Plate, taken approximately 2 weeks after the second landslip, trucks are evident removing debris from around the housing blocks. (ISD/30.8.1964/3276/1).

Plate 53. Oblique Aerial Photograph Looking Southeast across the Landslip near Tsui Ping Road Estate in 1964. Debris flowed from the fill slope (A) toward the housing blocks (B). (ISD/30.8.1964/3276/5).

Plate 54. Oblique Aerial Photograph of the Landslip near Tsui Ping Road Estate in 1964. The source of the failure is clearly evident at A. (ISD/30.8.1964/3276/6).

Plate 55. ***Enlargement to Accompany Stereopair of the Tsui Ping Road Area in 1964.*** This Plate accompanies Plate 56. Remedial works to the failure site are evident at A and debris is being removed from around the housing blocks at B. Landslips are evident to the north on newly formed slopes in the Sau Mau Ping Area (C), and a large gully is apparent on the fill slope at the site of the 1972 landslip (D). Compare this with Plates 107, 109 and 115. (13.12.1964/2539).

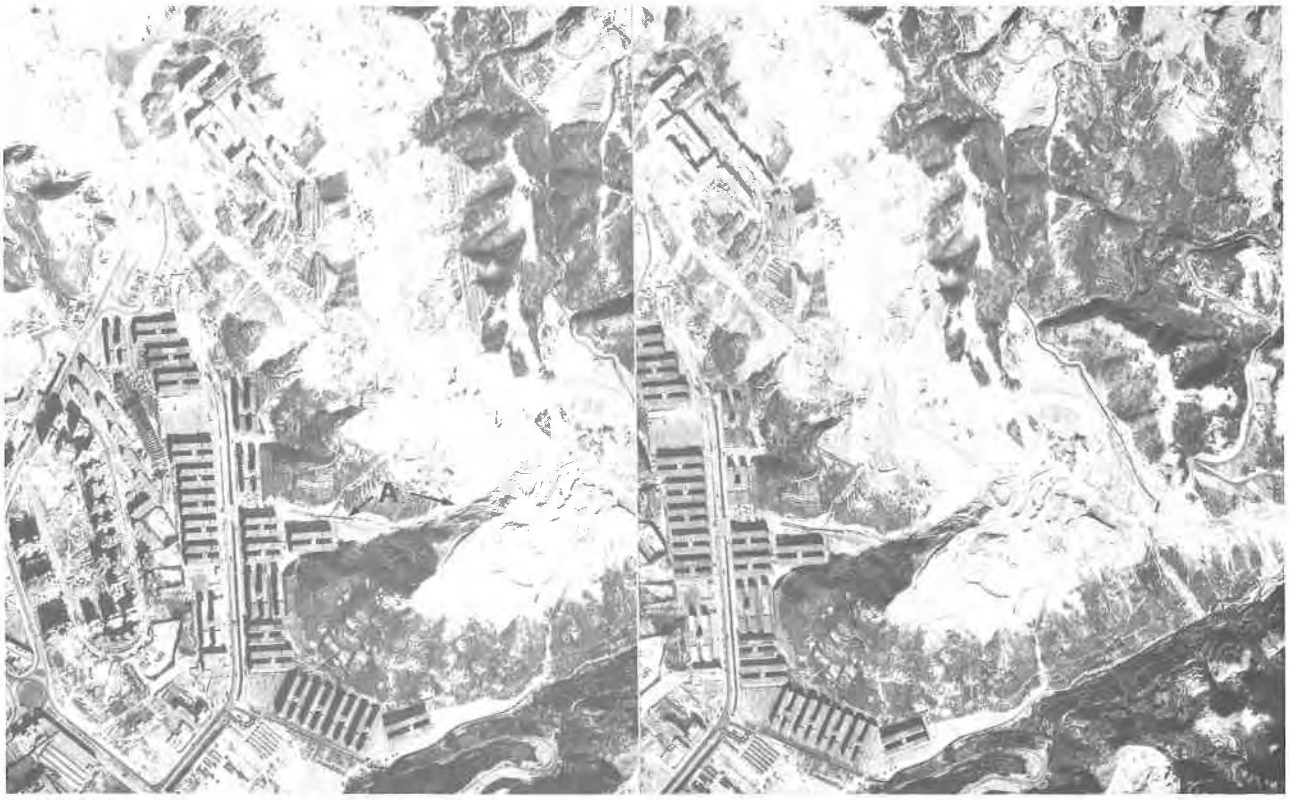


Plate 56. ***Stereopair of the Tsui Ping Road Area in 1964.*** This Plate accompanies Plate 55. Some 5 months after the failure, landslip debris and the extent of the failure zone are still apparent (A). Compare this with the Stereopair of the Sau Mau Ping area in 1976, at Plate 115. (13.12.1964/2539-40).

Plate 57. *Oblique Aerial Photograph of Landslip on Peak Road in 1983.* **The area at A failed in 1966 and the incident is highlighted in Plate 58. Plate 153 provides a view of the 1983 failure from the carriageway. (21.6.1983/49230).**

Plate 58. *Oblique Aerial Photograph of Landslip on Peak Road in 1966.* **This landslip occurred slightly to** the west of the position of the 1983 failure (Plate 57). Approximately 50 m of Peak Road was destroyed. Further remedial works were carried out on this site in 1987 (Plate 190), following investigations after the 1983 landslip. (Reproduced from Chen (1969), ISD/3982/404).

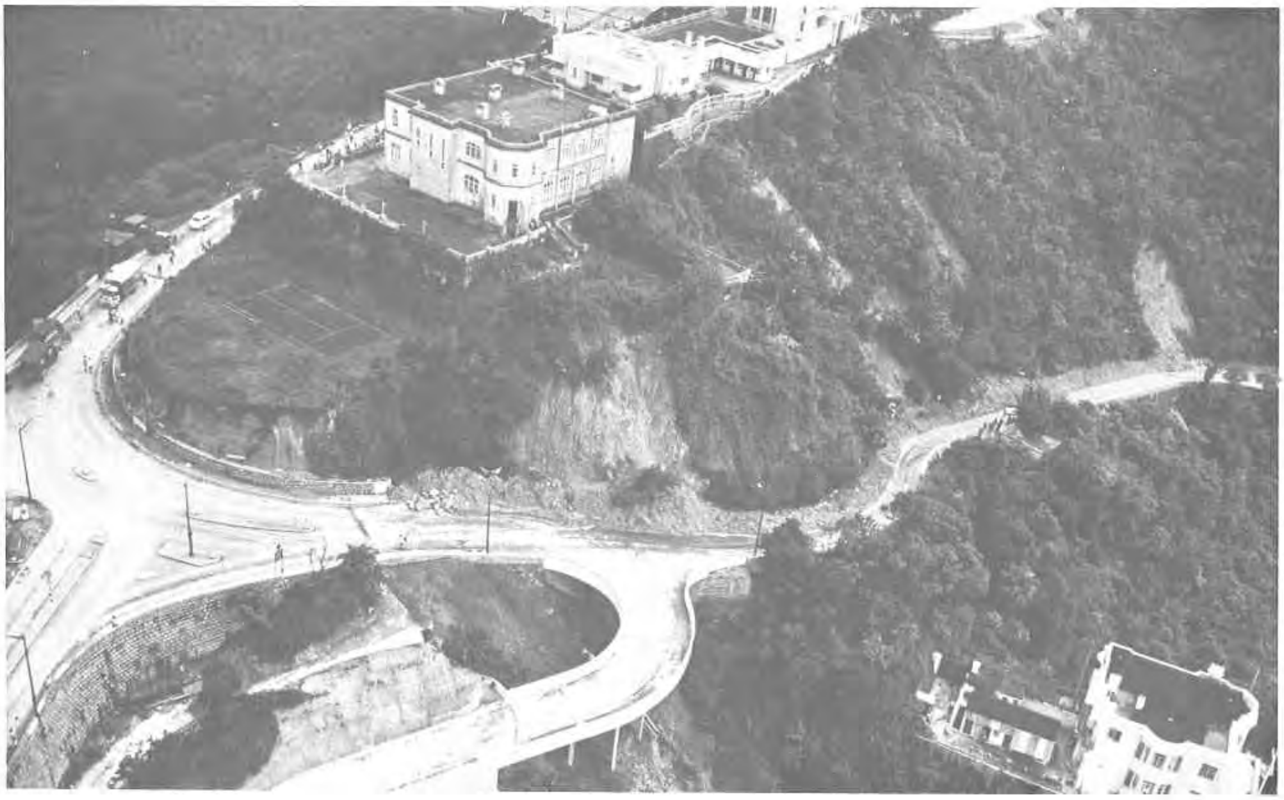


Plate 59. *Oblique Aerial Photograph of Landslips on Magazine Gap Road in 1966.* (Reproduced from Chen (1969), ISD/3982/388).

Plate 60. *Oblique Aerial Photograph of Braemar Reservoir in 1966.* Overflow from the Reservoir (A) caused serious flooding and damage evident in Plates 62–63 and 65–67. A large washout is evident on Tin Hau Temple Road (B). The severe damage in the Ming Yuen Street–King's Road area was caused by stormwater runoff which flowed along the natural stream course indicated in the western portion of the area (C). (Reproduced from Chen (1969), ISD/3982/275).

Plate 61. ***Oblique Aerial Photograph of Washouts on Braemar Reservoir Road and Tin Hau Temple Road in 1966.*** A large washout is evident at the intersection of Tin Hau Temple Road and Braemar Reservoir Road (A). The multi-storey development at B is near Kai Yuen Street. (Reproduced from Chen (1969), ISD/3982/318).

Plate 62. Rocks and Debris in King's Road in 1966. (Reproduced from Chen (1969), ISD/3982/104).

Plate 63. Wrecked Vehicles in Ming Yuen Street in 1966. (Reproduced from Chen (1969), ISD/3982/60).

Plate 64. ***Aerial Photograph of the Braemar Reservoir and North Point in 1945.*** **This photograph** dramatically illustrates the intimate relationship between the natural drainage course and Ming Yuen Street, some 21 years before the 1966 rainstorms. The results of these rainstorms are seen in Plates 61–63 and 65–67. The Reservoir is shown at A, the spillway at B, and the natural stream course at C. Ming Yuen Street is located (D) directly downslope of the main drainage line leading from the Reservoir spillway. The perspective seen in Plate 61 is shown by the arrow at E. (11.11.1945/681/6/4034).

Plate 65. Debris in Ming Yuen Street in 1966. (Reproduced from Chen (1969), ISD/3982/222).

Plate 66. Flooding and Debris in Ming Yuen Street in 1966. (Reproduced from Chen (1969), ISD/3984/91).

Plate 67. Clearing of Debris on King's Road in 1966. (Reproduced from Chen (1969), ISD/3982/114).

Plate 68. Large Landslip on Tai Hang Road in 1966. (Reproduced from Chen (1969), ISD/3982/262).

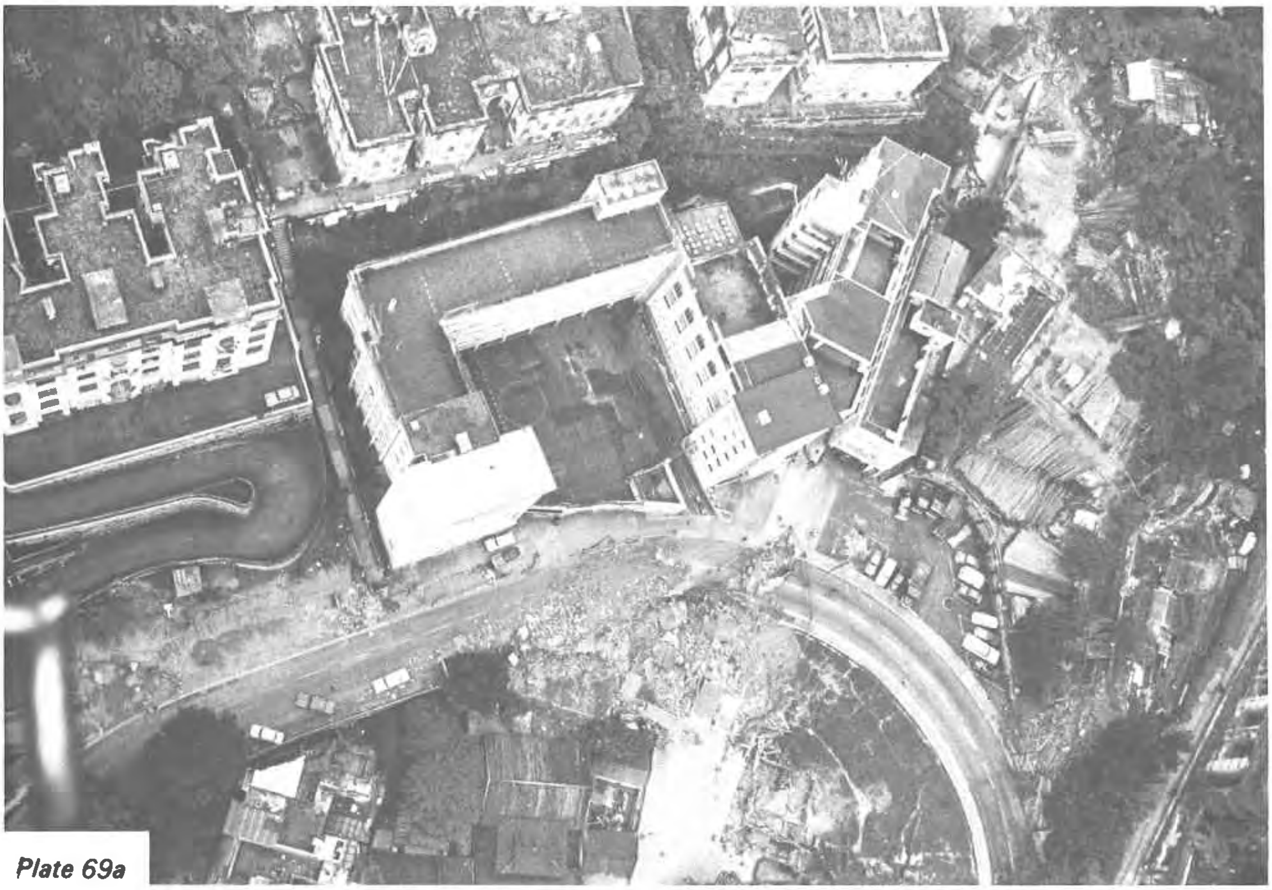


Plate 69a

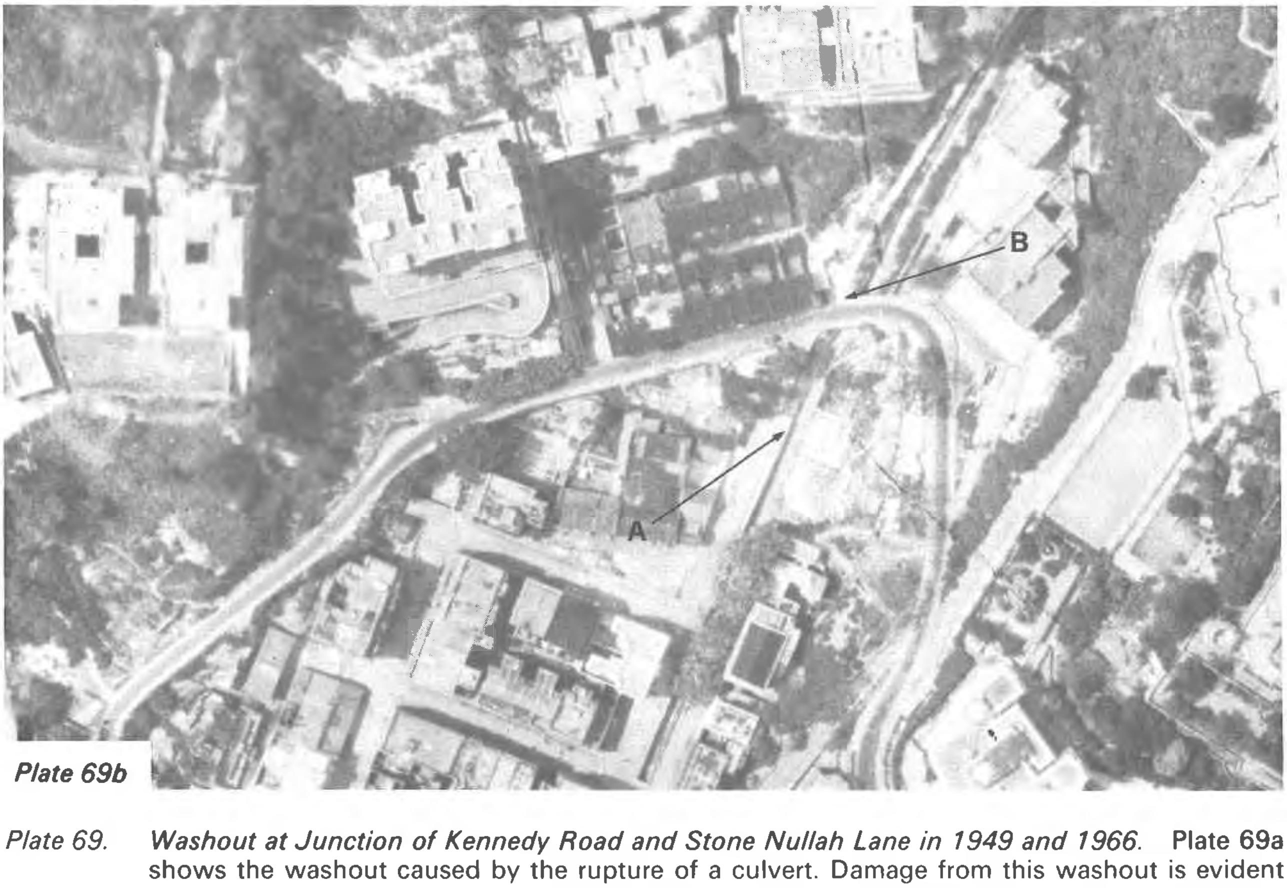


Plate 69b

Plate 69. ***Washout at Junction of Kennedy Road and Stone Nullah Lane in 1949 and 1966.*** **Plate 69a** shows the washout caused by the rupture of a culvert. Damage from this washout is evident in Plates 70 and 71 (reproduced from Chen (1969), ISD/3982/266). Plate 69b shows the uncovered drainage nullah (A) in 1949. The location of the blowout is shown at B. (8.5.1949/81A/128/6121).

Plate 70. Damage Caused by Debris and Flooding in Stone Nullah Lane in 1966. (Reproduced from Chen (1969), ISD/3982/194).

Plate 71. Damage to Drainage Culvert in Stone Nullah Lane in 1966. The concrete road slabs were washed away by floodwaters. (Reproduced from Chen (1969), ISD/3982/426).

Plate 72. Flooding in Happy Valley in 1966. The race course is inundated by floodwaters following torrential rains. (Reproduced from Chen (1969), ISD/3982/172).

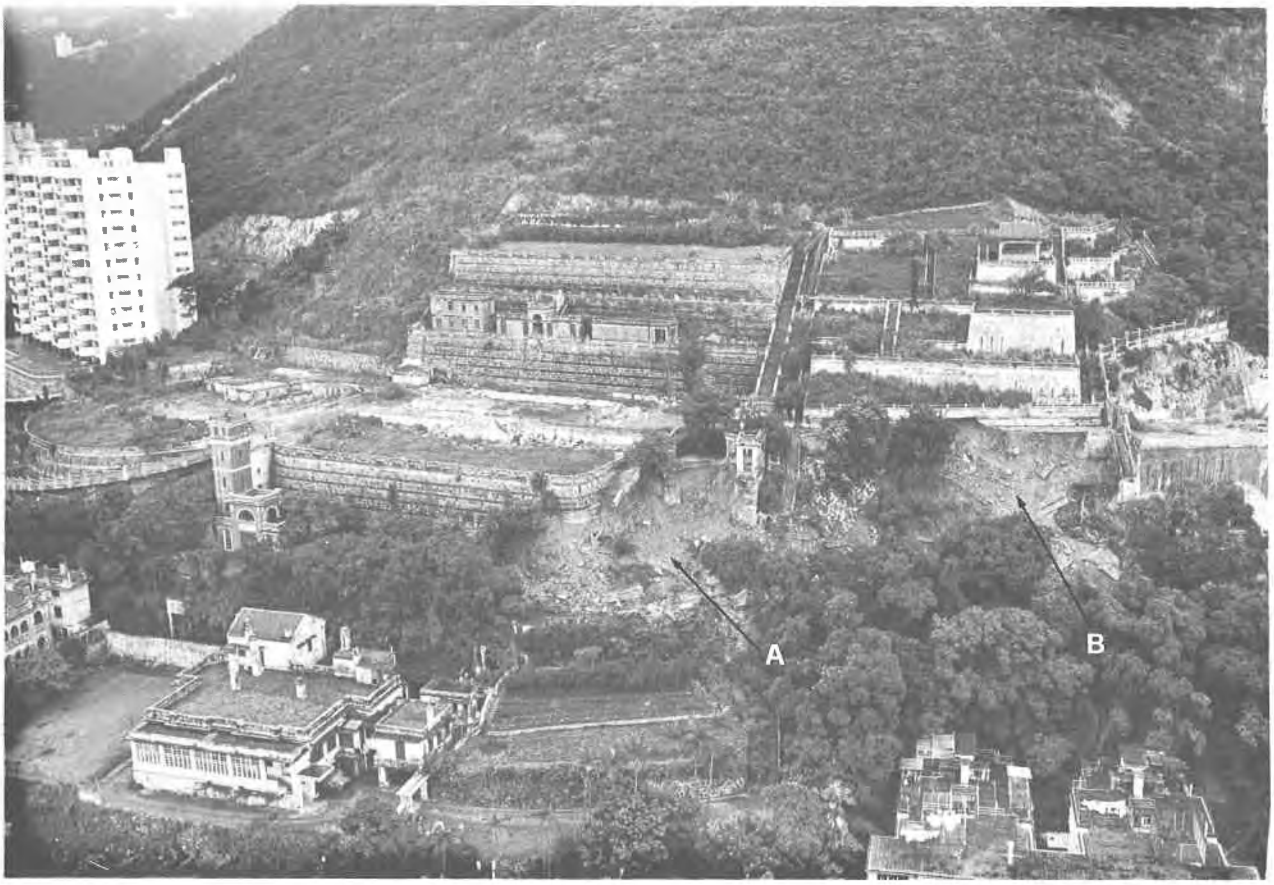


Plate 73. Oblique Aerial Photograph of a Retaining Wall Failure on Conduit Road in 1966. The site was developed as part of Realty Gardens during 1970–71. The failures are evident at A and B. (Reproduced from Chen (1969), ISD/3982/351).

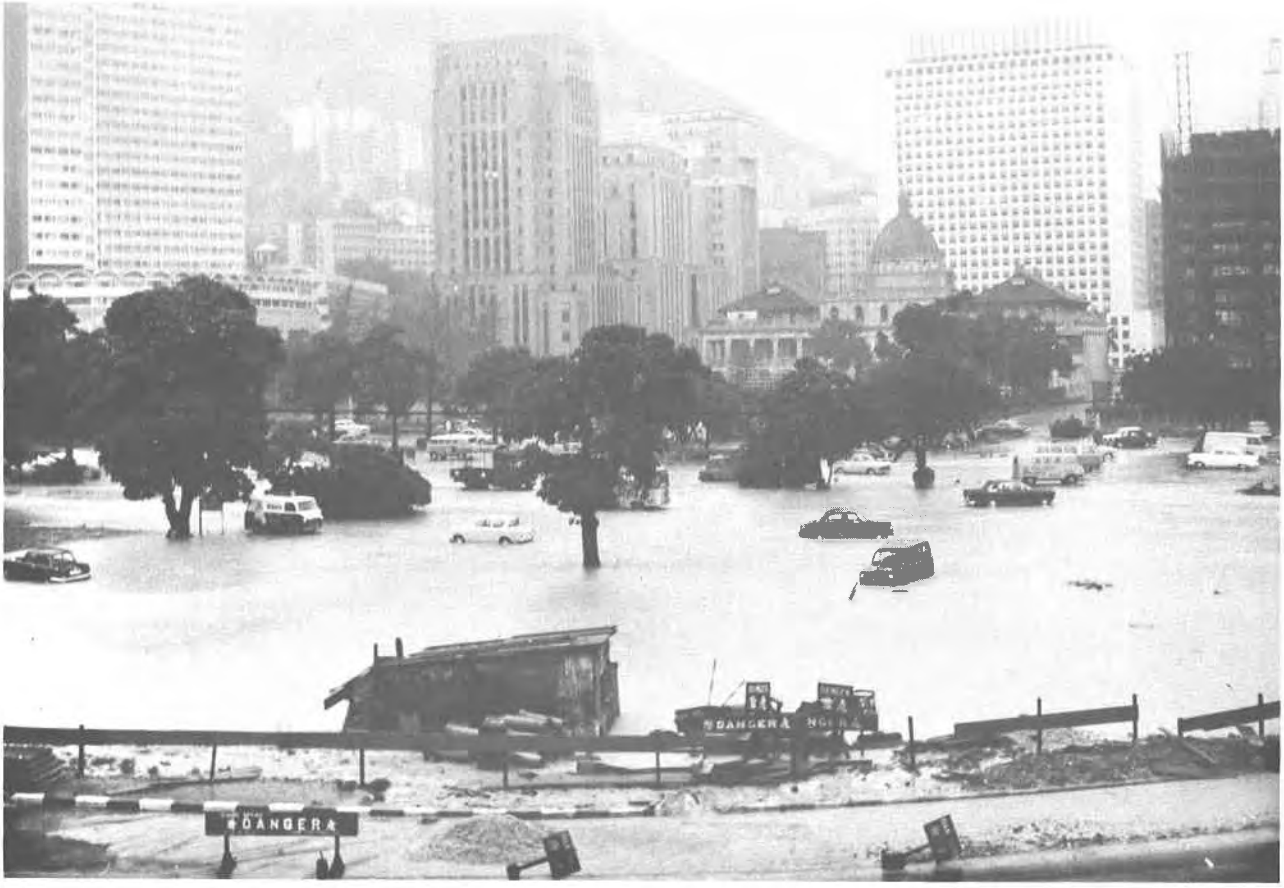


Plate 74. Floodwaters in the Central District in 1966. (Reproduced from Chen (1969), ISD/3982/157).

Plate 75. Floodwaters in the City Hall Concert Hall in 1966. It was reported that an eel weighing one catty was caught in the Hall. (Reproduced from Chen (1969), ISD/3982/1).

Plate 76. Oblique Aerial Photograph of a Landslip at the Junction of Broadwood and Link Roads in 1966. (Reproduced from Chen (1969), ISD/3982/265).

Plate 77. Oblique Aerial Photograph of a Landslip behind the North Point Government School in 1966. (Reproduced from Chen (1969), ISD/3982/373).

Plate 78. Oblique Aerial Photography of Landslips on Shek Pai Wan Road on Ap Lei Chau in 1966. (Reproduced from Chen (1969), ISD/3982/329).

Plate 79. Oblique Aerial Photograph of Landslips above Victoria Road in Pok Fu Lam in 1966. It was reported that a total of 29 landslips and 18 washouts occurred along Victoria Road during the period of storm activity following 10.6.1966. (Reproduced from Chen (1969), ISD/3982/382).

Plate 80. Oblique Aerial Photograph of Landslips above Victoria Road in Pok Fu Lam in 1966.
(Reproduced from Chen (1969), ISD/3982/384).

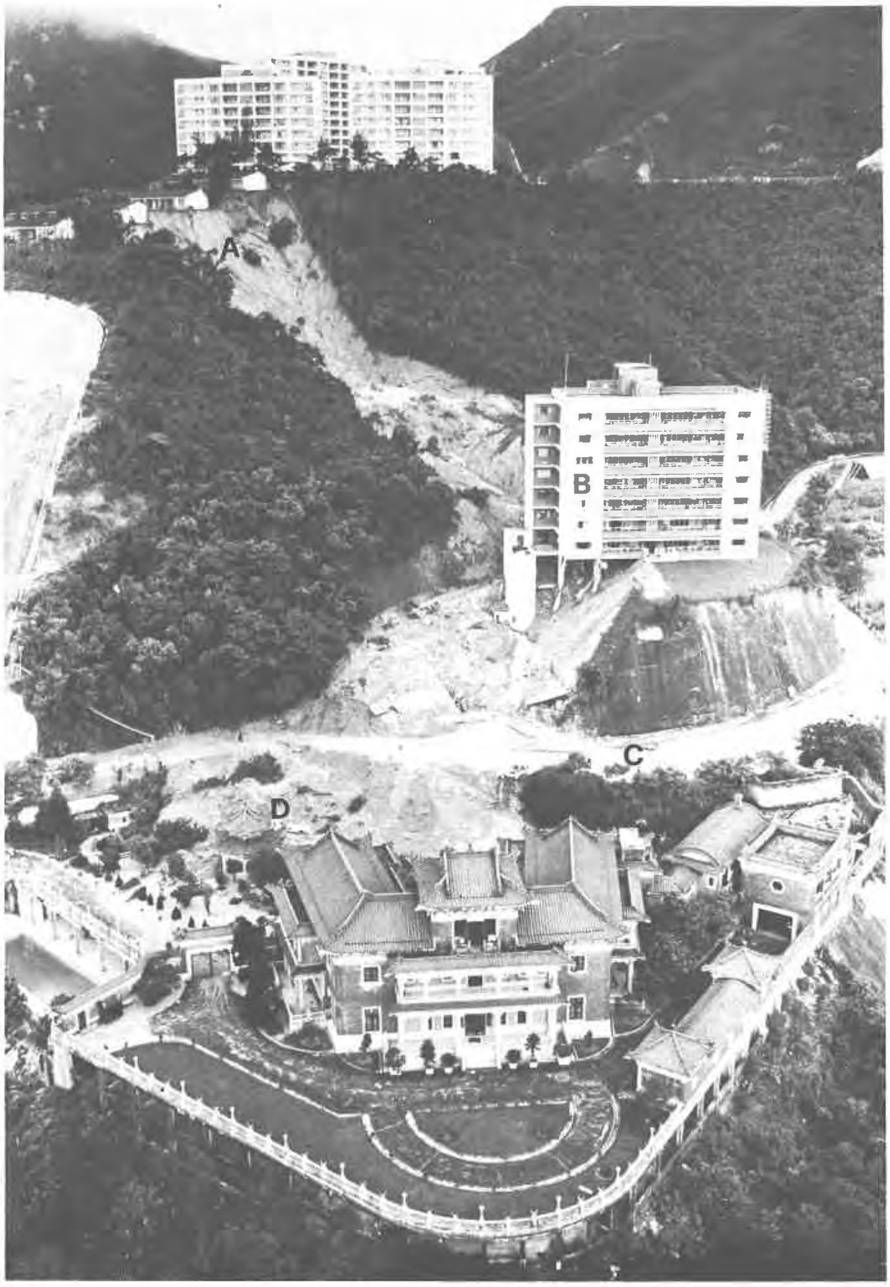


Plate 81. ***Landslip below Mt Nicholson Bungalows in 1966.*** **Failure (A) of portion of a fill slope,** forming part of the platform for the Mt Nicholson Bungalows, resulted in a large landslip which damaged Victoria Heights (B) and flowed across Stubbs Road (C) into a neighbouring garden (D). The Assistant Director of Education was fatally injured in the landslip. (Reproduced from Chen (1969), ISD/3982/284).

Plate 82. *Damage caused by the Mt Nicholson Landslip in 1966.* (Reproduced from Chen (1969), ISD/3982/136).

Plate 83. *Damage to Victoria Heights Flats in 1966.* (Reproduced from Chen (1969), ISD/3982/160).

Plate 84. Clearing of Landslip Debris from Stubbs Road in 1966. Clearance work following the Mt Nicholson failure. (Reproduced from Chen (1969), ISD/3982/415).

Plate 85. Landslip Debris in Garden below Victoria Heights in 1966. (Reproduced from Chen (1969), ISD/3982/449).

Plate 86. ***Landslip near Chater Hall in 1966.*** A section of May Road (Hornsey Road) was destroyed by this landslip, Plate 87 reveals the effects of the debris on the downslope terrain. A newspaper report at the time noted that the residents of Chater Hall were being accommodated at the Mandarin and Hilton Hotels 'at special rates'. (Reproduced from Chen (1969), ISD/3982/8).

Plate 87. ***Landslip on Robinson Road in the Upper Glenealy Area in 1966.*** **This was the result of the** landslip near Chater Hall shown in Plate 86. (Reproduced from Chen (1969), ISD/3982/320).

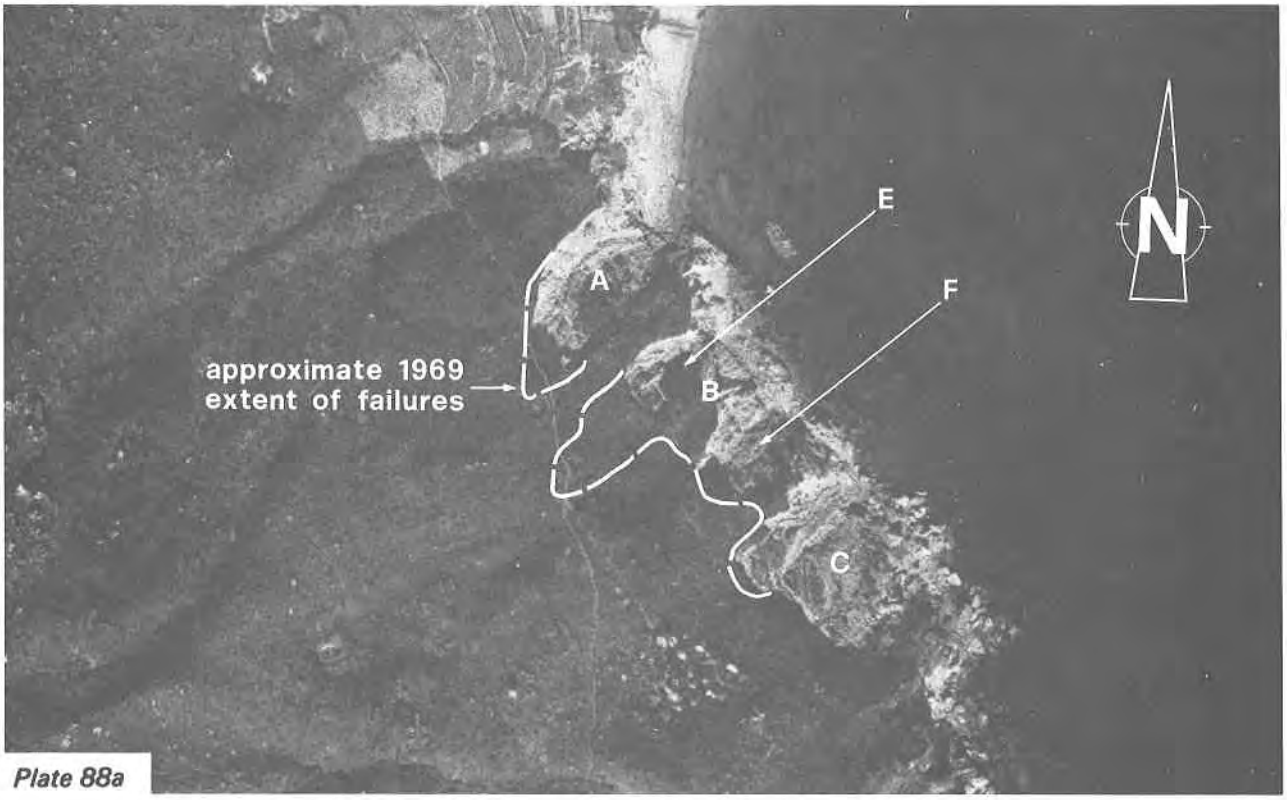


Plate 88a

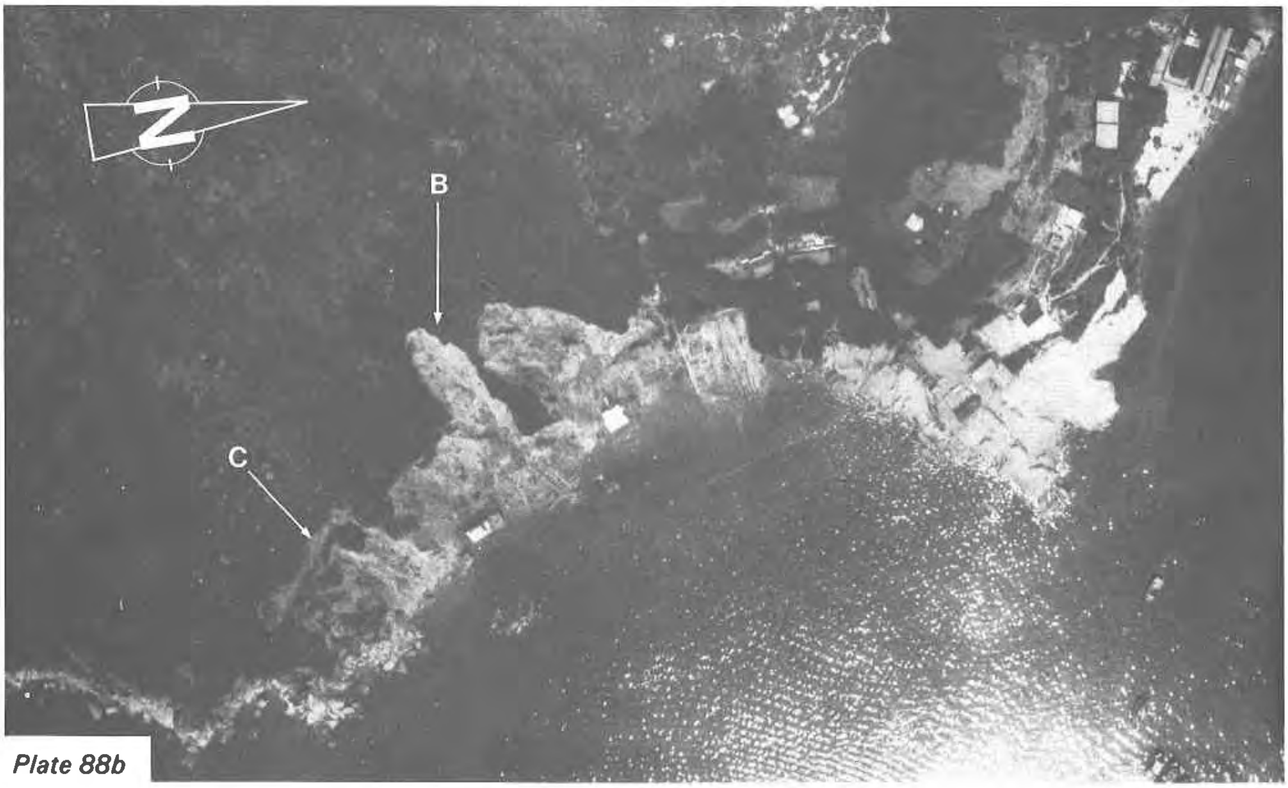


Plate 88b

Plate 88. *Enlargements of Aerial Photographs of Landslips at Ap Lei Chau in 1963 and 1969.* Plate 88a, taken in 1963, is an enlargement of part of the stereopair at Plate 89a. Three areas of instability are evident at A, B and C. Area B appears to consist of two landslips (E and F) which are joined by an upslope tension crack to form a larger area of mass movement. Plate 88b, taken in 1969, is an enlargement of part of the stereopair at Plate 89b. The landslips evident on the coastal terrain in 1963 have clearly worsened by 1969. The areas of instability at A and B have enlarged quite dramatically with considerable upslope progression. The lower portions of landslips E and F have merged. The approximate extent of the failures in 1969 is shown by the dashed line in Plate 88a. (1963/7497 and 1969/1730).

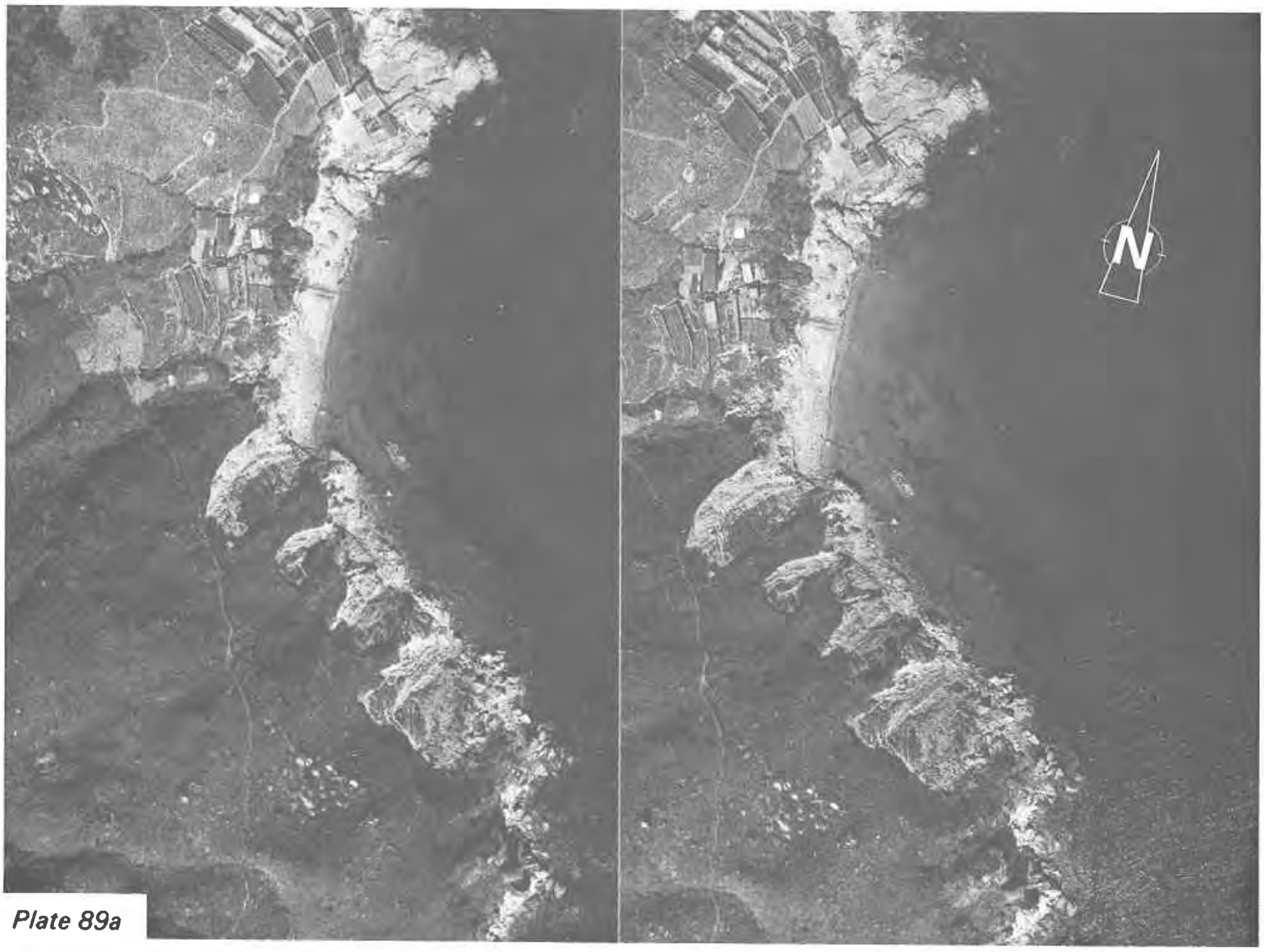


Plate 89a

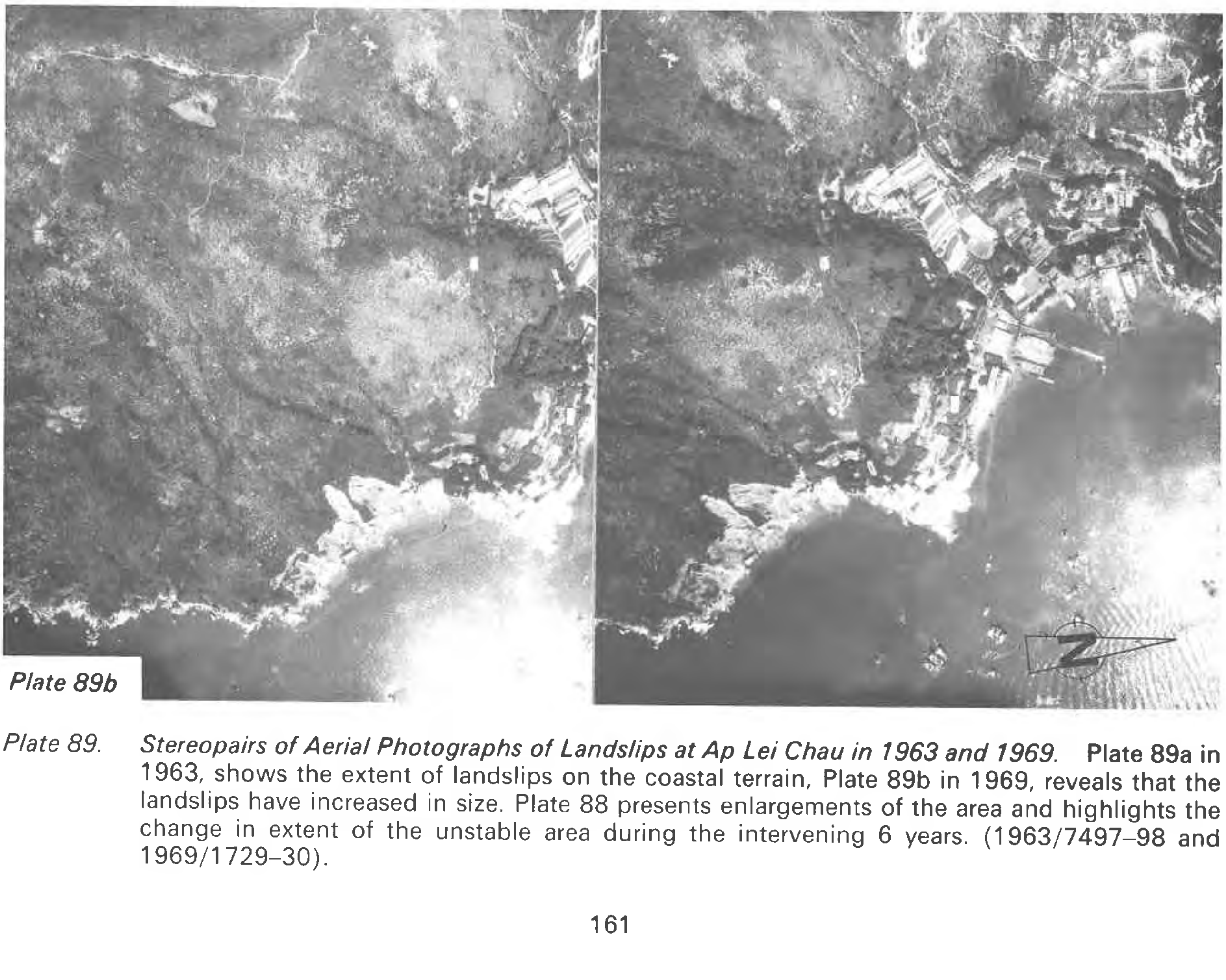


Plate 89b

Plate 89. *Stereopairs of Aerial Photographs of Landslips at Ap Lei Chau in 1963 and 1969.* **Plate 89a** in 1963, shows the extent of landslips on the coastal terrain, **Plate 89b** in 1969, reveals that the landslips have increased in size. Plate 88 presents enlargements of the area and highlights the change in extent of the unstable area during the intervening 6 years. (1963/7497–98 and 1969/1729–30).

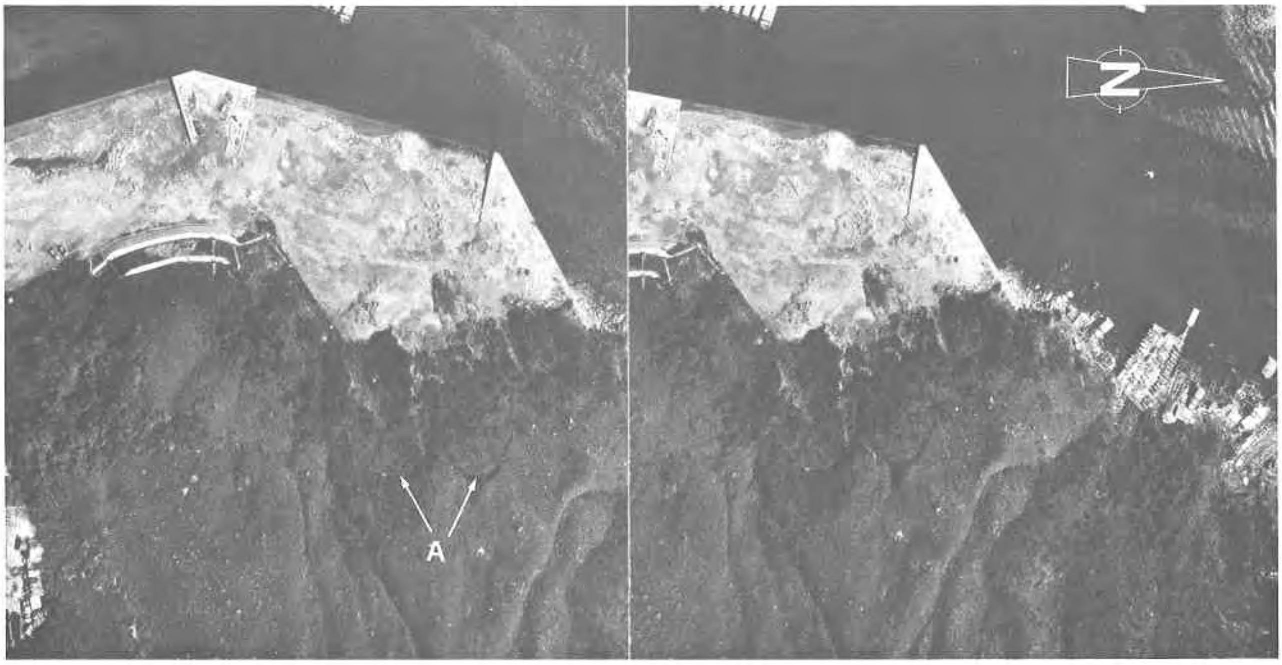


Plate 90. *Stereopair of Aerial Photographs of Landslips at Ap Lei Chau in 1986.* Reclamation is evident along the coast and large tension cracks (A) and backscars are apparent on the terrain upslope of the landslips. Compare with Plate 89a and b. (8.2.1986/A04086–87).

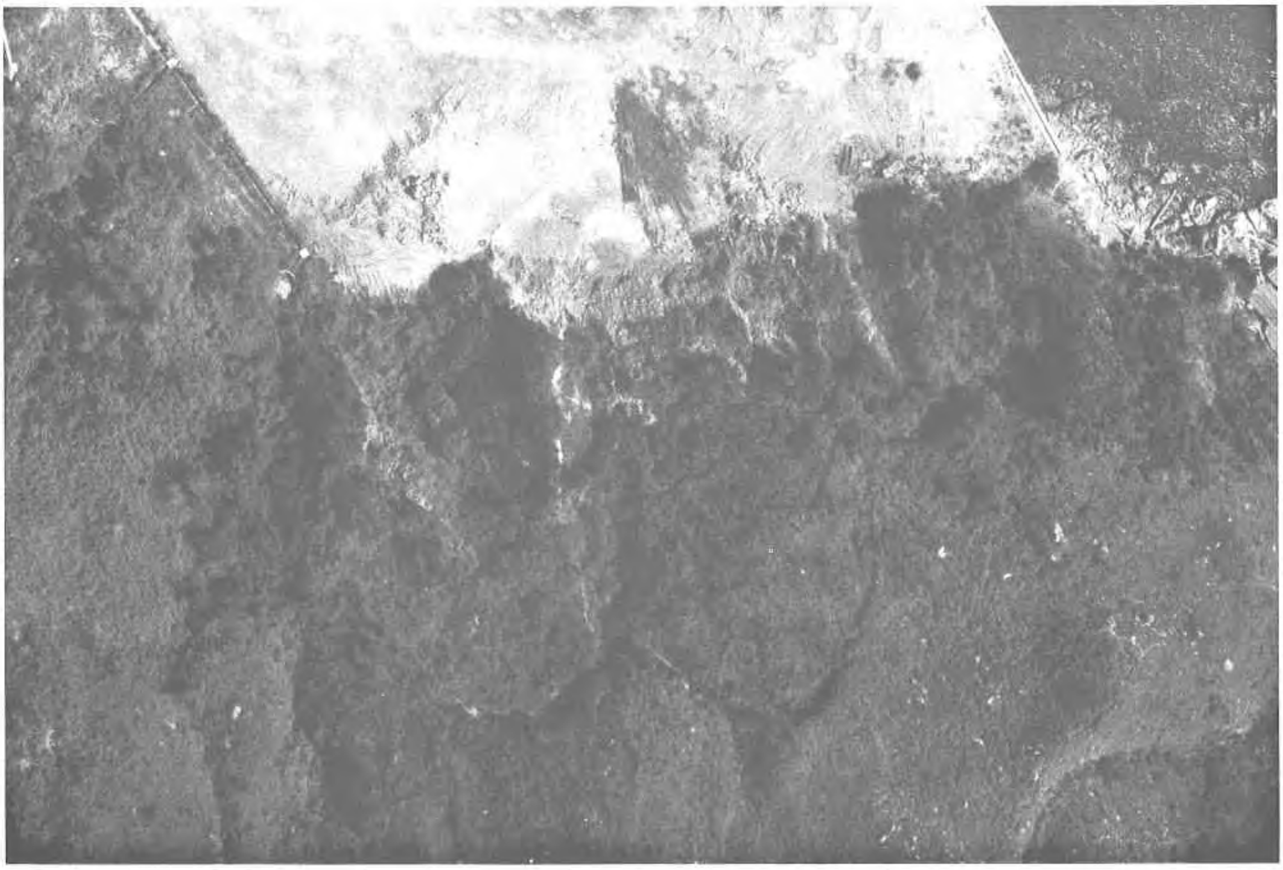


Plate 91. *Enlargement of Aerial Photograph of Landslips at Ap Lei Chau in 1986.* This Plate accompanies Plate 90 and shows that the dramatic rate of upslope progression evident between 1963 and 1969 (Plates 88a and b) has not continued; the failed soil masses retain the approximate dimensions evident in 1969 (Plate 88b) and appear to have revegetated in the intervening 17 years. In addition, an area of reclamation has been placed at the base of the slope which effectively prevents further basal erosion, and may have provided support to the toe of the landslip mass. (8.2.1986/A04087).

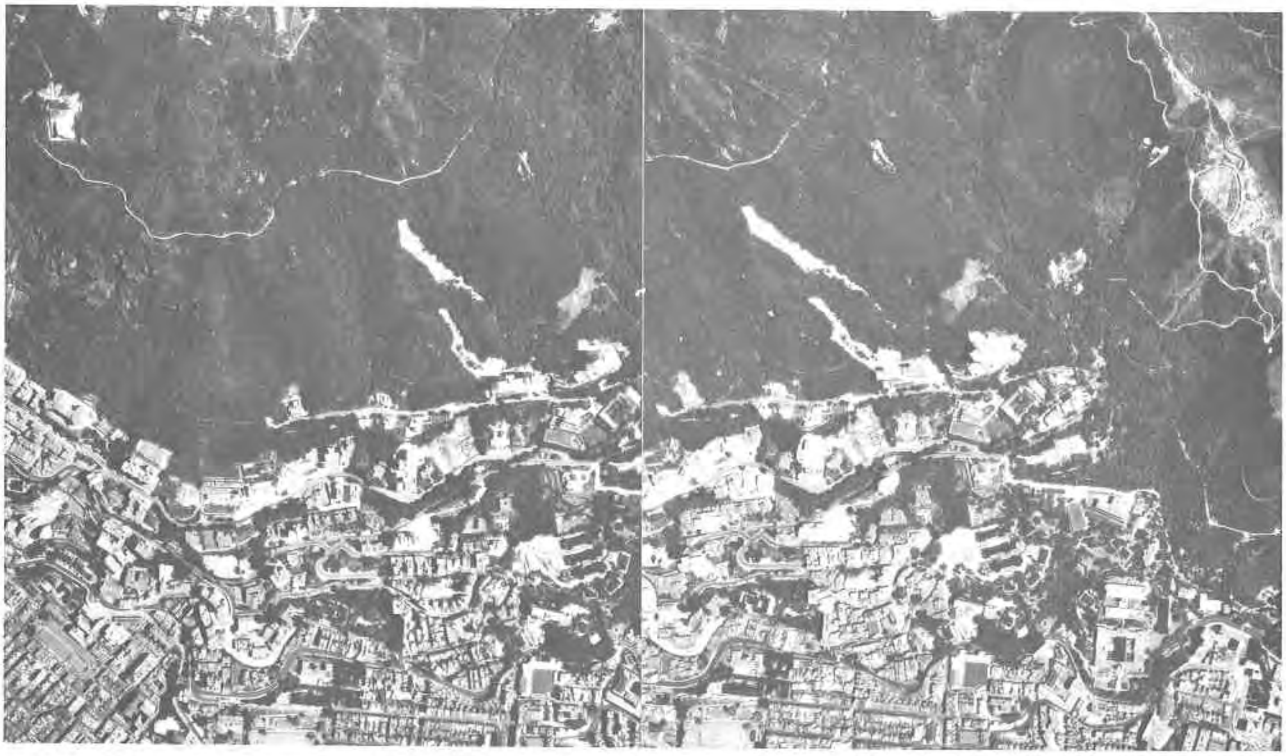


Plate 92. *Stereopair of Aerial Photographs of Landslips in the Mid-levels Area in 1967.* A number of landslips are evident on the upper footslopes area of the terrain below Victoria Peak. An enlargement of this area is shown in Plate 93. (1967/5606–7).

Plate 93. *Enlargement of Aerial Photograph of Landslips in the Mid-levels Area in 1967.* The major landslips are arrowed. The general extent of the Po Shan Road landslip in 1972 (Plates 94 to 100) is shown, and the location of Kotewall Court is indicated at A, and the house at 11 Kotewall Road at B. Both these structures were destroyed during the major Po Shan Landslip at about 9.00 p.m. on 18.6.1972. A large cut platform is evident at C, and seepage is also apparent across the platform. Remedial measures appear to be underway on the site of the retaining wall failure in 1966 (D), which is shown in Plate 73. This Plate accompanies Plate 92. (1967/5606).

Plate 94. ***Oblique Aerial Photograph of the Po Shan Road Landslip in the Mid-levels Area in 1972.*** On 18.6.1972, a large landslip occurred in the Mid-levels of Hong Kong Island. A multistorey residential building (Kotewall Court) collapsed during the failure. There were 67 fatalities and twenty injuries in this incident. The landslip occurred between 8.50 and 8.55 p.m., after three days of abnormally heavy rainfall. Part of the hillside above a cut slope failed and the debris descended across Conduit Road, and then to Kotewall Road. A witness indicated that the major landslip took only seven to ten seconds (Government of Hong Kong, 1972b). This landslip also destroyed a four-storey house which was evacuated following slope movement some 4 hours before the major landslip. The location of Kotewall Court and the House are shown at A and B respectively, and on Plate 93. Damage to the upper stories of Greenview Gardens is evident at C. Kotewall Court collapsed onto Greenview Gardens, which was unoccupied at the time. The top of the landslip was at an elevation of approximately 230m and the toe of the debris reached 110 m, a vertical fall of some 120 m (Lo, 1978). The horizontal distance was approximately 255 m. (21.6.1972/ISD/8264/5). The inset in the top left hand corner shows Kotewall Court and the House at 11 Kotewall Road before the disaster. The actual date of the photograph is unknown, but it is likely that this photograph was taken only a matter of weeks before the failure. Scaffolding is evident on Greenview Gardens. (6729/72).

Plate 95. Backscar of the Po Shan Road Landslip in 1972. Part of a vehicle is evident (A). This vehicle was probably parked on Po Shan Road at the time of the landslip, but has come to rest some 5m below the level of the road. (19.6.1972/ISD/8257/1).

Plate 96. ***Large Scale Aerial Photograph of the Po Shan Road Landslip in 1972.*** Note the large block of rock, probably of volcanic origin at (A), the failure of the lawn and garage at 21 Po Shan Road (B), the vehicle below Po Shan Road (C), the location of Kotewall Court (D), the location of the four storey private dwelling at 11 Kotewall Road (E), the damaged portion of Greenview Gardens (F), debris around Skyline Mansions (G), and the debris around a structure under construction (H). The residents of 11 Kotewall Road (E) were evacuated following a landslip at about 5.00 p.m. on 18.6.1972, some 4 hours before the major failure. The building was apparently buried up to the 2nd Floor by landslip debris after the 5.00 p.m. failure, and the occupants escaped without injury. (Government of Hong Kong, 1972b). The boulder on Po Shan Road referred to in Plate 99 is at I. (20.6.1972/1650).

Plate 97. *Oblique Aerial Photograph of the Po Shan Road Landslip Site in 1972.* The plate provides a perspective of the disaster site from the northeast, some 6 days after the landslip. Note the large landslip behind the partially constructed Hamilton Court (A); the lawn and garage area at 21 Po Shan Road have collapsed (B); compare this with the photographs in Plate 94. The vehicle is still evident (C). The landslip on the slope behind Hamilton Court occurred on the morning of 16.6.1972, some 2 days before the major incident and blocked Po Shan Road (Government of Hong Kong, 1972b). (24.6.1972/1805).

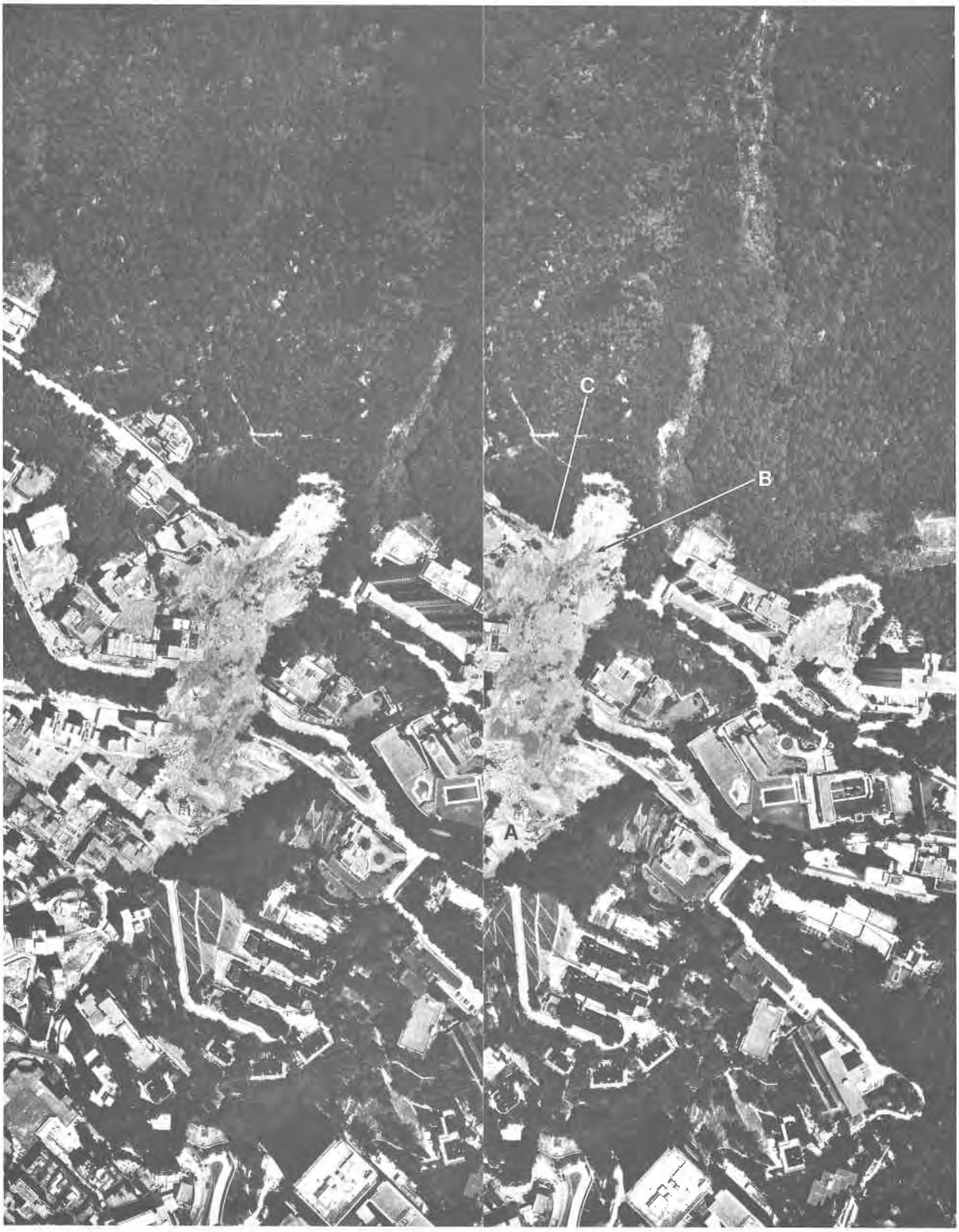


Plate 98. *Stereopair of Aerial Photographs of the Po Shan Road Landslip in 1972.* The photographs for this plate were taken on 24.6.1972, 6 days after the disaster. Earth moving equipment is evident on the eastern side of the landslip on Conduit and Kotewall Roads, and access to the construction site above Babington Path (A) is also being cleared. Many of the features highlighted on Plate 96 (20.6.1972) are still evident, although areas of seepage and saturated soil are now clearly apparent. These areas are indicated by the darker tones on the photographs, particularly in the landslip scar just above the level of Po Shan Road, where continued seepage (B) is evident. The boulder on Po Shan Road referred to in Plate 99, is at C. (24.6.1972/1816–17).

Plate 99. ***Damage to Lawn and Garage Area at 21 Po Shan Road in 1972.***

The boulder at A is evident in Plates 96 and 98. This photograph, probably taken on 26.6.72, highlights the damage caused on the eastern side of the Po Shan Road Landslip. (ISD 8371/7).

Plate 100. ***Distress Evident on the Lawn and Garage Area of 21 Po Shan Road prior to the Landslip in 1972.*** This photograph records the major distress evident on Po Shan Road prior to the Po Shan Road landslip on the evening of 18.6.1972. Apparently, cracks had developed in the middle of the carriageway between 8 & 21 Po Shan Road by noon on 16.6.1972 (Government of Hong Kong, 1972b). This photograph was probably taken after the partial failure of the cut slope of IL 2260, at about 10 a.m. on 17.6.1972. This resulted in the settlement, by approximately 2m, of half of the carriageway, and the garage and adjoining garden terrace of 21 Po Shan Road. The residents of the house were advised to evacuate on the 17.6.1972. Further settlement of this area probably occurred during the evening of the 17.6.1972 (Government of Hong Kong, 1972b). Compare this with Plate 99 taken sometime after the major landslip. (ISD/837/1).

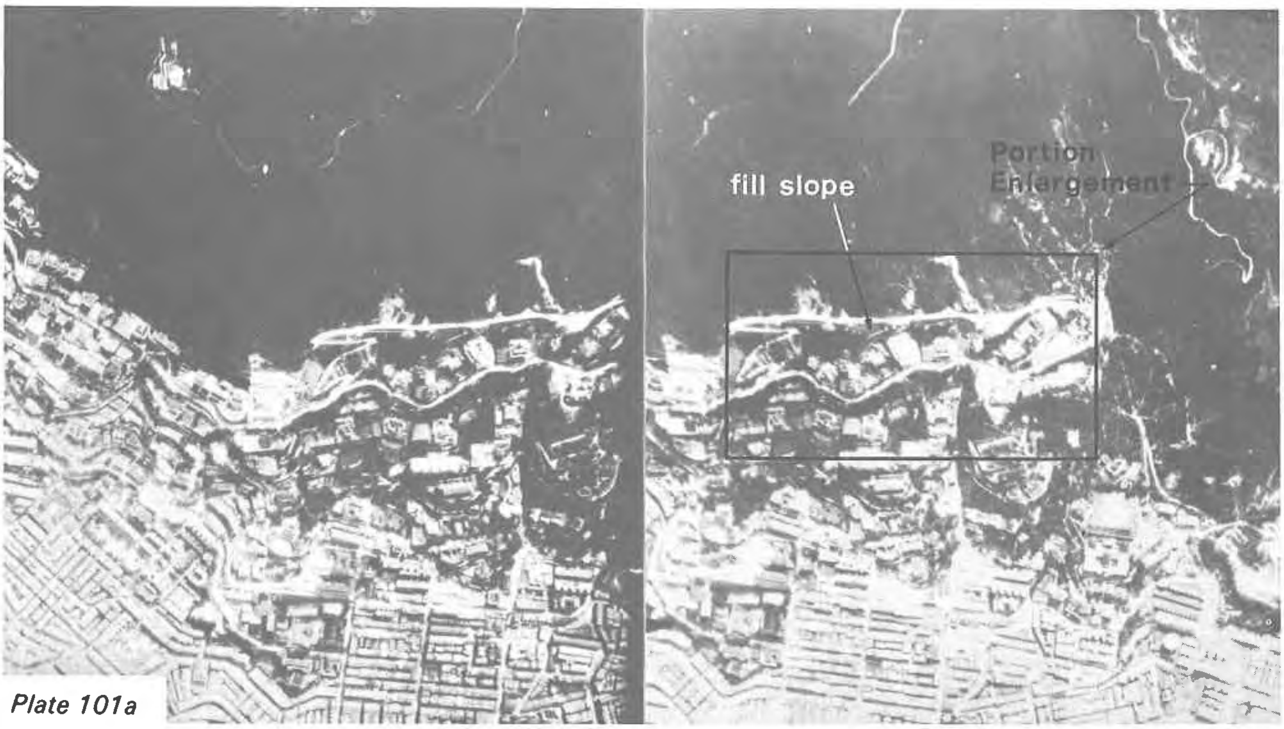


Plate 101a

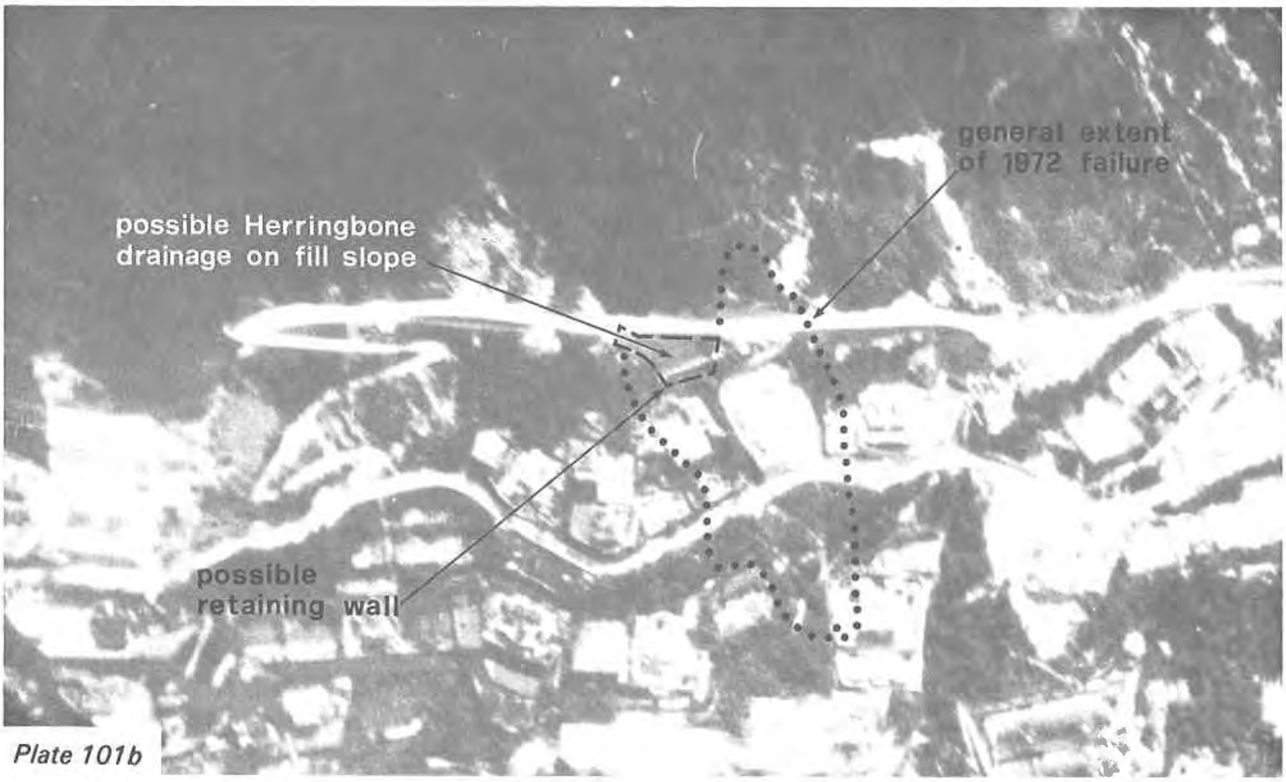


Plate 101b

Plate 101. Stereopair of Aerial Photographs of the Mid-levels and Enlargement of the Po Shan Road Area in 1924. The stereopair at Plate 101a, reveals the general characteristics of the terrain in the Mid-levels area in 1924. Much of the area is relatively undeveloped, and the general nature of the terrain is quite evident. Two- to three-storey houses are the characteristic form of development. Old photographs provide many interesting clues to the history of construction and development within the Territory. Enlargement of a portion of one of the 1924 aerial photographs (Plate 101b) provides evidence of several fill slope features along Po Shan Road. When viewed stereoscopically, a retaining wall and drainage features seem to be apparent in the approximate location of the Po Shan Road Landslip in 1972. It is interesting to compare the location of this feature with the general shape of the area affected by the Po Shan Road Landslip. The extent of the fill generally coincides with the area of settlement of Po Shan Road shown in Plate 100. (12.11.1924/H19/8–9).

Plate 102. Site of the Po Shan Road Landslip in October 1972. **This plate shows the state of remedial** works to the site some 3.5 months after the landslip. Access has been cleared across Conduit and Kotewall Roads. Clearing operations are still being carried out, and preliminary slope works appear to be underway. Debris has been removed from around Skyline Mansions (A), and the large boulder evident at A in Plate 96 has been removed (B). (3.10.1972/2303).

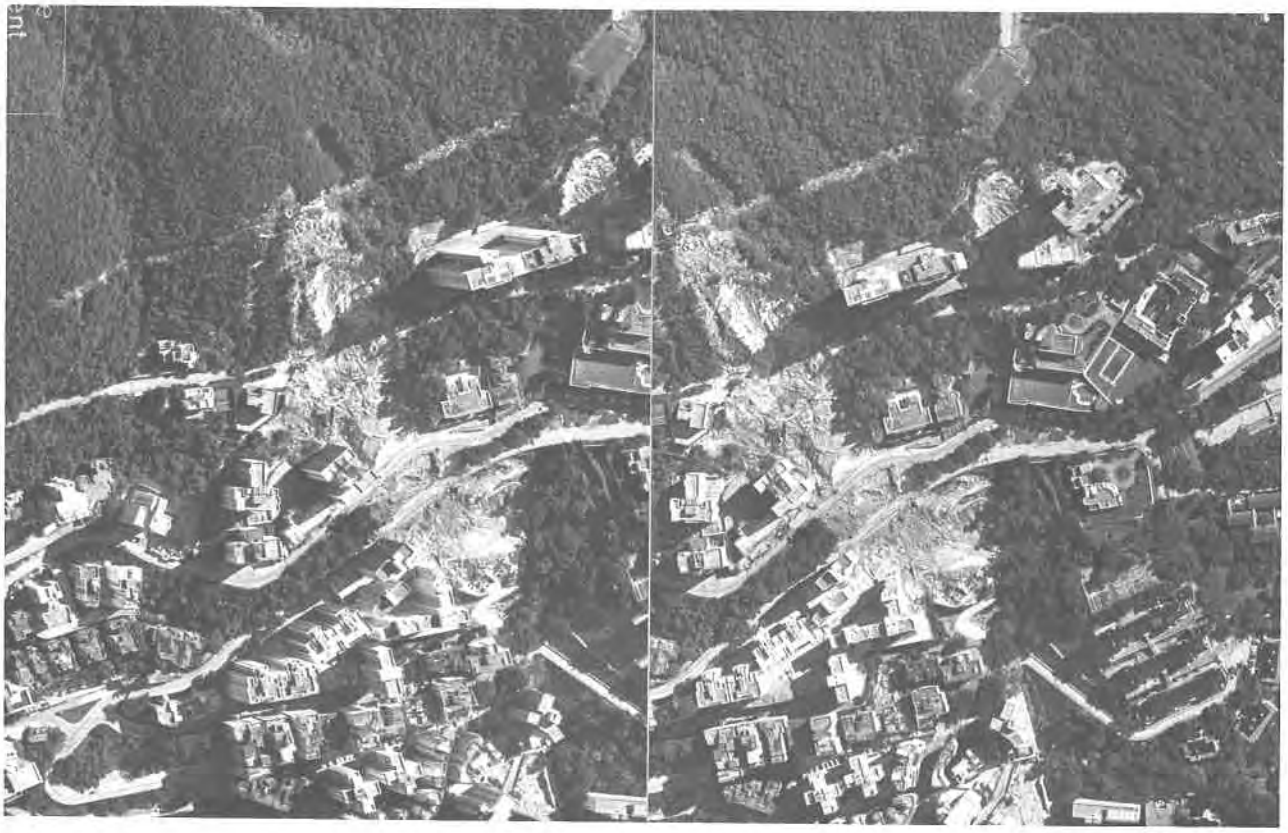


Plate 103. Stereopair of Aerial Photographs of the Po Shan Road Landslip Site in October 1972. This Plate accompanies Plate 102. (3.10.1972/2303–4).

Plate 104. Oblique Aerial Photograph of the Po Shan Road Landslip Site in November 1972. This photograph was taken some 9.5 months after the failure; compare this with Plates 102 and 103. An access track to the upper portions of the landslip scar is apparent, and clearance work has progressed on the lower slopes. The damage to the upper storeys of Greenview Gardens (Plates 94 and 96) appears to have been repaired (A). (3.11.1972/2363).

Plate 105. Oblique Aerial Photograph of Remedial Works to the Po Shan Road Landslip Site in October 1973. Reinstatement of the middle to upper portions of the landslip scar above Po Shan Road is clearly visible. Much of the slope is grassed, and surface drainage has been installed. Po Shan Road has been reinstated. (24.10.1973/5466).

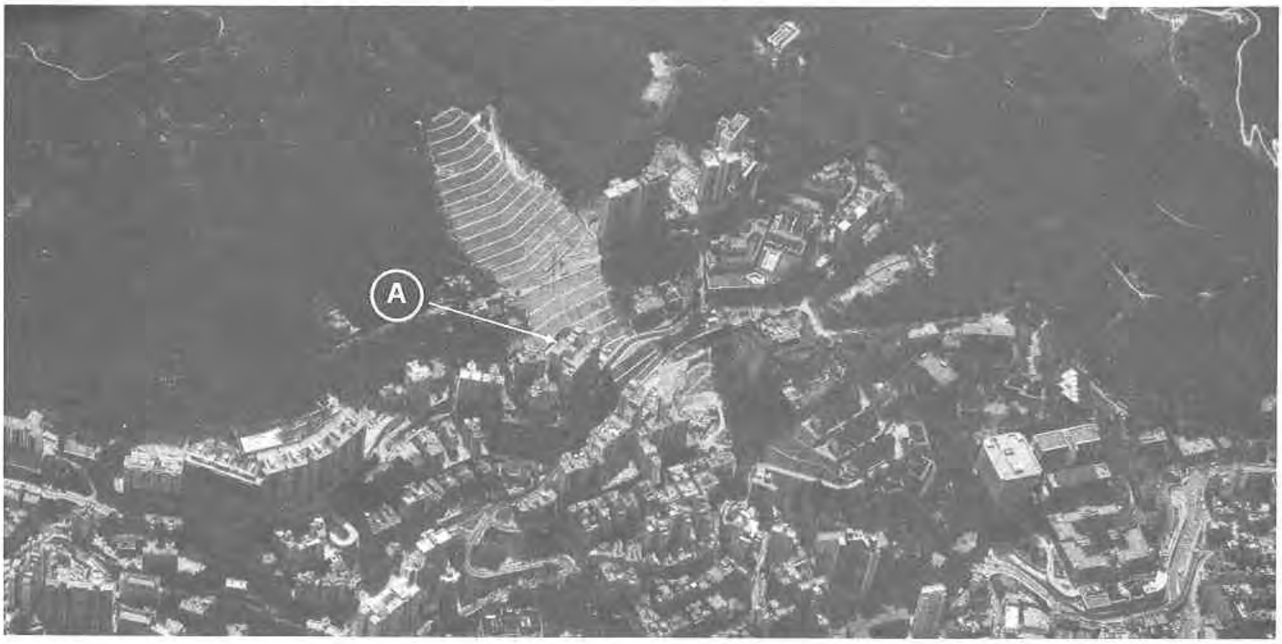


Plate 106. Oblique Aerial Photograph of Remedial Works to the Po Shan Road Landslip Site in February 1974. Reinstatement appears to be complete, with a large retaining wall behind Skyline Mansions (A). The new alignment of Conduit Road has been completed. Plate 117 shows the area in 1980. (28.2.1974/8264).

Plate 107. Oblique Aerial Photograph of Sau Mau Ping Landslip Site in 1972. **On the afternoon of** 18.6.1972, between 1.10 and 1.24 p.m., a massive landslip occurred on a fill slope between Hiu Kwong Street and Tsui Ping Road in Sau Mau Ping, Kowloon. This landslip followed some 6 weeks of continuous rainfall, culminating in 3 days of intense rain. The Royal Observatory recorded a total rainfall of 652.3 mm during the period 16–18.6.1972. This shallow failure took the form of a high velocity flowslide, and was probably due to 'liquefaction' caused by the super-saturation of uncompacted fill material. A large number of huts (A) were buried by mud, with 71 killed and 60 injured. The locations of Blocks 9 and 15 affected by landslips in 1976 are also shown. Compare this with Plate 111. Plates 108 and 109 provide further coverage of the 1972 failure. (ISD/21.6.1972/8264/11).

Plate 108. Landslip Debris at Sau Mau Ping in 1972. Debris is evident near Blocks 8 and 9 in Tsui Ping Road on 18.6.1972. The debris blocked Tsui Ping Road and Hui Ming Street. (ISD/18.6.1972/8255/32).

Plate 109a

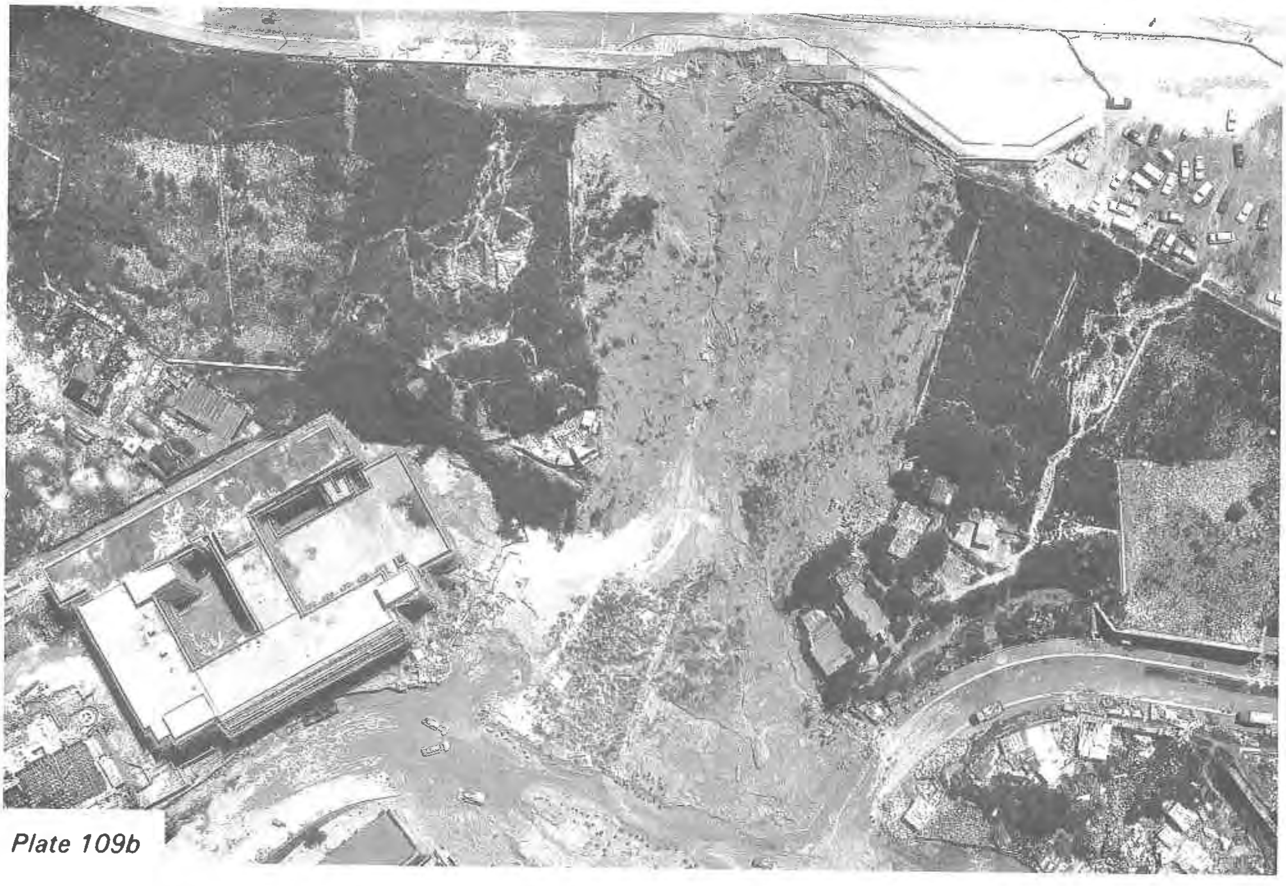


Plate 109b

Plate 109. Comparison of the Sau Mau Ping Area before and after the 1972 Landslip. **Plate 109a shows** the location of the Licensed Housing Area (A) near Tsui Ping Road prior to the landslip on 18.6.1972. Plate 109b, taken following the failure, shows the extent of damage. All the huts in the Licensed Area were destroyed. Compare this with Plate 107, which presents a view of the disaster scene 3 days after the landslip. Plate 115 shows the 1976 landslips and the remedial works to the 1972 landslip. (1972/30 & 31).

Plate 110a

Plate 110b

Plate 110. Landslip at Thorpe Manor in 1973. A retaining wall and fill slope in front of 1 May Road (Thorpe Manor) failed on 2.9.1973, following an intense rainstorm. According to newspaper reports at the time, there were two failures during the 30 minute period between 2.00 and 2.30 p.m. The Director of Public Works and the Principal Government Building Surveyor witnessed the second of the failures. Plate 110a shows the extent of the failure and the effect on the grounds of Thorpe Manor, whilst Plate 110b shows its dramatic position above a high-rise residential block. This failure, which occurred only a little over a year after the Po Shan (Kotewall) Road landslip disaster, received headline coverage in the daily press. At the time of the incident, Thorpe Manor was under demolition and collapsed scaffolding is evident on parts of the site. Debris from the failure severed May Road (located at A) and extended down a 40–50m cut slope onto the platform behind Grenville House. There were no injuries, but some 40 flats on the lower floors of this 12-storey residential block were evacuated for a period of several weeks. (ISD/OA/98/1973 and ISD/16A/98/1973).

Plate 111. Landslip at Sau Mau Ping in 1976. **Some four years after the 1972 landslip (Plates 107 to 109),** a further three landslips occurred on the fill slopes above Sau Lai Street. The embankment adjoining Block 9, Sau Mau Ping Estate collapsed at 10.12 a.m. on 25.8.1976. The landslip debris buried most of the ground floor of the residential estate building below the slope. As a result, there were 18 killed and 24 injured. This landslip occurred following intense rainfall on 25–26.8.1976. The Royal Observatory recorded more than 545 mm of rainfall in the 2 day period. The failure was very similar to the 1972 Sau Mau Ping landslip, involving the 'liquefaction' of uncompacted fill. The location of Block 9 in relation to the 1972 landslip is shown in Plate 107. Plates 55 and 56, taken at the time of site formation, provide an interesting comparison with the **location of the 1972 and 1976 failures highlighted in Plate 115. (ISD/25.8.1976/ 14949/76).**

Plate 112. Damage to a Coffee Shop on the Ground Floor of Block 9 in Sau Mau Ping Estate in 1976. Mud and debris resulting from the landslip on 25.8.1976 filled this Coffee Shop in Block 9. (ISD/25.8.1976/14949/13).

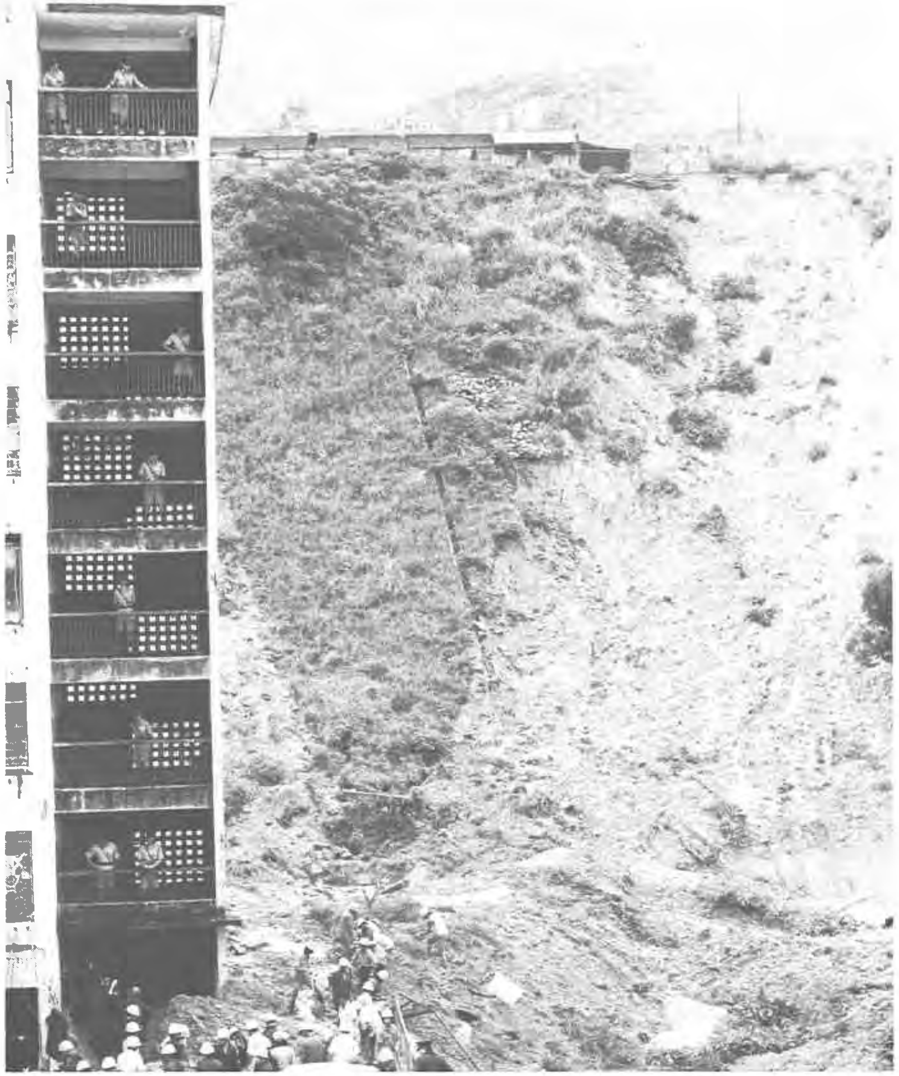


Plate 113. Debris near Block 8 in Sau Mau Ping Estate in 1976. Landslip debris is evident around the ground floor of Block 8. The largest of the landslips occurred on the slope behind and to the left of Block 8. The second smaller landslip is clearly evident at the right of the photograph.
(ISD/25.8.1976/14949/3).

Plate 114. Debris near Block 15 in Sau Mau Ping Estate in 1976. Landslip debris is being cleared from the vicinity of Block 15 following the landslip on 25.8.1976. Compare this with Plates 107, 111 and 115. (ISD/25.8.1976/14949/118).

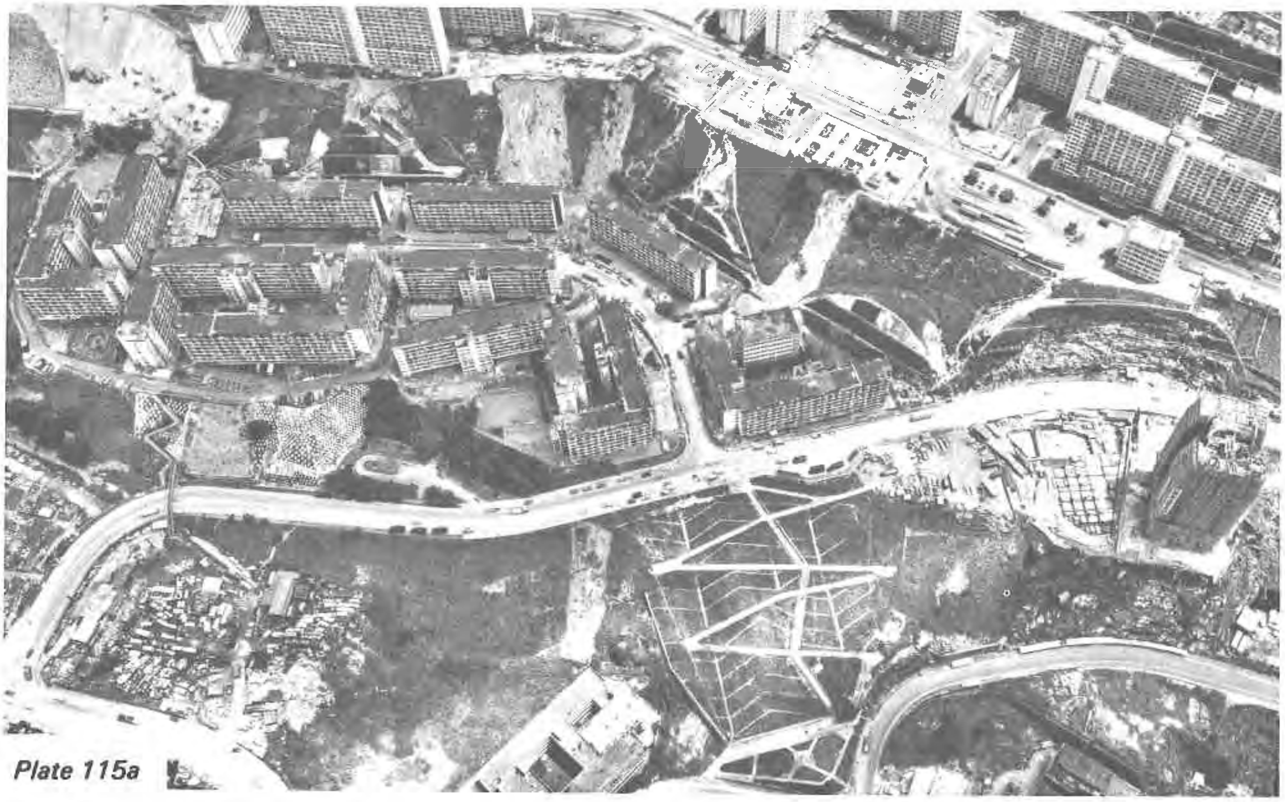


Plate 115a

Plate 115b

Plate 115. ***Oblique and Stereopair Aerial Photographs of the Sau Mau Ping Landslips in 1976.*** Plate 115a is an oblique aerial photograph taken on 26.8.1976, which shows the landslips behind Blocks 8 and 15 in Sau Lai Street, and the remedial works to the 1972 landslip. The 1972 landslip is shown in Plate 109. The stereopair of aerial photographs in Plate 115b shows the location of these features. These photographs were taken some 3 months later, on 26.11.1976. Compare the locations of the landslips with those of the site formation stage failures on the same slopes in 1964. Note that the large failure at Tsui Ping Estate, shown in Plates 55 and 56, occurred to the southeast. (26.8.1976/15058 & 24.11.1976/16574–5).

Plate 116. Aerial Photograph of the Caine Lane Retaining Wall Failure in 1976. The retaining wall between Caine Lane and Caine Road, in the Mid-levels District, collapsed on 25.8.1976. The failure (A) occurred at an elevation of approximately 70mPD. Three old masonry retaining walls supported Caine Road and Caine Lane, the lowest of which failed. Some 400 people were evacuated following this failure. Another retaining wall failure (B) occurred on the same day in Castle Road, collapsing onto the grounds of Merry Terrace. The wall was some 10m high and the failed portion was some 18m in length, at about 95mPD. (26.8.1976/15085).

Plate 117. Oblique Aerial Photograph of the Po Shan Road Landslip Site in 1980. Considerable development has occurred on the adjacent terrain since 1972. Plates 92 to 106 provide a site history during the period before and after the failure. (GCO/OAP/1980/ PS132-9A).

Plate 118. ***Oblique Aerial Photograph of the Lower to Mid-levels Area of Hong Kong Island in 1979.*** **The photograph illustrates the intensity of multistorey development within the area. The Moratorium on Building Development, imposed in May 1979, affected much of the mid to upper areas of the developed terrain. The Moratorium restricted development in the area whilst intensive geotechnical investigations were completed. (GCO/OAP/1979/PS37–7).**

Plate 119. Oblique Aerial Photograph of Landslip on Ching Cheung Road in 1982. **This photograph** shows the disruption of the east bound carriageway above Wai Man Tsuen in Butterfly Valley. The landslip resulted from the failure of a large cut slope. (GCO/OAP/PS336–12A).

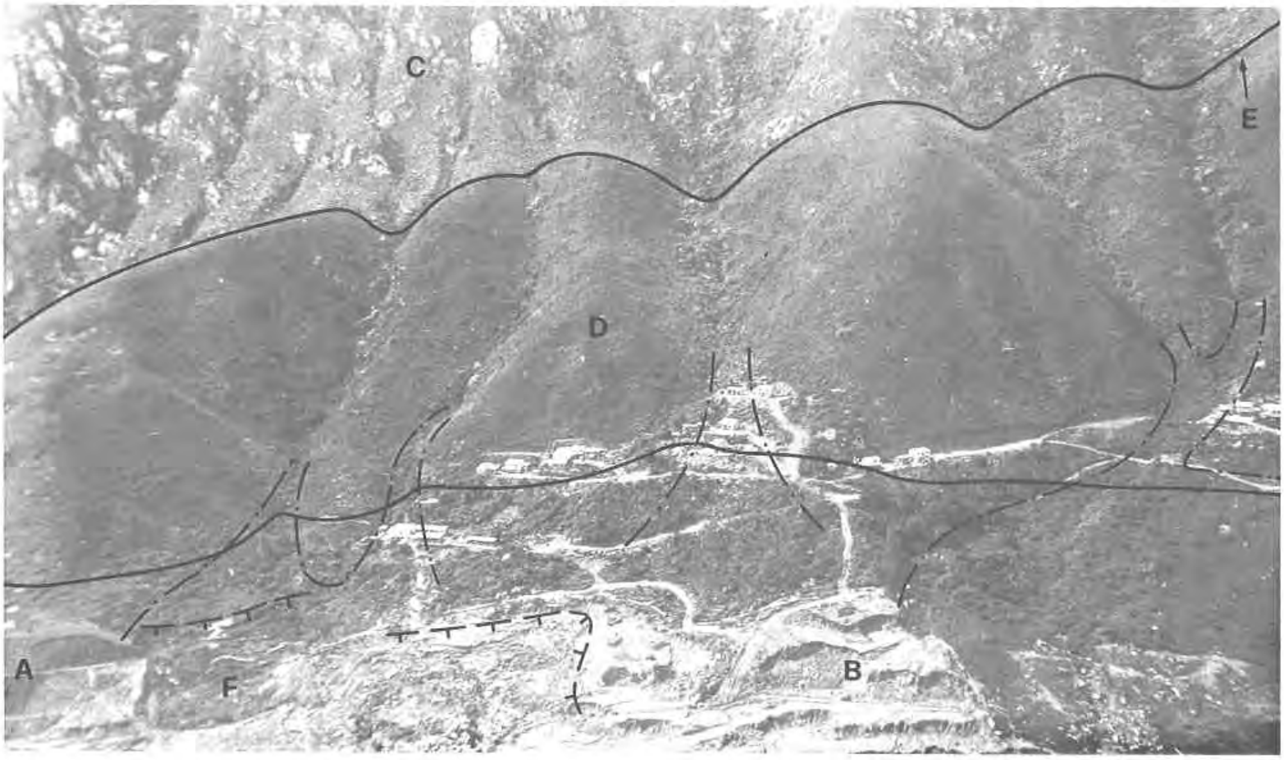


Plate 120. Oblique Aerial Photograph of Tuen Mun Borrow Area 19 in 1978. On the eastern slopes below Tsing Shan (Castle Peak), several areas of instability are associated with decomposed volcanic (A) and colluvial terrain (B). The upper slopes are formed of well-jointed granite (C) and decomposed metasediments (D), separated by a near-vertical fault (E). This Plate demonstrates the significance of the natural drainage pattern on instability. The zone of instability marked at F (shown in Plate 121) is within an area that receives discharge from the upper slopes. Numerous tension cracks are visible within the area. This view is to the west across the borrow area on 28.9.1978. The stereotriplet at Plate 122 shows the general nature of the terrain prior to development. (GCO/OAP/1978/PS9-1).

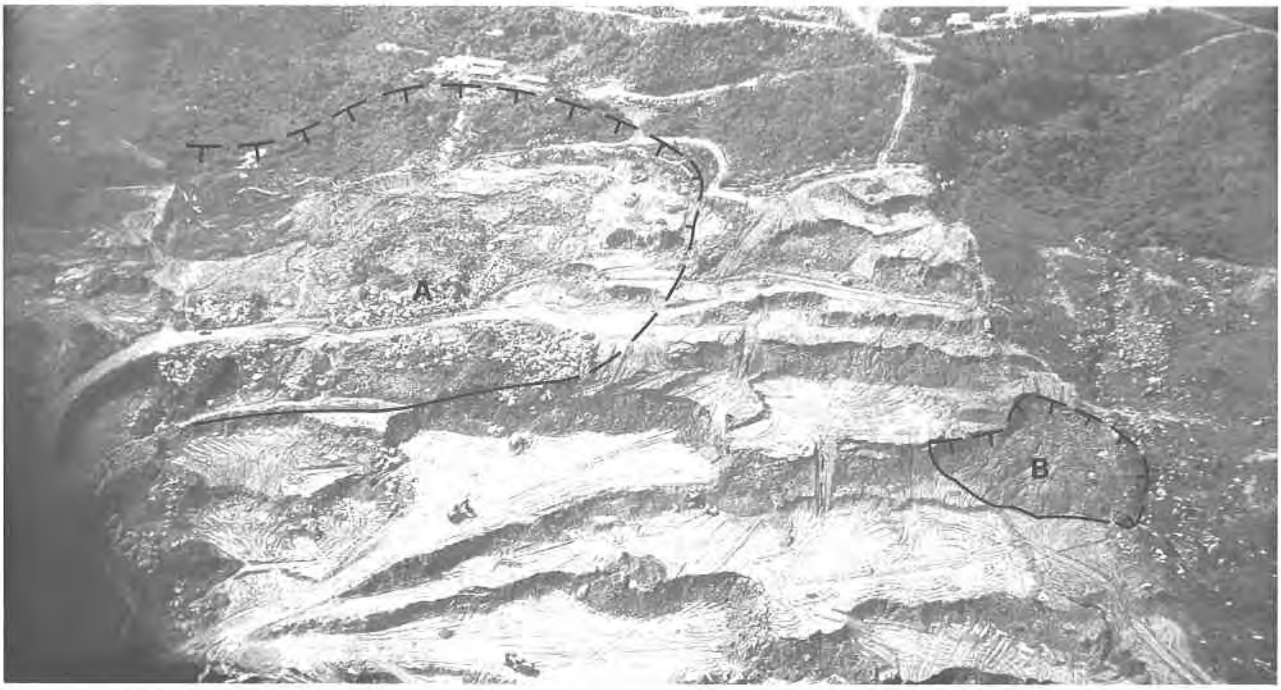


Plate 121. Oblique Aerial Photograph of Progress on Site Formation for Tuen Mun Borrow Area 19 in 1978. This photograph illustrates the state of extensive cutting of the footslope terrain in Area 19 on 28.9.1978. The general area of instability is indicated at A, whilst a smaller failure is at B. (GCO/OAP/1978/PS9–2).

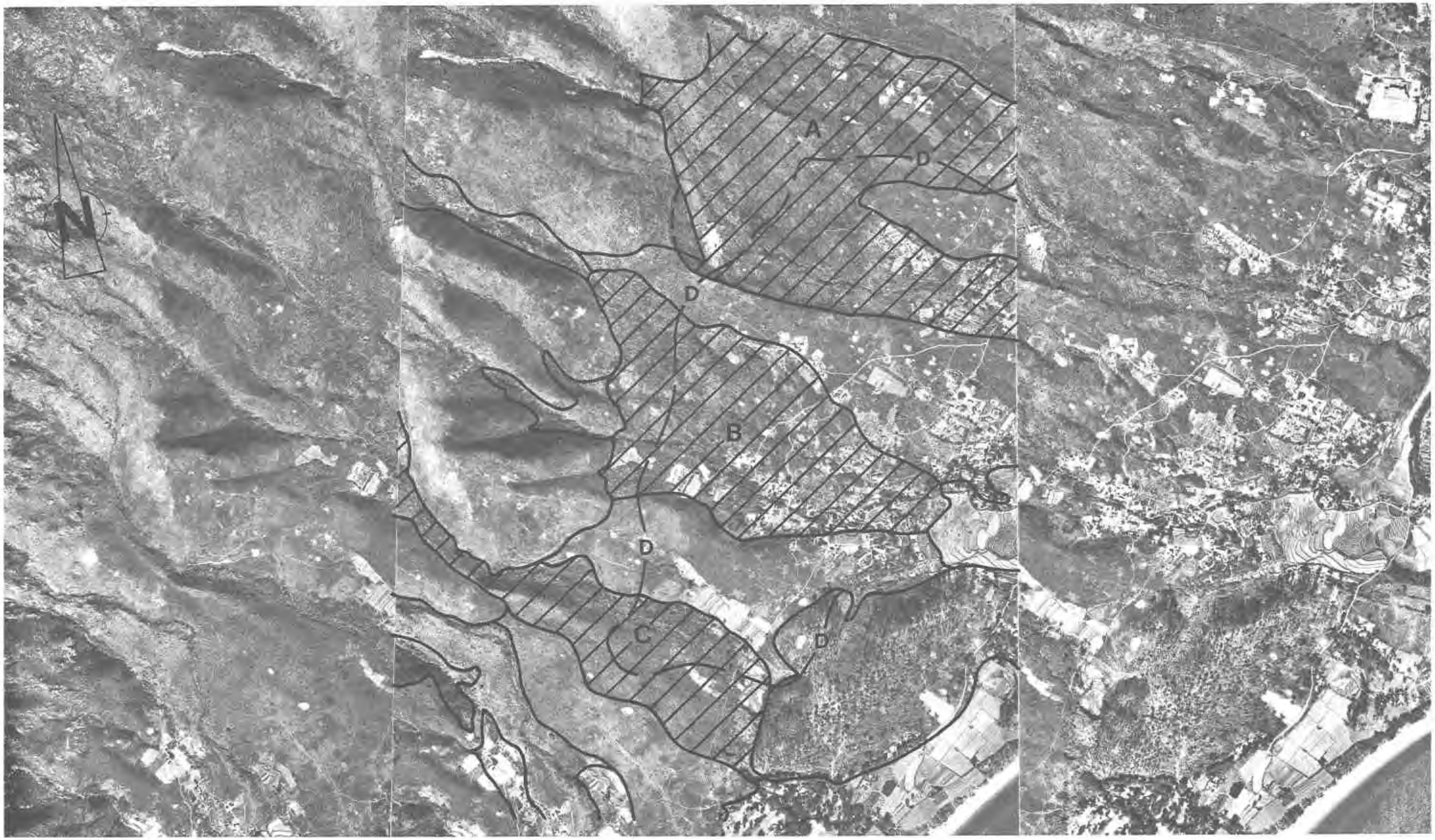


Plate 122. Stereotriplet of Aerial Photographs of the Footslopes of Tsing Shan (Castle Peak) in 1963. The plate shows the terrain in Tuen Mun Borrow Area 19 on 29.1.1963, some 15 years prior to development. There is considerable evidence of instability reflected in the disposition of the colluvium which covers the footslope terrain. Three areas of instability, associated with the footslope terrain, are indicated at A, B and C. These areas are characterised by hummocky and irregular terrain. These areas coincide with zones of surface runoff from the major drainage lines leading from Castle Peak. The general extent of Borrow Area 19 is shown at D. Plates 120, 121, 123 and 124 show the terrain within this area following site formation works. (1963/6111–2).

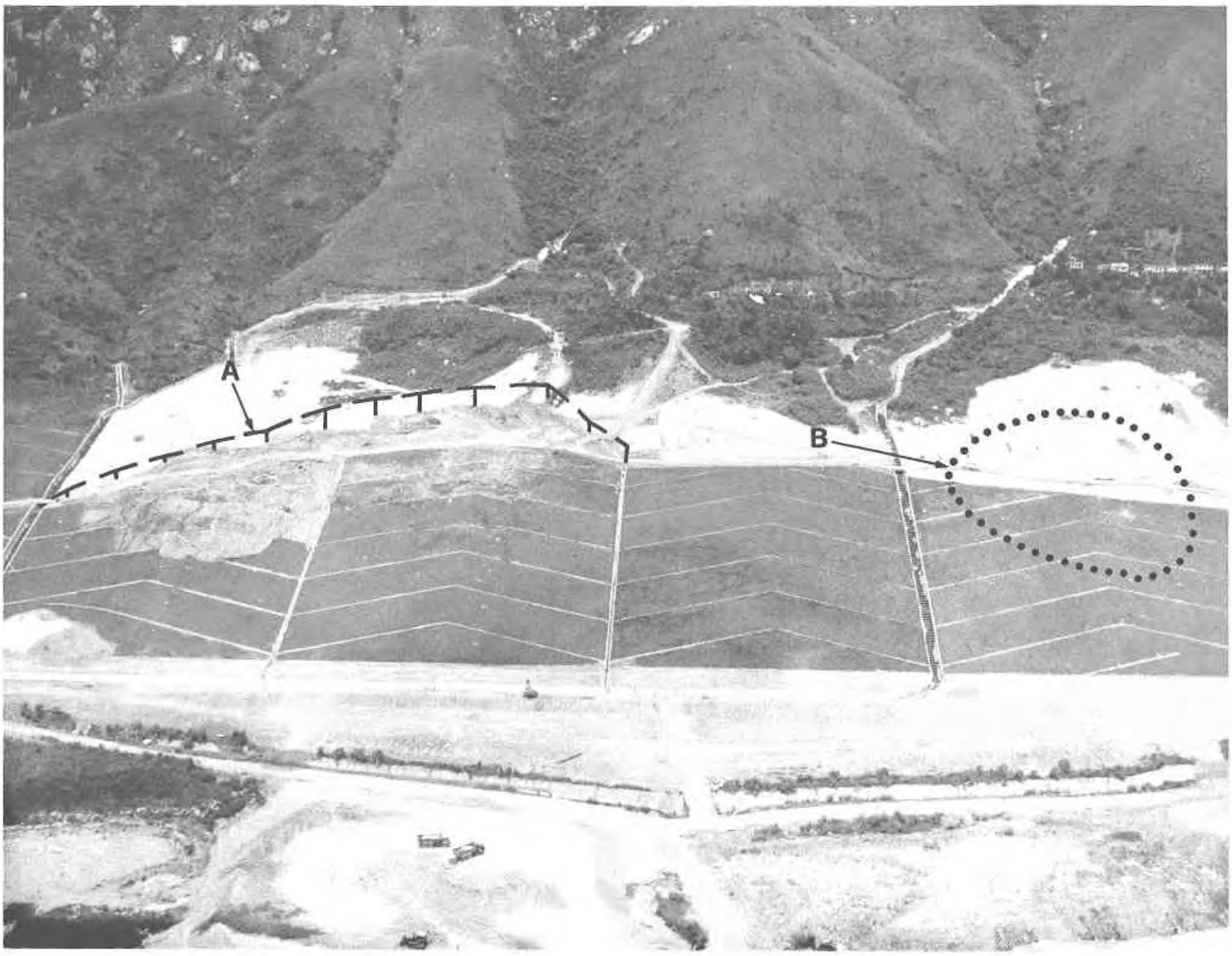


Plate 123. Oblique Aerial Photograph of Remedial Works to Tuen Mun Borrow Area 19 in 1984. The landslips that occurred between 1978 and 1983 have been reinstated with a large grassed and regraded cut slope. Instability within the southern portion (A) of the area has continued, with resultant disruption of the newly formed cut slope. Compare this with Plates 120 and 121 taken some 6 years before in 1978. The area to the north (B) failed shortly after this photograph was taken. (GCO/OAP/1984/PS468–4).

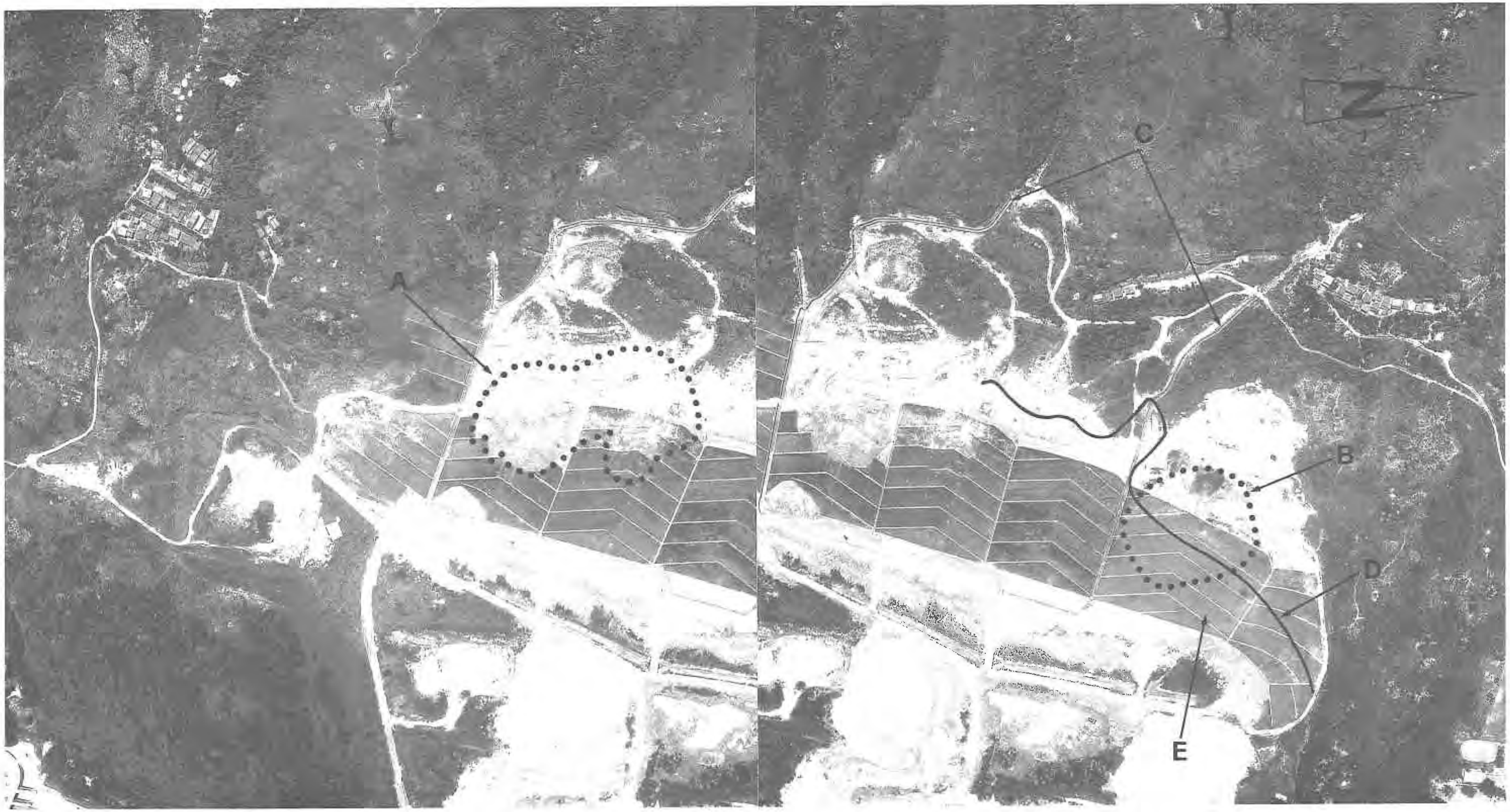


Plate 124. ***Stereopair of Aerial Photographs of Remedial Works to Tuen Mun Borrow Area 19 in 1984.*** This plate shows the general extent of failure of the southern portion of the area (A), and also indicates the general location of later failure in the northern portion of the slope (B). Large capacity concrete drainage channels collect surface runoff from the major drainage lines across the slope (C). Many photographs taken during construction and remedial works reveal large areas of groundwater seepage associated with the zones of surface water concentration. Large tunnels and voids were discovered in the colluvium within the zones of general instability (Areas A, B and C on Plate 122). The subsurface tunnels and voids do not appear to have any surface expression. The approximate downslope limit of the colluvium, following excavation, regrading and other remedial works, is indicated by line D. Following excavation of the overlying colluvium, decomposed volcaniclastic rocks form the lower cut slopes in the general area of E. Plate 123 provides an oblique perspective, taken at about the same time. (1984/55191–2).

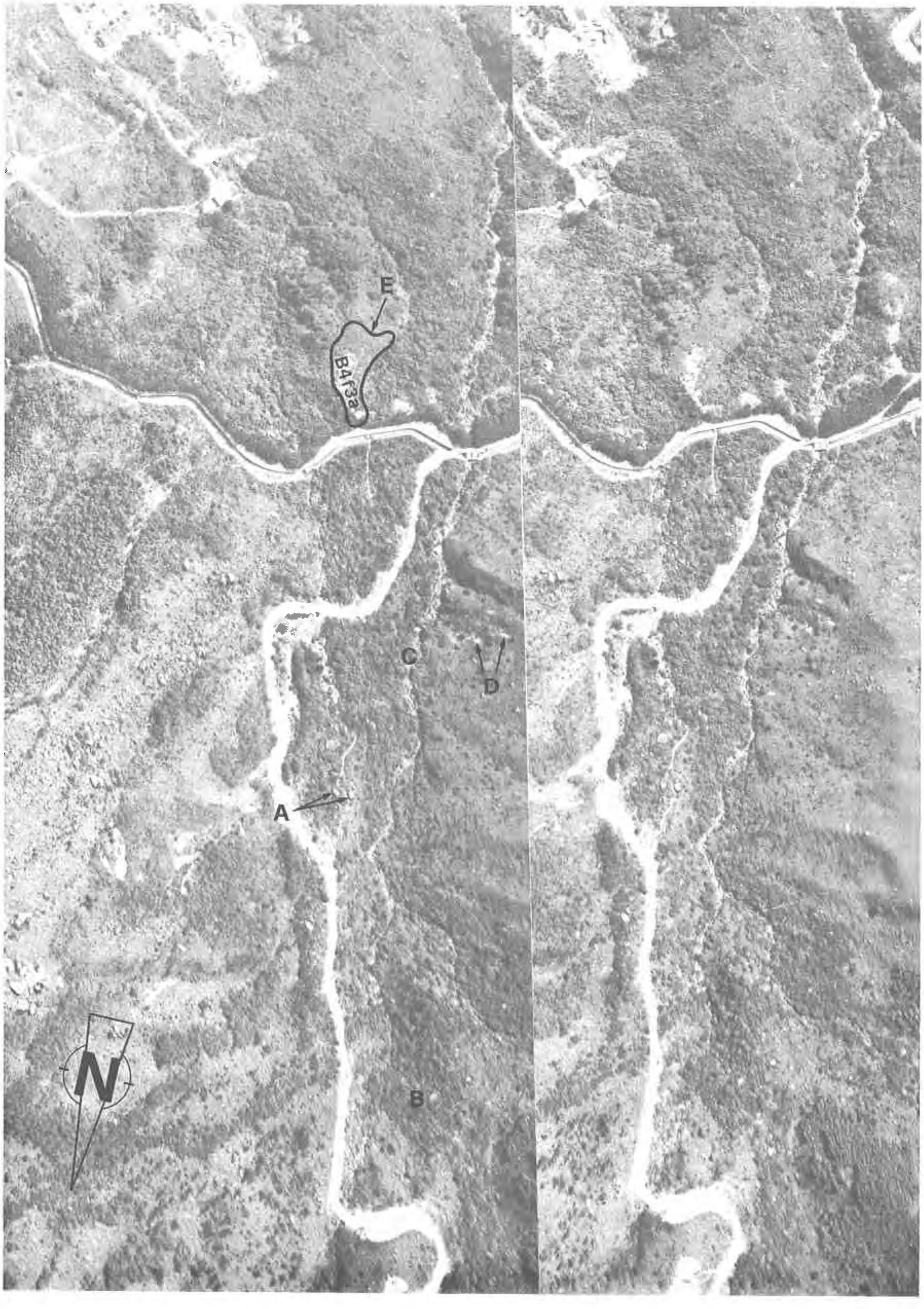


Plate 125. Stereopair of Aerial Photographs of Colluvial Terrain in the Cheung Sha Area of Lantau Island in 1980. The catchwater to Shek Pik Reservoir and the Tung Chung Road cross colluvial terrain. The area was mapped at a scale of 1:2 500 in the GASP District Stage 1 Study of Cheung Sha. Large colluvial boulders are evident at A, areas of general evidence of instability are apparent at B, and a knick point occurs on the major drainage line at C. A number of small landslips are also apparent in the insitu volcanic terrain (D). An example of a 1:2 500 scale terrain classification map unit is also given at E. The terrain map unit (B4f3a) represents an area of 5–15° gradient, on colluvial terrain with minor sheet erosion. Refer to Table A7 for 1:2 500 scale terrain classification codes. (12.11.1980/32897–98).

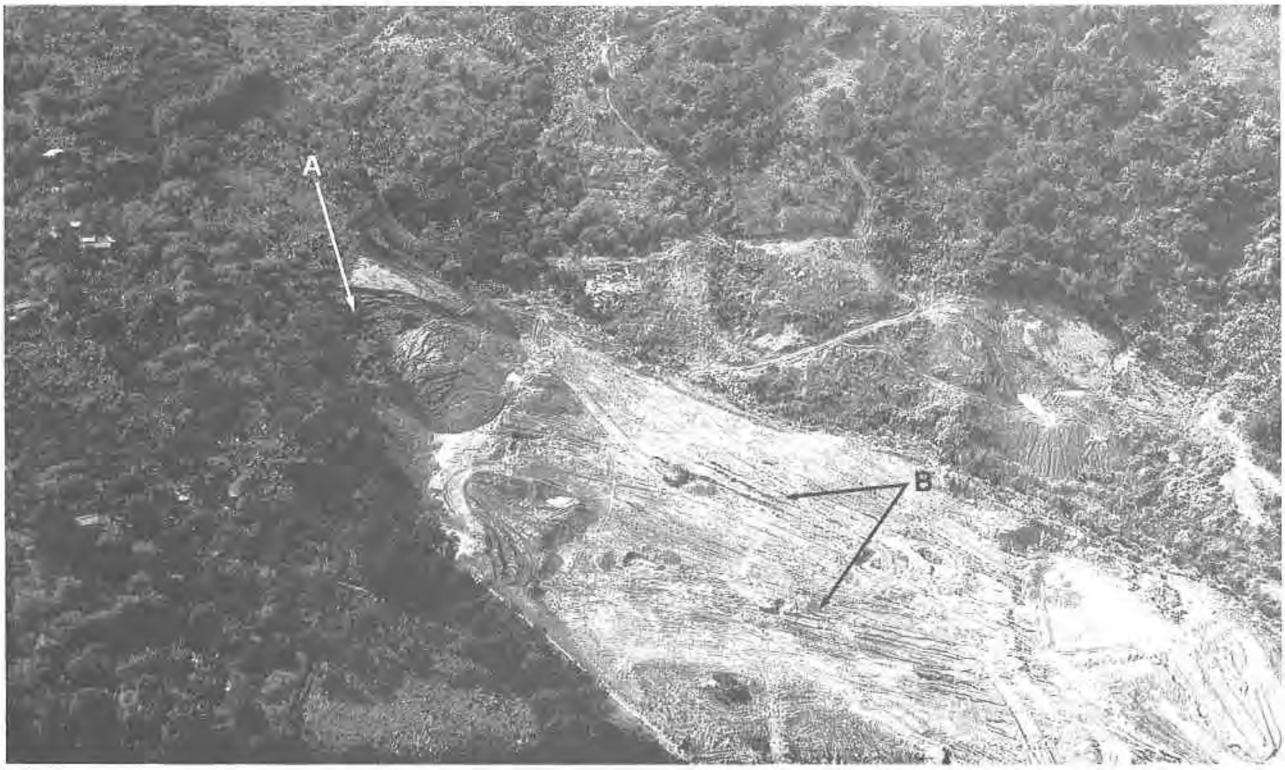


Plate 126. Oblique Aerial Photograph of Landslip in Tuen Mun Borrow Area 8 in 1978. **A small** landslip (A) occurred during site formation on deeply weathered volcaniclastic rocks. Severe erosion and soil tunnelling are also generally evident on the cut slope at B. Unlike Borrow Area 19 (Plates 120–124), colluvial deposits did not blanket the site prior to construction (GCO/OAP/1978/PS3–9).

Plate 127. Oblique Aerial Photograph of Landslip at Kau Tau in 1979. **Failure of a cut slope occurred in a** borrow area near the Chinese University of Hong Kong. (GCO/OAP/1979/PS52–17).

Plate 128. Oblique Aerial Photograph of Landslip at Ma On Shan Mine Site in 1979. The landslip associated with old mine workings at Ma On Shan is easily the largest area of instability within the Territory. Taken in 1979, this photograph shows the unstable mine workings, and the extensive system of tension cracks on the south-facing natural hillside. Instability was first apparent in 1954 in the area indicated at A. Evidence of the first incidence of the large tension cracks on the south-facing slope (B) was apparent in aerial photographs taken in 1969, and by 1973 they were clearly defined. The tension cracks have enlarged since 1973. Extensive underground operations associated with mining occurred between 1953 and 1976, and tunnels and shafts were constructed beneath the site. The Ma On Shan Mine has a long history of development commencing in 1906, when the first licence was issued to the Hong Kong Iron Mining Company. In 1934, the New Territories Iron Mining Company was granted a Crown Lease for 50 years. In 1940, South China Iron Smelters Limited took over with the intention of building a blast furnace on the sea-front. From 1942 to 1944, the mine was operated sporadically by the Japanese and employed about 1 500 workers. As there was no mechanical transport, the ore was carried by coolies to the seashore (Davis, 1961). In 1949, the Mutual Trust Company assumed the mining rights and in 1953 the Nittetsu Mining Company of Japan joined the Mutual Trust Company to operate the mine. In that year, the change-over from open cast to underground mining began and by 1959, all mining was underground. The mine ceased operations in 1976 (Addison, 1986). (GCO/OAP/1979/PS55–8).

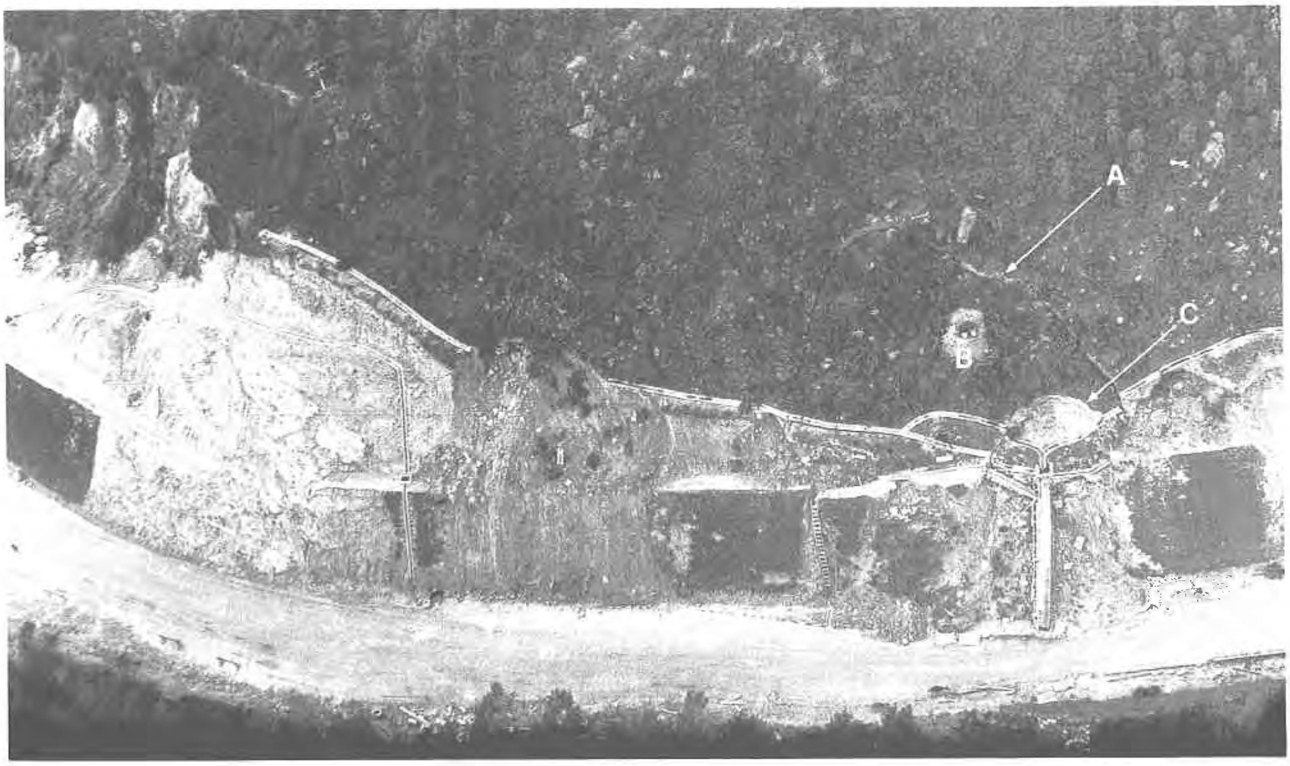


Plate 129. Oblique Aerial Photograph of Landslips on the South Lantau Road in 1979. **Failure of the cut** slopes occurred during the widening of the road at Shui Hau near Shek Pik Reservoir. A large tension crack is evident (A), whilst three workers excavate a hand-dug caisson (B), presumably to locate the slip surface. A small landslip, which occurred earlier during construction, is covered with chunam (C). (GCO/OAP/1979/PS37–33).

Plate 130. Oblique Aerial Photograph of Landslip at Ngau Chi Wan in 1979. **Failure at A, of a cut slope,** during site formation, in decomposed granite (B) and colluvium (C) is evident on a natural drainage line. A portion of Jats Incline is evident at D. (GCO/OAP 1979/PS55–23).

Plate 131. ***Oblique Aerial Photograph of a Landslip near Kwun Yam Shan in July 1979.*** **A landslip occurred during site formation for a large development near Kadoorie Farm. This photograph was taken during July 1979. Compare this with Plate 132, which was taken some 3 months later in October 1979. (GCO/OAP/1979/PS51–20A).**

Plate 132. Oblique Aerial Photograph of a Landslip near Kwun Yam Shan in October 1979. The site is viewed from the northwest, and the landslip is evident on a formed cut slope. Lam Kam Road is in the foreground. Compare this with Plate 131 taken some 3 months earlier. (GCO/OAP/1979/PS78–31).

Plate 133. Oblique Aerial Photograph of a Landslip below Victoria Road in 1979. This landslip occurred during Typhoon Hope in September 1979 and affected huts in a mid-slope position near Baguio Villa. (GCO/OAP/1979/PS75–6A).

Plate 134. Oblique Aerial Photograph of Remedial Works to Landslip Site near World Wide Gardens in Sha Tin in 1979. This photograph, taken in 1979, shows remedial works on the site of a landslip which occurred during Severe Tropical Storm Agnes in July 1978. (GCO/OAP/1979/PS19–12).

Plate 135. Oblique Aerial Photograph of a Severely Eroded Fill Slope in the Silverstrand Area in 1980. Severe gully and sheet erosion is evident on this large fill slope on the Clear Water Bay Peninsula. (GCO/OAP/1980/PS134–1).

Plate 136. Oblique Aerial Photograph of Remedial Works to a Landslip in the Cemetery at Pok Fu Lam in 1981. A landslip resulted in the exhumation of more than 500 grave sites and illustrates in a dramatic manner, that it is not always possible to 'rest-in-peace' from the dangers of slope failure. (GCO/OAP/ 1981/PS230–2A)

Plate 137. Oblique Aerial Photograph of a Landslip at Tai Wo Ping in 1981. This landslip occurred near the Crow's Nest, in the vicinity of Beacon Hill. Further detail of the landslip at A is given in Plate 138. (GCO/OAP/1981/PS232–17).

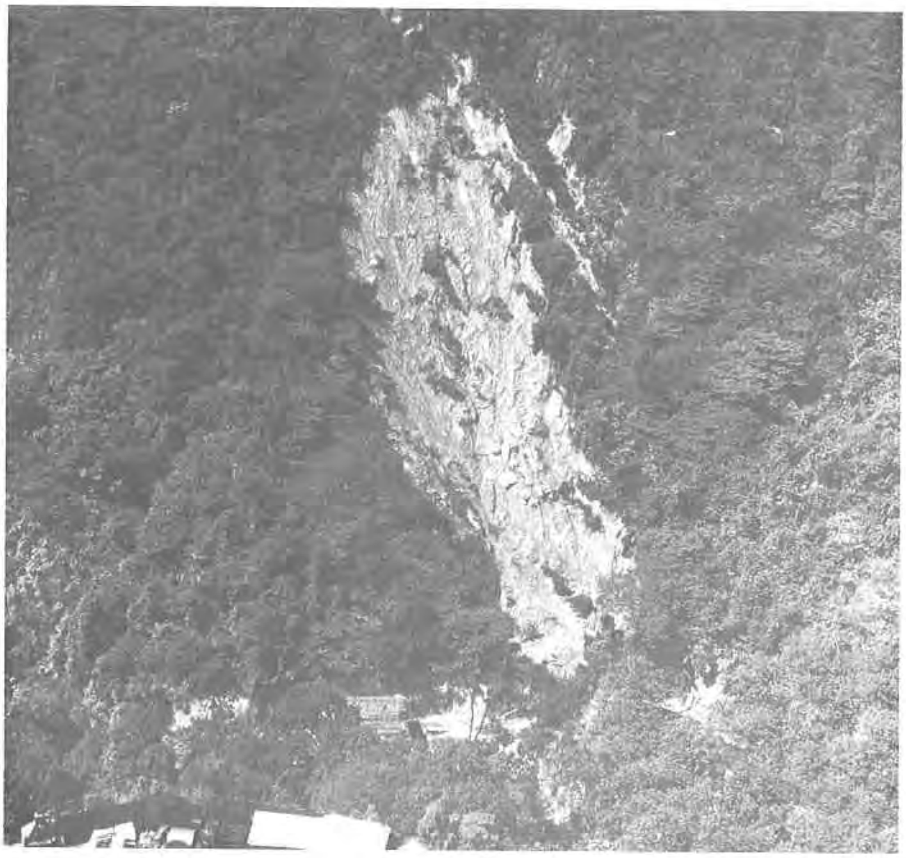


Plate 138. Oblique Aerial Photograph of Landslip near the Crow's Nest in 1981. This landslip occurred on natural granitic terrain in the vicinity of Beacon Hill, and is also shown in Plate 137. (GCO/OAP/1981/PS232–12).

Plate 139. Landslip at Tsin Shui Ma Tau in 1982. The landslip is viewed from the playground at the base of the slope, and the precarious position of the undermined squatter huts is evident. An aerial view of the landslip is presented in Plate 140. (GCO/ES/1982/206819).

Plate 140. Oblique Aerial Photograph of Landslip at Tsin Shui Ma Tau in 1982. Slope failure occurred on a cut slope and affected squatter huts at the crest of the slope and a portion of a children's playground. Plate 139 provides detail of the failure viewed from the playground at the base of the slope. (GCO/OAP/1982/PS297–9).

Plate 141. Landslips in a Squatter Village in East Kowloon in 1982. Several landslips are evident in this squatter village and resulted in the evacuation of a large number of the occupants. (GCO/ES/1982/211605).

Plate 142. Oblique Aerial Photograph of Erosion on a Fill Slope near Siu Lam San Tsuen in 1982. Severe erosion is evident on the road embankment, and a large area of sediment is apparent. (GCO/OAP/1982/PS275–12A).

Plate 143. Oblique Aerial Photograph of Landslips on a Road Embankment near Cafeteria Beach in 1982. Although these are relatively small failures, this type of incident has considerable impact in terms of maintenance costs for reinstatement and clearance of blocked access and drainage systems. (GCO/OAP/1982/PS275–5A).

Plate 144. Oblique Aerial Photograph of Landslips on Castle Peak Road in 1982. During heavy rain on 29.5.82, a number of failures occurred in the vicinity of Lai Shum Villa off Castle Peak Road. These included three minor cut slope failures behind the Villa, one larger cut slope failure on Castle Peak Road, the subsidence of a 30 m by 30 m wide section of Castle Peak Road due to failure of a fill embankment, and the failure of the edge of a fill platform associated with the cracking of a masonry retaining wall. The interesting aspect of the Lai Shum Villa incidents is that six failures occurred in a very small area, on both cut and fill slopes. This could be attributed to extremely intense local rainfall, perhaps for only a few minutes during the storm. (GCO/OAP/1982/PS272–23).

Plate 145. Oblique Aerial Photograph of Landslip in South Bay Close in 1982. The failure occurred in the upper 12 m of a slope under construction on 29.5.82, during heavy rain. More than 3 000 m^3 of debris was involved and affected much of the site for a multistorey residential block. The failure occurred along a pre-existing, persistent discontinuity some 700 mm thick in places. The infill material consisted of a 'gouge' of gravel sized fragments of volcanic rock in a silty matrix, with occasional bands and pockets of pink clay. After the failure, water flowed from the discontinuity at several points. Piezometers, read on a daily basis prior to the failure, did not confirm the existence of a perched water table. However, piezometer buckets were installed in existing standpipes after the failure, and readings taken during the August rainstorms in 1982 showed much higher water levels. The landslip occurred as a simple wedge failure along a pre-existing major discontinuity. (GCO/OAP/1982/PS286–8).

Plate 146. Oblique Aerial Photograph of Landslip above Kennedy Road in 1982. Failure occurred on the hilly terrain south of Wan Chai. (GCO/OAP/1982/PS260–23).

Plate 147. Oblique Aerial Photograph of Landslip in a Squatter Area at Lam Tin in 1982. A number of huts were destroyed by this failure above Junk Bay Road. (GCO/OAP/1982/PS297–5).

Plate 148. Oblique Aerial Photograph of Landslip near a Squatter Area at Lam Tin in 1982. A large cut slope failure occurred on Junk Bay Road near the location of the landslip in Plate 147. The general area had been cleared of squatters at the time due to a fire earlier in the year. Some details of the slope failure are presented in Plate 149. (GCO/OAP/1982/PS297–5A).

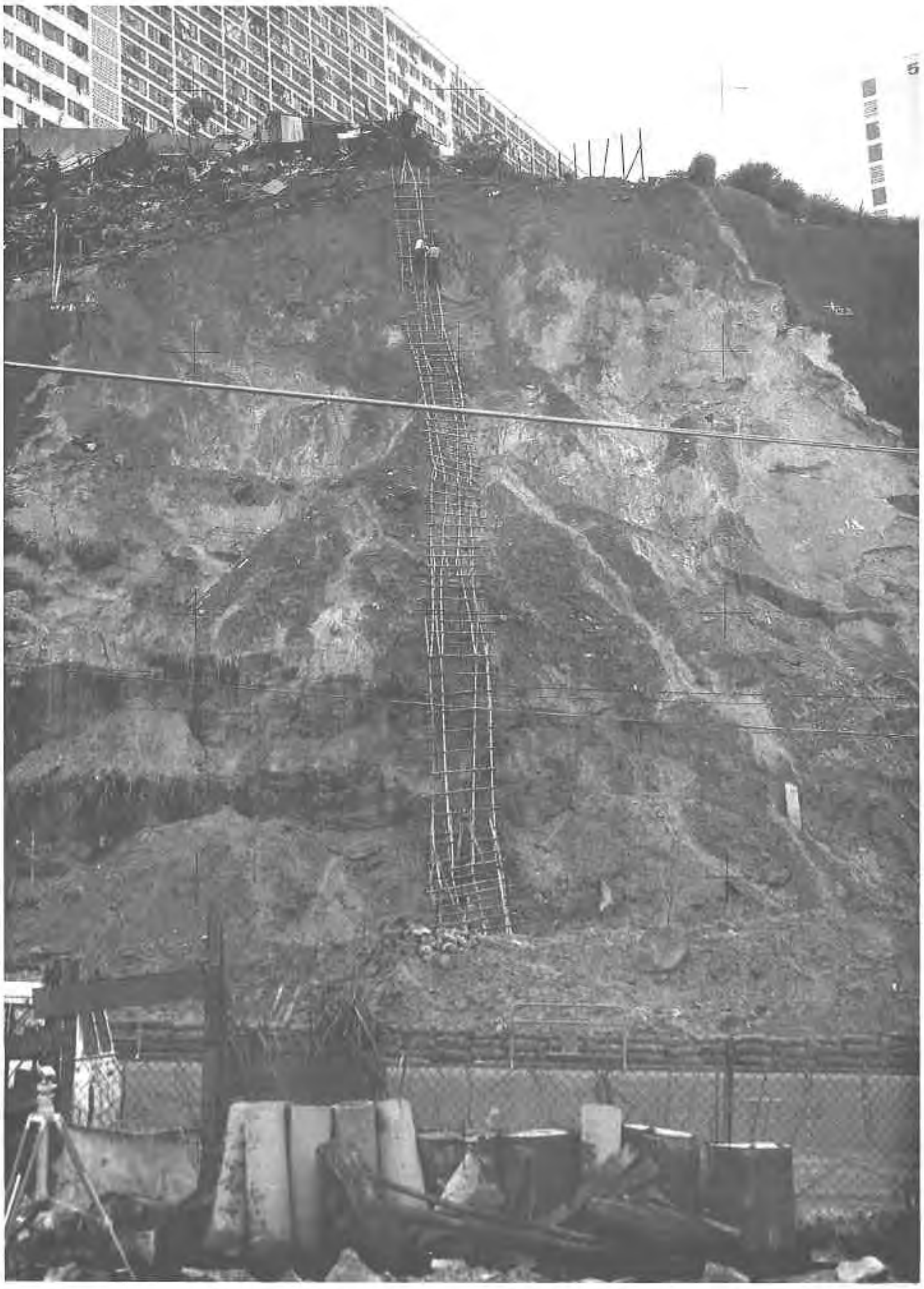


Plate 149. Landslip Site on Junk Bay Road in 1982. The upper 20 m of a 30 m high, 53° cut slope with chunam protection failed on 31.5.82 following heavy rain. Debris completely blocked Junk Bay Road, extending approximately 25m from the toe of the slope. The area had been investigated in early 1982 and a section of the slope, very close to that which failed in May, had been analysed and shown to have a factor of safety close to unity. One of the boreholes, which also had a piezometer installed, was located within a few metres of the crest of the subsequent failure scar. The slip surface passed through approximately 2.5m of Grade VI decomposed granite overlying Grade V decomposed granite, containing about 30% corestones of Grade IV (refer to Table A4 in Appendix A). A significant feature within the failure scar was the existence of parallel, daylighting joints infilled with up to 20mm of kaolin, which were exposed about halfway down the slip surface. Much of the lower part of the scar was coated with kaolin, indicating the continuous nature of these joints. The piezometer installed at the head of the slope was equipped with a maximum level recording device (bucket string) but indicated a peak water level lower than zones of active seepage noted from the failure scar. A second piezometer, which was further away, gave a peak level which agreed more closely with field observations. Failure occurred along a persistent discontinuity infilled with kaolin, which was not recognised during the original site investigation. High water pressures may have developed along the discontinuity with the formation of a perched water table. The piezometer located near the head of the failure, however, did not record this. (GCO/1982).

Plate 150. Landslip at Wa On Terrace in 1982. Failure of a cut slope and retaining wall caused damage to this residential property in the Tsuen Wan district. (GCO/1982/19/70/82).

Plate 151. Landslips on the Peak Tramway near May Road Station in 1982. This landslip severely disrupted tram services to the Peak. (GCO/ES/1982/216604).

Plate 152. Landslip on Road Embankment near Sui Wo Village in 1982. This landslip occurred near the 17.5 milestone on Castle Peak Road and damaged agricultural land. A vehicle, presumably parked on the carriageway at the time of failure, is evident at A. (GCO/OAP/1982/PS275-9A).

Plate 153. Landslip on Peak Road in 1983. This landslip severely damaged the westbound carriageway of Peak Road near the junction with Magazine Gap Road and resulted in the closure of the only access to The Peak for a week. An aerial view of site is given in Plate 57, and remedial works are shown at B in Plate 190. (GCO/1983/83/122/12A).

Plate 154. Landslip at Hing Man Estate in 1983. This landslip resulted from the failure of a colluvial slope beneath the car park podium of a housing estate under construction. Note the exposure of the foundations (A). Hing Man Estate is in the Chai Wan area. (GCO/1983/83/121/21).

Plate 155. Landslip at Pak Tin in 1983. This failure resulted from the collapse of a 5 m high masonry retaining wall. The landslip debris blocked a Water Supplies Department access road. (GCO/1983/83/150/13).

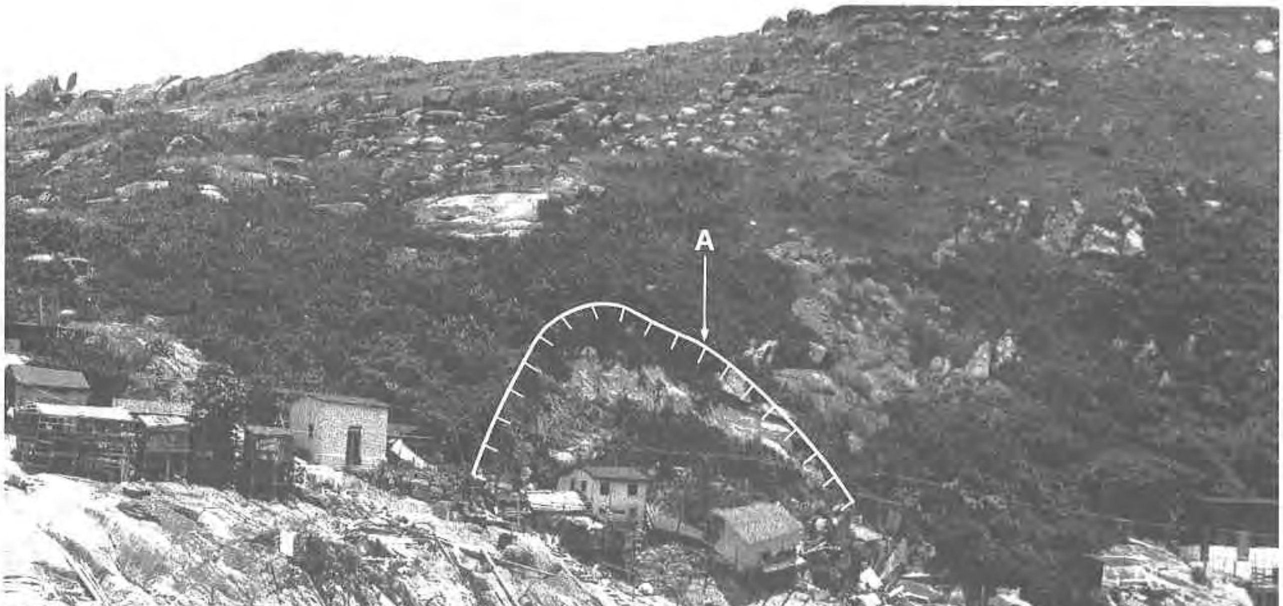


Plate 156. Landslip on Po Toi Island in 1983. Failure of a slope (A) on the relatively remote island of Po Toi resulted in severe damage to a number of huts. Even the relatively remote settlements in the Territory are not immune from the influence of slope failure. (GCO/1983/83/147/11).

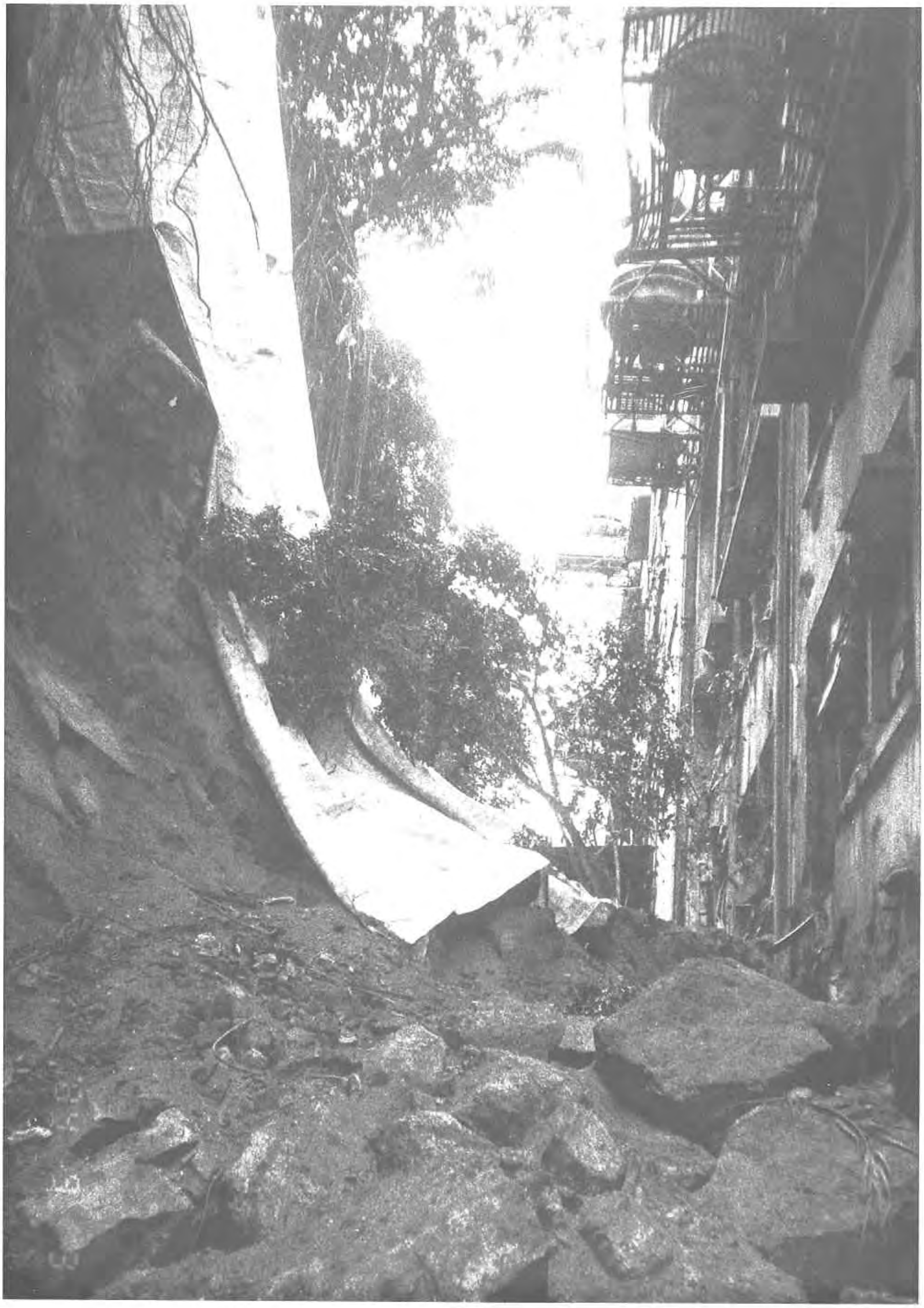


Plate 157. Landslip at Tsat Tsz Mui Road in 1984. Failure of a soil-rock cut slope behind 206–208 Tsat Tsz Mui Road caused damage to private buildings. (GCO/IE/1984/IE111/84/5).

Plate 158. Damage to Workshop at Tsat Tsz Mui Road in 1984. Failure of the cut slope, shown in Plate 157, resulted in damage to a workshop on the ground floor. (GCO/IE/1984/IE111/84/6A).

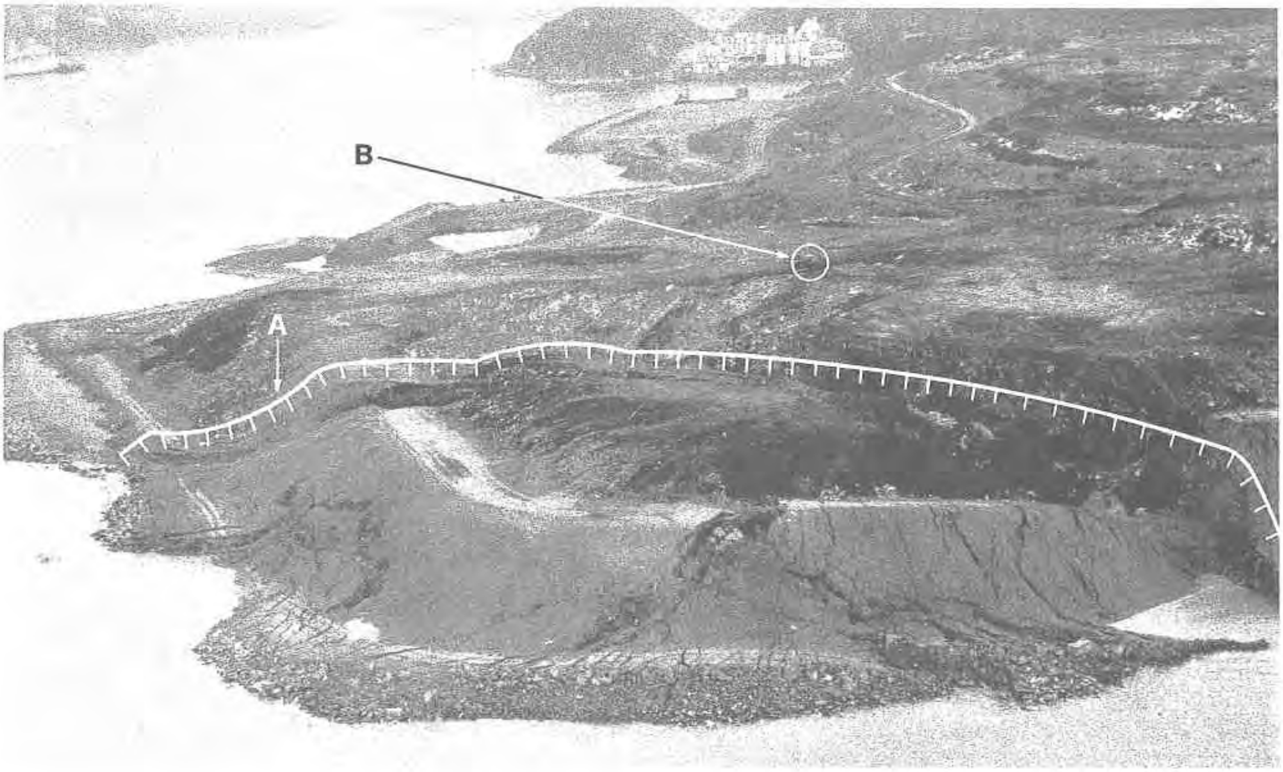


Plate 159. Oblique Aerial Photograph of Failure of Landfill at Junk Bay in 1984. This photograph shows a failure of the southwestern corner of the controlled tip. The general area of failure is indicated at A. Earthmoving plant (B) on the site provide an indication of the magnitude of the failure. (GCO/MW/1984/64/84/24).

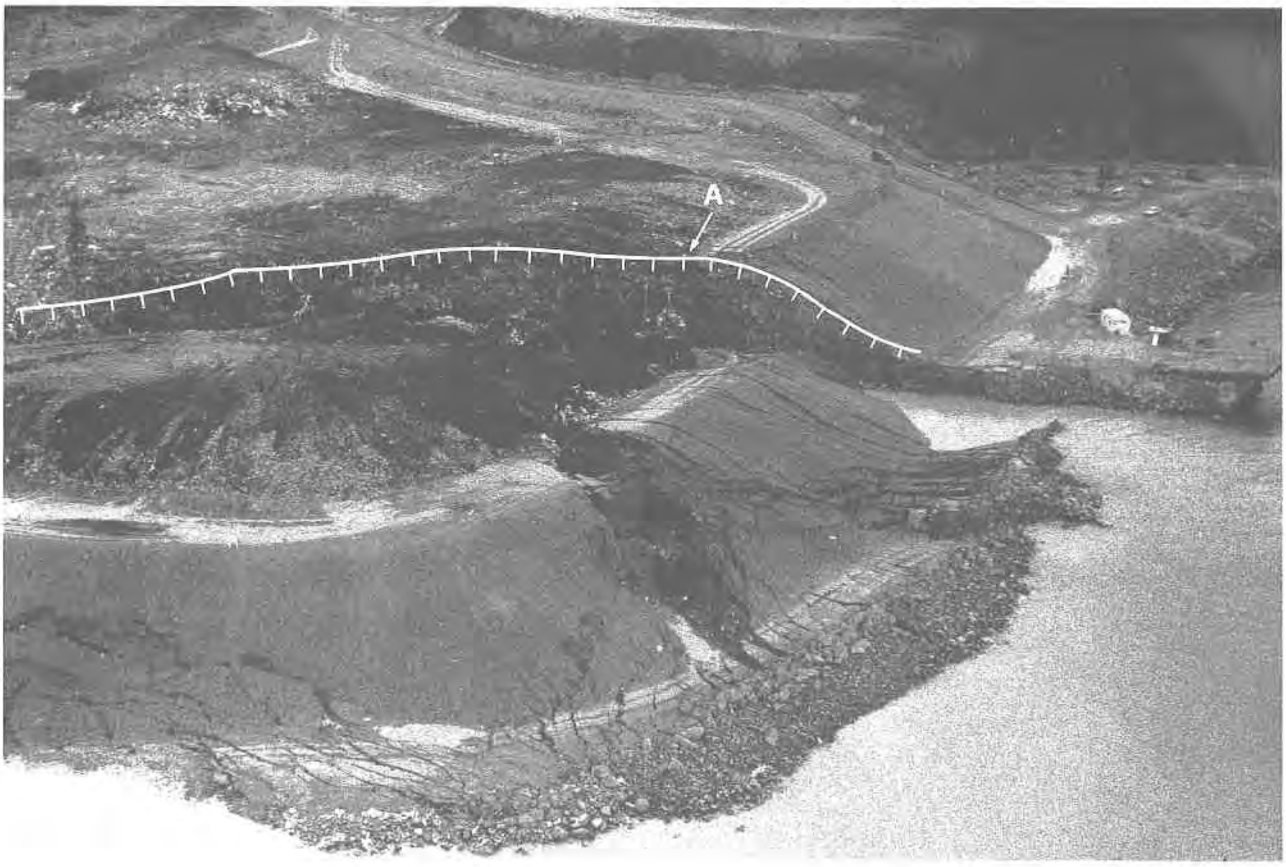


Plate 160. Oblique Aerial Photograph of Failure of Landfill at Junk Bay in 1984. This photogaph views the site in an easterly direction. The multiple sets of tension cracks are clearly evident. The major line of failure is indicated at A. (GCO/MW/1984/64/84/15).

Plate 161. Landslip on Stubbs Road in 1985. A landslip and rockfall near 34 Stubbs Road resulted in disruption of road traffic. (GCO/IW/1985/IW85/267/0).

Plate 162. Rockfall at Wo Yi Hop Road in 1986. This incident occurred on a construction site at Tsuen Wan. The light goods vehicle did little damage to the boulder. (GCO/HQ/1986/HQ8603015).

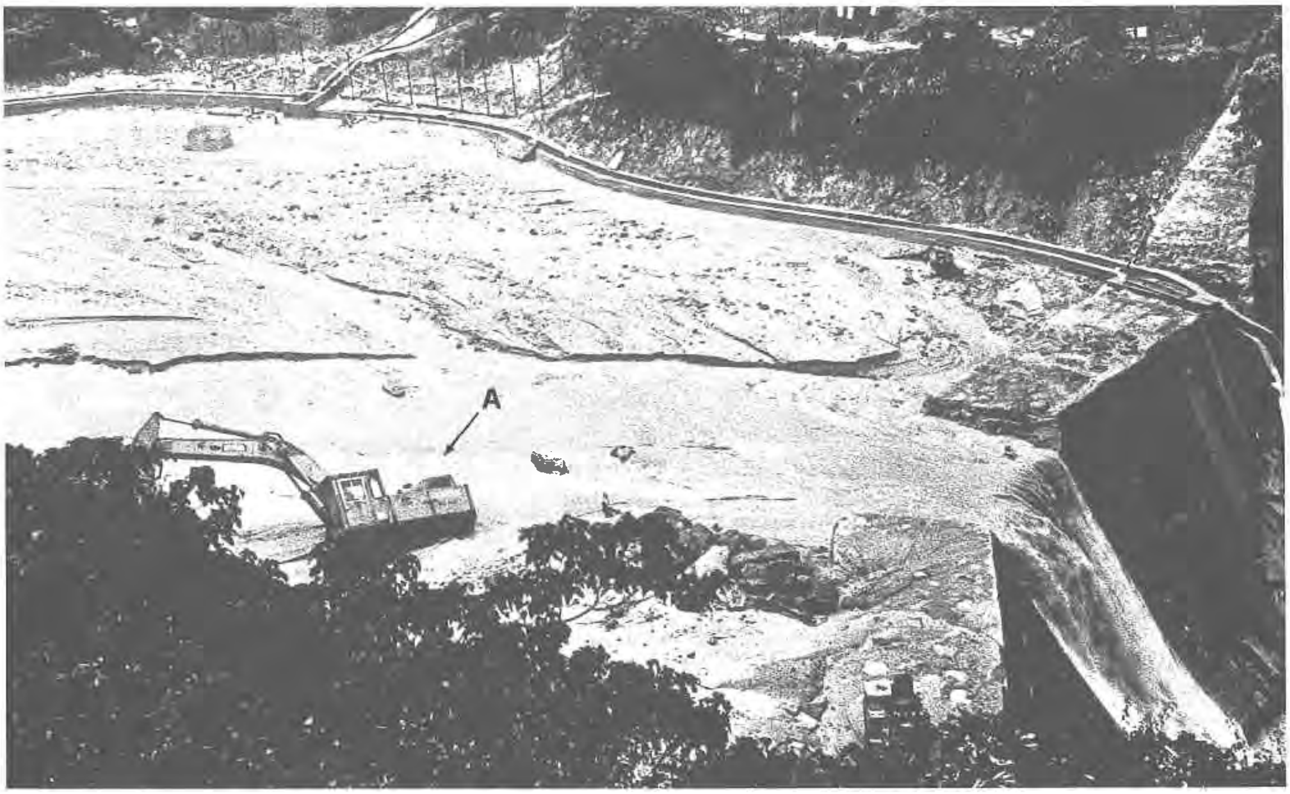


Plate 163. Erosion of Fill Area at Tai Koo Reservoir in 1986. Earthmoving plant (A) on a construction site has been damaged by erosion and floodwaters in the Quarry Bay area. The old reservoir was being filled to form a level platform for development. (GCO/SP/1986/SP8701833).

Plate 164. Rockfall at Kennedy Town Police Quarters in 1986. Parked vehicles were severely damaged as a result of this rockfall at Kai Wai Man Road. Fortunately there were no injuries associated with the incident. This photograph was reproduced from the South China Morning Post of 15.7.1986. (GCO/SP/1986/SP 8701832).

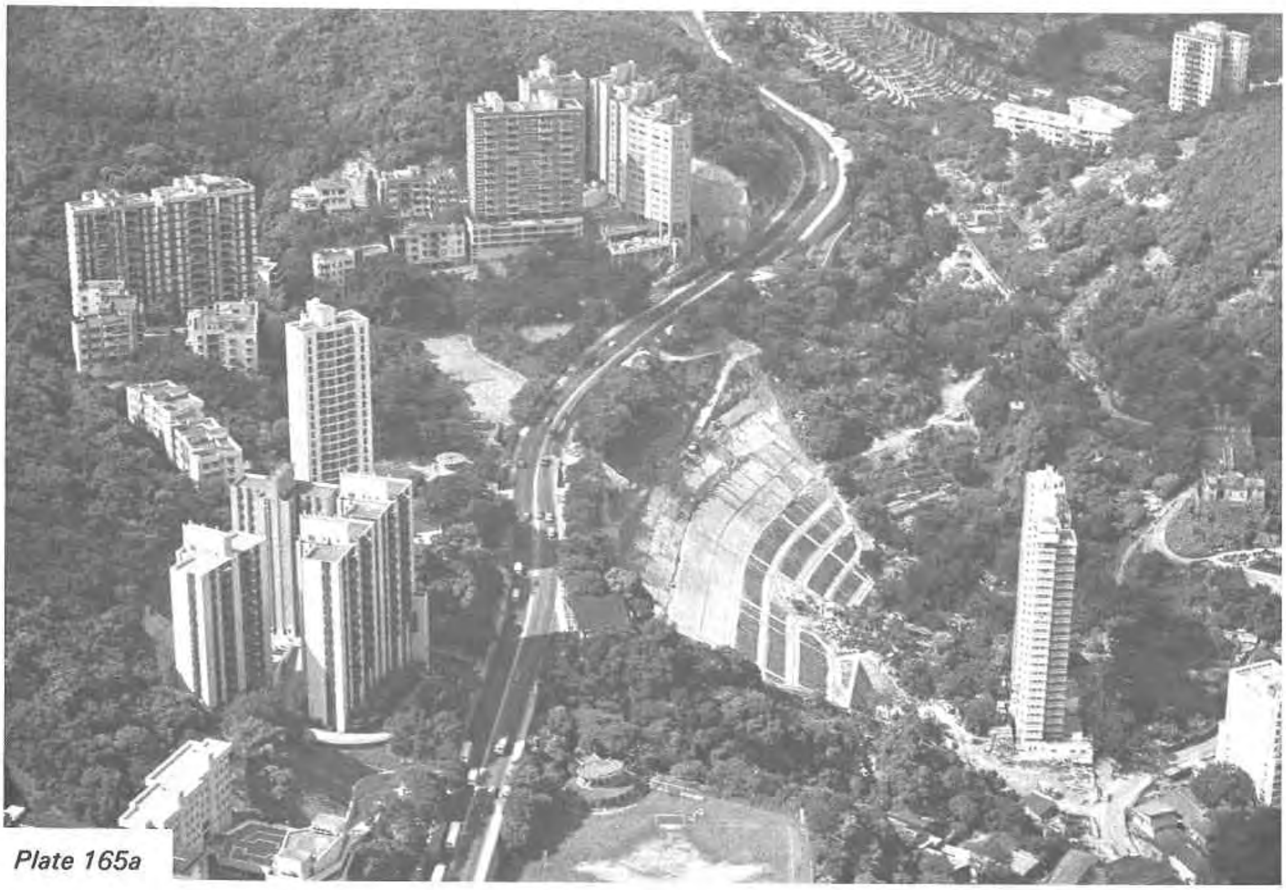


Plate 165a

Plate 165b

Plate 165. ***Oblique Aerial Photograph of Slope Stabilization on Pok Fu Lam Road in 1978 and 1979.*** The Pok Fu Lam dump site was reconstructed during 1978 and 1979 as part of the Landslip Preventive Measures (LPM) Programme. The site on Pok Fu Lam Road and another dump site at Mt Davis were recompacted in a contract worth some $14 million. Plate 165a shows the 50 m high by 200 m wide slope on 28.9.1978. Information on some of the early LPM sites is given in Bowler & Phillipson (1982). Plate 165b shows the slope some 7 months later. (GCO/OAP/1978/PS4–29A & 1979/PS11–7).

Plate 166a

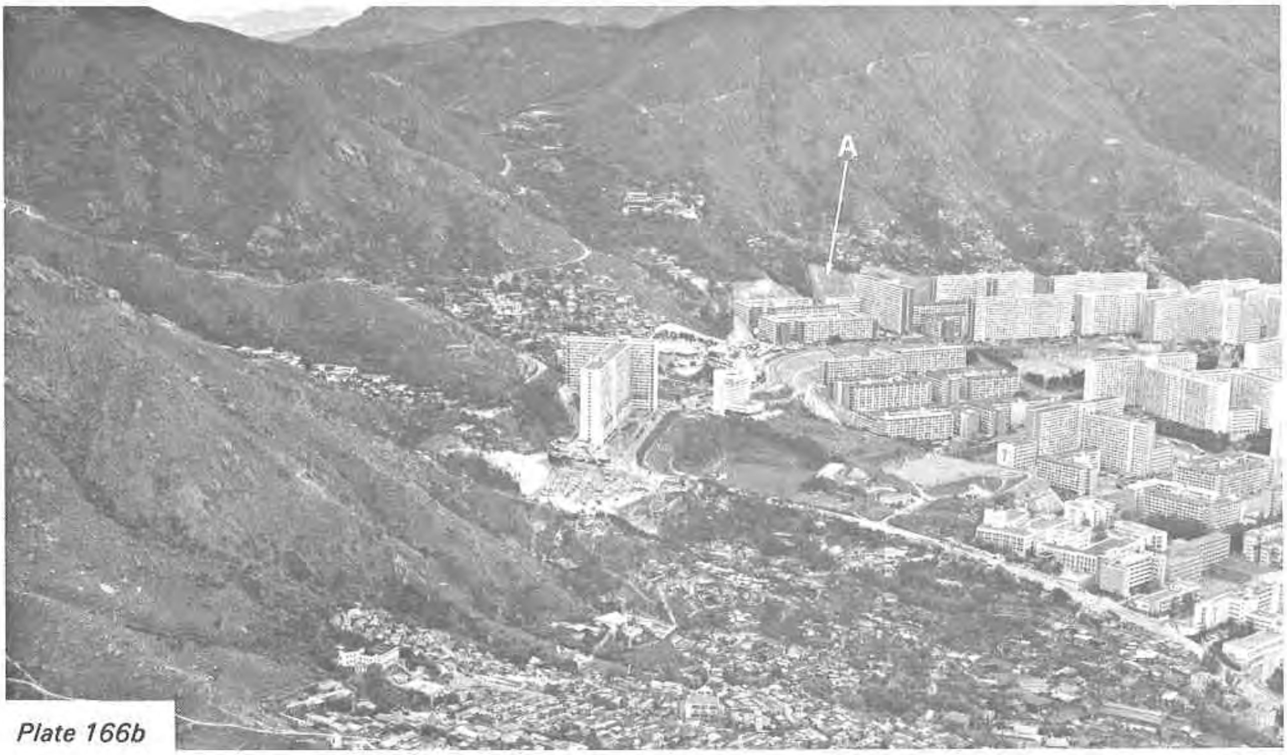


Plate 166b

Plate 166. Oblique Aerial Photograph of Slope Stabilization at Tsz Wan Shan Estate in 1979 and 1980. A large cut slope at A, north of the Tsz Wan Shan Public Housing Estate, was reconstructed by the Housing Department during the late 1970's. Prior to reconstruction, this slope was considered to pose a risk to the nearby housing blocks. The slope transects colluvial and highly weathered granitic terrain on the footslopes below the Kowloon hills. Plate 166a shows the regraded slope in 1979, and a large number of squatter huts are evident on the upslope terrain. Plate 166b illustrates the position of the slope (A) and associated development in relation to the steeply sloping terrain below Lion Rock. (GCO/TP/1979 & GCO/OAP/1980/PS103–E4).

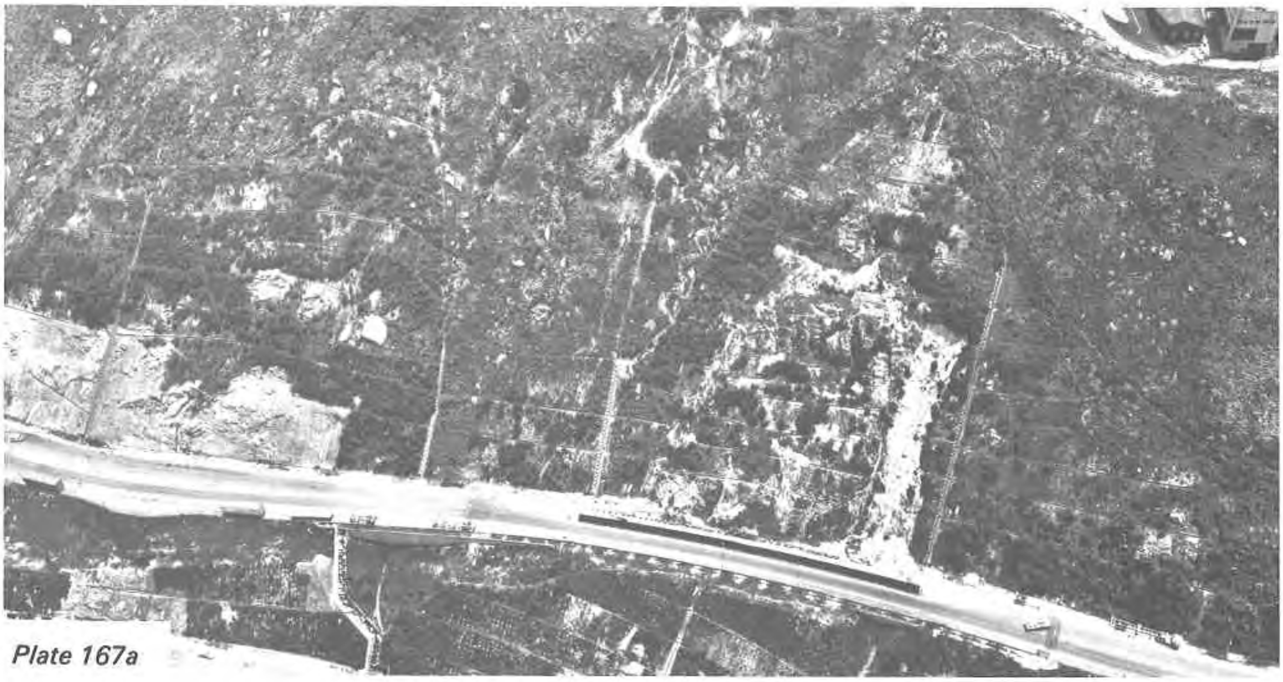


Plate 167a

Plate 167b

Plate 167. Views of the Landslip on Tsing Yi Island in 1983 and 1985. A large landslip (Plate 167a) on a cut slope in decomposed granite occurred in 1982 on the Tsing Yi Road, near Nam Wan. Signs of distress within a large section of a recently constructed 35° cut slope were observed on 28.6.82. The actual date of the failure is unknown, but it probably occurred during the severe rainstorms of May 1982. The slope failed again during heavy rainfall in August 1982. Despite careful site investigation, the location of the slip plane could not be identified with certainty with the boreholes. It is considered probable, however, that the failure surface was 10 m deep in parts. The boreholes revealed that depth to bedrock was much deeper than was assumed for the original design, and some of the original boreholes may have terminated in corestones rather than bedrock. Two piezometers, one near the head of the failure and the other near the toe, were monitored throughout the wet season of 1982. These showed that the piezometric surface was close to the ground surface; this was confirmed by heavy seepage from the lower face of the slope. It appears that horizontal drains, installed in the slope as part of the original design to lower the water table, were not effective following the failure. Boreholes after the failure, established the existence of a perched water table, although the reason for perching was uncertain. It was also unclear as to how this water table was recharged because the catchment area was very small. It was assumed that groundwater flowed towards the slope due to complex geological conditions. The slope surface consists of grassed areas of Grades IV and V decomposed rock, together with large corestones of Grade II rock. The gradation from Grade II to Grade IV is well-defined in places. The geology is complex with large intrusions of granite porphyry and feldspar porphyry through a country rock of equigranular, coarse-grained granite. The country rock is typified by close, mineralised joints and microfracturing. The existence of a deep-seated failure in a slope cut at 35° in decomposed granite should provide a cautionary note for practising engineers in Hong Kong. The failure occurred through a thick zone of weak decomposed material and was due to a high groundwater level. The presence of large boulders of rock at the surface together with similar corestones encountered in the boreholes had possibly been misinterpreted as bedrock during the initial investigation. As a result, the possibility of a critical deep seated failure was not considered at the design stage. Plate 167b shows the slope in 1985 following remedial works designed by the Geotechnical Control Office (1983/48423 and 1985/57794).

Plate 168. Oblique Aerial Photograph of Boulder Field Stabilization Measures on the Upper Slopes of Victoria Peak in 1985. This photograph taken in 1985, shows the location of the 'Boulder Fence' (A), upslope of Buxey Lodge. The Fence is located on an extensive boulder field, and was designed by GCO to counter the effects of possible rock and boulder falls from the steep colluvial footslopes and the precipitous cliffs on the north side of Victoria Peak. The geological contact between the volcanics and granitic bedrock is indicated at B. Lugard Road is indicated at C, and the general location of the rock outcrop shown in Plate 170 is shown at D. The natural slope above Conduit Road overlooks an area of intense development and has suffered from a number of boulder falls. In 1926, a 700-tonne boulder fell on a pumping station at 3 Conduit Road. In 1957, a boulder crushed a car parked on Conduit Road. In 1961, a 40-tonne boulder fell onto the west lawn of Buxey Lodge. More recently, incidents have been reported behind Pearl Gardens (1978), Conway Mansion (1979), Buxey Lodge (1981, 1982 and 1985), 39 Conduit Road (1981) and 41C Conduit Road (1982). The boulder field is located on the natural hillside behind 17 (Cliffview Mansion) to 37 (Buxey Lodge) Conduit Road. It is some 300m wide in an E-W direction and extends from the rear of the buildings (150mPD) southwards to the toe of Seymour Cliffs (280mPD). The total area is about 4.5 ha. (GCO/OAP/1985/PS514–5).

Plate 169. Boulder Fence below Victoria Peak in 1984. This photograph, taken from Buxey Lodge on 6.12.85, shows Segments 6 and 7 of the Fence under construction. These works were carried out within the Landslip Preventive Measures Programme. Construction of the Fence and associated boulder stabilization works cost in the order of $7.5m over a 2-year period. (Contract 1/GCO/93).

Plate 170. Oblique Aerial Photograph of Highly Jointed Volcanic Cliffs on Victoria Peak in 1979. This photograph, taken in 1979, shows the highly jointed nature of the volcanic terrain forming the Seymour Cliff area of Victoria Peak. A large boulder field occurs below these slopes. The location of this portion of the cliff face is shown at D in Plate 168. The Air Survey Unit, in collaboration with the RHKAAF, has developed a helicopter-borne oblique mounting system for a Wild RC10 air survey camera. The system was designed specifically for geotechnically-oriented photogrammetric applications on the steep terrain of the Territory. The mount is attached to the rear port door of an Aerospatiale Dauphine Helicopter as shown in the Inset. (GCO/OAP/1979/PS46–14 & 1988/PS658/10).

Plate 171. Oblique Aerial Photograph of Slope Failure on a Cut Slope at Pun Shan Tsuen in October 1983. Site investigation is in progress on the mid to lower portions of the cut slope following the slope failure shown in Plate 172. The general location of Plate 172 is shown at A. (GCO/OAP/1983/PS399–9).

Plate 172. Oblique Aerial Photograph of Slope Failure at Pun Shan Tsuen in October 1983. The backscar of the landslip caused major distress to a number of huts at the the crest of the slope. A vertical displacement of approximately 1m is evident at (A). A general view of the slope is given in Plate 171. (GCO/OAP/1983/PS400–7).

Plate 173. Oblique Aerial Photograph of Remedial Works at Pun Shan Tsuen in May 1984. The slope has been regraded and surface protection is being applied. (GCO/OAP/1984/PS448–3).

Plate 174. Oblique Aerial Photograph of Reinstated Cut Slope at Pun Shan Tsuen in September 1985. The slope has been regraded and has an extensive cover of vegetation. Soil piping, tunnel erosion and associated surface erosion are evident around A. (GCO/OAP/1985/PS523–10).

Plate 175. Oblique Aerial Photograph of Remedial Works to the Cut Slope at Pun Shan Tsuen in May 1986. Part of the upper slope has been chunamed and intensive drainage measures have been installed on the slope. Compare this with Plate 171, which shows the original cut slope in 1983. (GCO/OAP/1986/PS550–11A).

Plate 176. Stabilization of a Rock Slope on King's Road in December 1983. This large, almost vertical rock slope was treated by the Geotechnical Control Office within the Landslip Preventive Measures Programme, at a cost of some $710,000 over a period of 12 months. This photograph was taken on 6.12.83. (3/GCO/82 & 5/GCO/83, 11SE-A/C13 & 14).

Plate 177. Rhondda Road Slope in August 1984. This photograph, taken on 10.8.84, shows the slope prior to reconstruction by the Geotechnical Control Office within the Landslip Preventive Measures Programme. Site clearance and tree felling are in progress. Compare this with Plates 178 and 179. (EDD Contract No. 16/GCO/83-Slope 11NW B/FR 10).

Plate 178. Stabilization Works on the Rhondda Road Slope in December 1984. This photograph, taken on 10.12.84, shows recompaction of loose fill and surface drainage works in progress. Compare this with Plates 177 and 179.

Plate 179. Stabilization Works on the Rhondda Road Slope in July 1985. This photograph, taken on 12.7.85, shows a general view following reinstatement of the slope at a cost of some $1.3m over a 12-month period. Compare this with Plates 177 and 178.

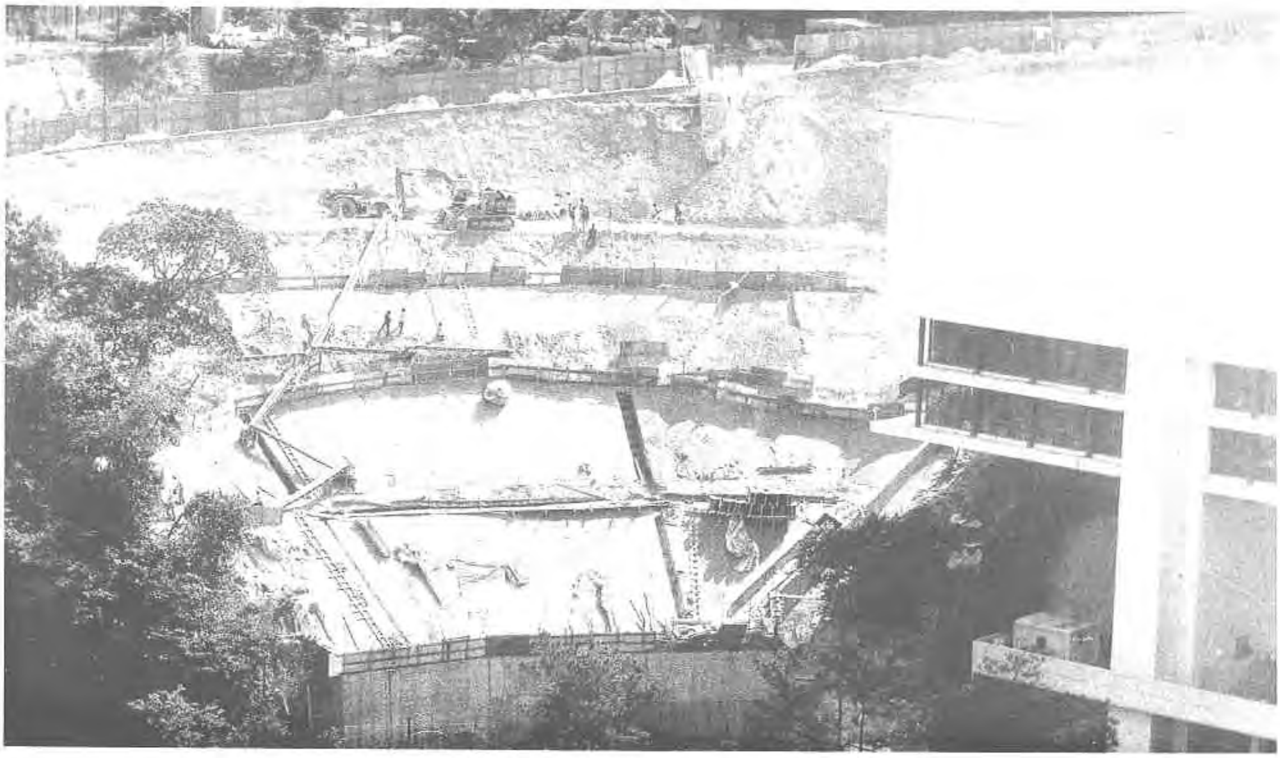


Plate 180. Slope Stabilization of the Kennedy Road Slope in February 1984. This photograph, taken on 6.2.84, shows the slope in the final stages of reconstruction. Plate 181 shows the slope following completion of works. (EDD Contract No. 2/GCO/82—Slope 11SW–B/FR56).

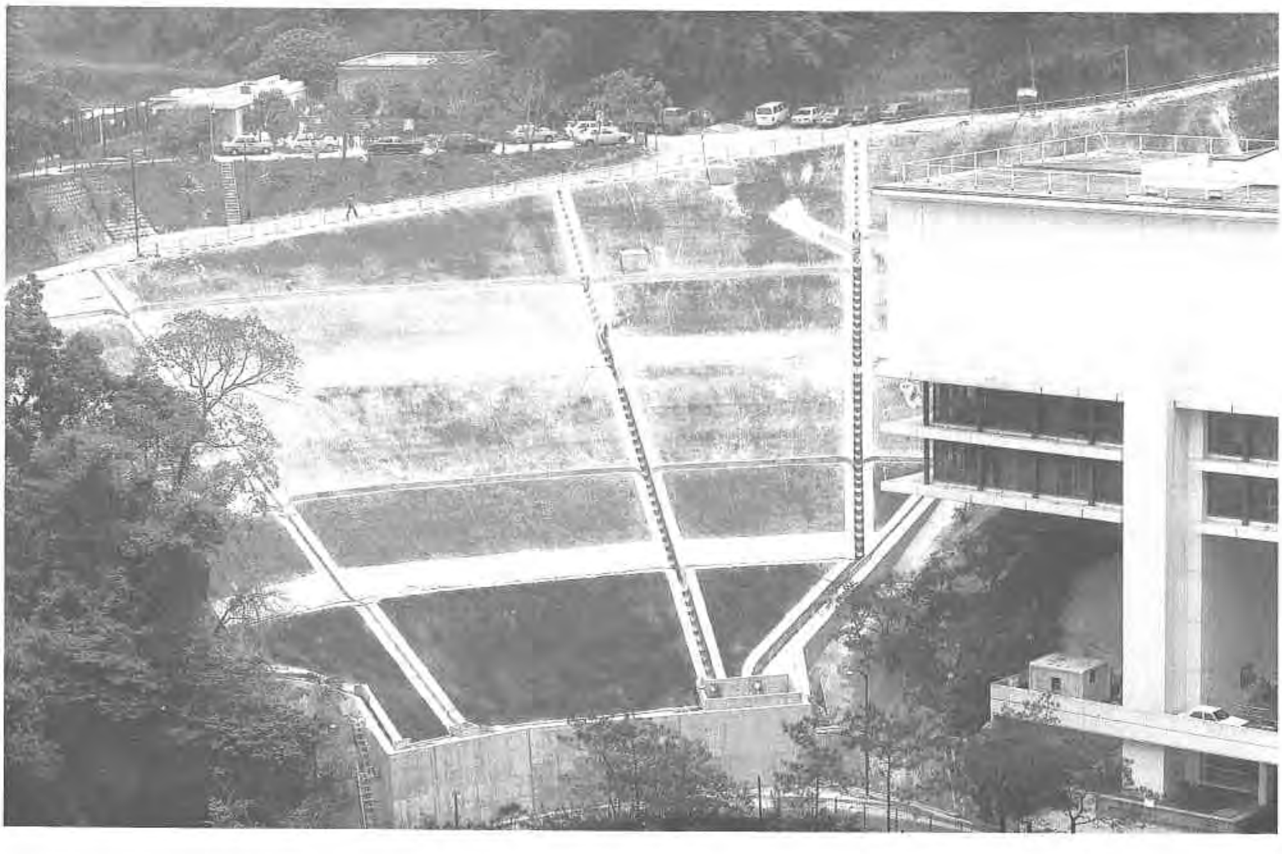


Plate 181. Slope Stabilization of the Kennedy Road Slope in 1984. This photograph shows the re-compacted fill slope above Kennedy Road late in 1984. Reconstruction of the slope was undertaken by the Geotechnical Control Office within the Landslip Preventive Measures Programme at a total cost of some $3.9m over a period of 12 months. Compare this with Plate 180 (EDD Contract No. 2/GCO/82—Slope 11SW–B/FR56).

Plate 182. Remedial Works on Rock Slope at A Kung Ngam Road in July 1983. This photograph, taken on 25.7.83, shows the drilling of a raking drain. This slope was treated within the Landslip Preventive Measures at an approximate cost of $1.7m over an 18-month period. (3/GCO/82 & 5/GCO/83 Slope 11SE-B/C87).

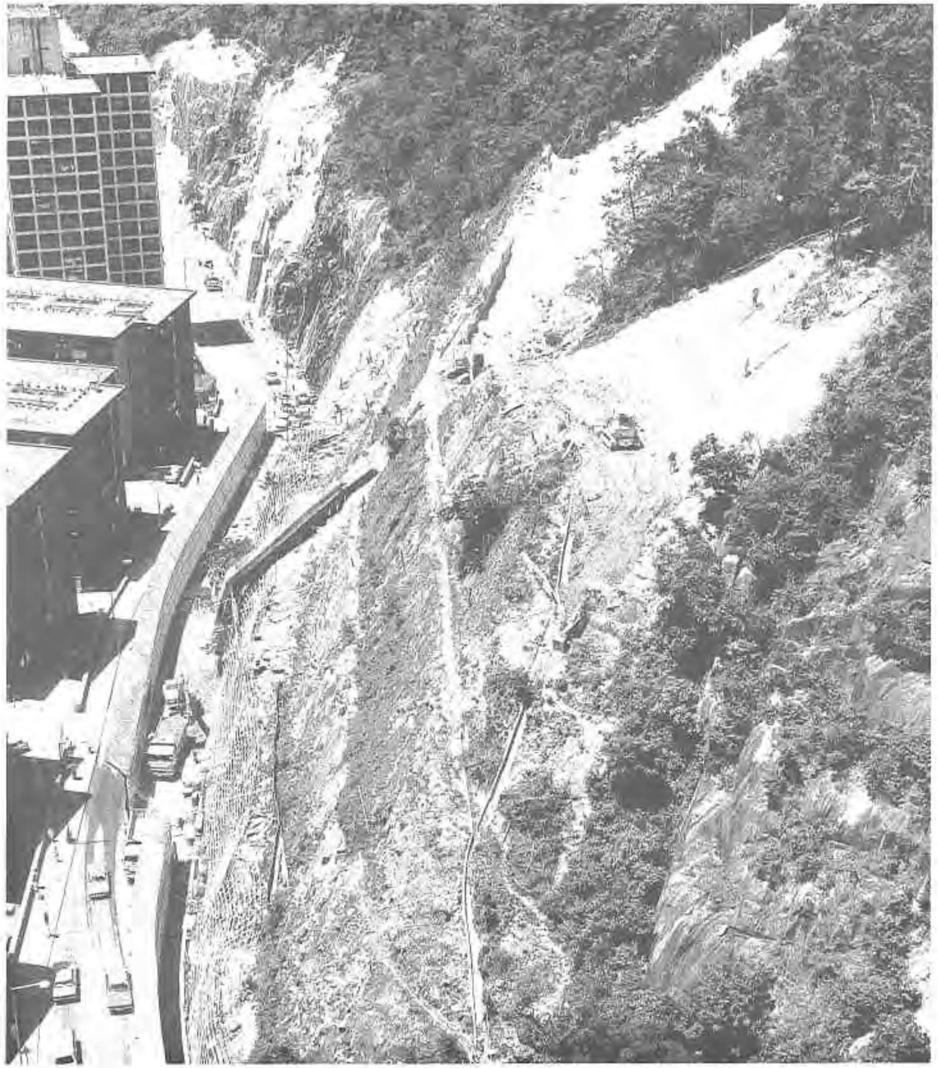


Plate 183. *Slope Reconstruction at A Kung Ngam Road in June 1985.* This photograph, taken on 29.6.85, shows the slope in the initial stages of remedial treatment within the Landslip Preventive Measures Programme. The rock slope shown in Plate 182 is located in the upper left hand corner of this Plate. Plate 184 shows the slope works nearing completion (Contract No. GC/84/02; Slope 11SE-B/C85 & 86).

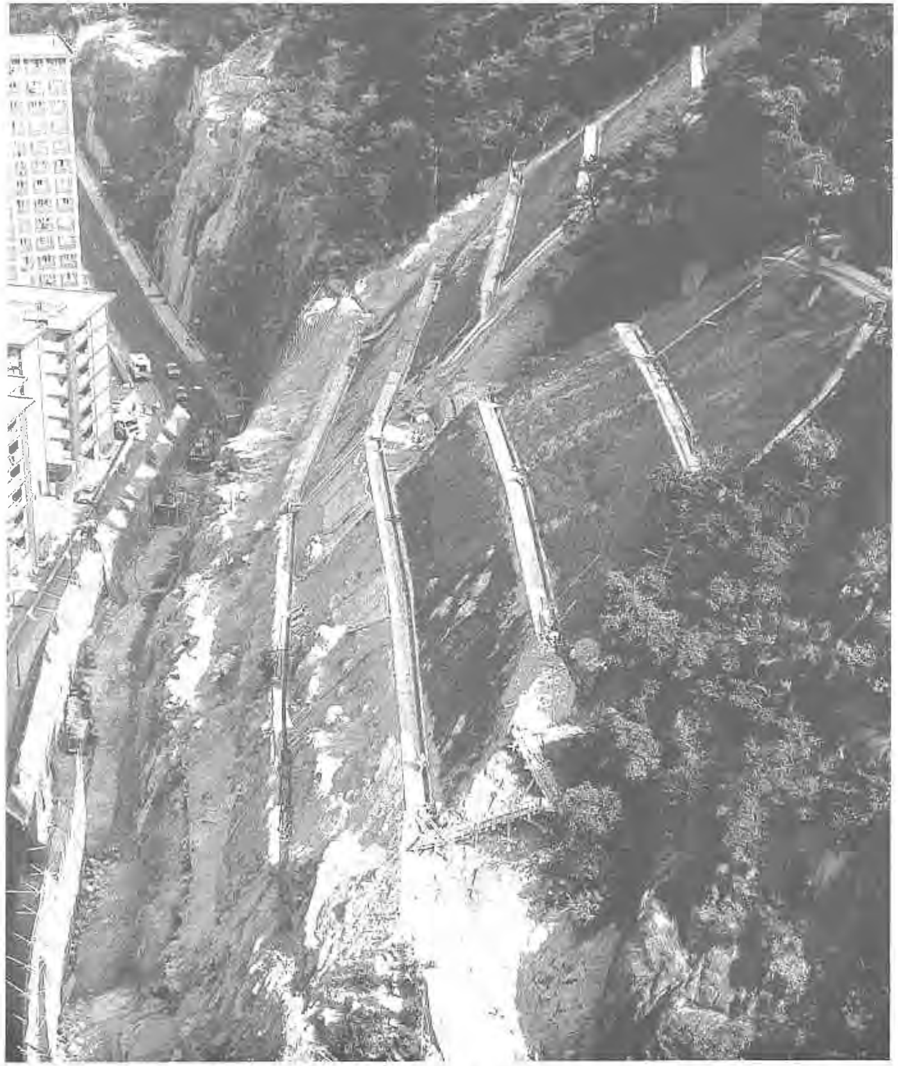


Plate 184. *Slope Reconstruction at A Kung Ngam Road in December 1985.* This photograph, taken on 2.12.85, shows the final stages of slope reconstruction. The approximate cost was $2.6 m over a 12-month period. Horizontal drains are in place on the upper portion of the slope. Compare this with Plate 183. (Contract No. GC/84/02; Slopes 11SE–B/C85 & 86).

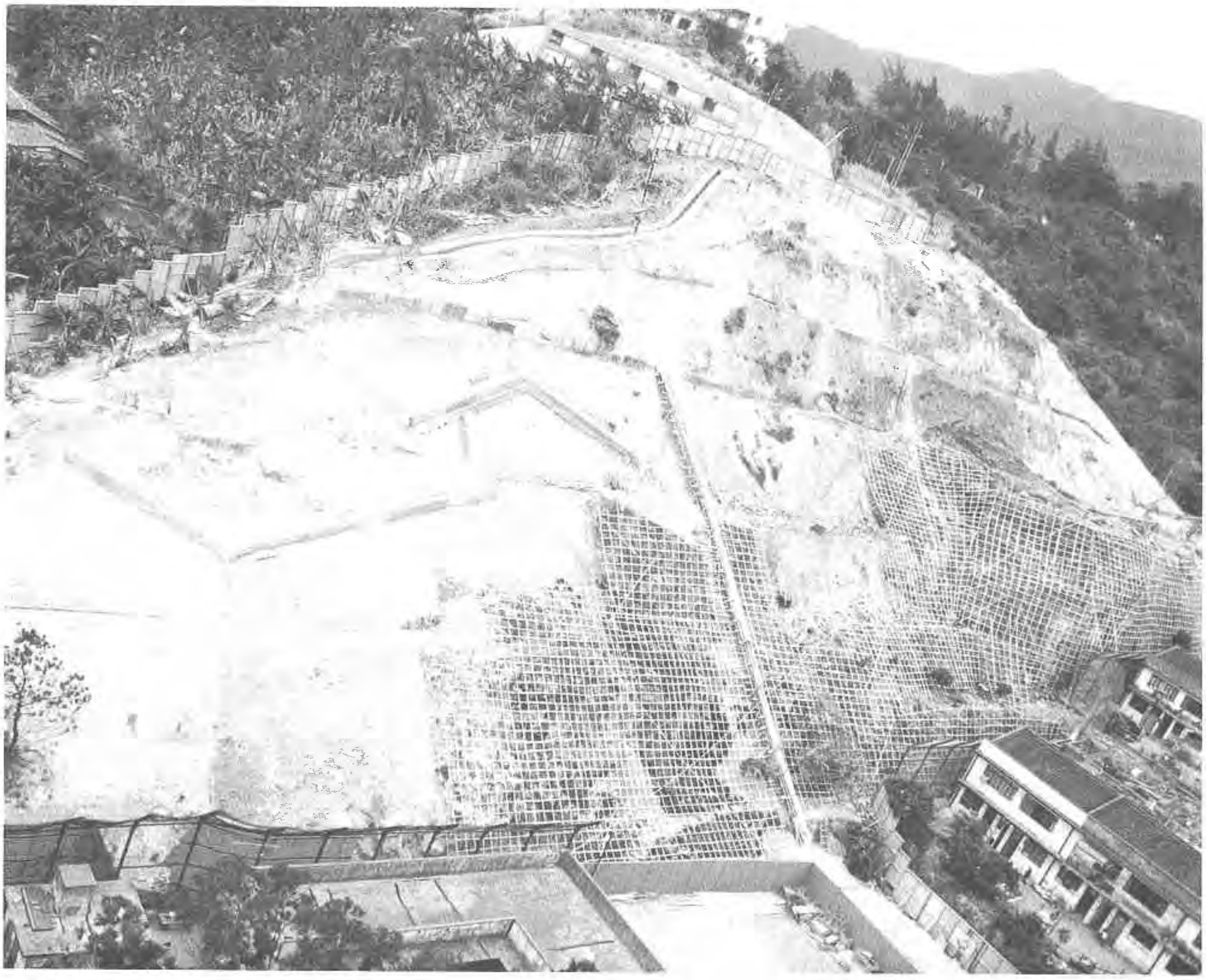


Plate 185. Slope Stabilization at Chung Kwai Chung in February 1986. This photograph, taken on 26.2.86, shows the reconstruction of a large slope within the Landslip Preventive Measures Programme. Plate 186 shows the slope nearing completion. (Contract No. GC/84/02; Slopes 7SW–C/C259/14).

Plate 186. Slope Stabilization at Chung Kwai Chung in October 1986. This photograph, taken on 31.10.86, shows the slope in the final stages of reconstruction. Total expenditure on slope works was in the order of $1.3m over a period of 14 months. Surface drainage is in place and netting is evident on many of the lower berms (A). Hydroseeding is applied to the netting, which becomes covered as the grass becomes established (B). Compare this with Plate 185. (Contract No. GC/84/02; Slope 7SW–C/C259/14).

Plate 187. Slope Reconstruction at King's Park in August 1986. This photograph, taken on 24.8.86, shows the initial stages of reconstruction of the slope within the Landslip Preventive Measures Programme. Plate 188 shows the slope works nearing completion. (Contract No. GC/84/03; Slope 11SW–D/F97).

Plate 188. Slope Reconstruction at King's Park in April 1987. This photograph, taken on 27.4.87, provides a general view of the site. Temporary chunam is evident (A) above 60mPD, and permanent chunam is in place (B) below the first berm. Reconstruction of this fill slope cost in the order of $1.6m over a 17-month period. (Contract No. GC/84/03; Slope 11NW-D/F97).

Plate 189. Oblique Aerial Photograph of Slope Stabilization at Leighton Hill in 1987. This slope has a history of failure and was reconstructed by the Geotechnical Control Office over an 18-month period between July 1986 and February 1988. Works in the order of $3.2 million were carried out within the Landslip Preventive Measures Programme. On this occasion, the design required that the finished slope be vegetated rather than chunamed. Geotextiles were used extensively during reinstatement. (GCO/OAP/1987/PS603–6).

Plate 190. Oblique Aerial Photograph of Remedial Works to the Site of the 1966 Landslip on Peak Road. This photograph was taken in 1987, and shows remedial works to the site of a landslip in 1966 (A) shown in Plate 58 and also Plate 153. Remedial works were carried out on the old landslip site following a very disruptive failure nearby in 1983. The location of the failure is shown at B in this Plate and in Plate 57. (GCO/OAP/1987/PS607–18).

Plate 191. Oblique Aerial Photograph of Slope Works near Quarry Bay in 1987. Extensive slope works are in progress behind Wai Hang Street. (GCO/OAP/1987/PS604–19).

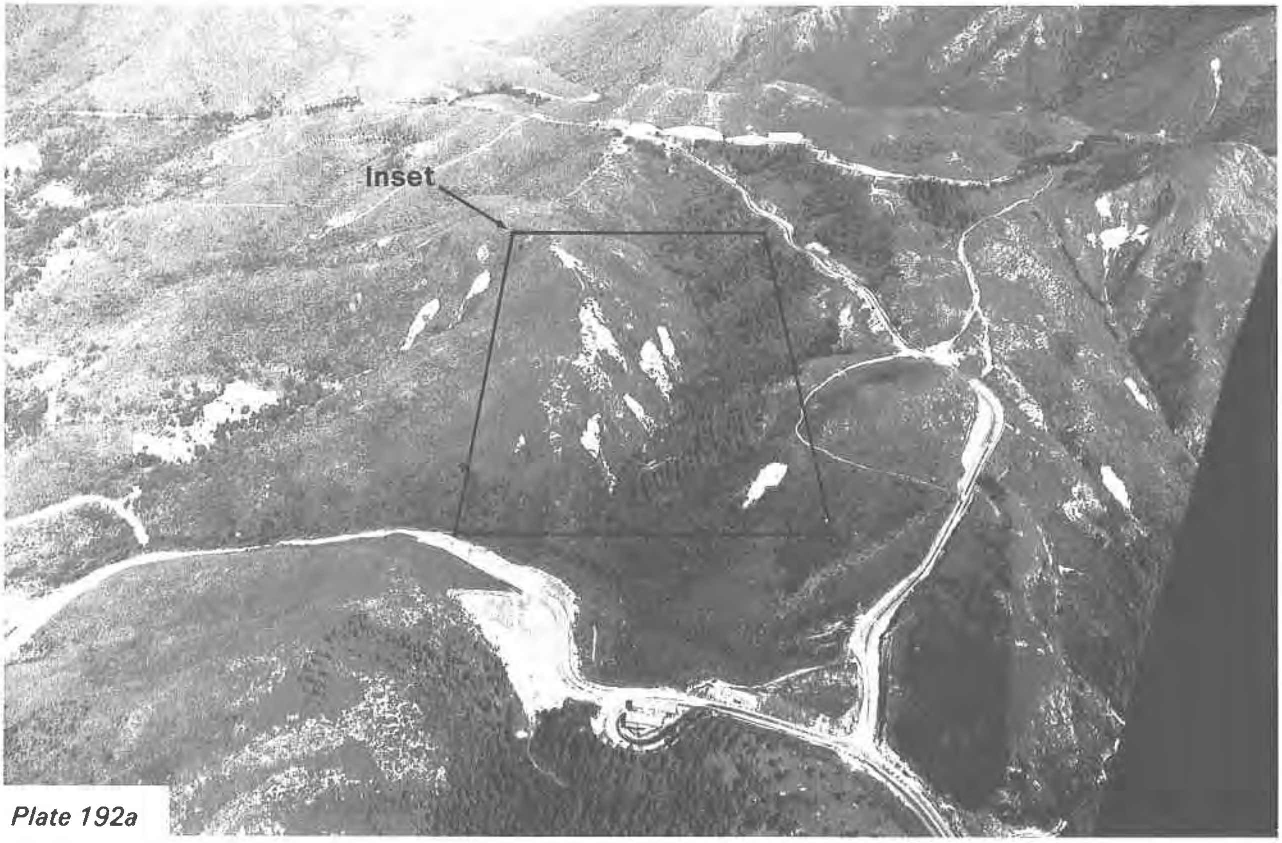


Plate 192a

Plate 192b

Plate 192. Comparison of Landslips near Ngong Ping on Lantau Island in 1984 and 1988. **Plate 192a** shows the location of a number of landslips near the Ngong Ping Road junction in November 1984. Plate 192b illustrates the degree of revegetation and nature of the landslips after four years. (GCO/OAP/1984/PS48–9 and 1988/PS661–10).

Plate 193a

Plate 193b

Plate 193. Comparison of Landslips on the Pat Sin Range in 1980 and 1981. Plate 193a shows the location of three landslips on midslope terrain, and major tension cracks are clearly evident (A). Plate 193b illustrates the degree of revegetation and nature of the unstable area some 12 months later. Note the establishment of vegetation (B) on the landslip debris and the less distinct nature of the tension cracks. (GCO/OAP/1980/PS45–33A and 1981/PS158–6A.

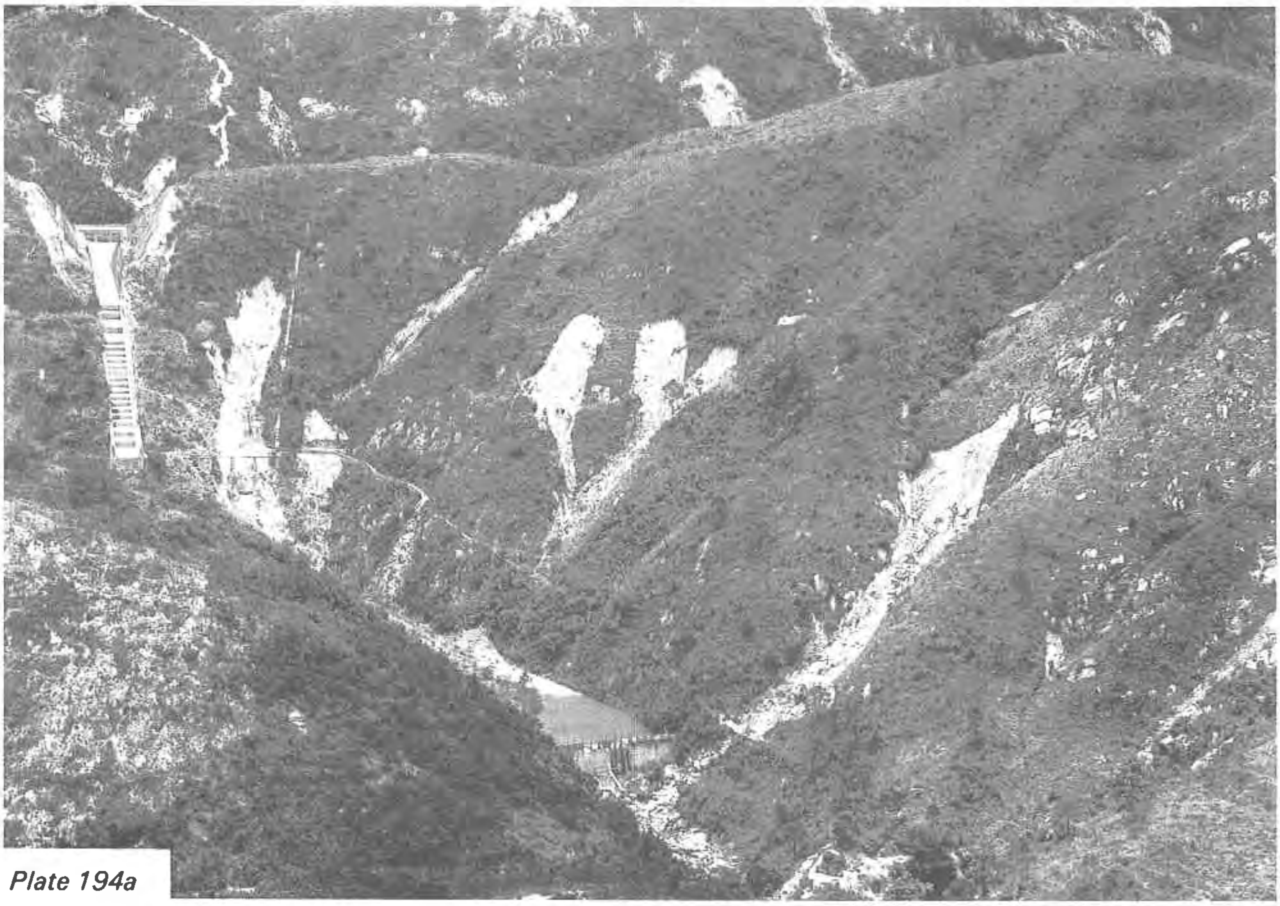


Plate 194a

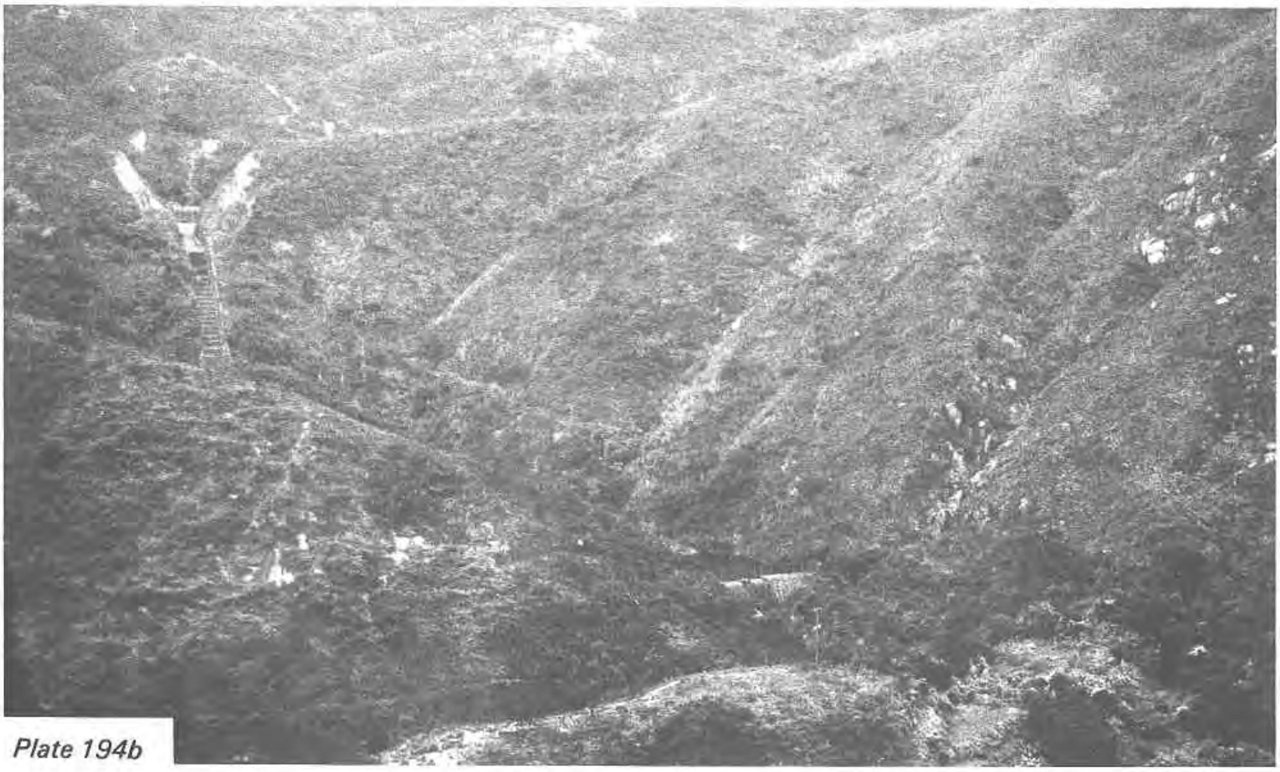


Plate 194b

Plate 194. Comparison of Landslips near the Catchwater at Sham Tseng in 1982 and 1988. A large number of landslips occurred on granitic terrain during intense rainstorms in May 1982, in the Tai Lam Chung Country Park. Plate 194a was taken in June 1982 and shows a number of failures on the slopes to the east of the catchwater overflow. Plate 194b illustrates the condition of the terrain 6 years later in 1988. (GCO/OAP/1982/PS292–10 and 1988/PS666–16).

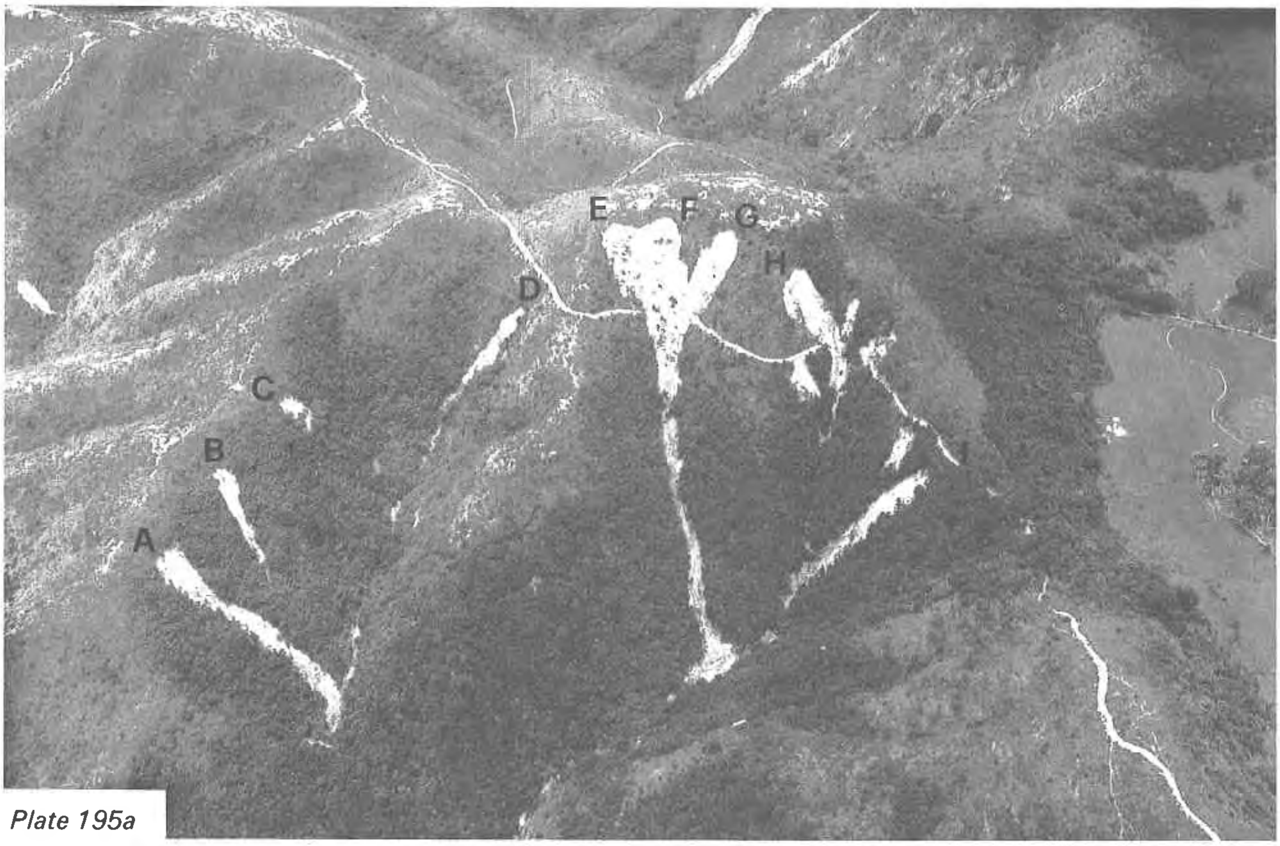


Plate 195a

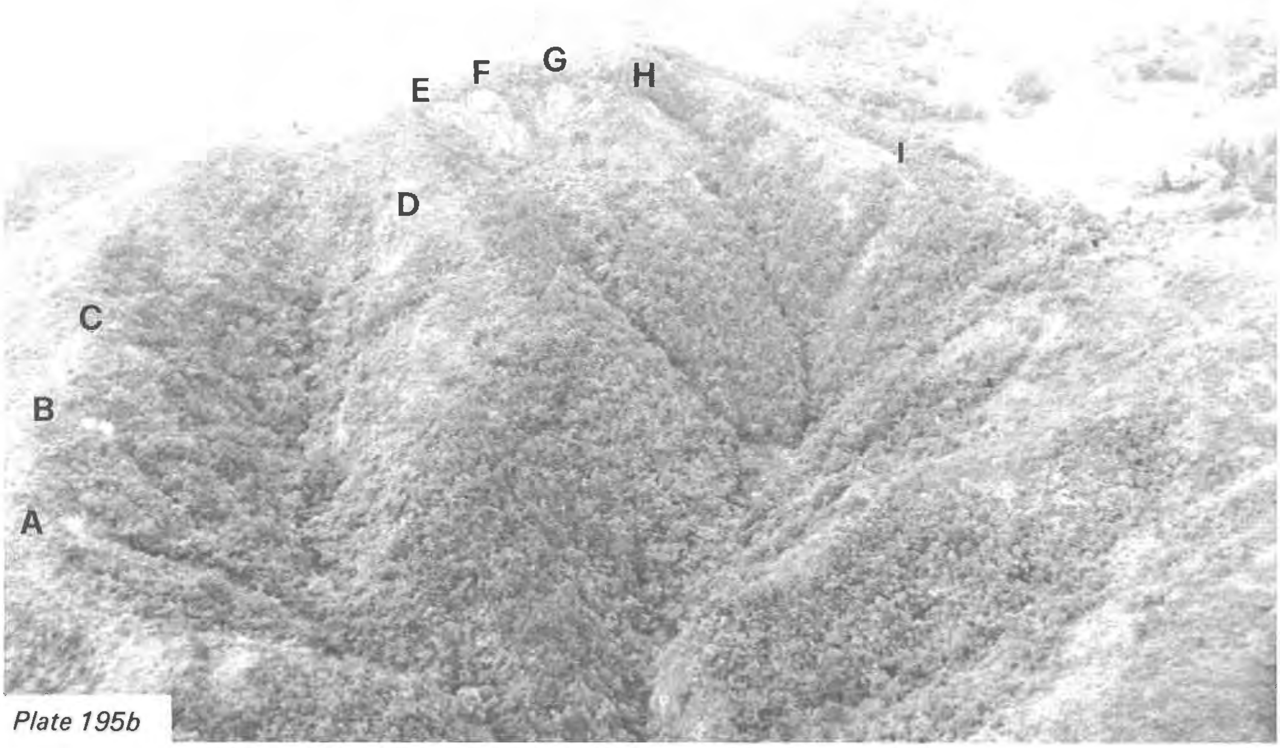


Plate 195b

Plate 195. Comparison of Landslips near Tsing Fai Tong in 1982 and 1988. The granitic terrain north of Sham Tseng was severely affected by landslips during the rainstorms of May 1982. Plate 195a, taken in June 1982, shows that many of the landslips are characterised by backscars which are marginal to the ridge crest and spurlines. This corresponds to the point of oversteepening of the gully heads (Refer Appendix D, Section D.4). Plate 195b illustrates the condition of the terrain 6 years later in 1988. (GCO/OAP/1982/PS306–9A and 1988/PS667–19).

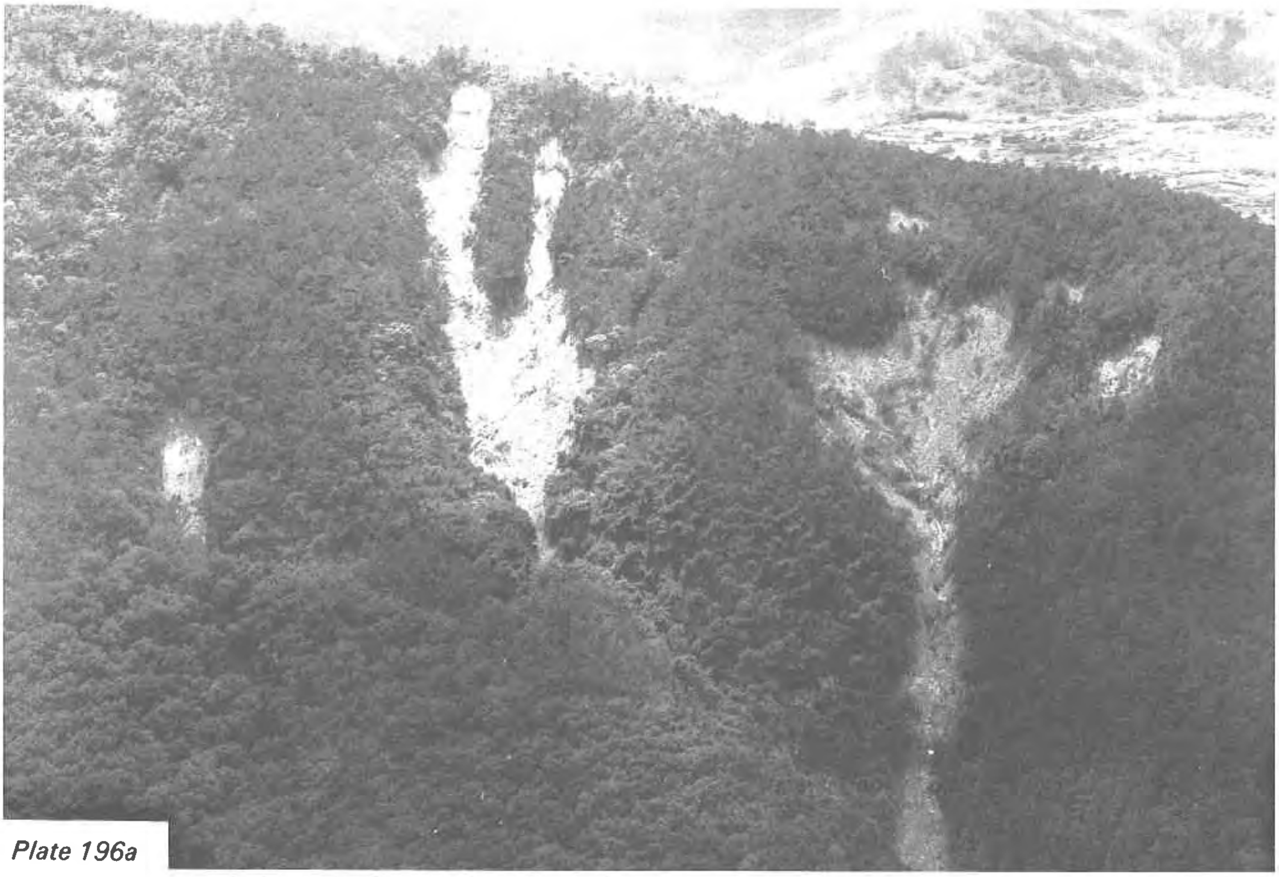


Plate 196a


Plate 196b

Plate 196. Comparison of Landslips near Kap Lung in 1982 and 1988. **Plate 196a shows a number of** landslips on reafforested terrain on the northeastern side of Route Twisk in the Shek Kong Valley in June 1982. Plate 196b illustrates the condition of this terrain 6 years later in 1988. (GCO/OAP/1982/PS295–6 and 1988/PS664–6).

Plate 197. Oblique Aerial Photograph of Severely Eroded Granitic Terrain near Ngau Tau Kok in 1984. This photograph shows the severely eroded nature of the hillcrests which is characteristic of much of the granitic terrain in the Territory. Gully erosion originates almost at the crest of the ridges and spurlines on this type of terrain. (GCO/OAP/1985/PS525–5A).

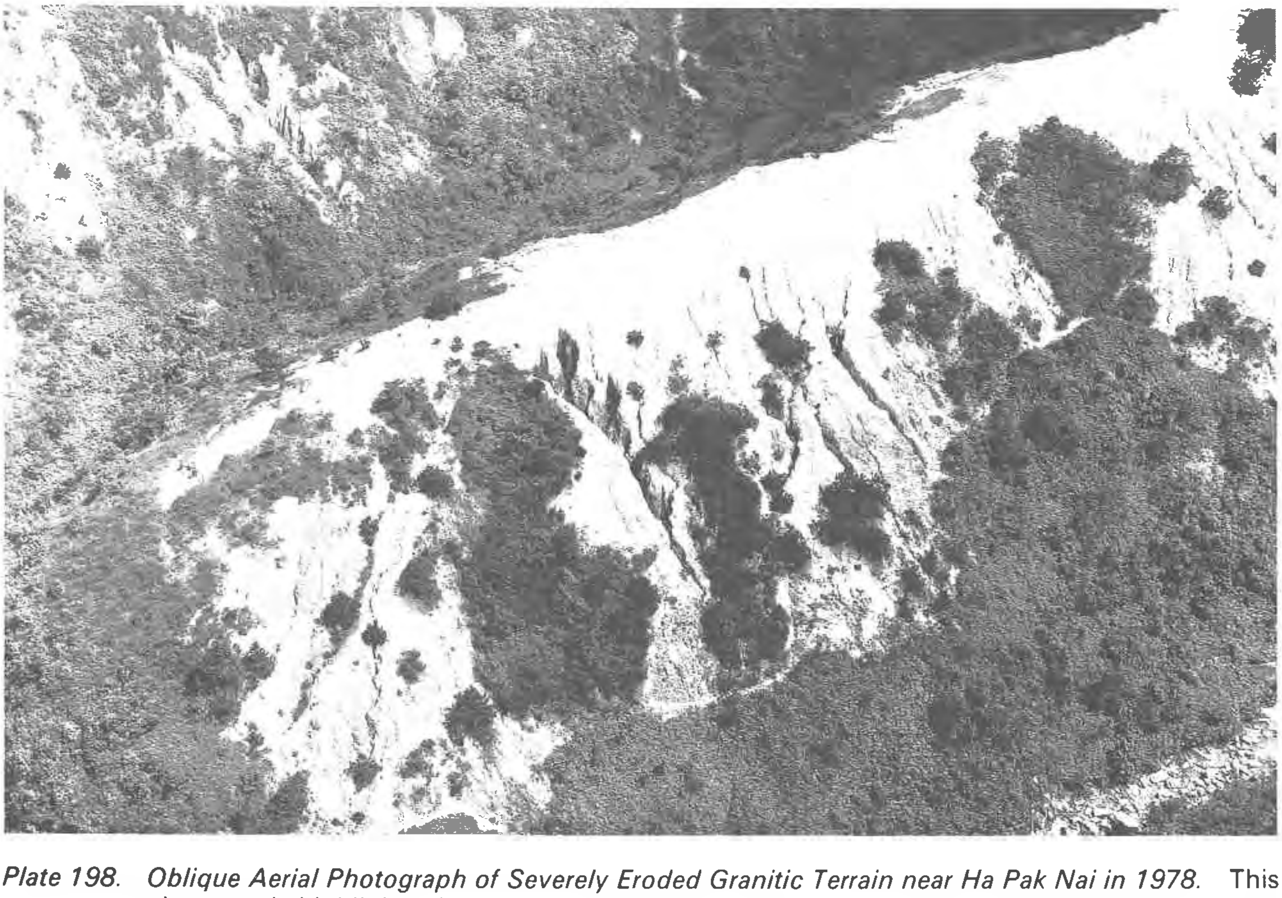


Plate 198. Oblique Aerial Photograph of Severely Eroded Granitic Terrain near Ha Pak Nai in 1978. This photograph highlights the nature and occurrence of gully erosion on granitic terrain in the western New Territories. Deep gully incision is evident near the crest of the slopes and becomes more shallow in a downslope direction. (GCO/OAP/1983/PS372–10).

Plate 199. Severe Erosion affecting Services near Braemar Hill in 1984. Severe sheet erosion marginal to a surface drainage system is evident. Erosion has undermined the drainage channel and culvert and has rendered the drainage system essentially ineffective. (GCO/TP/1984/TP 58–22).

Plate 200. Surface Erosion near Braemar Hill in 1984. This photograph shows the effects of surface erosion on boulders in granitic terrain. Erosion can gradually undermine the granitic boulders. (GCO/TP/1984/TP58–27).

Plate 201. Oblique Aerial Photograph of Lion Rock in 1981. This view from the south clearly shows the highly jointed and precipitous nature of the fine-grained granite forming the summit of Lion Rock. The rock is a well known feature which dominates the landscape of the Kowloon Hills. (GCO/OAP/PS213/8/16.9.81).

Plate 202. Oblique Aerial Photograph of Amah Rock in 1988. Amah Rock is another well known geological feature and is located on the southern side of the Sha Tin valley. It is composed of coarse-grained granite with Quartz Monzonite just to the south. (1988/82C/87-2).

Plate 203. Volcanic Terrain on Basalt Island in 1984. This photograph illustrates the spectacular volcanic terrain evident on many of the Territory's islands. This area is at Lam Wan Kok on the southeastern shore of Basalt Island. (GCO/OAP/1984/PS432–16A).

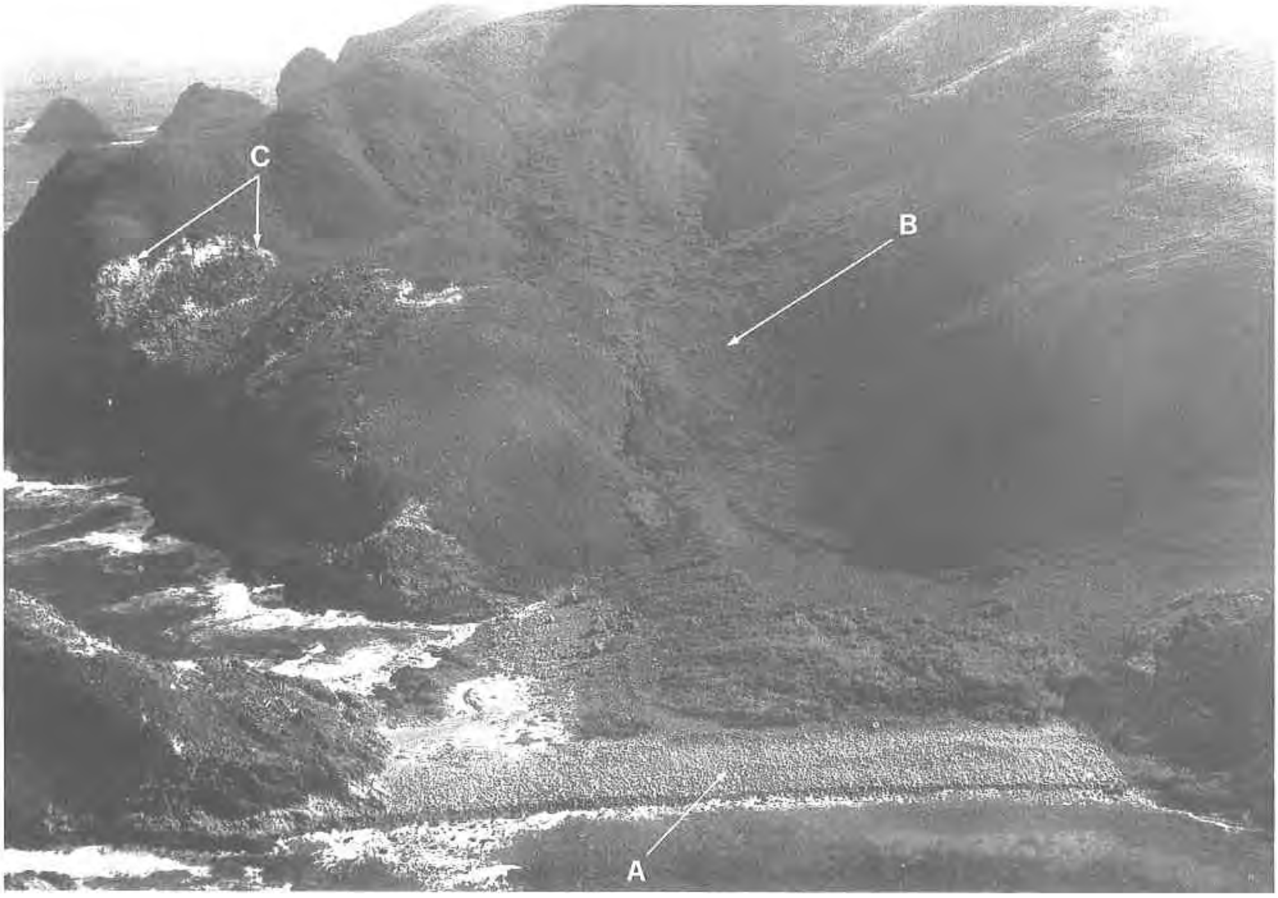


Plate 204. Coastal Terrain on Basalt Island in 1984. This photograph shows the development of a boulder beach (A), a small colluvial valley (B), and a number of landslips on natural terrain (C). The location is near Pyramid Rock on the northern shore of Basalt Island. (GCO/OAP/1984/PS432–19A).

Plate 205. Oblique Aerial Photograph of the Southwestern Coast of Ping Chau in 1982. This photograph shows the steep cliff face and wave cut platform developed on the southwest-facing metasedimentary terrain of the island. (GCO/OAP/1982/PS344–27).

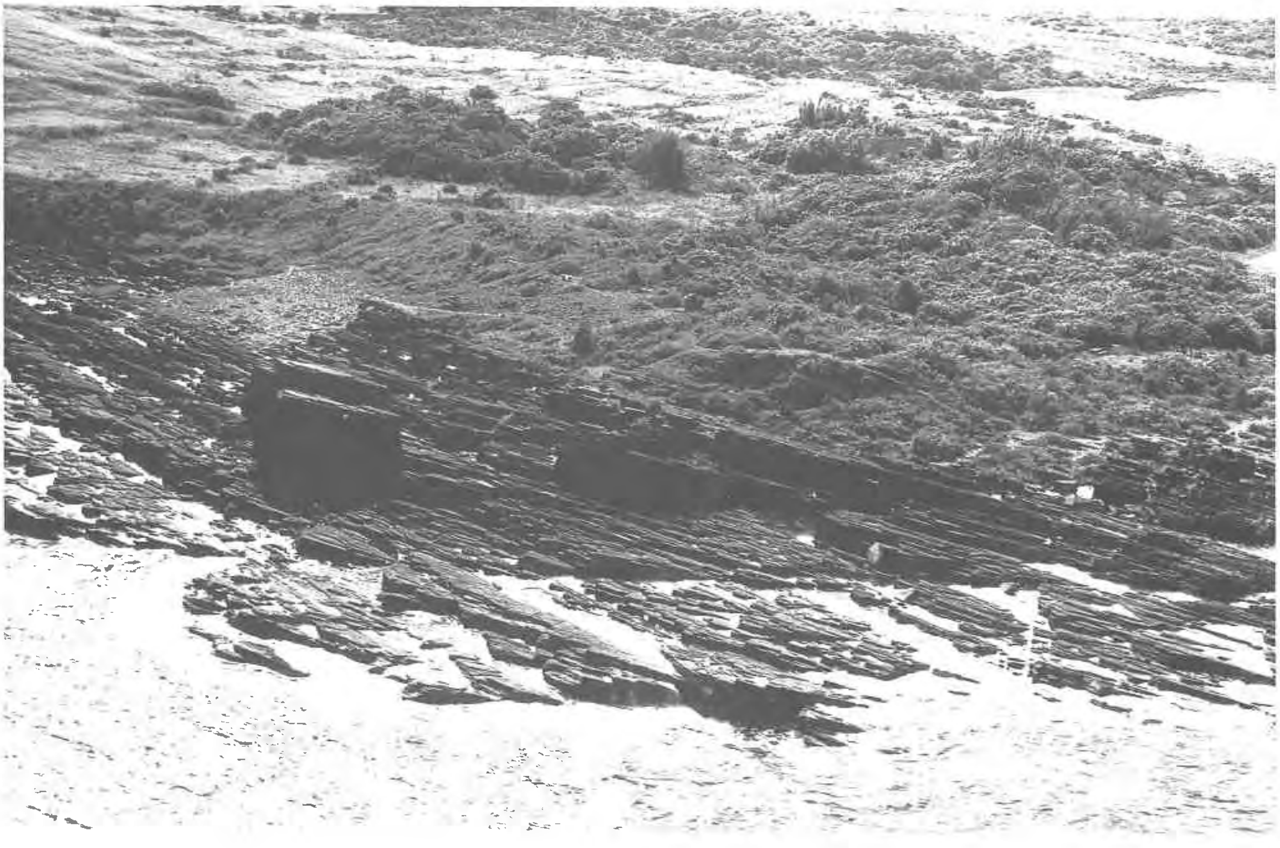


Plate 206. Oblique Aerial Photograph of Wave Cut Platform on Ping Chau in 1982. This photograph highlights the development of a dip-controlled wave cut platform in the metasedimentary terrain. (GCO/OAP/1982/PS344–33).

Plate 207. Natural Arch on Ap Chau in 1984. This photograph shows a natural arch formed in the coarse-grained sedimentary breccias of the Kat O Formation. Large, angular fragments with an imbricate structure aligned parallel to the pre-depositional topography are evident. The matrix is deep red in colour. (GCO/OAP/1984/TP39–14).

Plate 208. Oblique Aerial Photograph of Site Formation on the Reservoir in Jordan Valley in 1983. The reservoir was subsequently infilled to form a level platform. (GCO/OAP/1983/PS393–5A).

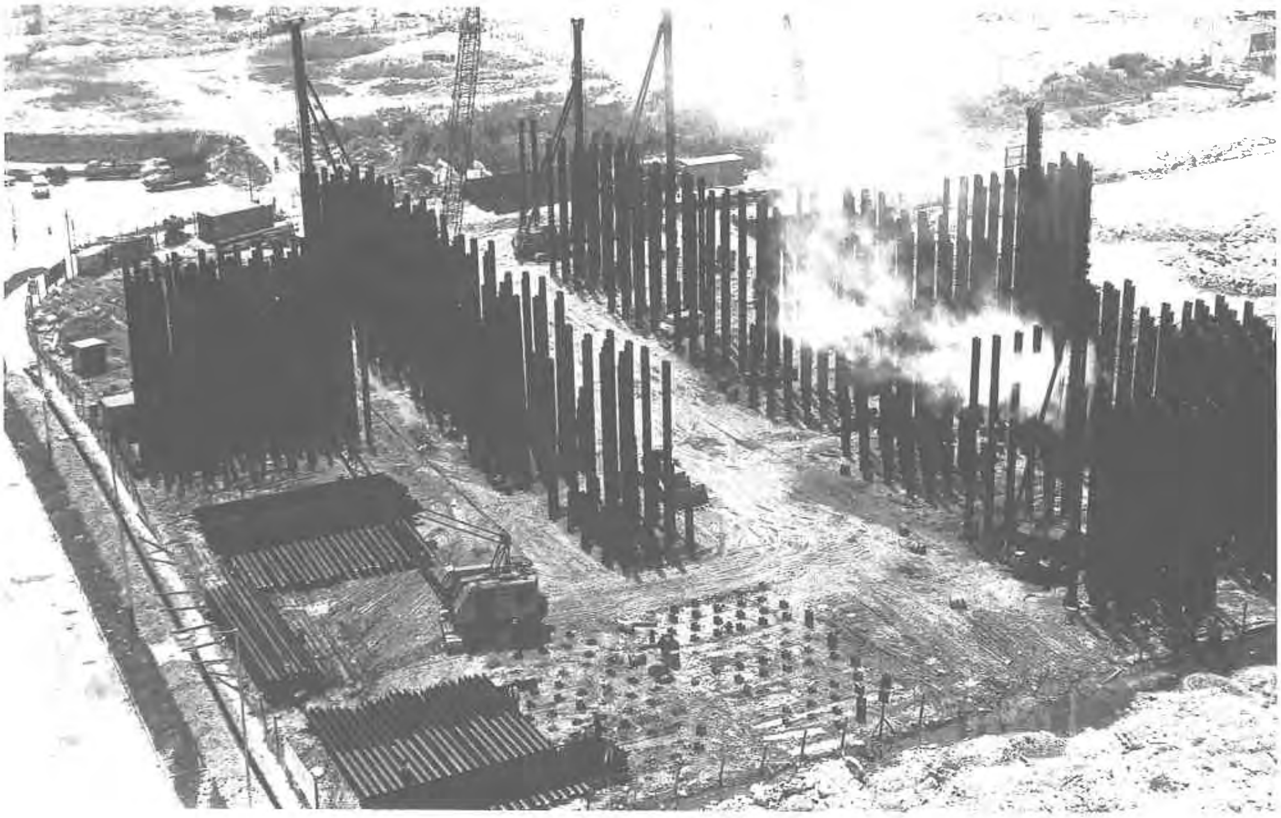


Plate 209. Oblique Aerial Photograph of Piling on Reclamation at Kowloon Bay in 1982. The photograph illustrates the intensity of foundation works on an area reclaimed some 10 years before. (GCO/OAP/1982/PS260–35A).

Plate 210. Oblique Aerial Photograph Looking Westwards from Devil's Peak toward Shau Kei Wan and Quarry Bay in 1980. This photograph shows the extent of development at the eastern end of the northern shore of Hong Kong Island. Since this photograph was taken, a large portion of the area has been reclaimed. The East Harbour Crossing will exit on Hong Kong Island (approximate location is shown at A) to link with the Eastern Harbour Corridor. Old military installations are evident on Devil's Peak in the foreground. (GCO/OAP/1980/PS165–9).

Plate 211. Oblique Aerial Photograph of Squatters near Sau Mau Ping in 1980. This photograph shows the contrast in development between the multistorey Government Housing Estates, squatters and the Anderson Road Quarries. (GCO/OAP/1980/PS165–2).

Plate 212. Oblique Aerial Photograph of Squatters in the Shau Kei Wan Area in 1980. This photograph illustrates the intensity of squatter huts in the Shing On and Holy Cross Path Village areas of Hong Kong Island. These structures occur on granitic and colluvial footslope terrain. There have been many landslips in this area over the years with considerable loss of life. All such 'dangerous' slopes are scheduled to be cleared of squatters by the early 1990s under the Housing Department's 'Non-development Clearance Programme'. (GCO/OAP/1980/PS151–18).

Plate 213. Oblique Aerial Photograph of Colluvial Footslopes below Lion Rock in 1979. This photograph shows squatter and housing estate development on the footslope terrain below the Kowloon Hills. Large boulders are also evident (A). Many of the footslopes have now been cleared of squatters and these have been replaced by the development of public housing estates. (GCO/OAP/1979/PS91–33).

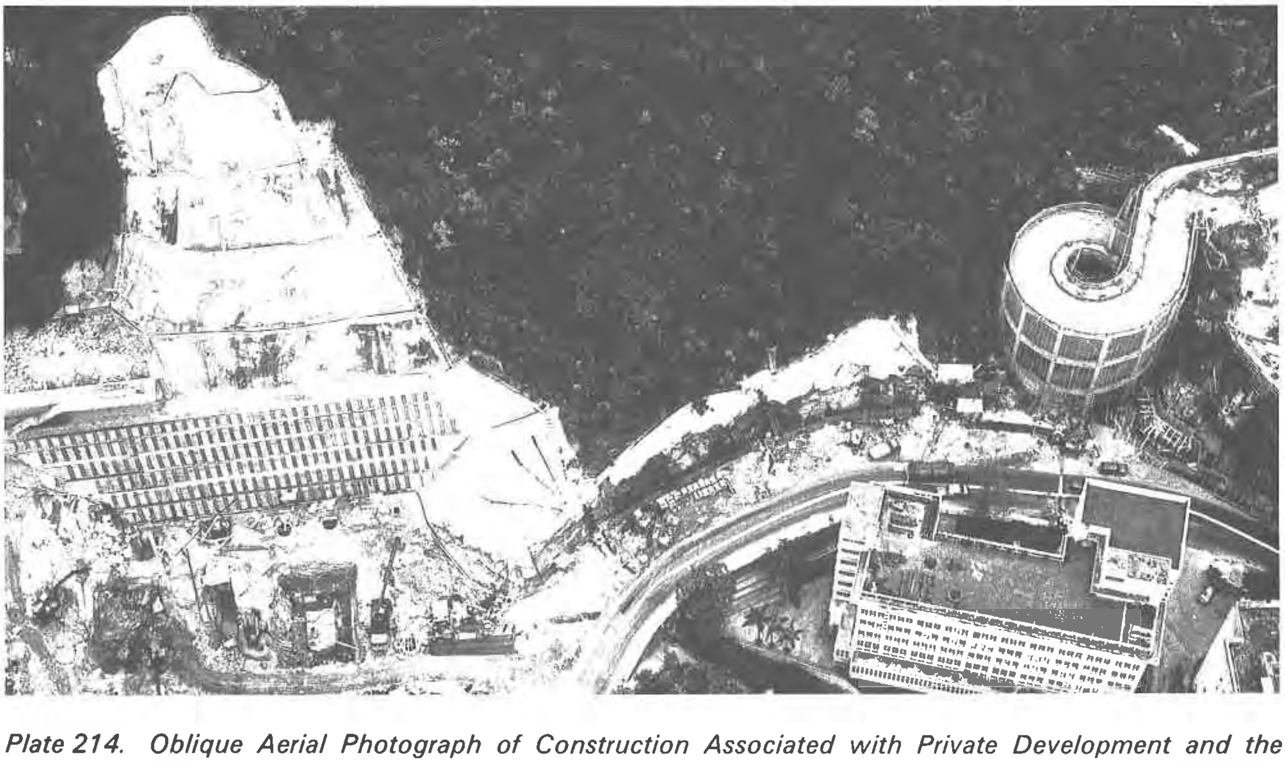


Plate 214. Oblique Aerial Photograph of Construction Associated with Private Development and the Realignment of Kennedy Road in 1979. Major slope works were carried out as part of the realignment of Kennedy Road and associated residential development. A spiral ramp has been used to provide access to a nearby apartment block. (GCO/OAP/1979/PS28–31).

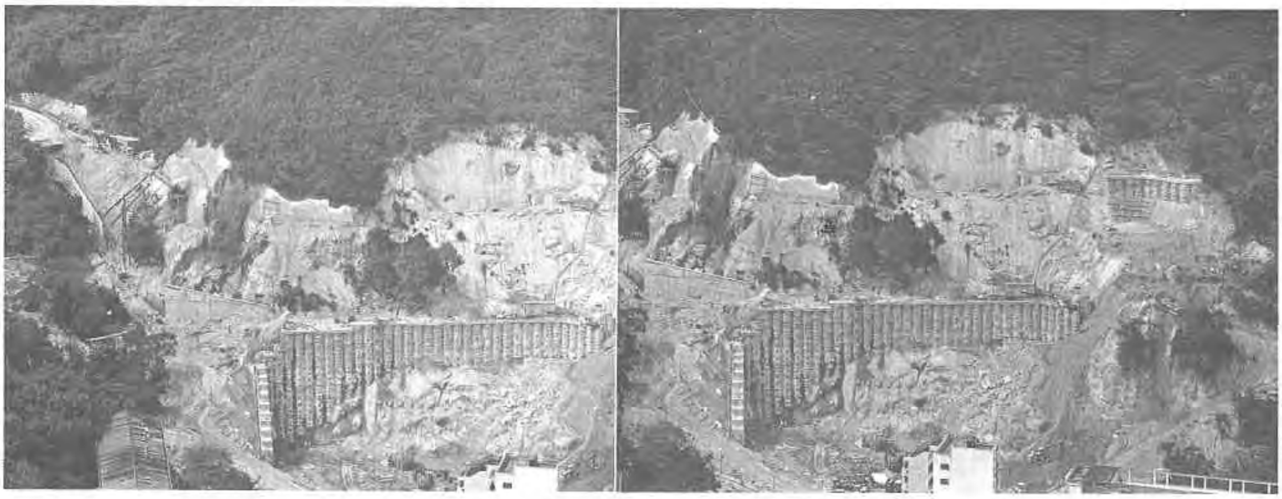


Plate 215. Stereopair of Oblique Aerial Photographs of Caisson Wall Construction at the University of Hong Kong in 1979. This Plate demonstrates the use of oblique aerial photographs for the preparation of stereopairs. A large caisson wall was constructed on a site south of Pok Fu Lam Road, as part of the development associated with the Haking Wong Building at the University of Hong Kong. This building now houses the Civil Engineering Department of the University. (GCO/OAP/7.6.1979/PS41–36 & 36A).

Plate 216. Oblique Aerial Photograph of the Tai O Region of Lantau Island in 1986. This photograph shows the pleasant environment of one of the more remote settlements within the Territory. Much of the area is undeveloped with substantial tracts of Country Park surrounding the town. (GCO/OAP/1980/PS555–11).

Plate 217. Oblique Aerial Photograph of the Terrain near Anderson Road Quarry in 1986. The photograph illustrates the contrasting forms of development which co-exist in the district. Fei Ngo Shan (A) dominates the terrain in the background. When compared with Plate 211, the area of squatters (B) has decreased in the intervening 6 years since 1980, due largely to the expansion of public housing projects. (GCO/OAP/1986/PS562–1A).

Plate 218. Oblique Aerial Photograph of the Quarry Bay Area in 1985. The photograph illustrates the contrast in intensity of development on the northeastern side of Hong Kong Island. Extensive private development is evident in the Mt Parker Road, Quarry Bay Street and Greig Road areas (A). A steep disused quarry slope (B), a Service Reservoir (C) and squatters in the Wai Hang Village Area (D), illustrate the broad range of land uses occurring in a relatively small area. This type of development produces many problems for land management and future planning within the Territory. (GCO/OAP/1985/PS532–8).


Plate 219a


Plate 219b

Plate 219. ***Oblique Aerial Photograph of Site Formation on the Clear Water Bay Peninsula in 1985.*** Plates 219a and b dramatically illustrate the extensive nature of site formation practices adopted in many of the new town developments in the Territory. Much of the natural terrain has been completely obliterated in the quest for level building platforms. The impression created by this large site formation is almost surrealistic in nature. (GCO/OAP/1985/PS542–7A & 9).

Plate 220a

Plate 220b

Plate 220. Comparative Oblique Aerial Photographs of the Kowloon Walled City Area in 1983 and 1988. The Walled City is indicated at A in the 1983 photograph in Plate 220a. Compare this with Plate 22 and 40. By 1988, shown in Plate 220b, the area surrounding the 'City' has been cleared of huts. A plan for demolition and redevelopment of the Walled City was announced by Government in 1987. (GCO/OAP/1983/PS387–34A and 1988/PS646–19).

Plate 221. Oblique Aerial Photograph of Development Associated with the Mass Transit Railway Terminus in East Kowloon in 1983. This photograph, taken in 1983, contrasts the different forms of development and infrastructure associated with the urban environment. A multistorey residential complex (Telford Gardens) is located on the podium deck above the MTR Terminus, whilst a complex road flyover system provides yet another means of transport. (GCO/OAP/1983/PS393–11).

Plate 222. Oblique Aerial Photograph of the Route 5 Road Tunnel in 1987. The new system of tunnels will improve the road link between Kwai Chung and Sha Tin. (GCO/OAP/1987/PS599–3).

Plate 223. Oblique Aerial Photograph of the Eastern Portion of Yuen Long in 1987. This photograph shows the contrast between intensive urban development and rural land use in the northwestern New Territories. The site of the proposed Light Rail Transit Terminal (A) is shown. Geotechnical problems have arisen within the area because some of the alluvial terrain is underlain by cavernous marble. (GCO/OAP/1987/PS592–8).

APPENDIX A

SYSTEM OF TERRAIN EVALUATION AND ASSOCIATED TECHNIQUES

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APPENDIX A

SYSTEM OF TERRAIN EVALUATION AND ASSOCIATED TECHNIQUES

A.1 Background

A.1.1 *Terrain Evaluation*

Terrain evaluation involves the identification of landform and terrain related features, usually by the interpretation of aerial photographs. This technique is used both to identify land use limitations and also 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 the Geotechnical Area Studies Programme, 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 the Programme is illustrated in Figure A1.

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 conventional and computer 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 (1983 & 1985), Styles et al (1982, 1984, 1986), Brand et al (1982 a & b), Burnett & Styles (1982), Burnett et al (1985) and Brand (1988b). In addition, a chart illustrating the regional terrain classification system is located in the Map Folder.

A.1.2 *Terrain Classification in the Geotechnical Control Office*

During 1978, there was concern regarding the lack of understanding of the behaviour of the different geological materials within the Territory. The Mid-levels District of Hong Kong Island was an area of particular interest due to the degree of existing development, the amount of construction and redevelopment, the uncertain geology, steep slopes and a history of disastrous slope failures. For example, a landslip at Po Hing Fong resulted in a large number of fatalities in 1925 and in the Po Shan (Kotewall) Road failure in 1972, more than 60 died (refer to Section 8.2.6).

In May 1979, the Government imposed a Moratorium on Building Development across a large portion of the Mid-levels District. The Geotechnical Control Office (GCO) was concerned that there were substantial deposits of colluvium within the Mid-levels and that this material, and other factors, required investigation to ensure that further development would not increase the risk of slope failure. Arising from the Moratorium, the GCO undertook to delineate other areas of the Territory which may have similar deposits of colluvium, and to assess the need for similar restrictions elsewhere. It should be noted that the extensive deposits of colluvium in the Mid-levels were not shown on the Geological Map prepared at a scale of 1:50 000 by Allen & Stephens (1971).

In response to the GCO's commitment arising from the Mid-levels Moratorium, a programme of reconnaissance level colluvial mapping was completed during May and June of 1979. Aerial photograph interpretation and terrain classification techniques were utilised to map the general location of colluvium within the Territory at a scale of 1:20 000.

The terrain classification approach adopted for the regional colluvial deposit study enabled five terrain-related attributes to be identified, encoded and mapped using the stereoscopic interpretation of small-scale aerial photographs. This information was recorded onto the fifteen 1:20 000 scale topographic base maps covering the Territory. The colluvial information included the type-morphology of the deposit, parent materials, general slope angle, evidence of instability and evidence of groundwater. An example of this type of mapping is shown at Figure A20. The study systematically mapped the colluvium within the Territory, but did not treat any of the non-colluvial terrain. This study took two man months and was for in-house use only.

From the colluvial study, a number of areas were identified for further investigation. Since systematic terrain classification mapping techniques had been successfully applied at quite large scales during the Mid-levels investigation, it was decided to pursue the systematic approach at a scale of 1:2 500. This investigation became known as the Geotechnical Area Studies Programme.

The Geotechnical Area Studies (GAS) Programme commenced in September 1979 following recommendations to the Chief Secretary arising from the regional colluvial study of the Territory. A total of twenty areas were included in a schedule for investigation using terrain classification techniques at a scale of

1:2 500. An initial programme was established for *nine* study areas, occupying some 2 160 ha within Hong Kong Island, the Kowloon footslopes, Tsuen Wan and southern Lantau. The areas were selected because of their general similarity to the Mid-levels situation, their relative importance from the point of view of existing development, and in some cases, their potential for future development.

In November 1979, it was decided to incorporate the remaining eleven areas into a regional GAS Programme at a scale of 1:20 000. The regional programme also enabled the completion of the Territory-wide land inventory which had commenced in September 1978, but had been in abeyance since December 1978. Most of the eleven areas were undeveloped. In many cases, strategic planning decisions regarding their future development were likely within the short term. The availability of regional, small scale maps of these areas, showing the distribution of geotechnical limitations assists the planning of development. Adoption of a regional approach removed the immediate need for detailed 1:2 500 scale terrain classification and resulted in the production of general planning maps and a land resource inventory of the entire Territory. If development is required on any of the eleven areas of geotechnically-problematical colluvial terrain, then detailed terrain classification at a scale of 1:2 500 or a similar level of investigation can be completed.

Separate terrain classification systems were designed for use at scales of 1:2 500 and 1:20 000. The 1:2 500 scale system is quite complex, with six attributes: slope gradient, terrain component, terrain morphology, erosion and instability, slope condition and surface hydrology. The 1:20 000 scale system is more general in nature, containing only three attributes: slope gradient, terrain/geology, and erosion/instability.

Throughout the Geotechnical Area Studies, a systematic approach was used to collect and characterise the natural variations which occur across the terrain. The location of colluvial and other superficial deposits were mapped, and although shortcomings in the Allen & Stephens bedrock geology were apparent, no attempt was made to remap the bedrock geology within the context of the terrain classification studies. The terrain was classified according to slope gradient, occurrence of superficial or insitu terrain and the degree of erosion and instability at a regional or district level. The Allen & Stephens (1971) bedrock geology was inserted into the areas mapped as 'insitu terrain' in the Terrain Classification Maps.

A.2 Terrain Classification in the Geotechnical Area Studies Programme

A.2.1 *General*

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 assists with the collection of physical resource information and many other types of data. Any object or feature which can be recorded as a photographic image can be identified using API.

The main benefits of API lie in the speed and uniformity of data acquisition and, for mapping purposes, a reduction in the amount of field work (Styles, 1982). Access into, and evaluation of, remote or hazardous terrain can also be simplified using API.

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

Terrain classification has been carried out in the Geotechnical Area Studies Programme at two levels of intensity. Regional mapping was conducted at a scale 1:20 000 and detailed district mapping was undertaken at a scale of 1:2 500. Considerable input has been expended by the GCO in the Programme, with the involvement of some 22 Geotechnical Engineers within the period September 1979 and September 1984. It is estimated that about 20 man years of input by professional staff were required in various aspects of the mapping and report production for the internal GASP up to May 1987. During the same period (to May 1987), in the order of 50 man years of cartographic effort was required to prepare in excess of 120 maps.

The regional terrain classification programme for the Territory covers some 110 000 ha, and the large-scale district mapping approximately 2 160 ha of geotechnically-problematical terrain. A comparison of the two mapping systems is provided in Section A.14, Figures A16 and A17. Data relating to the classification schemes are presented in Tables 1.3, A11 and A12. Table A1 illustrates the general method of data acquisition and the maps produced in the programme.

A.2.2 *Regional Studies*

Eleven Terrain Classification Maps at a scale of 1:20 000 provide coverage of the Territory. These maps form the basis of the eleven Regional GASP Reports, which are all available to the public. They are in conventional line form, and examples are included in Figures A8b to A14b. The GLUM, PCM, EGM and usually the GLEAM, accompany GASP Reports I to XI. Terrain Classification Maps have not been published, as they are 'working maps' essentially for in-house use; however, if required, copies of the full-size Terrain Classification Maps are available through the Geotechnical Information Unit of the Geotechnical Control Office. The Terrain Classification Map for the regional studies is discussed in Section A.3. and a Chart illustrating the system is presented in the Map Folder.

A.2.3 *District Stage 1 Studies*

Nine Terrain Classification Maps at a scale of 1:2 500 were completed in the District Stage 1 Studies. The mapping areas ranged in size from 130 ha to 460 ha. The Terrain Classification Maps are in conventional line form and an example of a district level map is presented in Figure A15. The classification scheme is discussed in Section A.12. Large scale Terrain Classification Maps are available through the Geotechnical Information Unit of the Geotechnical Control Office.

A.3 Terrain Classification Map for the Regional Studies

A.3.1 *General*

Three characteristics (attributes) are delineated on the 1:20 000 scale Terrain Classification Map. An example is given in Figure A8b. The three terrain attributes adopted for the regional studies are:

(*a*) Slope gradient.

(*b*) Terrain component and morphology.

(*c*) Erosion and instability.

The terrain classification schedule for use at 1:20 000 scale is presented in Table A1. The information is presented in alphanumeric form, which enables the 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 '2Fa' represents a concave slope at an angle of 5–15°, composed of colluvium, in a footslope location which contains a well-defined recent landslip. An example of the classification is given in Figure A2.

The physical resource information collected in the Territory-wide programme of systematic terrain classification at a scale of 1:20 000, is integrated into a data base management system known as the Geotechnical Terrain Classification System (GEOTECS). GEOTECS is discussed briefly in Sections 1.3.9 and A.11.

A brief description of the three terrain attributes which are included in the terrain classification is given below (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.

Table A1 Terrain Classification Attributes for Regional Studies

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	—relict	r
		—concave	O	Coastal instability	w
		—convex	P		
		Fill —straight	R		
		—concave	S		
		—convex	T		
		General disturbed terrain	V		
		Wave cut platform	W		
		Alluvial plain	X		
		Reclamation	Z		
		Waterbodies:			
		Natural stream	1		
		Man-made channel	2		
		Water storage	3		
		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.3.2 *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.3.3 *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.

The following 14 major terrain component classes are used:

(*a*) Hillcrest (Code A).

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

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

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

(*e*) Floodplain (Code I).

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

(*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*) Wave cut platform (Code W).

(*n*) 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 (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.3.4 *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:

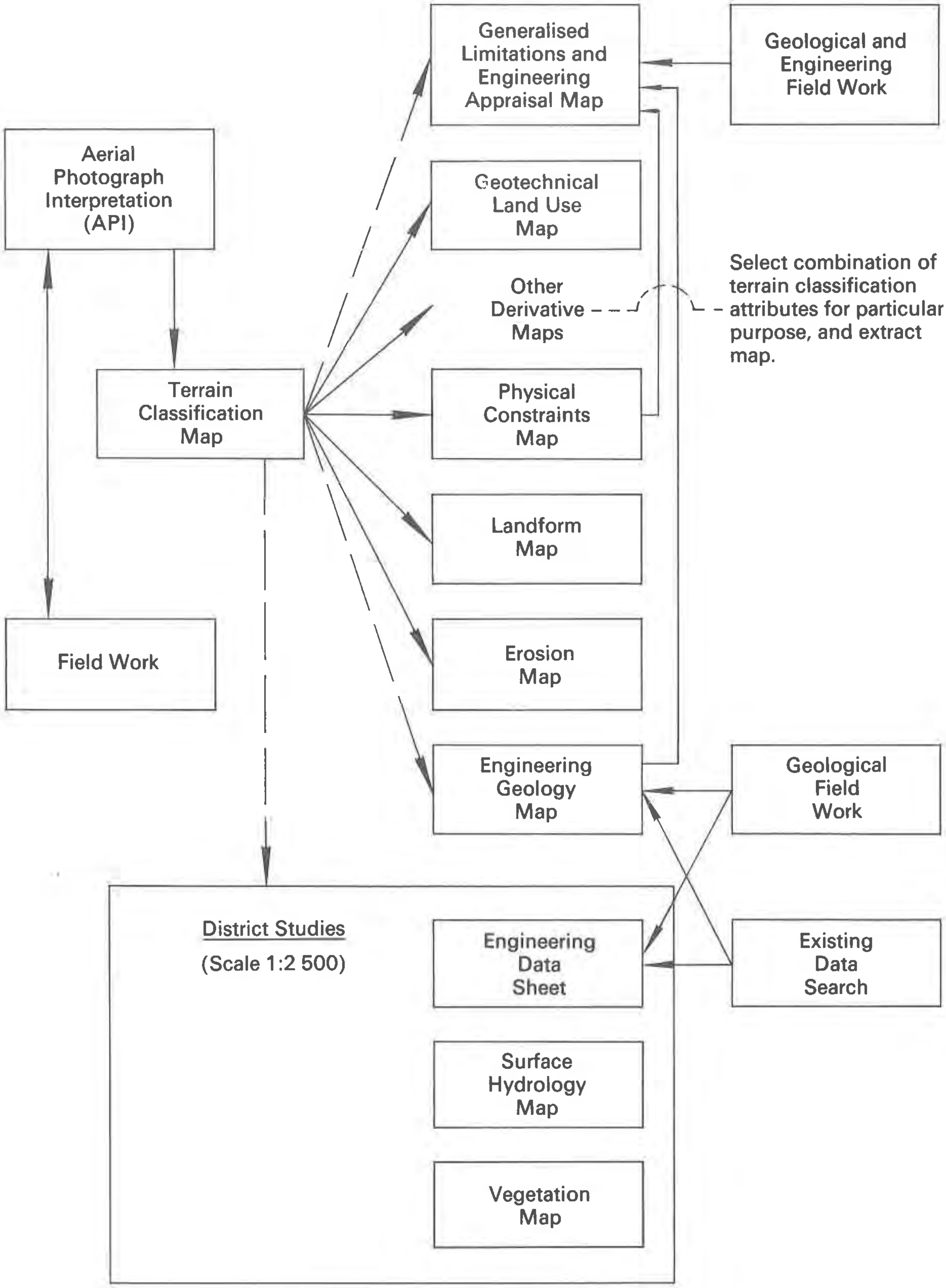
(*a*) No appreciable erosion (Code .).

(*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 increasingly lighter tones in aerial photographs. Severe sheeting appears as a highly reflectant white tone, which indicates the absence of almost all vegetative 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.

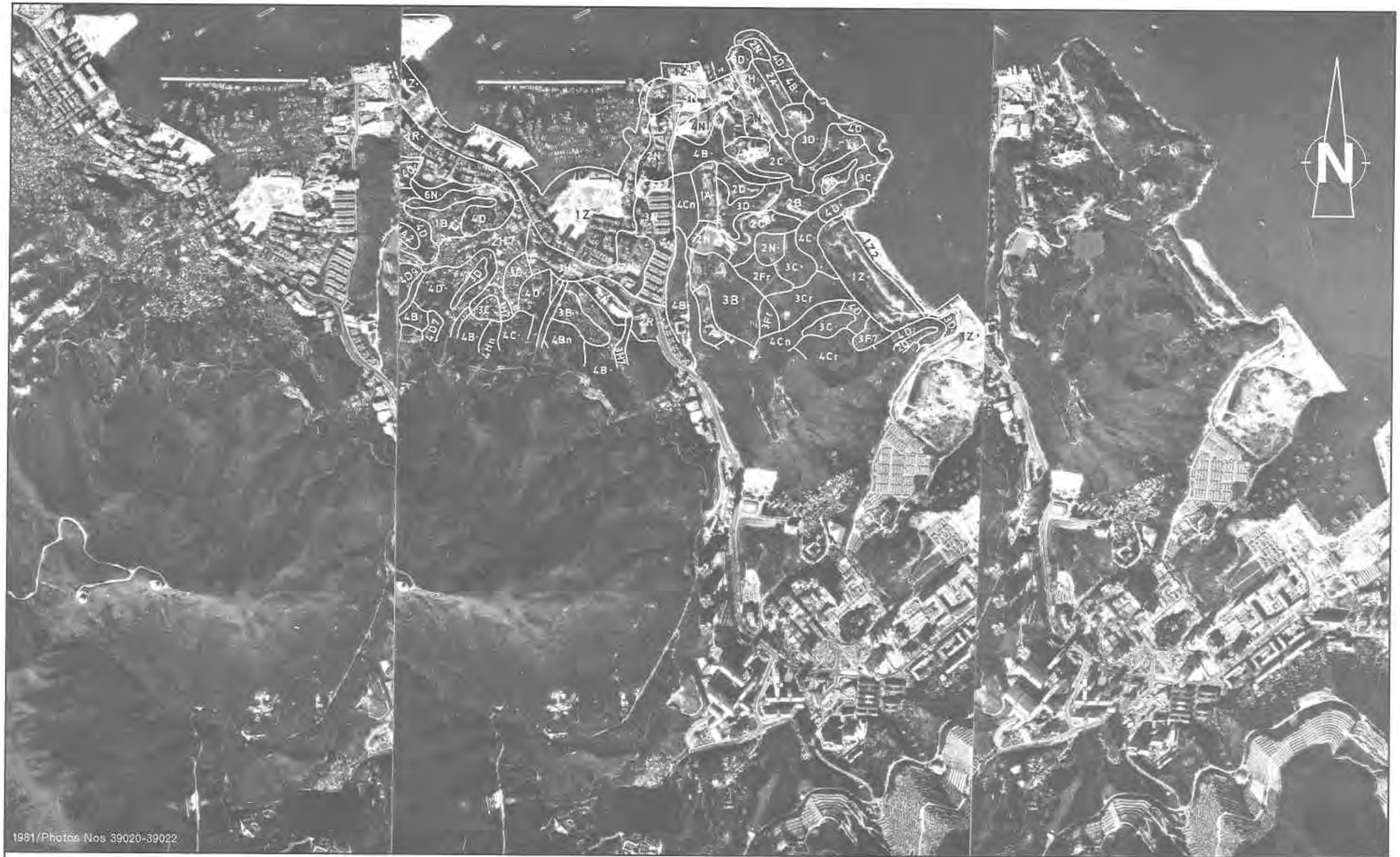
(*c*) Rill erosion (Codes 4, 5, 6) is a form of denudation which occurs typically on exposed cut and fill slope batters. It is characterised by subparallel drainage rivulets which produce a typically striated appearance and result in significant soil loss.

(*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 small landslips as discrete map units on a 1:20 000 scale map.



Technique of Data Acquisition and Derivation of Maps | Fig. A1



Stereotriplet with Example of Regional Terrain Classification

Fig. A2

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. The Landform Map (example in Figure A13a) 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.

(*j*) Wave cut platforms.

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 reservoirs), 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. 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 A14a.

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).

(*k*) Wave cut platforms.

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. It is extracted from the Terrain Classification Map and is designed specifically to supplement the GLUM. An example is presented in Figure A10a.

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 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 exceed 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 for Regional Studies

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

This Figure illustrates a few of the relationships between terrain features and GLUM class:

(i) GLUM Class I:

(*a*) gently sloping spur crests and lines (slope gradients 0–15°) on insitu terrain.
(*b*) cut platforms on insitu terrain.

(ii) GLUM Class II:

(*a*) gently sloping spur crests and ridge lines which are colluvium covered.

(*b*) moderately steep sideslopes (slope gradients 15–30°) on insitu terrain with evidence of appreciable erosion (sheet, rill, gully erosion) and boulders.

(iii) GLUM Class III

(*a*) steep sideslopes (slope gradients 30–40°) on colluvium or insitu terrain.

(*b*) moderately steep sideslopes on insitu terrain with moderate to severe gully erosion.

(iv) GLUM Class IV:

(*a*) natural drainage lines with associated thick, remnant deposits of colluvium (slope gradients generally greater than 15°).

(*b*) severe to very severe gully erosion on steep sideslope terrain (slope gradients greater than 30°).

(*c*) steep and high cut slopes on insitu terrain (slope gradients generally greater than 60°).

Example of GLUM on Natural Terrain | Fig. A3

This Figure illustrates a few of the relationships between features associated with developed terrain and GLUM class. Moderately steep sideslopes and lenticular colluvial deposits aligned along concave drainage depressions typify the GLUM Classes III & IV terrain visible on the sideslopes in the centre of the Plate. Landslips, which are common on the cut slopes above the catchwater, are identified by the chunam surface protection applied to the slide scar (GLUM Classes III & IV visible at the top centre of the Plate). Downslope, concentrations of temporary structures (squatters) occupy the moderately steep sideslopes and some of the colluvial hillside depressions. Terrain marked with an asterisk (*) are concave depressions which may be locally affected by concentrations of overland flow following intense storm rainfall. In the left portion of the plate, corestones and detrital boulders litter the terrain. These also represent a potential threat to developments downslope. At the bottom of the Plate, low rise, low density development associated with a New Town area encroaches upon the sideslope terrain.

Example of GLUM on Developed Terrain	Fig. A4

imposed on development. An appropriate GLUM class can therefore be allocated to each landform unit identified during terrain classification. These are represented on the GLUM, an example of which is presented in Figure A9a. 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 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 (where available).

(*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*) The Regional GLUM System 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 0.1 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.

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 the regional reports with regard to the engineering geology are intended for use at a planning level and are based on the following:

(*a*) Extraction of selected information from the API source data, 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.

A.8.2 *Production of the Engineering Geology Map*

For each of the regional studies, 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 Engineering Geology Map presents on one map the bedrock and superficial geology of the area and indicates the general geomorphology and material properties of the lithological units.

An example of the Engineering Geology Map is located at Figure A11a. Note that the geology shown on these maps 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 are:

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

(*b*) Major photolineaments.

(*c*) Major topographic features.

(*d*) Isopachs of submarine superficial deposits (where information was available at the time of the study).

(*e*) Boundaries of major catchments.

(*f*) Zones of general instability.

(*g*) Zones of reclamation.

The catchment boundaries are indicated on the Engineering Geology Maps 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.

Table A3 Derivation of GLUM Classes from the Regional Terrain Classification

	Slope Gradient	Terrain Component	Erosion Classification				
			General Erosion		Landslip Features		
			., 1, 2, 3, 4, 5, 6, 7	8, 9	a	n, r	w
TERRAIN CLASSIFICATION	1	A	I	II	III	III	III
	2	A	II	III	III	III	III
	3	A	II	III	III	III	III
	4	A	III	IV	IV	IV	IV
	1	+BCD	I	III	III	III	III
	2	BCD	I	III	III	III	III
	3	BCD	II	III	IV	III	III
	4	BCD	III	III	IV	IV	IV
	5	BCD	III	IV	IV	IV	IV
	6	BCD	IV	IV	IV	IV	IV
	1	* E F G	II	III	III	III	III
	2	E F G	III	III	IV	III	III
	3	E F G	III	IV	IV	IV	IV
	4	E F G	III	IV	IV	IV	IV
	5	E F G	IV	IV	IV	IV	IV
	6	E F G	IV	IV	IV	IV	IV
	1	° H	III	III	IV	IV	IV
	2	H	III	III	IV	IV	IV
	3	H	IV	IV	IV	IV	IV
	4	H	IV	IV	IV	IV	IV
	5	H	IV	IV	IV	IV	IV
	6	H	IV	IV	IV	IV	IV
	1	I	II (subclass)	III	IV	IV	IV
	2	I	II (subclass)	III	IV	IV	IV
	1	K	II	III	III	III	III
	2	K	II	III	III	III	IV
	1	L W	Not classified				
	2	L W					
	1	M	I	III	III	III	III
	2	M	II	III	III	III	III
	3	M	II	III	III	III	III
	4	M	III	III	IV	IV	IV
	5	M	IV	IV	IV	IV	IV
	6	M	IV	IV	IV	IV	IV
	1	NOP	I	III	III	III	
	2	NOP	II	III	III	III	
	3	NOP	II	III	IV	IV	
	4	NOP	III	III	IV	IV	
	5	NOP	III	IV	IV	IV	
	6	NOP	IV	IV	IV	IV	
	1	RST	II	III	III	III	
	2	RST	II	III	III	III	
	3	RST	III	III	IV	IV	
	4	RST	III	III	IV	IV	
	5	RST	IV	IV	IV	IV	
	6	RST	IV	IV	IV	IV	
	1	V	II	III	III	III	
	2	V	II	III	III	III	
	3	V	III	III	IV	IV	
	4	V	III	III	IV	IV	
	5	V	IV	IV	IV	IV	
	6	V	IV	IV	IV	IV	
	1	NOP NOP	II	III	III	III	
	2	NOP NOP	II	III	III	III	
	3	NOP NOP	III	IV	IV	IV	
	4	NOP NOP	III	IV	IV	IV	
	5	NOP NOP	IV	IV	IV	IV	
	6	NOP NOP	IV	IV	IV	IV	
	1	RST RST	II	III	III	III	
	2	RST RST	III	III	IV	III	
	3	RST RST	III	IV	IV	IV	
	4	RST RST	III	IV	IV	IV	
	5	RST RST	IV	IV	IV	IV	
	6	RST RST	IV	IV	IV	IV	
	1	V V	II	III	III	III	
	2	V V	III	III	IV	III	
	3	V V	III	IV	IV	IV	
	4	V V	III	IV	IV	IV	
	5	V V	IV	IV	IV	IV	
	6	V V	IV	IV	IV	IV	
	1	Z	II	II	III	III	
	2	Z	II	II	III	III	
	3	Z	III	III	IV	IV	
	4	Z	III	III	IV	IV	
	1	X	II	III	III	III	
	2	X	II	III	III	III	
	3	X	III	III	IV	IV	

Notes: + Terrain Components BCD—insitu terrain
* Terrain Components E F G—colluvial terrain
° Terrain Components H —drainage plain across colluvial terrain

This table should be read in conjunction with Table A1 & A2.

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 sediment derived.

(*d*) Essentially metasediment derived.

(*e*) 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 base.

A.8.4 *Data Collection*

The information presented on the Engineering Geology Maps contained in the regional studies, 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.

A.8.5 *Description of Rock Weathering*

The method of description used during the GAS Programme is presented in Table A4. This system since has been revised by the Geotechnical Control Office (1988k) with the publication of 'Geoguide 3–Guide to Rock and Soil Descriptions'. The systems described in Tables 4 & 10 on pages 76 & 82 of Geoguide 3 are commended to users.

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 Territory has been influenced by the geotechnical constraints associated with the terrain since the start of urban expansion. 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.

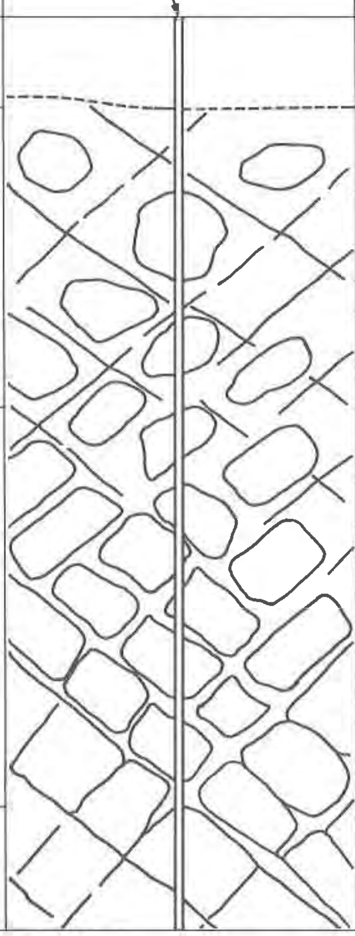
A.9.2 *Derivation of the GLEAM*

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 A5.

The GLEAM identifies areas of potential for development. Continuous areas of already developed land are excluded from comment. 'Man-made' restrictions such as Country Park, catchwaters and water supply 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 A5.

Table A4 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 (Refer Section A.8.5)

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). (Refer Section A.8.5)

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 A6. 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.

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*

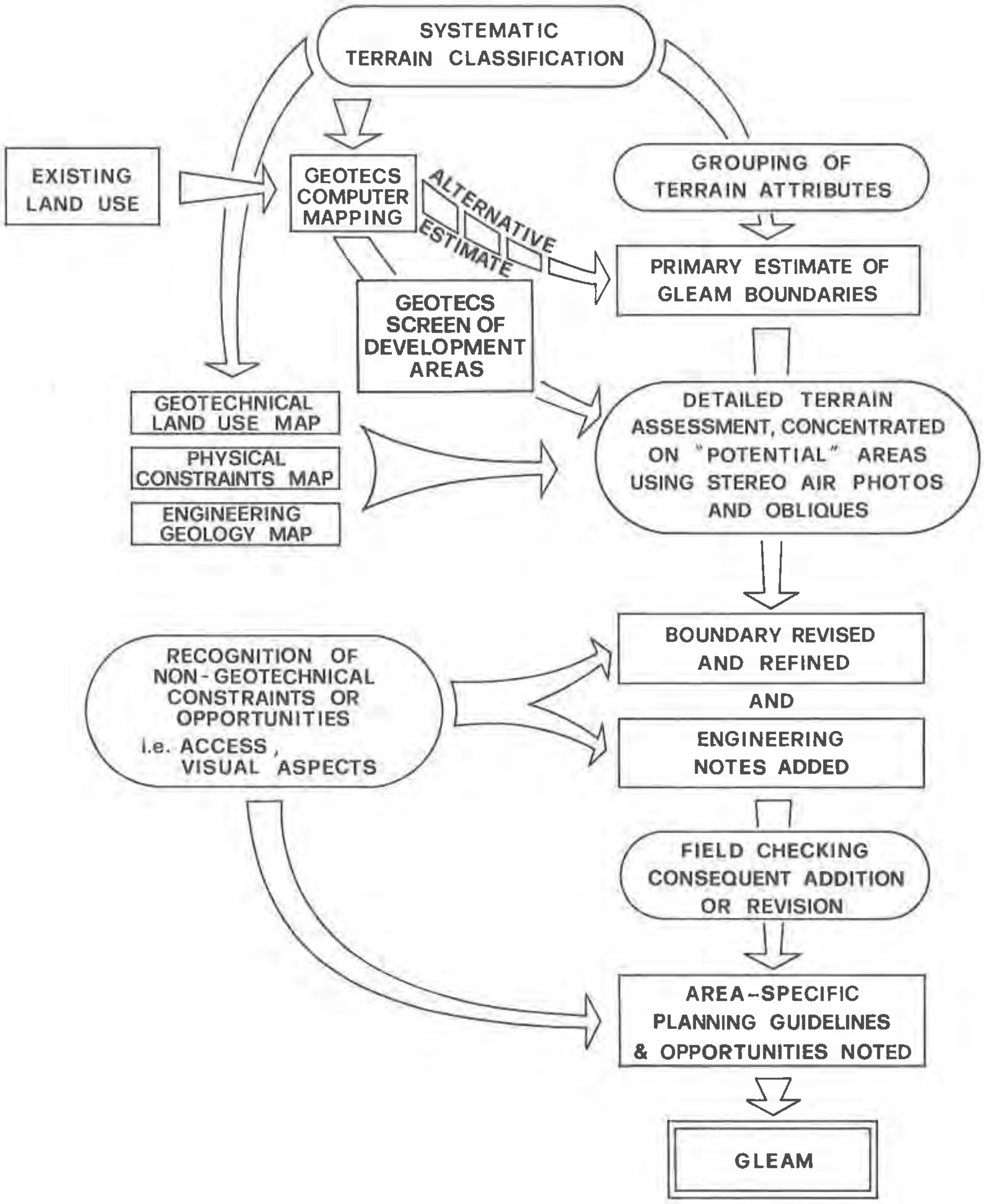
After the identification of areas for development, planners, architects and engineers prepare the form, layout and design details of the scheme. At this stage, the GLEAM is also of value because it indicates the particular nature of local geotechnical difficulties which influence the design aspects of 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. Too often, designs reach an advanced stage before major geotechnical constraints are identified.

Table A6 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 Appendix D.

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 1.3.9, 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.



Derivation of Generalised Limitations and Engineering Appraisal Map | Fig. A5

Table A5 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
N, O, P** R, R, S T, V, V	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.

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 Sections 1.4 & 4.2.3. The potential for sources of rock, assessed in geotechnical terms, is an example.

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 the regional studies. 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 and are most suitable for use at 1:50 000 or 1:100 000 scale.

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

A data base has been established for each of the eleven regional GASP areas and all the data was merged for this Territory-wide study. This facilitates the examination and analysis of the distribution of the physical resource attributes occurring in the Territory and their planning and engineering implications. It also provides a method of investigating the interrelationships among various terrain-related and other resource attributes.

Table A6 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 individual GASP Reports and Appendix 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 terrain classification constitutes a regional-scale (1:20 000) systematic terrain classification for the entire Territory of Hong Kong. The GASP XII data base consists of over 53 400 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 in Sections 1.3.9 & 1.4. 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, rainfall, and vegetation.

The area measurements are calculated on the number of grid cells which occur within the Territory. 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 minimises 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, B11 and B13).

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

A.12 Terrain Classification for the District Stage 1 Studies

Following the colluvial inventory of the Territory, completed in 1979, to delineate areas similar in terrain characteristics to the Mid-levels District, nine areas were selected for detailed terrain classification at a scale of 1:2 500.

A terrain classification system consisting of six attributes and 79 classes was applied to some 2 159 ha in nine District Stage 1 Studies. The legend is presented at Table A7 and consists of: slope gradient (6 classes), terrain component (27 classes), terrain morphology and materials (15 classes), erosion and instability (18 classes), slope condition (9 classes) and hydrology (4 classes).

Each terrain classification map unit was based on a minimum of four attributes, namely: slope gradient, terrain component, terrain morphology and materials, and erosion and instability. In situations where cut, fill and seepage were evident, the map unit could have as many as 6 codes. The codes are recorded on the Terrain Classification Map in alphanumeric form in a similar manner to the regional studies. An example of a District Stage 1 Study Terrain Classification Map is presented in Figure A15.

The Terrain Classification Map formed the basis of the District studies and derivative maps were extracted totally or partially from it. The process of classification is essentially the same as that for the regional studies, illustrated in Figure A6, and described in Section A.13. Examples of the Geotechnical Land Use Map (GLUM), the Engineering Geology Map (EGM), and Terrain Classification Map for the District Stage 1 Studies are shown in Figure A15. Each terrain classification map unit is allocated to one of four GLUM classes in a similar way as for the regional studies. However, the 1:2 500 scale Engineering Geology Map is designed to decode the GLUM, whereas the Physical Constraints Map (PCM) achieves this in the regional mapping system.

The relationship between the 1:2 500 scale maps and the Terrain Classification Map is shown in Figure A1. An Engineering Data Sheet provides factual information about the locations of boreholes, piezometers, traverses, and designated slopes. The Surface Hydrology Map defines the catchment and drainage characteristics of the terrain, and a Vegetation Map was also produced for each district level study.

A.13 Method of Terrain Classification

A.13.1 *Introduction*

This Section describes the processes involved in the technique of terrain classification. A generalised sequence of the procedures required to produce a Terrain Classification Map is presented in Figure A6. Additional steps may need to be inserted depending on the nature of the project, type of terrain, availability of maps, aerial photography and cartographic assistance.

A.13.2 *Assessment of User Requirements and Selection of Map Scale*

This is the first, and probably the most critical step in the process of terrain classification. Failure to identify user requirements will lead to failure of the terrain classification process. It is essential that the needs of the user or client are determined prior to:

(*a*) decision being made to use a terrain classification approach,

(*b*) selection of terrain attributes,

(*c*) selection of map scale, and

(*d*) decision on the final form of the maps and or reporting medium.

There are many issues that must be addressed and these include whether the:

(*a*) user or client requires the information for technical or non-technical purposes or both,

(*b*) task is for an outside client, or

(*c*) task is in-house with release for public use.

In most instances, potential users or clients are unfamiliar with the techniques and methodology of terrain classification. It is extremely important that their needs are fully identified before making any decision regarding the classification system, map production or in fact, whether a terrain classification approach is suitable and practical for the task. It may be necessary to extract from the user, the nature and purpose of the task. In order to do this it is necessary to understand his background knowledge relating to the physical land resources of his area of interest, and his basic understanding of the terrain classification approach. This is a two-way exchange which is the first step in the process of terrain classification.

A list of questions aimed at this process of user assessment and user/producer education is given in Table A8. These questions are designed to provide insight to:

(*a*) the user, of the situations in which terrain classification may be pertinent,

(*b*) the producer, as a gauge of how well the user has identified and understood his own problem and his familiarity with the terrain classification technique.

A non-technical user may be unfamiliar with the types of information which are common background to his need. An informed user may be able to provide crucial information about previous investigations or related studies which might influence the decision to proceed with a terrain classification approach, and which may affect the actual design of the classification system.

It is necessary for the map producer to review the limitations and the technique with the user before any decisions are finalised. In particular, the general rules for map usage, given in Section A.7 and A.10, should be understood. This particularly applies to the validity of information mapped at a given scale.

Terrain classification may provide a practical mapping approach in situations where:

(*a*) terrain information is required on a repetitive basis,

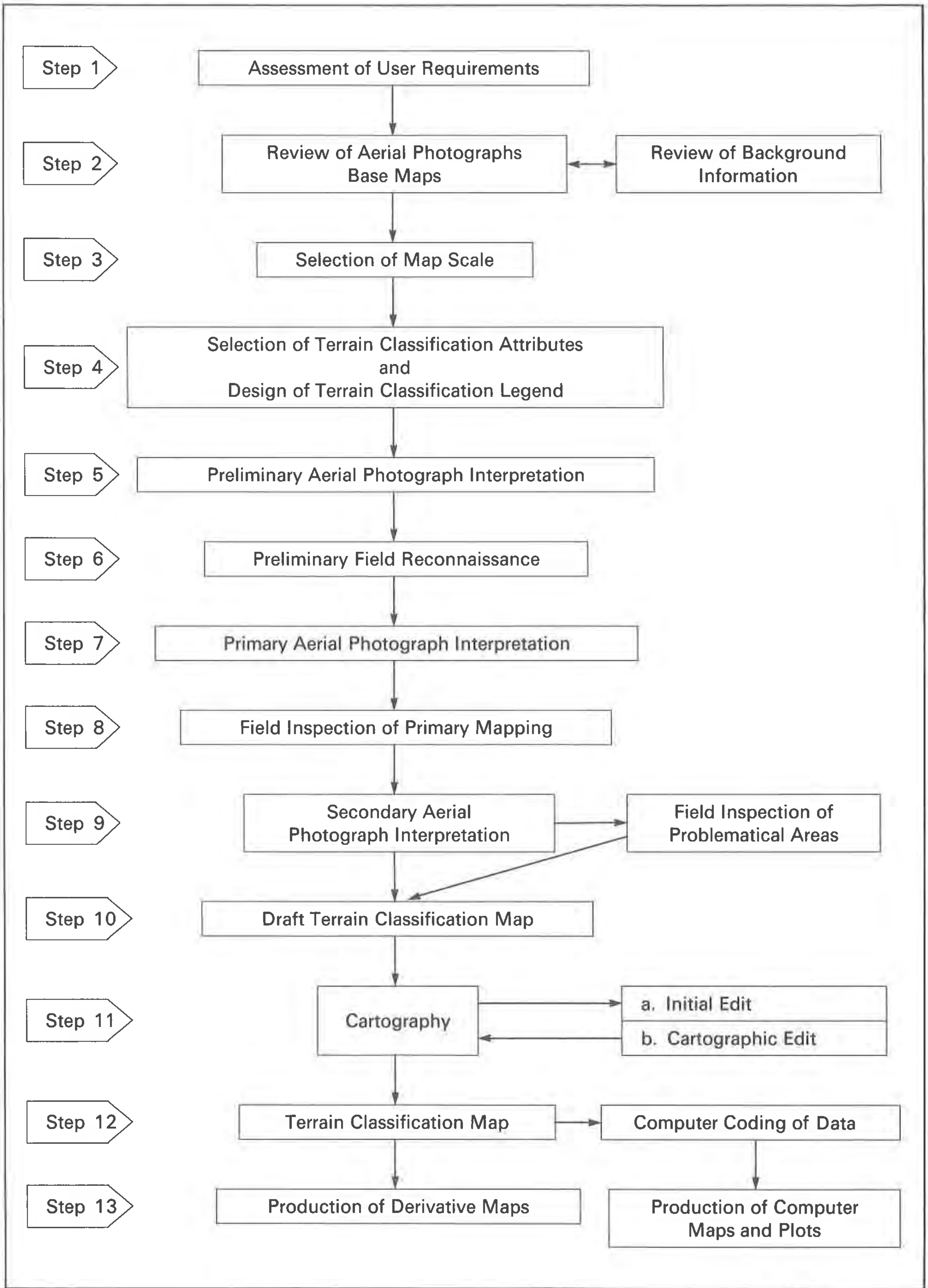
(*b*) assessment of physical land resource information is required in the form of a land inventory,

(*c*) decisions regarding the physical capability of the terrain for land usage are required on a repetitive basis,

(*d*) information or maps are required for a range of users in a technical and or non-technical format, and

(*e*) interrelationships between terrain-related features need to be evaluated.

Once a decision to use a terrain classification approach is made, then the relationship between map scale, user requirements and mapping attributes must be equated. This is necessary not only from the point of view of the validity of the mapping system but also in terms of cost-benefit. If one of these factors is out of balance with the others then the terrain classification process will fail. The detail of terrain attributes specified in the mapping legend must equate with the level of recognition of the attributes as depicted at a given scale on the map (compare Tables A1 and A7). For example, it would be inappropriate to apply the classification scheme for the 1:2 500 scale GASP mapping to the regional studies at a scale of 1:20 000 and vice versa. Scale, user requirements and the classification scheme must be in balance, otherwise irregularities in classification will result. Irregularities usually occur in the form of under or over-classification. Under-classification at the design stage will result in failure to meet user requirements, and over-classification will result in a decrease in cost-benefit caused by cost/time over-run. General guidelines for effective terrain classification are reviewed in Section A13.12. The stages at which under or over-classification can occur are summarised in Table A9. In addition, a guide to good practice in terrain classification is presented in Table A10, in which the need for the assessment of user requirements is stressed.



Method of Terrain Classification

Fig. A6

Users often request the largest map scale possible in the belief that, because larger scale maps may contain more information, the result will be better. Unfortunately, this is a common misconception in terrain classification and the mapping of land resources in general; the level or intensity of data to be collected should be in balance with the mapping scale.

In many situations, a large scale map is not required to fulfill a user's need. It is important to highlight to users that once a commitment to a scale and legend is made, then the accuracy and viability of the resulting maps cannot be changed without major modifications to the mapping programmes. Obviously, a decision on map scale, if it is a determining factor, depends ultimately on the purpose, time and financial resources available for the project. The final option lies somewhere between generalised mapping of large areas and detailed mapping of small areas. On occasions, the decision will be biased by the availability of topographic base maps, especially if specialist cartographic resources are unavailable.

A.13.3 *Availability of Base Maps and Aerial Photography*

The availability of base maps and aerial photography is a critical factor in determining the viability of terrain classification. Interpretation of aerial photographs provides the means of systematic terrain mapping, and base maps are essential for compilation of data extracted from the photographs.

In situations where aerial photographs are unavailable, it may be necessary to commission an aerial survey, and if suitable base maps are also unavailable it may be necessary to produce them using photogrammetric means.

If aerial photographic coverage is satisfactory, it is desirable to select a photographic scale which is in balance with the scale of the base map used to record the terrain classification. From an aerial photograph interpretative point of view, it is recommended that stereomodels should be viewed at approximately the same scale as that of the base map. Therefore, when using a binocular mirror stereoscope with a 3X magnification head, the scale of the aerial photograph should be approximately three times that of the base map. For example, for 1:20 000 scale mapping the photographs should ideally be at a scale of 1:50 000 to 1:60 000. Photographs of a larger scale will result in the tendency to over-classify the terrain. In the case of 1:2 500 scale mapping, photographs at a scale of approximately 1:8 000 are most suitable. When the aerial photographs are orders of magnitude larger in scale than this very general ratio, over-classification of the terrain is likely to result. This is due to the ability of the interpreter to identify small elements of terrain, and in consequence to map in more detail than is required. Under-classification results if the photographic scale is too small in relation to the base map.

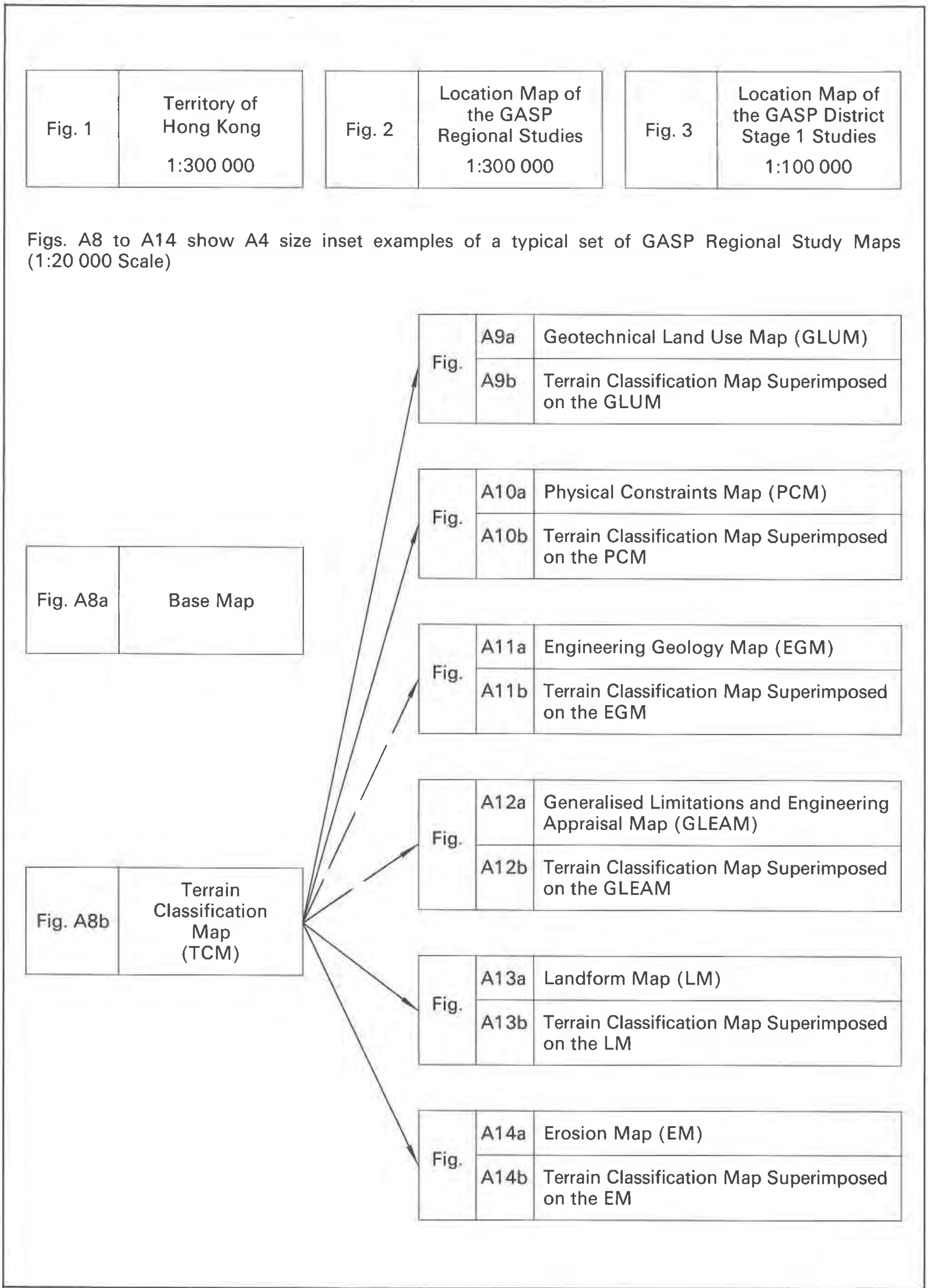
A.13.4 *Selection of Terrain Classification Attributes*

Following the assessment of user requirements and the general selection of base mapping scale, the attributes to be recorded in the terrain classification should be specified. It is recommended that the attributes are discussed in some detail with the potential users, because certain elements of terrain, or of the range and intensity of their occurrence, may be critical to the success of the mapping. In the case of the GASP studies, the regional and detailed classification systems shown in Tables A1 and A7 were formulated with the assistance of experienced geotechnical and civil engineers, and engineering geologists.

The attributes which can be included in the classification scheme can relate to any feature which has surface expression in the terrain, or is otherwise evident on an aerial photograph. Attributes may include a combination or selection of the following terrain-related features: slope gradient, slope aspect, terrain component, superficial/bedrock geology, erosion, instability, land use and vegetation. Depending on the scale and the mapping procedure, these features can be divided into an alphanumeric system of codes, with each feature subdivided according to its range of values or intensity of occurrence. In this way, slope gradient for example, can be classified into various classes of slope angle; terrain according to genesis, position on a hillslope or morphology; erosion according to type and degree of denudation; instability according to presence of landslips or other evidence of instability; and cut or fill slopes according to height.

The terrain classification attributes may be integrated so that all data or a combination of the data can be collected in one phase, i.e. as a multiple attribute map unit. In some instances the map scale and/or other operational reasons may necessitate that all the data necessary for a particular study cannot be recorded on a single map sheet. Nonetheless, the Terrain Classification Map forms a two-dimensional inventory of information interpretated from aerial photographs observed in three dimensions. The terrain classification legend should be retained in draft form until completion of the primary aerial photograph interpretation and field reconnaissance phases of a mapping programme. It is quite common for features not predicted in the earliest phases of the mapping programme to be encountered during systematic mapping. These features then need to be added to the Terrain Classification Legend.

The method of classification relies on the delineation of the terrain in a systematic manner, with a number of observations being recorded for each map unit. The size of the map unit is generally determined by the level of detail built-in to the classification system, which in turn is a function of map scale. The size of map units for the GASP studies is discussed in Section A.14.



Presentation of Maps

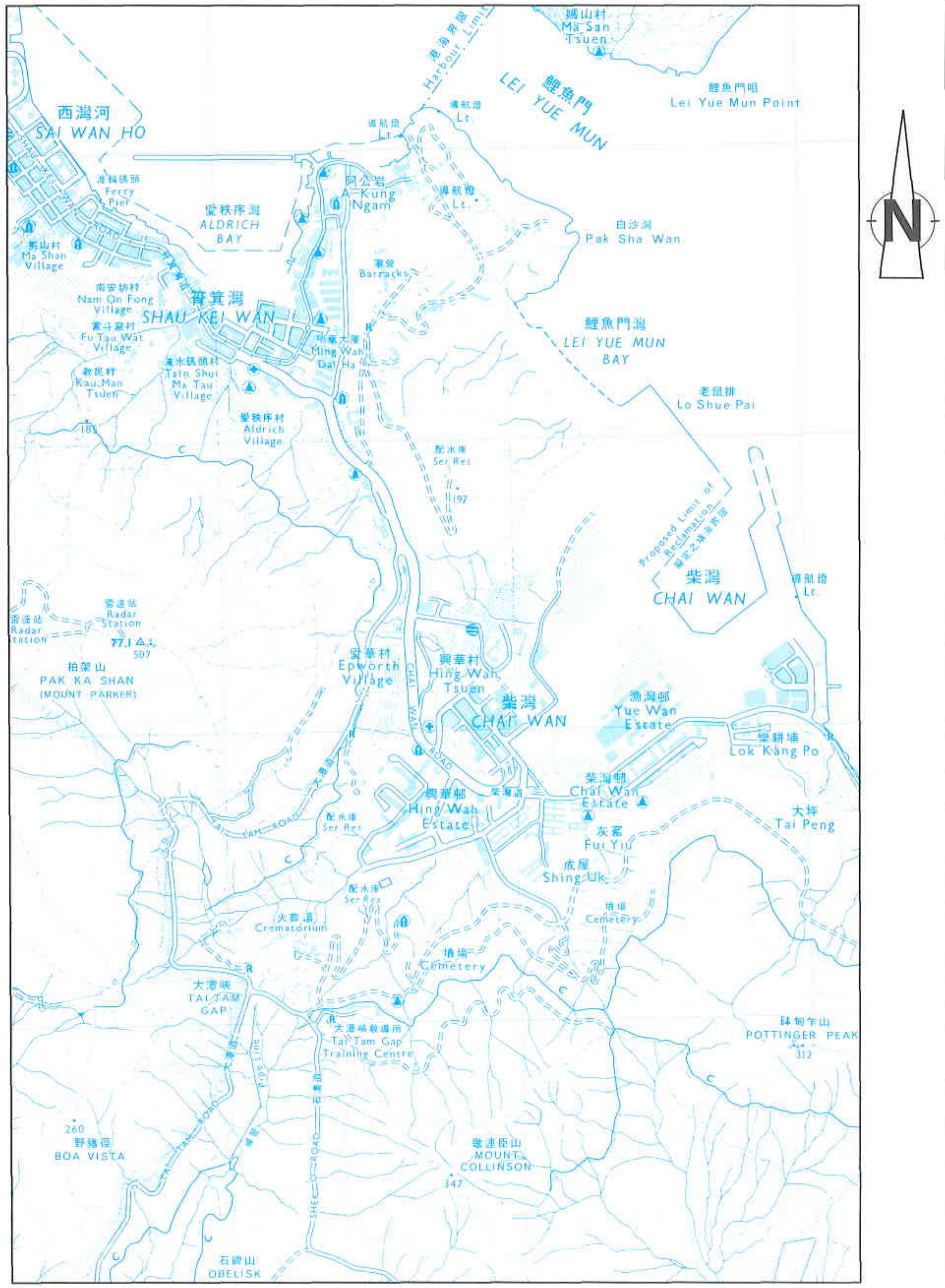
Fig. A7

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. A8b)

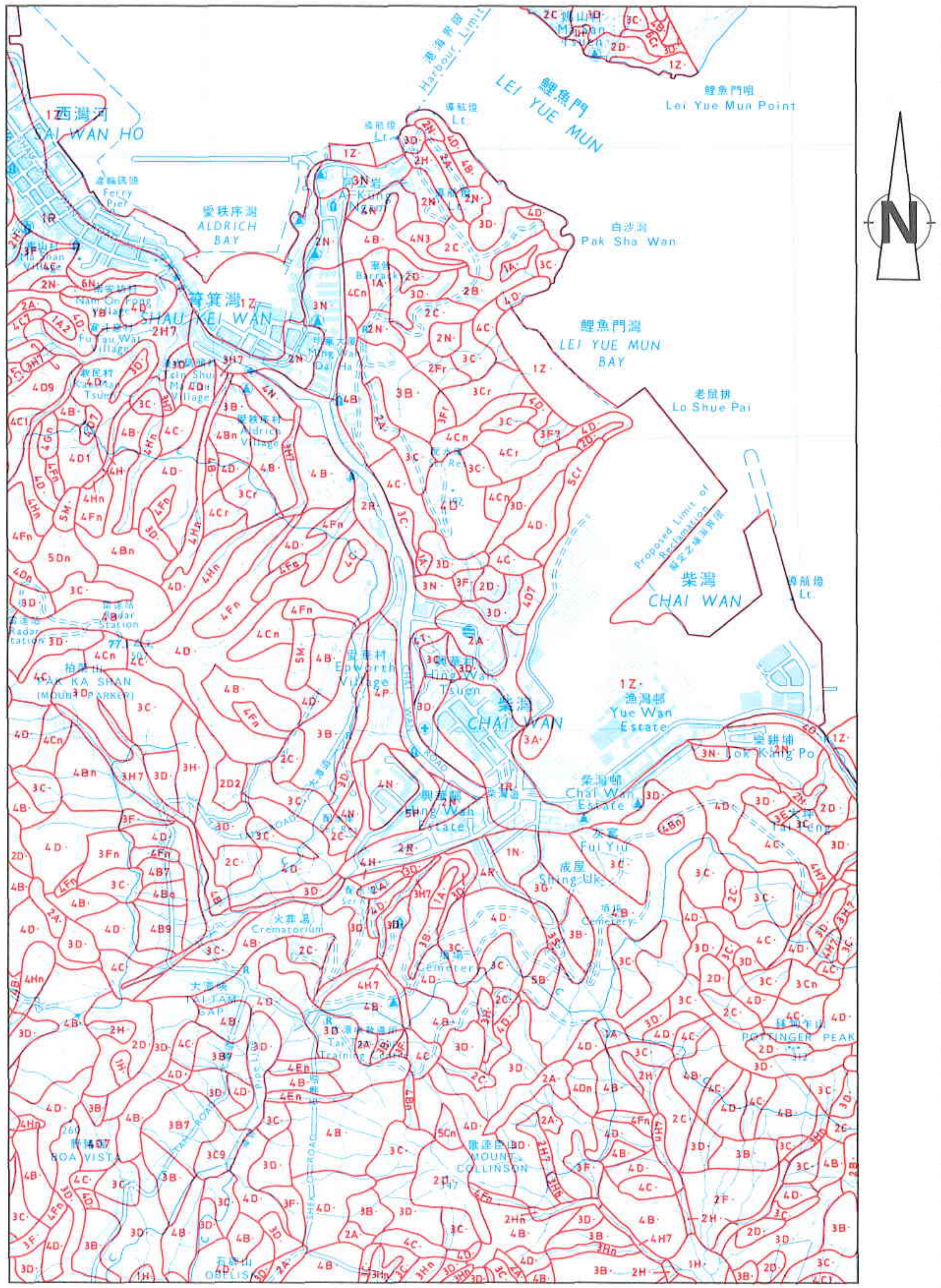
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
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

EROSION	CODE
No appreciable erosion	.
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General instability) recent	n
General instability) relict	r
Coastal instability	w



Scale 1:20 000	Example of the Base Map	Fig. A8a



Scale 1:20 000	Example of the Terrain Classification Map (TCM)	Fig. A8b

LEGEND FOR GEOTECHNICAL LAND USE MAP (Fig. A9a)

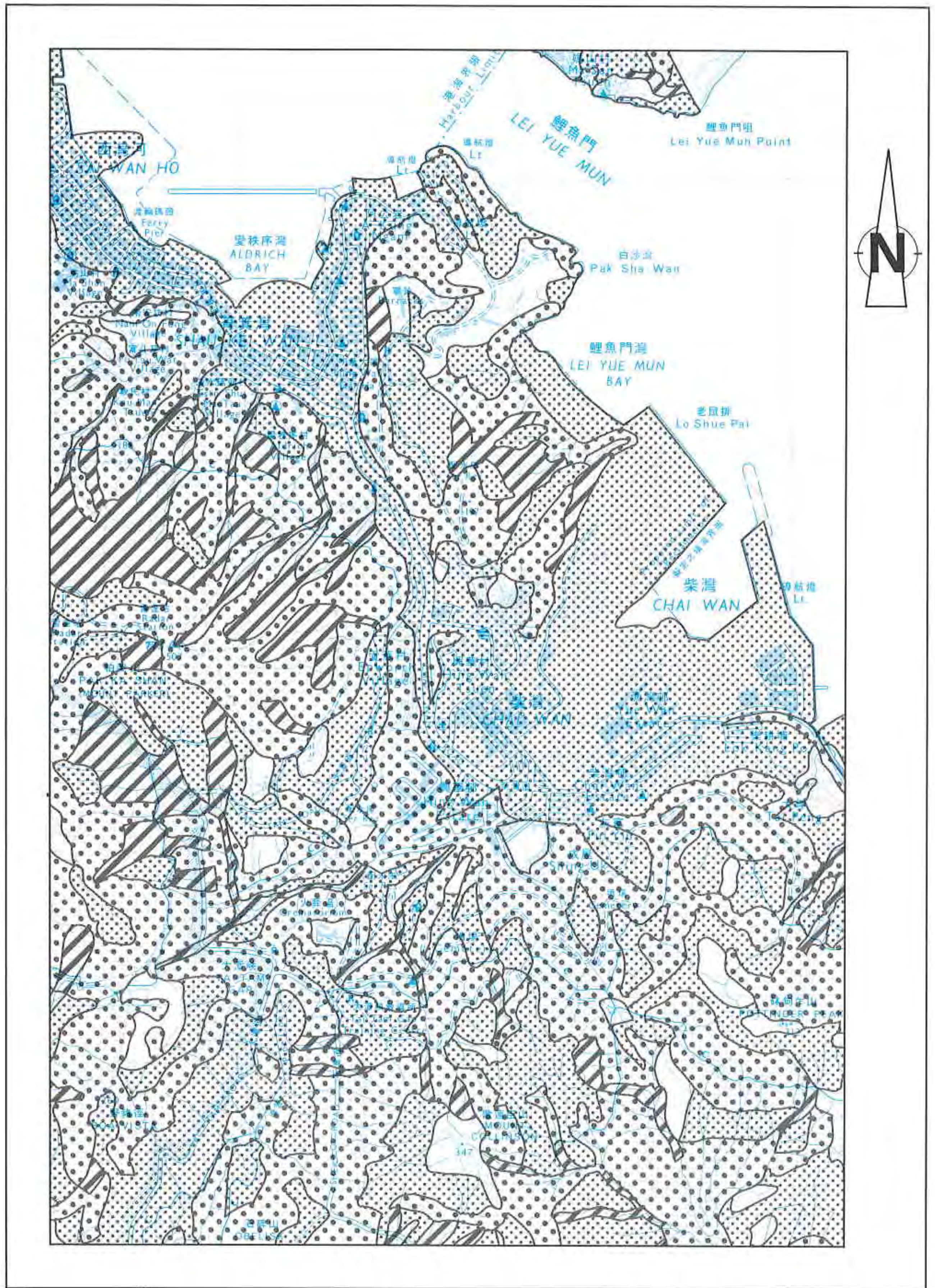
Class I - Low Geotechnical Limitations	
Class II - Moderate Geotechnical Limitations	
Class IIS - Moderate Geotechnical Limitations (including flooding)	
Class III - High Geotechnical Limitations	
Class IV - Extreme Geotechnical Limitations	
Waterbodies (streams, man-made channels, storage dams)	Unclassified
Ponds	Unclassified
Littoral zone (generally subject to tidal action)	Unclassified

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. A9b)

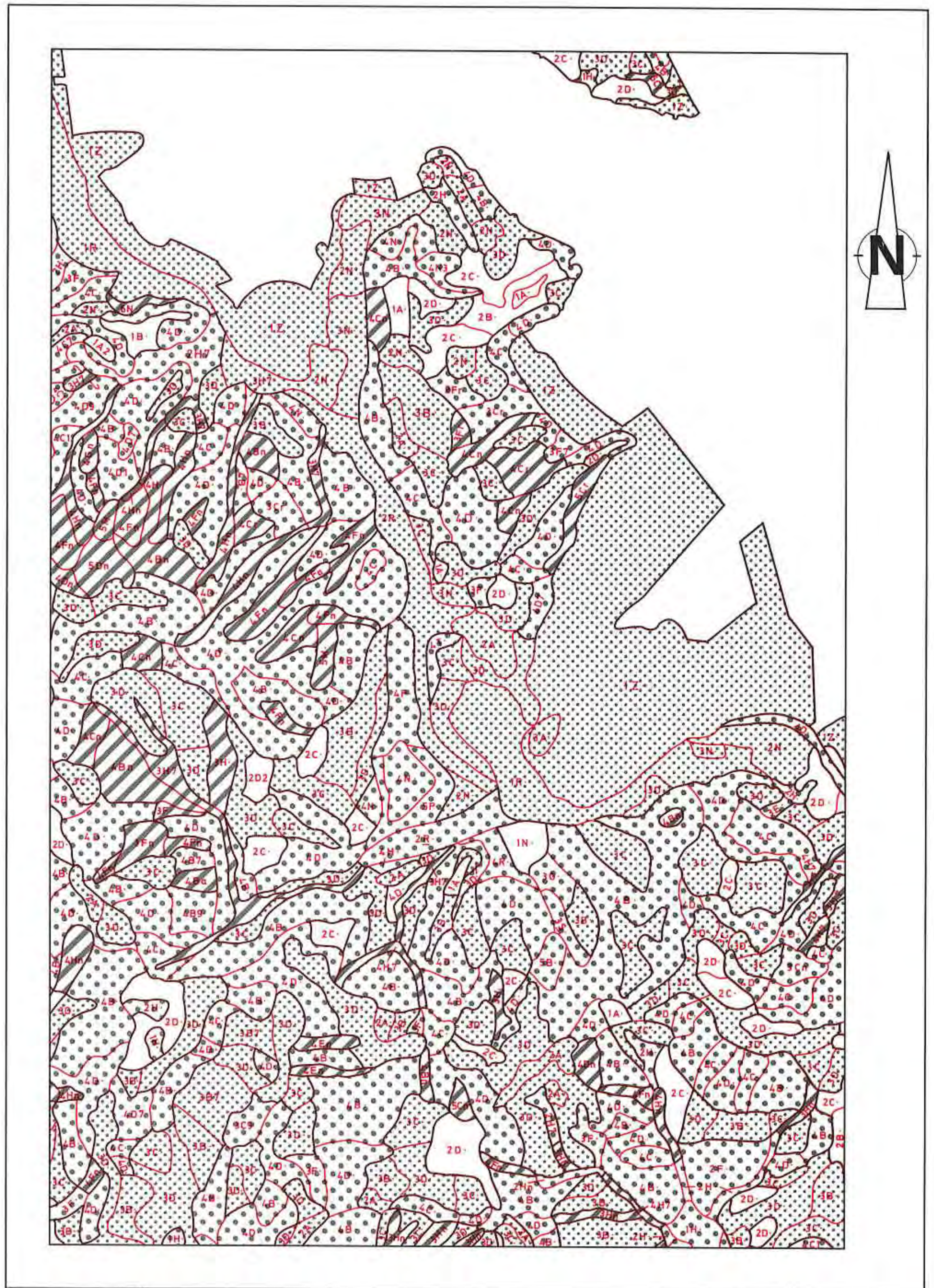
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
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

EROSION	CODE
No appreciable erosion	-
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General instability) recent	n
General instability) relict	r
Coastal instability	w

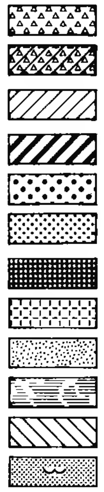


Scale 1:20 000	Example of the Geotechnical Land Use Map (GLUM)	Fig. A9a



Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the GLUM	Fig. A9b

LEGEND FOR PHYSICAL CONSTRAINTS MAP (Fig. A10a)



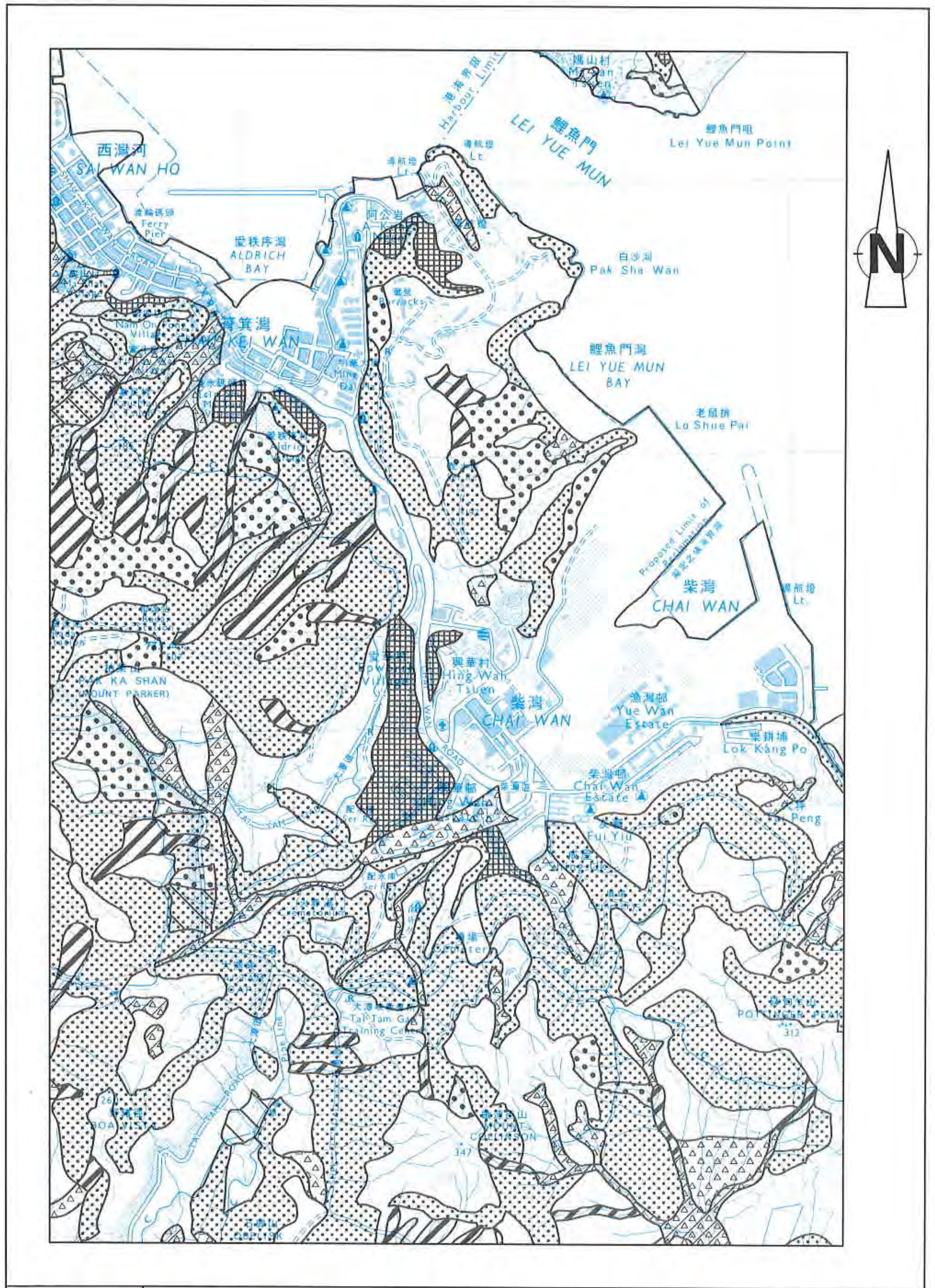
- Colluvium
- Zones of colluvium which are subject to overland flow and periodic inundation. Evidence of unusual groundwater regime (delineated as drainage plain on Landform Map)
- Floodplain - subject to overland flow and regular inundation. Evidence of unusual groundwater regime (delineated as floodplain 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
- 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)

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. A10b)

SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
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

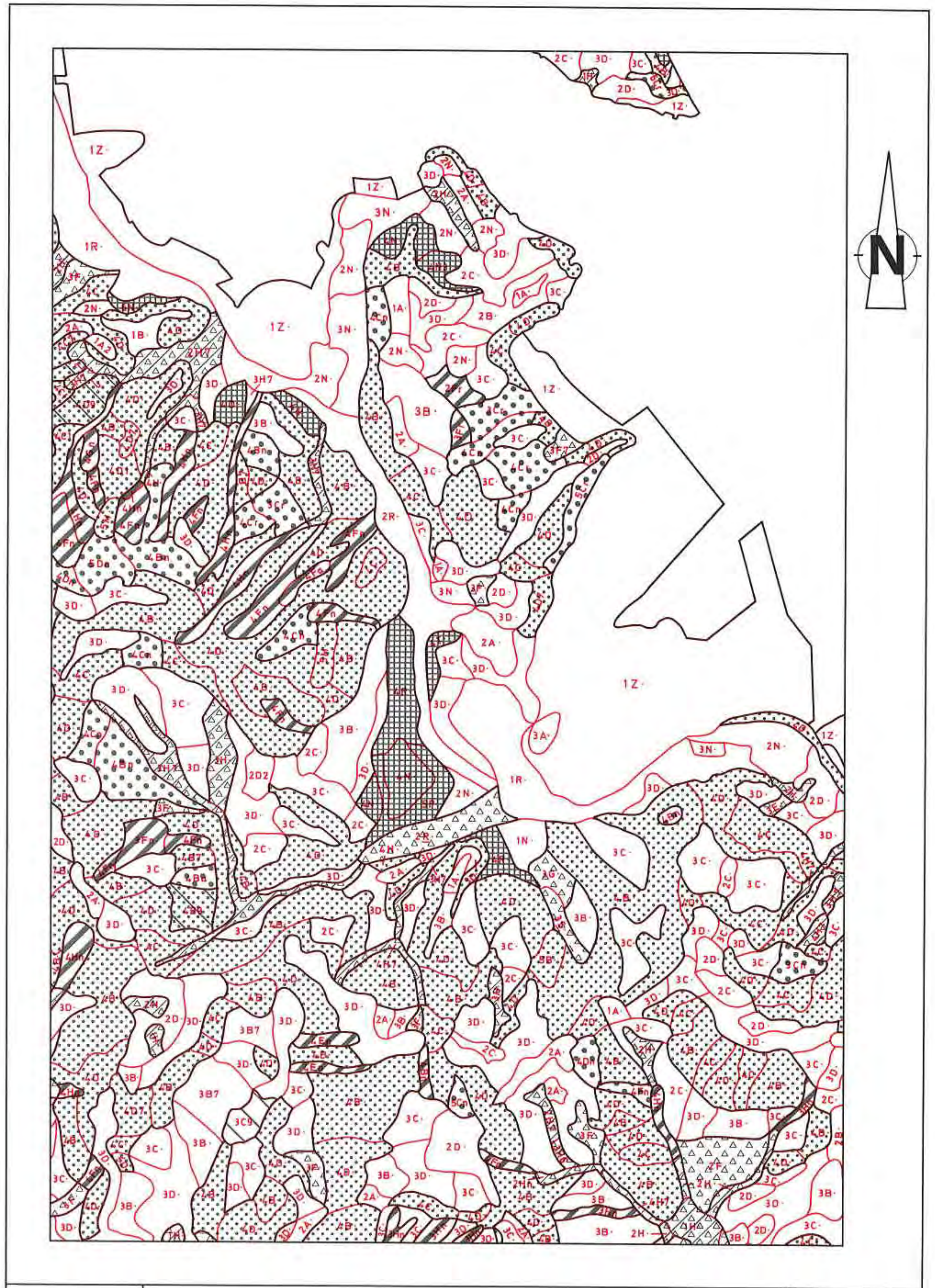
EROSION	CODE
No appreciable erosion	.
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General) recent	n
instability) relict	r
Coastal instability	w



Scale 1:20 000

Example of the Physical Constraints Map (PCM)

Fig. A10a



Scale 1:20 000

Example of the Terrain Classification Map Superimposed on the PCM

Fig. A10b

LEGEND FOR ENGINEERING GEOLOGY MAP (Fig. A11a)

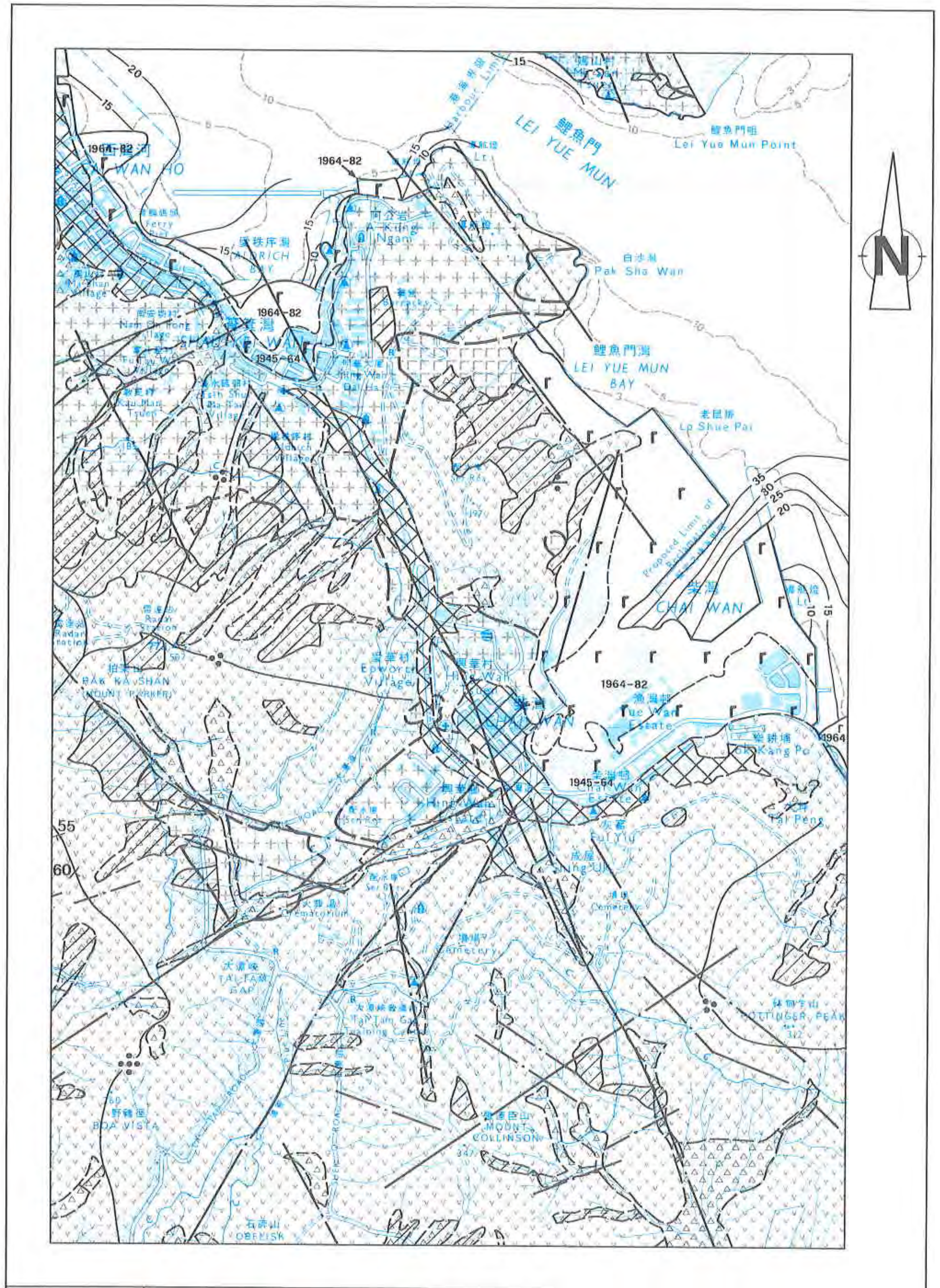
- Fill
- Reclamation
- Colluvium (Undifferentiated)
- Hong Kong Granite
- Quartz Monzonite
- General Instability
- Dominantly Pyroclastic Rocks with Some Lavas (Repulse Bay Formation)
- Geological Boundary (solid)
- Geological Boundary (superficial)
- Geological photolineament
- 30 Strike and Dip of Beds
- Strike of Bedding - Dip Unknown
- Catchment Boundary

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. A11b)

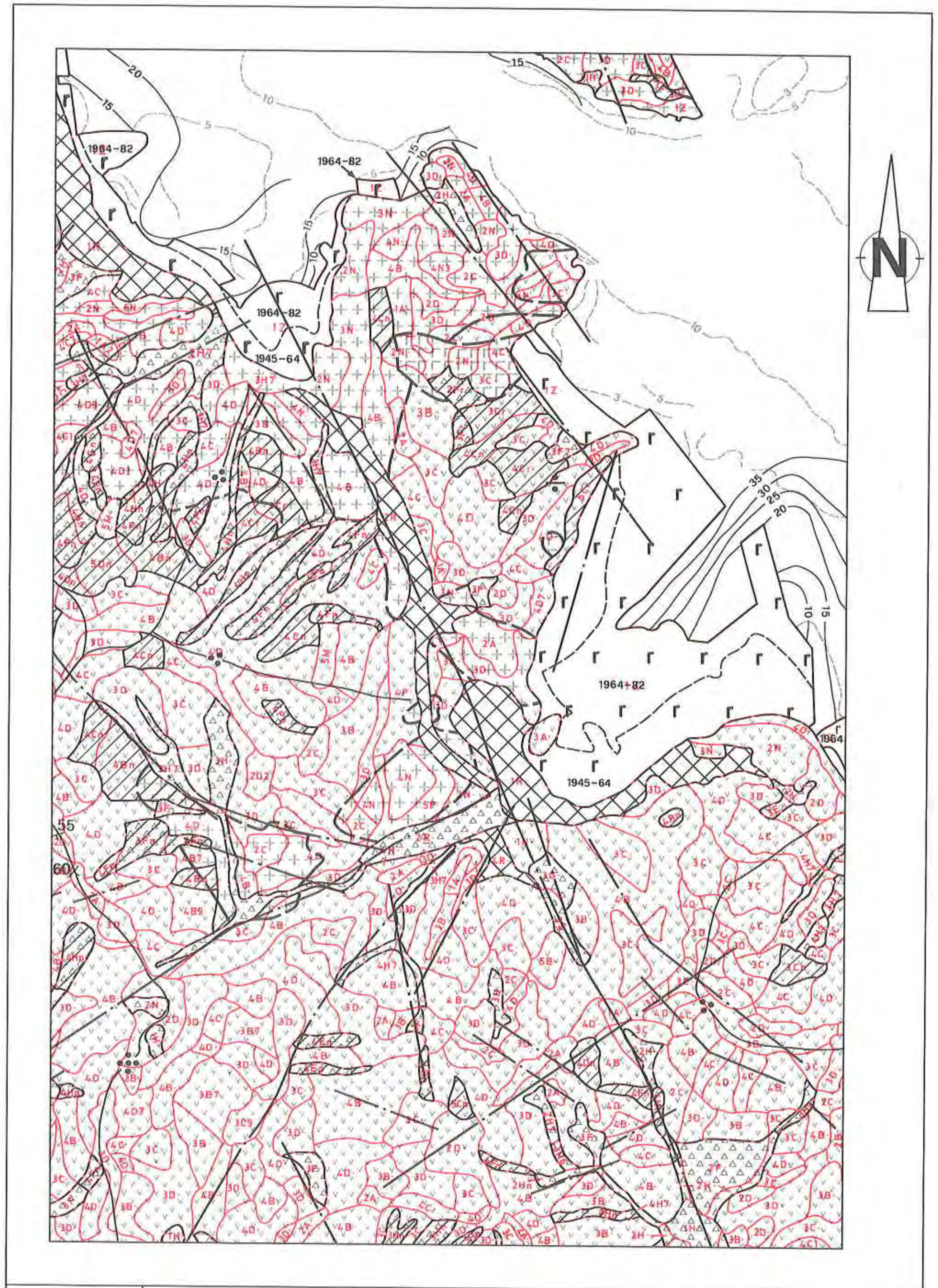
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
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

EROSION	CODE
No appreciable erosion	.
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General instability) recent	n
) relict	r
Coastal instability	w



Scale 1:20 000	Example of the Engineering Geology Map (EGM)	Fig. A11a



Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the EGM	Fig. A11b

LEGEND FOR GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP (Fig. A12a)

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.	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)
(hatched box)	Potential for borrow or extensive cut and fill : opportunity to create site formation in 'constrained' area, or larger site formation in 'potential' area.

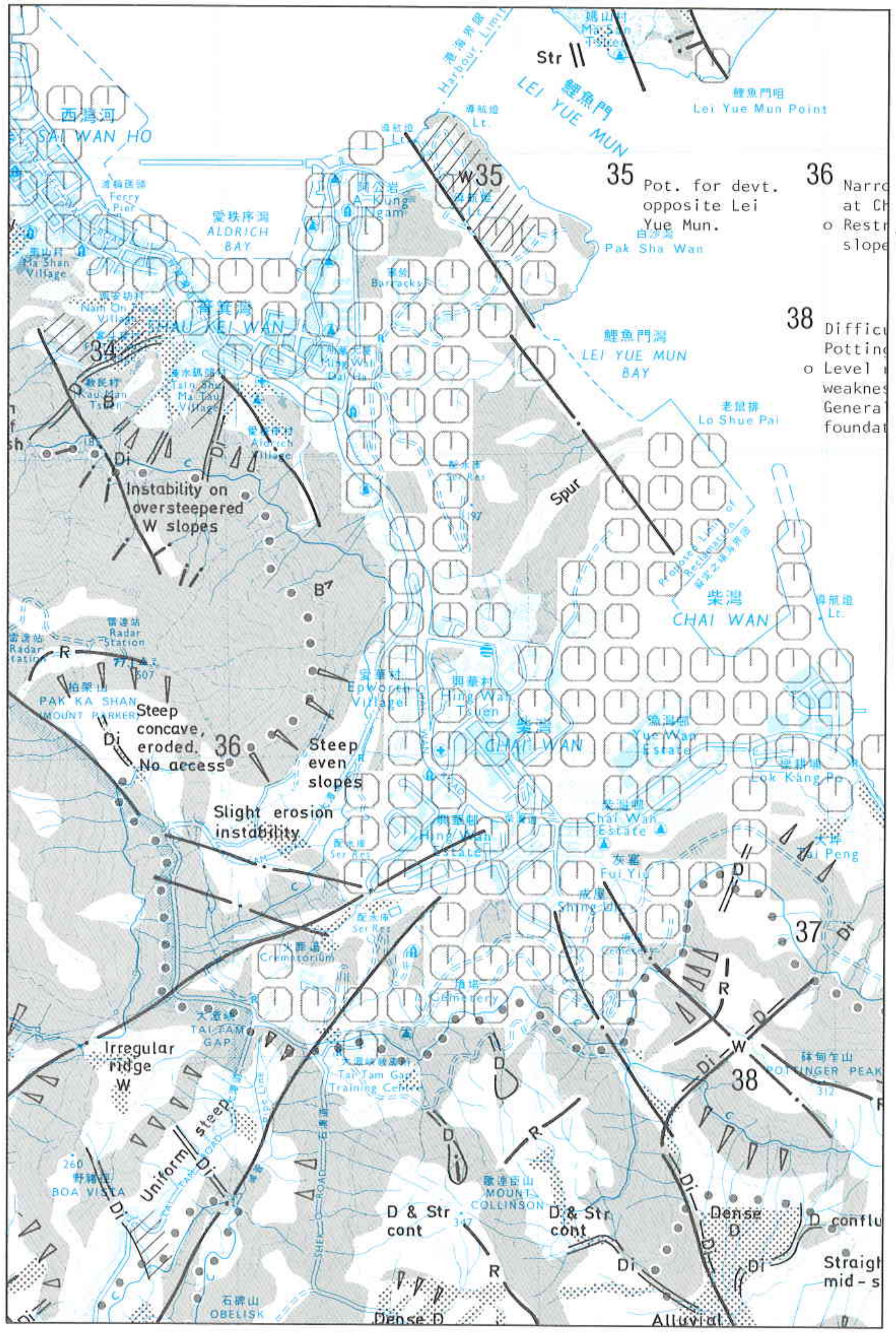
NOTES
i) Features are generally indicated only where of significance to identified potential areas.
ii) *Explanations of the significance of identified features are given in Table A6, and in the Regional GASP Reports.*
iii) Geological boundaries and photolineaments are shown in full on the EGM's contained in the Regional GASP Reports.

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. A12b)

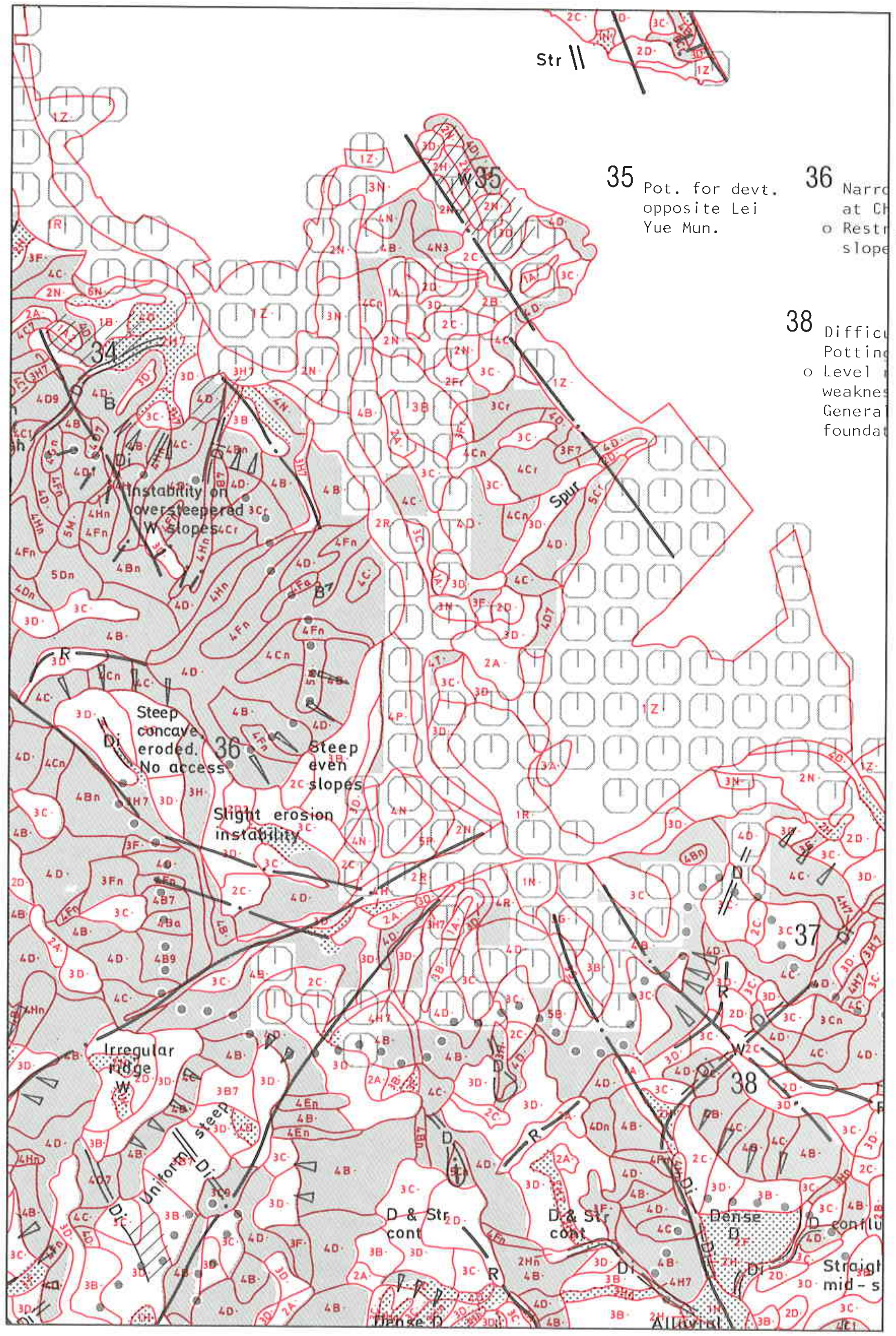
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
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

EROSION	CODE
No appreciable erosion	.
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General instability) recent	n
General instability) relict	r
Coastal instability	w



Scale 1:20 000	Example of the Generalised Limitations and Engineering Appraisal Map (GLEAM)	Fig. A12a



Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the GLEAM	Fig. A12b

LEGEND FOR LANDFORM MAP (Fig. A13a)

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

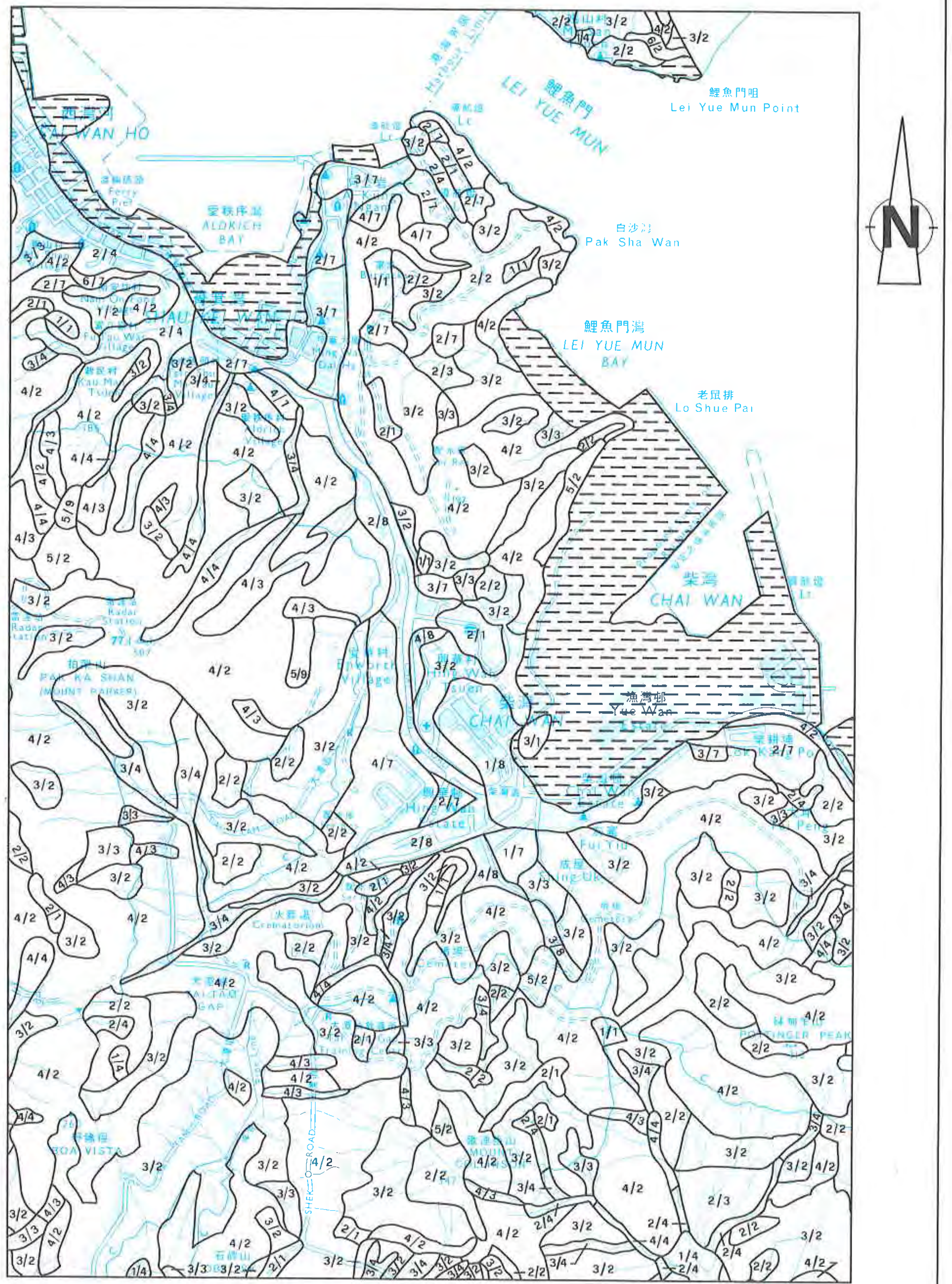
DESCRIPTION	CODE
Crest or ridge	1
Sideslope - insitu	2
Footslope - colluvium	3
Drainage plain - colluvium subject to overland flow and regular inundation. Unusual groundwater regime.	4
Alluvial plain - includes raised terraces.	5
Flood plain - portion of alluvial plain subject to overland flow and regular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

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. A13b)

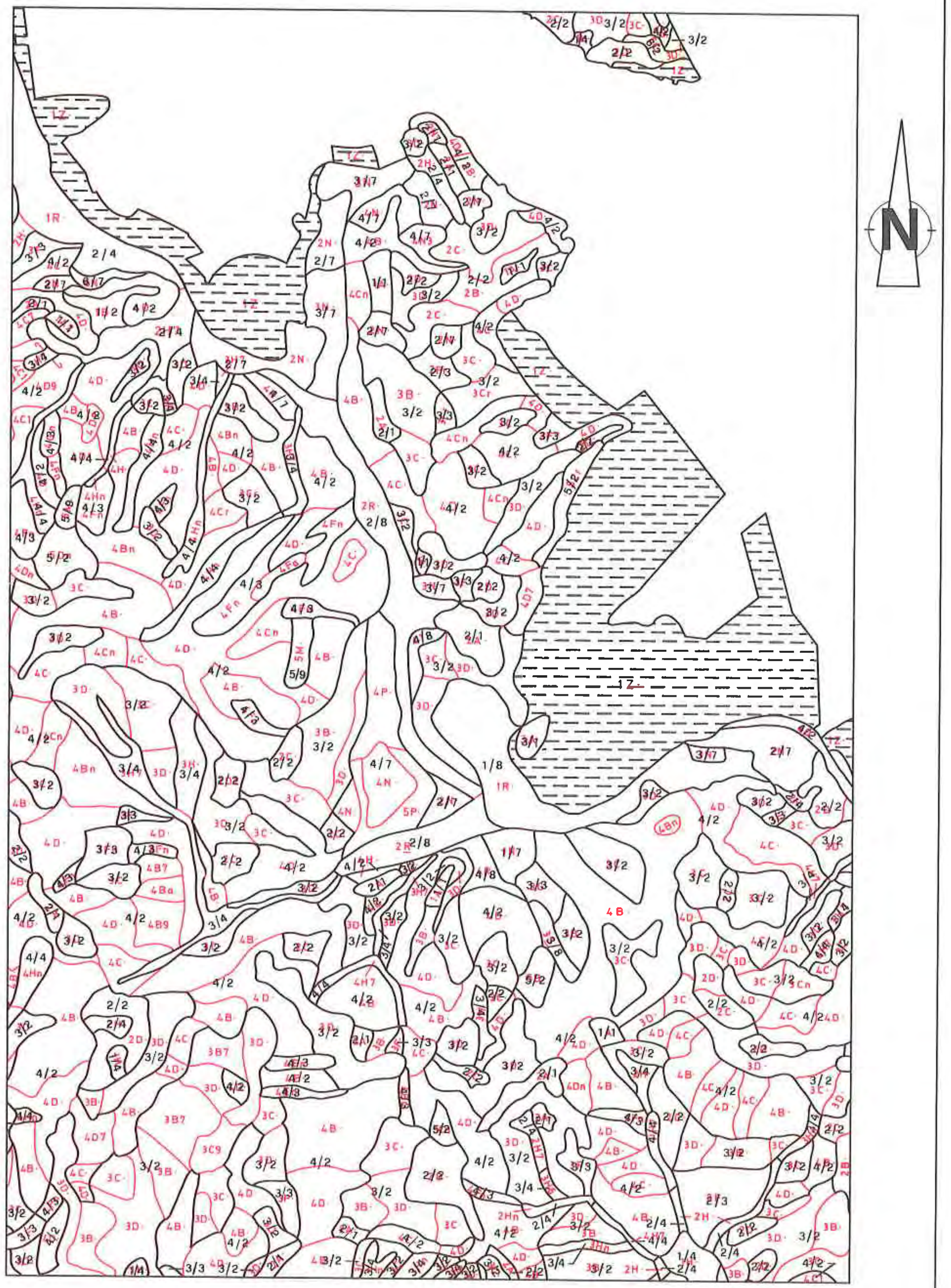
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
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

EROSION	CODE
No appreciable erosion	.
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General) recent	n
instability) relict	r
Coastal instability	w



Scale 1:20 000 | Example of the Landform Map (LM) | Fig. A13a



Scale 1:20 000 | Example of the Terrain Classification Map Superimposed on the LM | Fig. A13b

LEGEND FOR EROSION MAP (Fig. A14a)

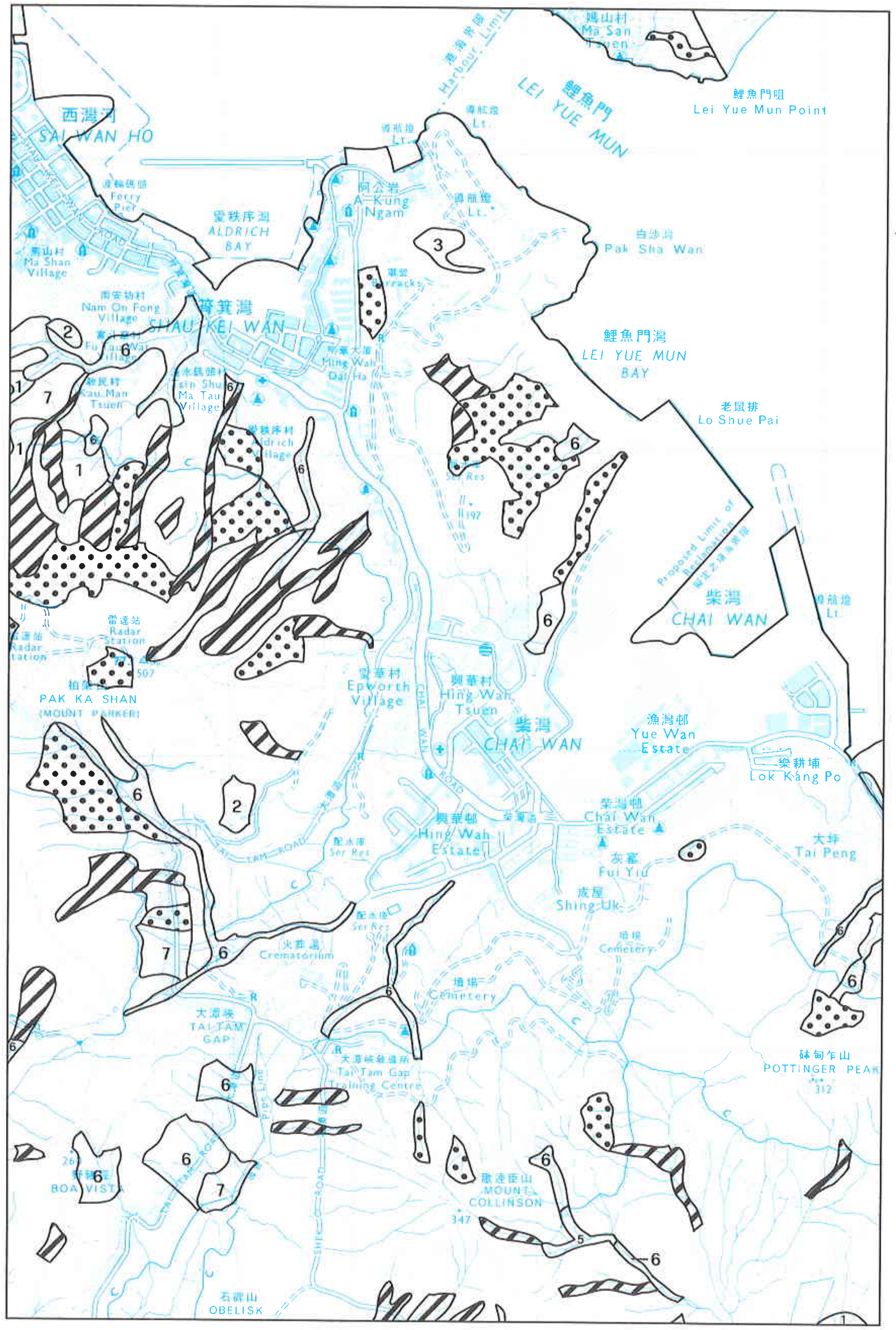
	No appreciable erosion
1	Minor sheet erosion
2	Moderate sheet erosion
3	Severe sheet erosion
4	Minor rill erosion
5	Moderate to severe rill erosion
6	Minor gully erosion
7	Moderate to severe gully erosion
	Zones of general instability associated with predominantly insitu terrain
	Zones of general instability 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. A14b)

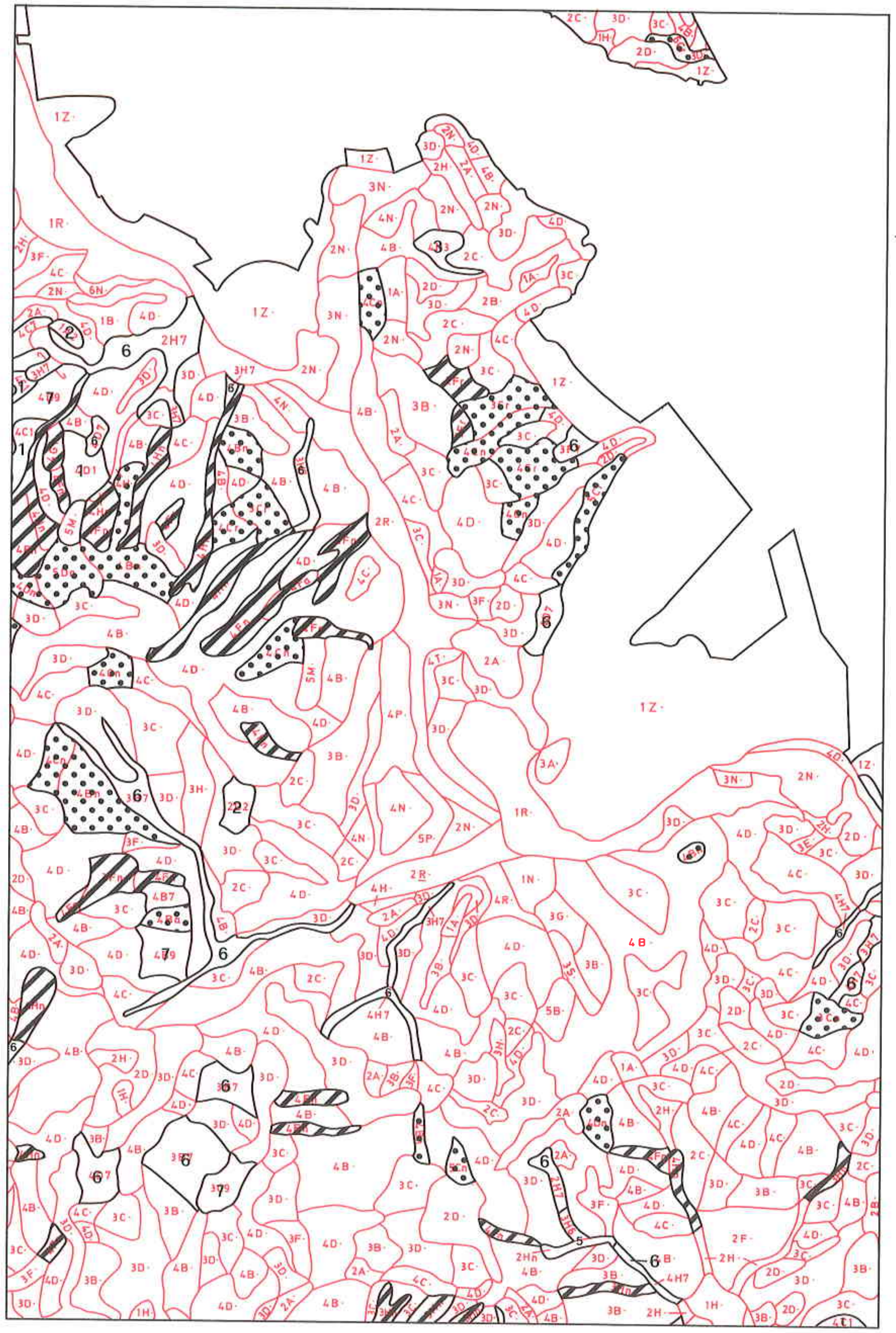
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
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

EROSION	CODE
No appreciable erosion	-
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip *> 1ha in size*	a
General instability) recent	n
General instability) relict	r
Coastal instability	w



Scale 1:20 000	Example of the Erosion Map (EM)	Fig. A14a



Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the EM	Fig. A14b

Table A7 Terrain Classification Attributes for the District Stage 1 Studies

LEGEND FOR TERRAIN CLASSIFICATION MAP

Slope Gradient

Code	*Description*
A	0 – 5°
B	5 – 15°
C	15 – 30°
D	30 – 40°
E	40 – 60°
F	> 60°

Terrain Component*

Code	*Description*
1.	Hillcrest
2.	Ridge
3.	Sideslope
4.	Footslope
5.	Drainage plain
6.	Incised drainage channel
7.	Disturbed terrain
8.	Disturbed terrain/drainage
9.	Rock exposure
10.	Alluvial plain
11.	Floodplain
12.	Coastal plain
13.	Stream course (perennial)
14.	Stream course with rock exposure in bed (perennial)
15.	Stream course with rock exposure in bed (ephemeral)
16.	Man-made channels (including catchwaters)
17.	Water storage
18.	Swamp/marsh
19.	Reclamation
20.	Beach
21.	Dune

Terrain Morphology

Code	*Description*
a	Straight—insitu terrain
b	Concave—insitu terrain
c	Convex—insitu terrain
d	Straight—colluvial terrain (Relict d)
e	Concave—colluvial terrain (Relict e)
f	Convex—colluvial terrain (Relict f)
g	Straight—< 2m thick colluvium
h	Concave—< 2m thick colluvium
i	Convex—< 2m thick colluvium
j	Straight—corestones on insitu terrain
k	Concave—corestones on insitu terrain
l	Convex—corestones on insitu terrain
m	Straight—alluvial terrain (relict m)
n	Concave—alluvial terrain (relict n)
o	Convex—alluvial terrain (relict o)

* Minor disturbance of terrain is indicated by underlining the terrain attribute code. This is used in three situations:
(i) Squatter development on either natural terrain or terrain subject to major disturbance.
(ii) Development of minor roads, cemeteries or small lots, where the constituent components of cut and fill slopes and platforms are too small to be individually delineated.
(iii) Apparently natural terrain which may have been subject to a minor degree of disturbance during landscaping.

Erosion (Terrain Denudation)

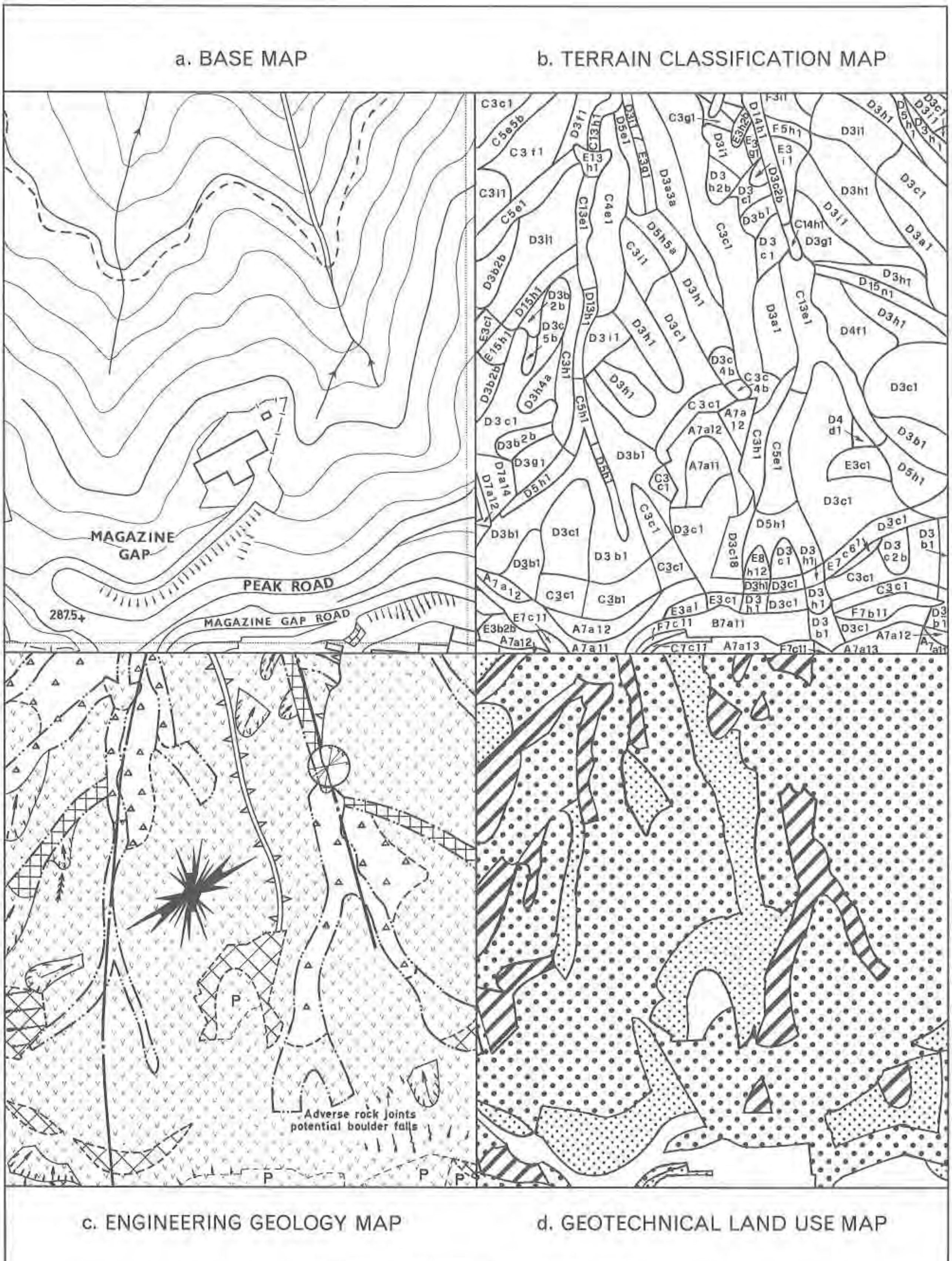
Code	*Description*	*Code*	*Description*
1.	No appreciable erosion		
2.	Landslip Well defined landslip	a	Integral (integral should only be used for rotational failures with minimal displacement)
		b	Scar
		c	Debris
	General evidence of instability on	d	Colluvial terrain (hummocky terrain, tension cracks or compression ridges etc.)
		e	Insitu terrain (terracetting, tension cracks or compression ridges without well defined failures)
3.	Sheet erosion (assessed from ground cover)	a	Minor—(1–10 percent bare ground)
		b	Moderate-severe—(11–40 percent bare ground)
		c	Very severe—(> 40 percent bare ground)
4.	Rill erosion	a	Minor—(incipient parallel rivulets—spacing generally > 2m apart)
		b	Moderate-severe—(deeply incised parallel rivulets—generally < 20cm in depth—spacing generally < 2m apart)
		c	Very severe—(deeply incised parallel rivulets—generally between 20–50cm in depth—spacing generally < 2m apart)
5.	Gully erosion	a	Minor—a single gully generally < 0.5m in depth
		b	Moderate-severe—a single incised gully which is generally 0.5 to 5m in depth or a multiple system of gullies
		c	Very severe—a single deeply incised gully which is generally > 5m in depth and/or a multiple system of incised gullies.
6.	Highly jointed boulders or rock exposure, including cut slopes, with adverse jointing.		

Slope condition

Description	*Code*	*Height in metres*
Cut	1	0 – 5
	3	5 – 10
	5	10 – 20
	7	20 – 30
	9	> 30
Fill	2	0 – 5
	4	5 – 15
	6	15 – 30
	8	> 30

Hydrology

Description	*Code*
Inlet zone	a
Outlet zone	b
Water ponding area	c
Surface groundwater movement	d



Examples of Terrain Classification Map, Geotechnical Land Use Map and Engineering Geology Map for District Stage 1 Studies at a scale of 1:2 500

Fig. A15

Table A8 Assessment of User Requirements

1. What is your professional background?
   - (a) Accountant/Financial Manager. ☐
   - (b) Architect. ☐
   - (c) Civil Engineer. ☐
   - (d) Engineering Geologist. ☐
   - (e) Estate Surveyor. ☐
   - (f) Forestry Officer. ☐
   - (g) Geologist. ☐
   - (h) Geomorphologist. ☐
   - (i) Geotechnical Engineer. ☐
   - (j) Land Agent/District Officer. ☐
   - (k) Landscape Planner. ☐
   - (l) Local Government Executive Administrator. ☐
   - (m) Quantity Surveyor. ☐
   - (n) Soil Conservationist/Agronomist. ☐
   - (o) Town Planner. ☐
   - (p) Other (Please specify). ☐

   ....

2. Have you used aerial photographs?

   Yes ☐ No ☐

3. Have you used any Terrain Evaluation (Routine or Systematic) to assist your work?

   Yes ☐ No ☐

4. Are you aware that maps can be produced at different scales and that the information contained should reflect the scale?

   Yes ☐ No ☐

5. In the course of your duties do you search for existing geotechnical, engineering, geological, and or other natural resource information?
   - (a) Always ☐
   - (b) Usually ☐
   - (c) Sometimes ☐
   - (d) Never ☐

6. What is your general attitude toward maps and reports which contain geotechnical, engineering geological, and or other natural resource information?
   - (a) I'm enthusiastic, the information is definitely required. ☐
   - (b) The information is needed but it's just another set of data I have to incorporate. ☐
   - (c) I'm unenthusiastic, the information serves no useful purpose. ☐
   - (d) Trying to use the information is a waste of time and more trouble than its worth. ☐

7. List the existing geotechnical, engineering geological, and or natural resource information that you are aware is currently available for the site or area:
   - (a) ....
   - (b) ....
   - (c) ....
   - (d) ....
   - (e) ....

8. In relation to their technical content, do you find that existing maps and reports are:
   - (a) readable? ☐
   - (b) too specialized? ☐
   - (c) too simplistic? ☐
   - (d) full of undecipherable jargon? ☐

9. Do you use existing maps:
   - (a) Frequently? ☐
   - (b) Occasionally? ☐
   - (c) Rarely? ☐
   - (d) Not all all? ☐

10. Do any of the existing sources supply you with:
    - (a) None. ☐
    - (b) Some. ☐
    - (c) Most. ☐
    - (d) All. ☐

    of the information you require?

11. Will any of the following factors influence your planning activities?

	Yes	No
(a) Distribution of slope angles? —Are there critical slope angles in the work you do, if so please specify:	☐	☐
(b) Location of landslides.	☐	☐
(c) Location of general instability.	☐	☐
(d) Location of fill.	☐	☐
(e) Location of cut slopes.	☐	☐
(f) Location of reclamation.	☐	☐
(g) Location of colluvium.	☐	☐
(h) Location of poorly drained colluvium where voids and tunnels may occur.	☐	☐
(i) Boundaries of different rock types.	☐	☐
(j) Boundaries of different soil types.	☐	☐
(k) Extent of marine clays beneath reclamation.	☐	☐
(l) Location of photolineaments and faults.	☐	☐
(m) Trend of joint patterns.	☐	☐
(n) Location of springs and seepage zones.	☐	☐
(o) Location of areas subject to periodic inundation, flooding and high infiltration.	☐	☐
(p) Location of rill, sheet or gully erosion.	☐	☐
(q) Potential areas of groundwater concentration associated with structural discontinuity.	☐	☐
(r) Location of catchment boundaries and drainage lines.	☐	☐
(s) Distribution of vegetation types.	☐	☐
(t) Slope morphology (straight, concave, convex in profile).	☐	☐
(u) Catchment form and drainage pattern.	☐	☐

12. Do you require any of the above information on a regular basis?

    Yes ☐ No ☐

13. In your work do you commonly assess:

	Yes	No
(a) Sites of less than 0.5 ha (10×50 m)?	☐	☐
(b) Areas 0.5 to 2 ha?	☐	☐
(c) Areas 2 to 10 ha?	☐	☐
(d) Areas in excess of 10 ha?	☐	☐

14. Do the decisions you need to make require the following information:

	Yes	No
(a) General lithological description?	☐	☐
(b) Characteristic topographic form of the terrain associated with specific material types?	☐	☐
(c) Weathering and soil description?	☐	☐
(d) General guide to material properties?	☐	☐
(e) Engineering comment?	☐	☐
(f) Material uses and excavation characteristics?	☐	☐

15. If you are responsible for any type of planning, do you have geotechnical, engineering geological and or other natural resource maps displayed?

	Yes	No
(a) In a working area.	☐	☐
(b) A conference room.	☐	☐
(c) Not at all.	☐	☐

16. Are you aware that the smallest terrain unit shown on a 1:20 000 scale map can be 0.3 ha in size and that the smallest unit shown on a typical 1:2 500 map can be 0.003 ha (4×8 m) in size?

    Yes ☐ No ☐

17. Are you aware that 1:20 000 scale maps are not recommended for evaluation of sites less than approximately 3 ha in size?

    Yes ☐ No ☐

18. What is your level of understanding of the methods employed to derive geotechnical, engineering geological, and or other natural resource maps?

	Yes	No
(a) Fully conversant.	☐	☐
(b) A general understanding.	☐	☐
(c) Some idea.	☐	☐
(d) Don't have a clue but interested to find out if the opportunity arises.	☐	☐
(e) Don't have a clue and <u>not</u> interested.	☐	☐

19. Have you used any geotechnical, engineering geological, and or other natural resource information and were disappointed?

    Yes ☐ No ☐

20. Is there any specific information (geotechnical or otherwise) that you consider necessary?
    - (a) Yes, please qualify ....
      ....
      ....
      ....
    - (b) No

21. Considering the purpose you have in mind what scale do you consider fulfills your need? Please state why?

    ....
    ....
    ....
    ....
    ....
    ....
    ....
    ....

22. What time constraints exist for the completion of the study?

    ....
    ....
    ....

23. What is the budget?

    ....

A.13.5 *Preliminary Aerial Photograph Interpretation (API)*

Once the draft Terrain Classification Legend has been produced a preliminary aerial photograph interpretation (API) stage of the mapping programme is necessary. Aerial photographs of the study area should have been reviewed during the assessment of user requirements.

This stage represents the first occasion to apply the draft Terrain Classification Legend to the terrain, albeit in a very general way. The purpose is to get a 'feel' for the terrain, and to identify features requiring field inspection and verification. Preliminary API also provides an opportunity to map a small area, and to identify a range of terrain-related elements and other features which should be checked during the preliminary field inspection. It is normal practice to interpret slope angles across the mapping area for different types of terrain. Subsequent field inspection will provide ground control as well as an indication of the degree of optical distortion in the aerial photographs for the study area.

A.13.6 *Preliminary Field Reconnaissance*

This phase provides an opportunity to establish ground control points and to develop a level of familiarity with the mapping area. It should involve the transiting of all major access routes, and checking of the range of terrain features identified in the preliminary API. A number of standard slopes of various angles should be established at regular intervals across the mapping area. These provide control points for systematic mapping.

In some instances, it may not be possible to carry out a preliminary field reconnaissance due to remoteness of the mapping area, and this stage would then need to be combined with the field inspection of the primary mapping (Section A.13.8).

A.13.7 *Primary Aerial Photograph Interpretation*

This stage presents the first opportunity for systematic mapping, and involves the delineation of terrain classification map units (TCMU). The map units are defined in terms of the classification scheme devised for the particular study, and the TCMU's are usually based on slope angle and terrain component with further codes for additional attributes. In the regional GASP, additional attributes relate to erosion and instability (Table A1.), whilst in the District Stage 1 Studies further attributes relating to disturbed terrain, groundwater and seepage, and joint pattern are included (Table A7).

The object of terrain classification mapping is to define areas of general homogeneity within the landscape. The procedure enables landform, and terrain-related and other features which are observed in three dimensions on aerial photographs, to be recorded in a two-dimensional form. The Terrain Classification Map forms a two-dimensional model of the land surface and constitutes an inventory of physical resources.

The usual sequence of mapping is to delineate:

(*a*) drainage lines and drainage plains, and to subdivide them according to slope gradient and any other attributes,

(*b*) hillcrests and ridges, and to subdivide them according to slope gradient and any other attributes,

(*c*) footslopes, and to subdivide them according to slope gradient and any other attributes,

(*d*) sideslopes and areas of rock outcrop, and to subdivide them according to slope gradient and any other attributes, and

(*e*) reclamation and other areas of disturbed terrain, and to subdivide them according to slope gradient and any other attributes.

The key to recognition of areas of terrain homogeneity lies in the perception of 'breaks-in-slope' evident in the stereoscopic model, and the linking of them to various components of the terrain. An experienced aerial photograph interpreter should be able to delineate areas of similar slope angle and terrain. Sometimes it is possible to identify areas of colluvium, alluvium, fill, and insitu rock, direct from aerial photographs without field inspection. Slope gradient and the terrain component form the framework of any terrain classification system. An example of the system used in the 1:20 000 scale regional studies of the Territory is shown in Figure A2. This Figure consists of a stereotriplet, part of which is annotated with the regional terrain classification. An alphanumeric system is normally used to record the terrain classification code.

During primary API, it is normal practice to map approximately 30% of a study area, and then to field check the mapping. If this procedure is followed there is less likely to be a need to re-map large portions of the terrain following field inspection (Section A.13.9). Modification of mapping may be necessary due to under or over estimation of slope gradient or because there has been a change in other attributes such as slope stability, erosion, vegetation or land use, since the date of photography. However, field checking which is integrated with primary mapping is not always feasible because of the remoteness of the study area or other practical limitations.

Primary mapping can either be carried out direct onto aerial photographs or it can be transferred direct to the base map for field checking. This decision depends largely on the interpreter, and it is to some extent a matter of personal preference. Unless sophisticated cartographic resources are available to allow direct transfer of finalised mapping from aerial photographs to the final base map, this method is not recommended because it invariably requires greater interpreter time. The interpreter, having field checked the terrain classification marked on the aerial photographs, must then transfer the information to the base map.

A.13.8 *Field Inspection of Primary Mapping*

This often provides the first opportunity to field check the systematic mapping. The procedure involves traversing all forms of access within the study area, and checking the field occurrence of the various attributes. The intensity of field work depends on the scale of the mapping. Detailed site specific field work is not necessarily required for small scale regional mapping.

The field inspection should enable 30 to 50% of all the terrain classification map units (TCMU) to be checked, any modifications to the mapping can be annotated on the base map or aerial photographs. If up to 50% of all TCMU's are checked, then considerable ground truth and control is available for secondary API on the unchecked areas of the mapping.

A.13.9 *Secondary Aerial Photograph Interpretation*

This provides the opportunity to systematically examine all the terrain classification map units in relation to the information collected during the field inspection. Systematic errors in interpretation which are identified in the field check can be corrected for the entire mapping area. If dealing with difficult terrain, a further field inspection may be necessary.

A.13.10 *Draft Terrain Classification Map*

On completion of the secondary API, the terrain classification map units are finalised, usually by 'inking-up' in some form or other. Particular attention must be given to multiple map sheet studies to ensure that the map units on the boundary of adjoining sheets coincide.

Only at this stage, when all map units are re-checked for continuity, coding and closure, is it possible to finalise the Terrain Classification Legend.

A.13.11 *Cartography*

The draft Terrain Classification Map should now be in a form suitable for cartography. Depending on the user requirements, the terrain classification may need to be traced direct onto a base map in conventional line form, or be transferred from aerial photographs onto a standard base, or be computerised in some form or other. There are normally four general stages in the production of the Terrain Classification Map for the conventional line maps in the GASP studies:

(i) *Preparation of Fair Draft*
The Map is traced or scribed onto a standard base map, formatted, and compiled with a topographic slice. The draft base map is then annotated with the Terrain Classification attribute codes to form a fair draft for edit.

(ii) *Initial Edit*
A copy of the fair draft is returned to the aerial photograph interpreter for checking. The interpreter should 'colour-up' every map unit to ensure map unit continuity, map unit closure, and correct coding. A check must be made of the fair draft against the Draft Terrain Classification Map, and any anomalies be either corrected, modified or re-interpreted from the aerial photographs. At this stage, a convenient method of checking is to prepare a draft of a derivative map, such as the Geotechnical Land Use Map (GLUM), by colouring up all the Terrain Classification Map Units (TCMU). The interpreter can identify any amendments, as each TCMU is allocated to one of the four GLUM classes.

(iii) *Cartographic Edit*
The amended copy of the fair draft of the Terrain Classification Map is returned for cartographic edit and further production to proof stage. The proof copy of the Terrain Classification Map is returned to the interpreter for final checking and any minor amendments are indicated.

(iv) *Final Production*
The amended proof is produced in final form for printing.

A.13.12 *Production of Derivative Maps*

The Terrain Classification Map forms the basis of the mapping system, and provides a framework and data bank from which other maps are generated. Figures A1 and A7 highlight the maps produced in the GASP studies. Some of these maps, such as the Geotechnical Land Use Map (GLUM), the Physical Constraints Map, the Landform Map and the Erosion Map are totally derived from the Terrain Classification Map, whilst others such as the Engineering Geology Map (EGM) and the Generalised Limitations and Engineering Appraisal Map (GLEAM) are only partially derived. These maps are described in Sections A4 to A9.

Maps can be derived from the Terrain Classification Map provided they are based on a selection of any of the attributes recorded in the Terrain Classification Legend. The normal process is for the interpreter to 'colour-up' a Terrain Classification Map to form a draft derivative map for cartography, or in the case of computer map, to specify the codes for the derivative map required.

A.13.13 *Guidelines for Terrain Classification*

There are a number of factors which contribute to effective and efficient terrain classification. These relate to the phenomena of under and over-classification during systematic terrain classification. There are three general stages during which this effect may arise: at the design stage, at the operational/collection stage, and at the user application stage. The general influence on the quality of the mapping caused by under or over-classification is summarised in Table A9. This Table highlights common problems associated with systematic terrain classification which stem from the need for the information collected to be equalised with the information required. If inbalance occurs at any stage, then problems will arise and the integrity of the terrain classification will be compromised in some way.

In addition, generalised guidelines for effective terrain classification are presented in Table A10. This Table takes the form of a checklist of recommended practice.

Table A9 Common Problems Associated with Terrain Classification

Stage of Classification / Intensity of Classification	Under-classification	Over-classification
1. Design Stage	(i) Too little information to answer problem (ii) Scale to small to reflect problem	(i) Too much information to answer problem (ii) Scale to large to reflect problem (iii) More time to answer problem, increase in effort, increase in cost
2. Operational/Information Collection Stage	(i) Interpreter is a 'lumper', fails to highlight critical terrain (ii) Ground control is inadequate	(i) Interpreter is a 'splitter', delineates map units which are too small to answer problem (ii) Too much information is collected, increase in effort, increase in cost, increase in time, overrun on schedule
3. User Application Stage	(i) Terrain Classification fails due to inadequate information or unreliable data	(i) Terrain Classification is not cost effective, too much information for the desired need (ii) May result in confusing and unnecessary detail

Table A10 Guide to Effective Terrain Classification

Good Practice	Bad Practice
Always; (i) Spend a great deal of effort determining user requirements. Map scale must balance with end use! (ii) Undertake a pilot study of a small area, if user is in any doubt. (iii) Ensure effective and adequate ground control during survey stage. (iv) If possible, publish final maps at a scale which is smaller than the scale of the maps or photographs used for data collection. (v) Provide guidelines for use of each map, especially special purpose interpretive maps (e.g. GLUM), and recommend scales at which the maps should be used. (vi) Ensure effective editing of cartography, or data base, if a computer system is used. (vii) Spend a great deal of effort in familiarising the users with the end product.	Never; (i) Commence a task without agreeing the specification. Failure will probably result! (ii) Enlarge the scale of any land resource map. The information shown will *not* match or be applicable at the enlarged scale. (iii) Provide a false impression of what the system can achieve! There are many situations when the systematic approach is not suitable or cost effective. (iv) Hand over a Report or Maps to the user without detailed explanation, particularly of limitations to use.

All maps, especially derivative maps, should contain guidance notes for their correct use and application. This is important because it underscores a fundamental point which land resource mappers risk losing sight of, that is, 'every map or document is produced for a purpose or a specific function'. However, maps are often applied to all sorts of problems or uses for which they are not designed. In some cases, the collector of information may be too close to the data, and he may fail to realise that the many relatively simple principles associated with variability of the data, map scale, reliability and accuracy are not necessarily appreciated nor understood by users. This may even arise in situations where users have been involved in project planning.

Considerable effort is required to educate and guide users in the application of information presented in map form. Instead of criticising users for misinterpreting or otherwise misusing maps, there should be more involvement in the 'selling' of the map. One of the ways in which this can be achieved is the provision of an 'after-care' service. Unfortunately, such is the nature of mapping that in many cases this is not practicable. Follow-up or 'after-care' with users is an aspect which is often neglected or overlooked entirely, with predictably adverse results. For the guidance of map users, notes should be included on maps and supporting documents to describe how and under what circumstances the data/information should be applied.

A.14 Size of Map Units and Mapping Rates

A.14.1 *Different Schemes of Mapping*

In the terrain classification studies for the GASP, two different schemes have been adopted for regional and district mapping. In order to summarise the intensity and general nature of the input required for the two levels of terrain classification mapping, data relating to these studies are presented in Tables A11 and A12. These tables contain information on the average size of the terrain classification map units for the twenty studies completed within the Territory. A comparison of map unit size is presented in Figures A16 and A17. An indication of the level of information transfer from the Terrain Classification Maps into the AREACALCS and GEOTECS computer systems is also given in Tables A11 and A12.

The estimates of average daily mapping rate for terrain classification at the two levels of GASP mapping are; 300 ha per day at 1:20 000 scale, and 5 ha per day at 1:2 500 scale. The unit area involved in the two systems is illustrated in Figure A16, and the results for the GASP studies are extrapolated for mapping at intermediate scales in Figure A17.

A.14.2 Regional GASP Studies at 1:20 000

The eleven regional studies cover an area of approximately 110 000 ha, and the studies vary in size from the 3 200 ha for the Islands (GASP X), to 16 100 ha for the North New Territories (GASP V). The average map unit size ranged from a high of 2.72 ha per unit in the Hong Kong and Kowloon (GASP I) study, to a minimum of 1.20 ha per unit in the North East New Territories (GASP VIII). This is probably due to the large areas of level terrain in the Kowloon area, as compared with the more complex terrain in the northeast of the Territory. Variation in map unit size may also be attributed to variation in the mapping characteristics of individual aerial photograph interpreters, as well as to the general nature of the terrain. Some interpreters tend to classify the terrain into small units (splitters) whist others may tend to over-simplify the terrain (lumpers). Ideally, supervisory control in the terrain classification mapping stages should minimise the likelihood and incidence of interpreter variation. However, in the study of large areas, with the involvement of a number of interpreters, it is practically impossible to eliminate some form of operator variation.

In summary, some 56 920 terrain classification map units (TCMU) were delineated for the regional studies, with an Average Map Unit (AMU) size of 1.91 ha. The Minimum Map Unit (MMU) is 0.24 ha, representing an area of terrain some 30 m × 80 m in size. Terrain information was coded into the GEOTECS computer data base consisting of over 53 400 sample points (grid cells), with each grid cell representing an area of approximately 2.04 ha (143 m × 143 m). The ratio of regional AMU to the GEOTECS grid cell size is 1.07, that is, the regional AMU size is only slightly smaller in size than the GEOTECS grid cell. If the GEOTECS grid cell size was substantially larger that the AMU for the regional studies, information loss would result during data transfer from conventional line map to computer data base. This information is summarised in Table A11.

A.14.3 District GASP Studies at 1:2 500

The nine District Studies covered an area of some 2 159 ha, and the studies varied in size from 132 ha for Shau Kei Wan to 462 ha for Tsz Wan Shan. The Average Map Unit (AMU) size for the 1:2 500 scale mapping ranged from a high of 0.102 ha per unit to a minimum of 0.047 ha per unit.

In summary, some 29 353 terrain map units were delineated for the District Studies, with an AMU size of 0.074 ha per unit. The Minimum Map Unit (MMU) is 0.003 ha or an area of terrain, some 4 m×8 m in size.

The various 1:2 500 scale Terrain Classification Maps were coded into nine, small AREACALCS computer databases consisting of some 34 700 sample points (grid cells). Each grid cell represented an area of approximately 0.062 ha and the transfer ratio of AMU to grid cell size is 0.85, i.e., slightly more sample points than map units.

Table A11 Analysis of Terrain Classification Map Units for Regional Studies

GASP	Name	No. of TCM Units	No. of GEOTECS Cells	Area (ha)	Average Size of TCM Unit -AMU (ha)	AMU-TCMU/GEOTECS Index	% Slope Gradient		TCMO
							<5°	<15°	
I	Hong Kong & Kowloon	4 635	6 170	12 587	2.72	0.75	28	40	KE/KAS
II	Central N.T.	7 200	6 553	13 368	1.86	1.10	15	30	AH
III	West N.T	4 995	4 388	8 952	1.79	1.14	16	27	MJD
IV	North West N.T.	6 472	7 713	15 734	2.43	0.84	62	66	PDH
V	North N.T.	8 704	7 890	16 095	1.85	1.10	36	56	RM
VI	North Lantau	4 320	3 629	7 403	1.71	1.19	9	28	RM
VII	Clear Water Bay	1 908	1 831	3 735	1.96	1.04	13	33	RJP
VIII	North East N.T.	6 651	3 906	7 968	1.20	1.70	18	28	MJD
IX	East N.T.	6 351	6 031	12 303	1.94	1.05	11	24	AH
X	Islands	1 764	1 560	3 184	1.81	1.13	7	18	AH
XI	South Lantau	3 920	3 720	7 589	1.94	1.05	5	17	AH
Total		56 920	53 391	108 918	1.91	1.07			

Note: TCMO—Terrain Classification Mapping Operator.
AMU—Average Map Unit.
TCMU—Terrain Classification Map Unit.

Table A12 Analysis of Terrain Classification Map Units for District Stage 1 Studies

GASP	Name	No. of TCM Units	No. of AREACALCS Cells	Area (ha)	Average Size of TCM Unit -AMU (ha)	AMU-TCMU/AREACALCS Index	% Slope Gradient		TCMO
							<5°	<15°	
1	Pok Fu Lam	2 133	3 633	218	0.102	0.59			KAS
2	Tsz Wan Shan	4 761	7 393	462	0.097	0.67	9	20	DC
4	Cheung Sha	3 194	4 356	273	0.086	0.73	19	41	KAS
5	Fei Ngo Shan	2 628	3 931	246	0.094	0.67	11	15	NK
6	Shau Kei Wan	2 055	2 106	132	0.064	0.98	21	32	KC
8	Chai Wan	2 479	3 038	190	0.063	0.82	18	24	NK
9	Tai Wo Ping	3 722	2 934	183	0.049	1.27	27	41	DC
11	North Tsuen Wan	5 208	3 885	243	0.047	1.34	30	44	DC
12	Magazine Gap	3 173	3 382	211	0.067	0.94	31	36	AH
Total		29 353	34 658	2 158	0.074	0.85			

Note: TCMO—Terrain Classification Mapping Operator.
AREACALCS—Computer System for 1:2 500 scale District Studies Stage 1.
AMU—Average Map Unit.
TCMU—Terrain Classification Map Unit.

A.14.4 Comparison of Studies

A comparison of scale, map unit size and mapping rate for the 1:20 000 and 1:2 500 scale studies is presented in Figure A16. The difference between the size of 1 ha at 1:20 000 and 1:2 500 scale is highlighted as a means of illustrating the relative size of an unit area in plan. The size of this area effectively determines the amount of information that can be recorded in the Terrain Classification Map at the two scales. A three symbol terrain classification code can be conveniently recorded in a 1 ha box at 1:20 000 scale, whereas, there is a sixty four-fold increase in the size of the same area at a scale of 1:2 500.

The Average Map Unit sizes are recorded in Tables A11 and A12 and the relationship between the two levels of GASP mapping is illustrated in Figure A16. The Average Map Unit size of the 1:2 500 scale mapping (0.074 ha) is some 26 times smaller than the AMU size for 1:20 000 scale mapping (1.91 ha). However in contrast, the Minimum Map Unit size for 1:2 500 scale mapping is 80 times smaller (0.003 ha) than the smallest unit identified in the regional studies (0.24 ha).

Figure A16 also provides an indication of the average daily mapping rates and the level of detail contained in the 1:20 000 and 1:2 500 scale studies. Extracts of two Terrain Classification Maps are included for comparison. For the 5 ha box highlighted at 1:20 000 scale in Figure A16, only eleven 1:20 000 Terrain Classification Map Units (TCMU) are delineated. In contrast, there are some 150 TCMU's delineated in the comparable area at 1:2 500 scale.

1:20 000 Studies	1:2 500 Studies

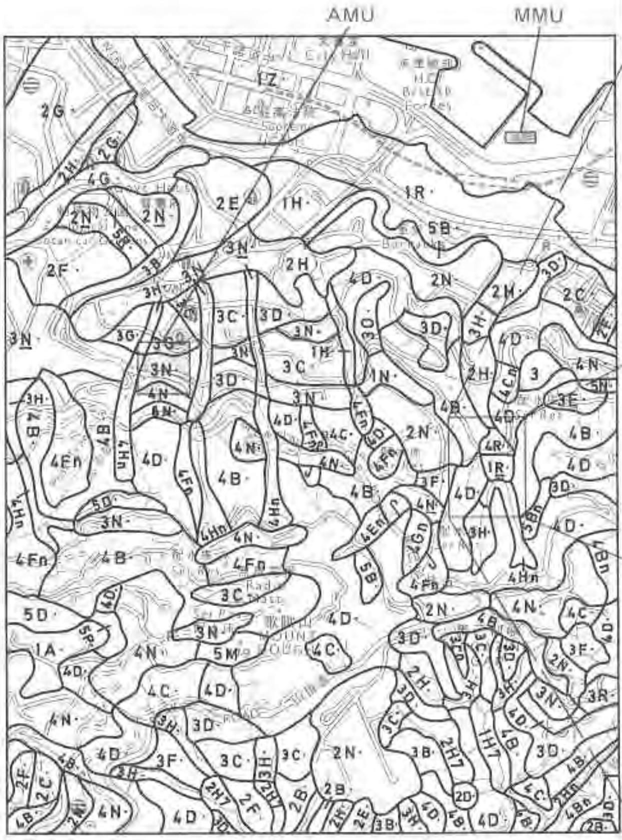
1:20 000 Studies

i) SCALE 1:20 000

1 ha at 1:20 000

ii) MAP UNIT SIZE

300 ha at 1:20 000



Average Map Unit (AMU) = 1.91 ha (138 m X 138 m)

Minimum Map Unit (MMU) = 0.24 ha (30 m X 80 m)

iii) MAPPING RATE AT 1:20 000

(based on typical Hong Kong Study Area)

15 000 ha = 10 weeks

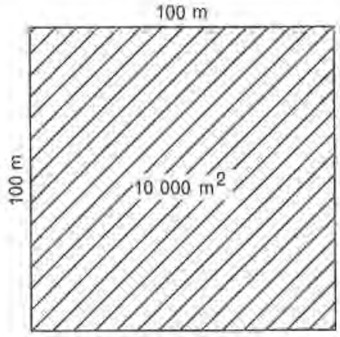
1 500 ha per week

300 ha per day

1:2 500 Studies

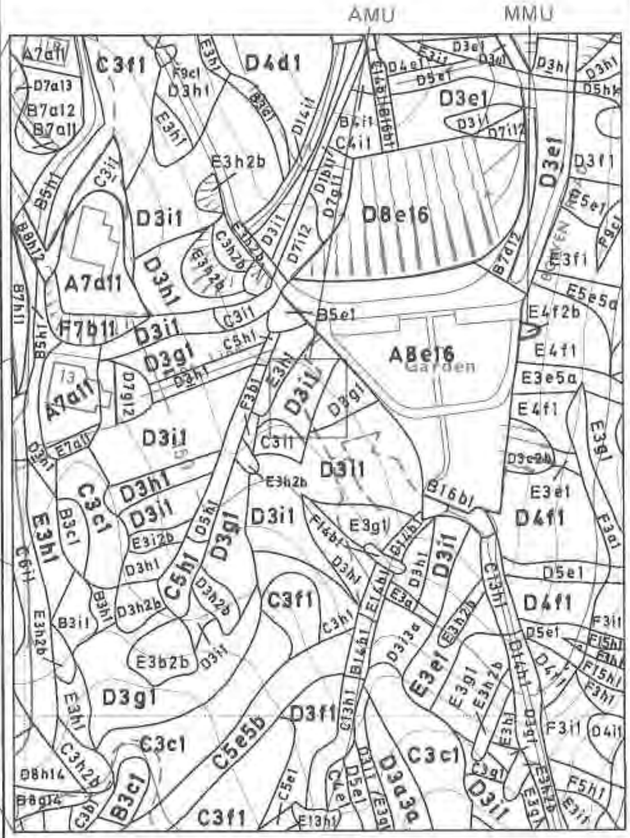
i) SCALE 1:2 500

1 ha at 1:2 500



ii) MAP UNIT SIZE

5 ha at 1:2 500



Average Map Unit (AMU) = 0.074 ha (28 m X 28 m)

Minimum Map Unit (MMU) = 0.003 ha (4 m X 8 m)

iii) MAPPING RATE AT 1:2 500

(based on typical Hong Kong Study Area)

250 ha = 10 weeks

25 ha per week

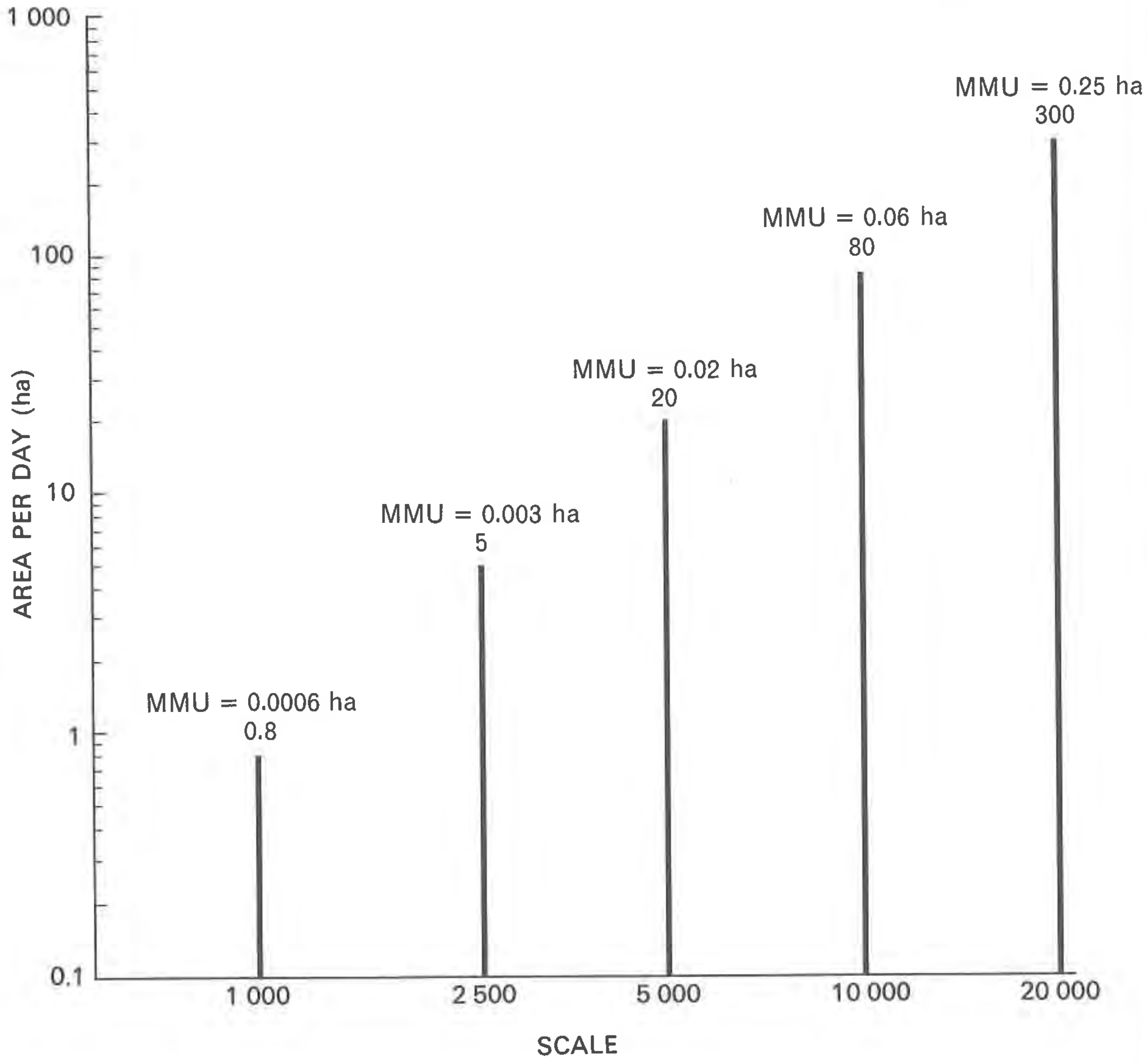
5 ha per day

Comparison of Scale, Map Unit Size and Mapping Rate — Fig. A16

SYSTEMATIC TERRAIN CLASSIFICATION MAPPING RATES : AREA vs SCALE

COMPARISON OF MAPPING RATES FOR TERRAIN CLASSIFICATION AT A RANGE OF SCALES

Minimum Map Unit (MMU) for a map of any scale ≑ 2.5 mm X 2.5 mm



Mapping Rates, Scale and Map Unit Size	Fig. A17

The plan area covered by a 5 ha block at 1:2 500 is identical with the area covered by a 300 ha block at 1:20 000. For the two areas highlighted in Figure A16, there are some 163 TCMU's identified at 1:20 000, whilst 151 TCMU's are delineated at 1:2 500 scale. The number of TCMU's identified at both levels of mapping for the 300 ha and 5 ha are of the same order of magnitude, despite the large difference in scale.

Mapping rates for the two terrain classification schemes are also presented in Figure A17. The average daily rate for the regional mapping programme is some 300 ha per day in comparison with 5 ha per day for the District Studies.

A.15 Assessment of the Mapping Systems

A.15.1 *Background*

During the mapping programme an attempt was made to assess the reliability of the regional mapping system (Burnett & Styles, 1986), and the district level mapping (Styles et al, 1984).

A.15.2 *Regional Terrain Classification*

During 1983, a large number of landslips were reported to the Geotechnical Control Office, many of these were the result of intense rainfall early in the wet season. Some 263 incidents are summarised in Table A13. The location of these incidents were plotted onto three of the 1:20 000 scale maps produced for the Hong Kong and Kowloon area. The results for the Geotechnical Land Use Map (GLUM), the Physical Constraints Map, and the Generalised Limitations and Engineering Appraisal Map (GLEAM) are tabulated in Tables A14, A15 and A16 (Burnett & Styles, 1986). Some 189 or 72% of the incidents occurred on terrain classified in the GLUM as having high to extreme geotechnical limitations (Table A14), whilst 57 incidents or a further 22% occurred on terrain with moderate limitations.

In the case of the Physical Constraints Map (Table A15), some 90% of the failures occurred on terrain mapped as having some form of physical constraint. For the GLEAM, some 60% of failures occurred in areas of constraint outside of areas identified as having potential for development (PDA), whilst 6% were located in areas of localised geotechnical constraint within the PDA's, and a further 28% occurred in areas of existing development.

Table A13 Landslip Incidents in the Hong Kong Island and Kowloon Area Reported to the Geotechnical Control Office in 1983

Incident Map Symbol	Description	No. of Incidents	% Distribution
△	Landslip Incident in Squatter Areas	163	62
▲	Landslip Incident Associated with Private Buildings	20	8
O	Landslip Incident Associated with Roads	65	24
•	Landslip Incident Associated with Natural Slopes	15	6
		263	100

Table A14 Distribution of Landslip Incidents within the Geotechnical Land Use Map (GLUM) Classes for the Hong Kong Island and Kowloon Area at a scale of 1:20 000

Level of Geotechnical Limitation	No. of Landslips	% Distribution
Low (Glum Class I)	17	6
Moderate (Glum Class II)	57	22
High (Glum Class III)	150	57 } 72
Extreme (Glum Class IV)	39	15 }
Total	263	100

Table A15 Distribution of Landslip Incidents within the Physical Constraints Map (PCM) Classes for the Hong Kong Island and Kowloon Area at a scale of 1:20 000

Constraints	No. of Landslips	% Distribution
Colluvium	30	11 } 27
Zones of Colluvium Subject to Inundation	43	16 } 27
Zones of Colluvial Instability	20	8
Zones of Insitu Instability	24	9
Slopes > 30°	83	32
Disturbed Terrain	37	14
Instability on Disturbed Terrain	1	—
No Constraints	25	10
	263	100

Table A16 Distribution of Landslip Incidents within the Generalised Limitations and Engineering Appraisal Map (GLEAM) Classes for the Hong Kong Island and Kowloon Area at a scale of 1:20 000

GLEAM Areas	No. of Landslips	% Distribution
Constraint Classes	166	63
Potential Development Areas	7	3
Potential Development Areas (with Minor Constraints)	16	6
Currently Developed Areas	74	28
	263	100

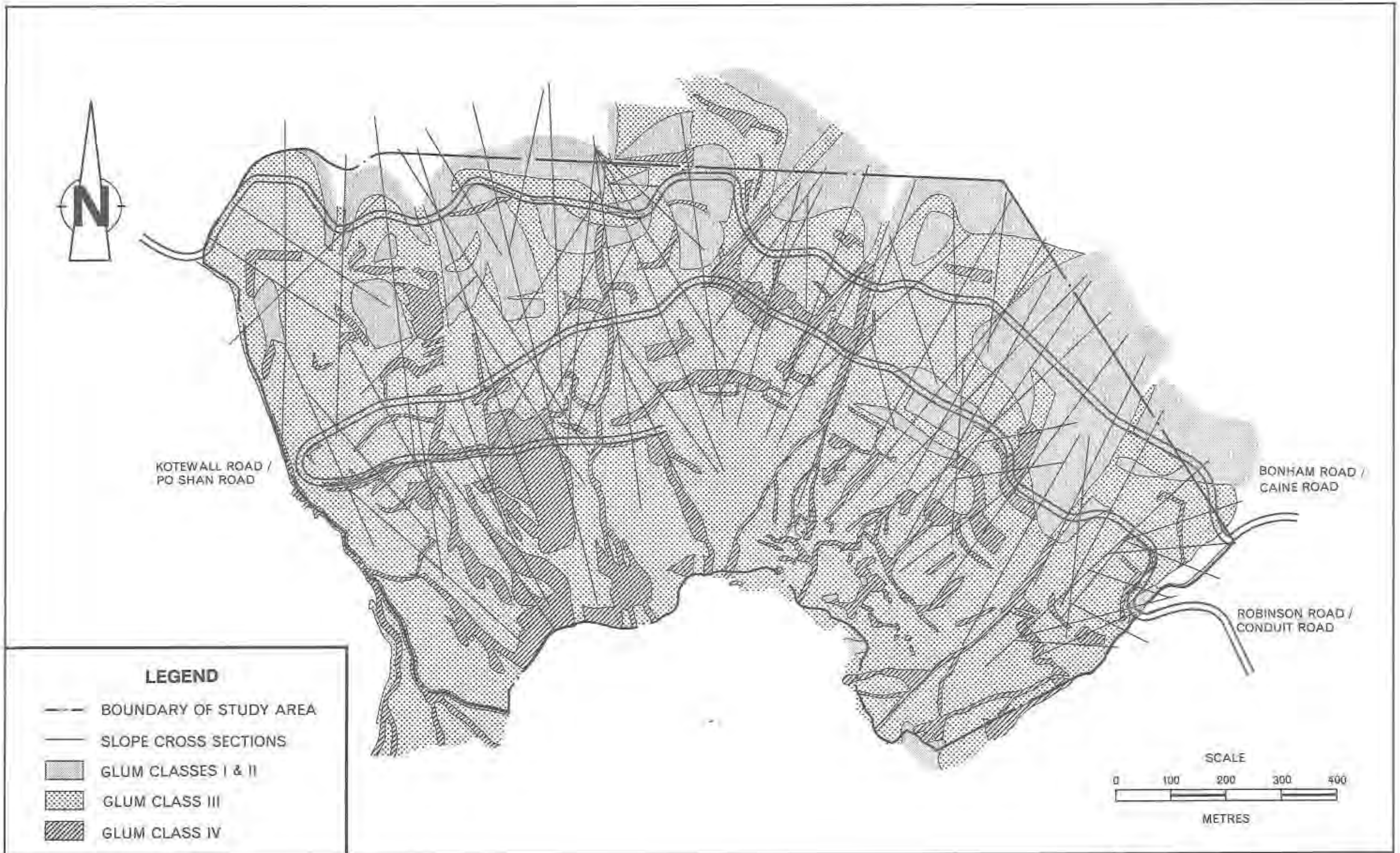
A.15.3 District Terrain Classification

In order to assess the 1:2 500 scale mapping, data available from stability analyses of a number of cross-sections in the Mid-levels Area of Hong Kong Island was evaluated. These cross-sections were superimposed on a Geotechnical Land Use Map produced at a scale of 1:2 500. The area is shown in Figure A18. Styles et al (1984) compared the Factor of Safety calculated for segments along the cross-sections with the GLUM class for the corresponding area of terrain. Some results are summarised in Figure A19. It was concluded that the predictability of the terrain classification approach, as expressed in a four class classification of geotechnical limitations, appears to be reasonably consistent with Factor of Safety values calculated by traditional engineering techniques. Very nearly all of the terrain with Factor of Safety values calculated at less than 1.4, had been defined in the terrain classification as being subject to high or extreme geotechnical limitations.

If terrain classification is to be accepted as an engineering tool, then in the first instance at least, areas calculated as having a low Factor of Safety should be classified as being subject to high or extreme geotechnical limitations. This appears to be the case. Conversely, it should be expected that as the calculated Factor of Safety increases, especially for Factors of Safety greater than 2.5, then the occurrence of high (Class III) and extreme (Class IV) limitations should be low. Whilst this is generally true, some areas with a calculated Factor of Safety greater than 1.8 coincided with GLUM Classes III and IV. This may indicate that the GLUM criteria are slightly conservative with respect to present slope stability. However, the terrain classification technique is also intended to highlight potential problem areas where stability problems are more likely to be created by development. These may not be revealed by a conventional stability assessment of existing terrain.

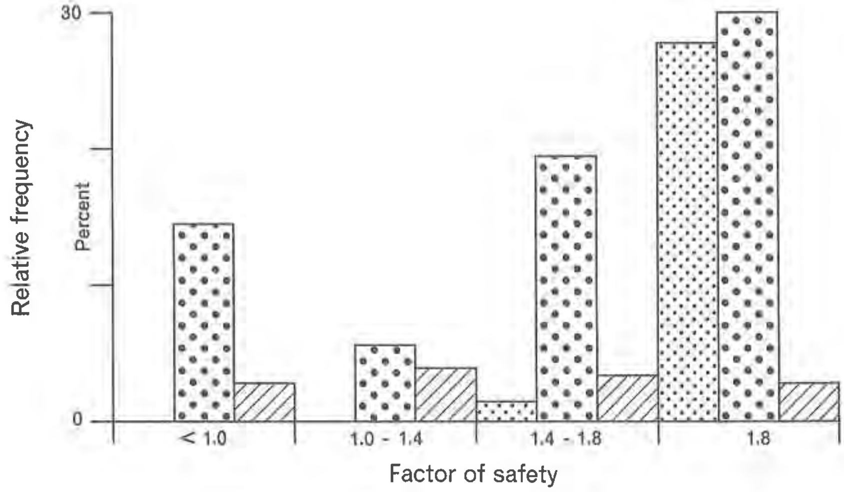
In addition, the terrain classification technique is capable of delineating many small map units which are missed, overlooked or not included in slope stability analyses calculated along individual slope profiles. In the engineering assessment of an area only a finite number of stability calculations are possible. Even in intensive studies, such as the one described in Styles et al (1984), where some 32 km of sections were evaluated, it was not possible to cover all the terrain with conventional stability analyses, and gaps existed between slope profiles. In some instances, the straight line profiles did not follow the line of maximum slope gradient.

Terrain classification could effectively be used to extend the information derived from stability analyses to adjacent terrain.

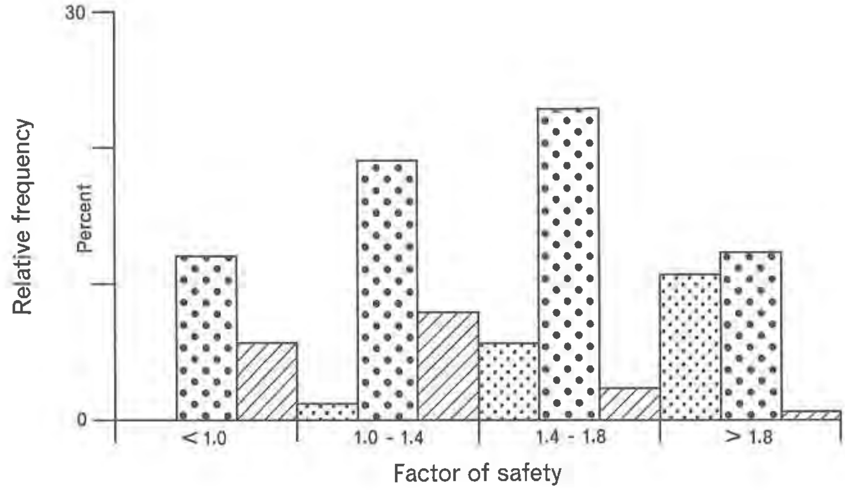


Geotechnical Land Use Map of the Mid-levels Area with Location of Cross-sections

Fig. A18

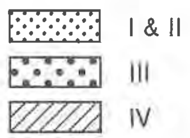


a. Comparison of GLUM Class with Factor of Safety Isoline Map Based on Pre-Development Terrain.



b. Comparison of GLUM Class with Computed Factors of Safety Using Cross-sections of the Existing Terrain.

GLUM CLASS



GLUM Class and Factor of Safety for the Mid-levels Area

Fig. A19

LEGEND FOR COLLUVIAL DEPOSIT MAP

A LANDSLIP SCARS

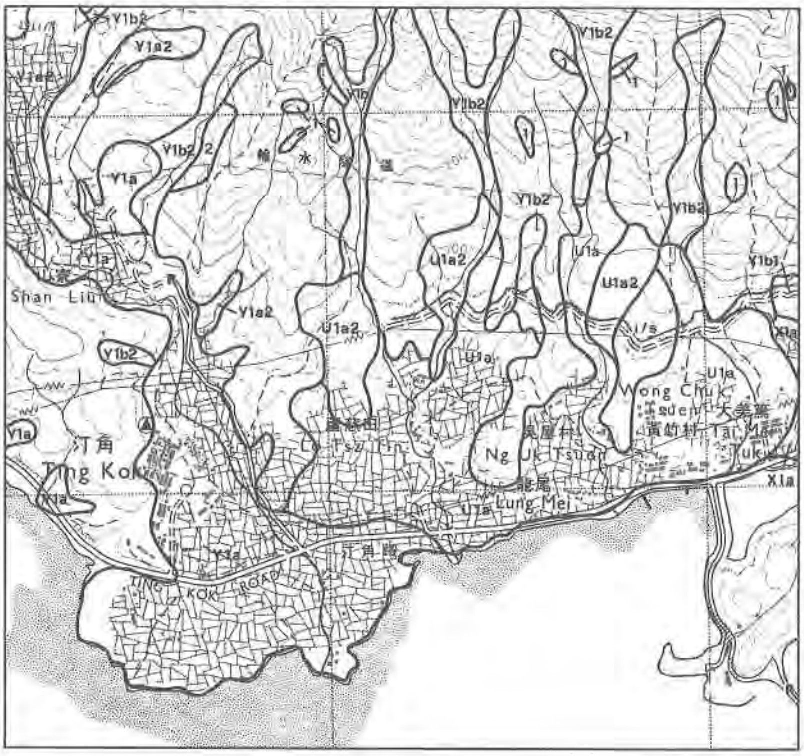
Code	Age of Scar
1	Recent
2	Very old

B COLLUVIAL DEPOSITS

Code	Colluvium Type	Code	Parent Material	Code	Slope Gradient	Code	Groundwater Condition
X	Lenticular deposits along drainage lines	1	Volcanic pyroclastic	a	< 15°	1	Seepage inlet zone
Y	Fan deposits	2	Granitic	b	> 15°	2	Outlet zone
U	Relict fan deposit	3	Combination				
Z	Boulder scree and talus >30% large boulders						

C INSITU DEPOSITS

i/s	Area of insitu terrain within zone of colluvial deposits



Scale 1:20 000	Example of Colluvial Deposit Map at a Scale of 1:20 000	Fig. A20

APPENDIX B

DATA TABLES FOR THE TERRITORY OF HONG KONG

Table B1 Slope Gradient

Slope Gradient	% of Total Area	Area (ha)
0– 5°*	24.8	27 063
5–15°	12.4	13 498
15–30°	33.5	36 557
30–40°	26.0	28 335
40–60°	3.0	3 214
>60°	0.3	362
	100.0	109 029

* Approximately 5 391 ha of uncovered reservoirs, artificial channels and ponds are included in the 0–5° Class.

Table B2 Erosion and Instability

Erosion		% of Total Area	Area (ha)
Instability			
—well-defined landslips and coastal instability		1.2	1 335
—general instability		20.4	22 188
Appreciable Erosion	Sheet erosion—minor	9.6	10 437
	—moderate to severe	5.7	6 269
	Rill erosion —minor	0.3	372
	—moderate to severe	0.7	712
	Gully erosion—minor	5.5	6 029
	—moderate to severe	1.7	1 875
No Appreciable Erosion*		54.9	59 812
		100.0	109 029

* Approximately 5 764 ha of streams, artificial channels, reservoirs and ponds are included within No Appreciable Erosion.

Table B3 Aspect

Aspect	% of Total Area	Area (ha)
North	8.0	8 731
Northeast	10.0	10 878
East	8.2	8 916
Southeast	11.7	12 786
South	7.4	8 078
Southwest	10.6	11 606
West	8.4	9 122
Northwest	10.9	11 849
Flat/Unclassified*	24.8	27 063
	100.0	109 029

* Approximately 5 391 ha of uncovered reservoirs, artificial channels and ponds 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	1 424	3 743	3 222	306	36	8 731
Northeast	1 631	4 645	4 057	506	39	10 878
East	1 484	3 908	3 088	381	55	8 916
Southeast	2 210	5 808	4 200	517	51	12 786
South	1 610	3 663	2 433	327	45	8 078
Southwest	1 832	5 496	3 819	400	59	11 606
West	1 427	4 022	3 306	326	41	9 122
Northwest	1 880	5 272	4 210	451	36	11 849
0–5° (Flat/Unclassified)						27 063
						109 029

Table B5 Landform

Terrain (Landform)	Slope Gradient	% of Total Area	Area (ha)
Hillcrest		3.8	3 841
Sideslope	0– 5°	0.6	667
"	5–15°	3.3	3 614
"	15–30°	27.0	29 402
"	30–40°	23.4	25 529
"	>40°	1.6	1 772
Cliff/Rock outcrop	0–30°	0.3	345
"	>30°	1.8	1 980
Footslope (colluvium)	0– 5°	1.8	1 914
"	5–15°	2.3	2 555
"	15–30°	2.3	2 518
"	>30°	0.8	859
Drainage plain (colluvium)	0– 5°	1.7	1 835
"	5–15°	2.6	2 804
"	15–30°	2.2	2 424
"	>30°	0.5	502
Alluvial plain	0– 5°	3.4	3 692
"	>5°	0.1	112
Floodplain	0– 5°	4.8	5 237
"	>5°	0.2	198
Littoral zone		1.3	1 404
Wave cut platform		0.1	100
Cut platforms : insitu	0– 5°	1.1	1 214
: colluvium	0– 5°	<0.1	80
: alluvium	0– 5°	<0.1	2
Cut slopes : insitu	>5°	2.1	2 341
: colluvium	>5°	0.2	227
: alluvium	>5°	<0.1	8
Fill platforms : insitu	0– 5°	0.2	206
: colluvium	0– 5°	0.2	263
: alluvium	0– 5°	0.6	702
Fill slopes : insitu	>5°	0.3	308
: colluvium	>5°	0.2	167
: alluvium	>5°	<0.1	65
Reclamation	0–30°	3.4	3 698
General disturbed terrain/platforms: insitu	0– 5°	<0.1	90
: colluvium	0– 5°	<0.1	16
General distrubed terrain/slope: insitu	>5°	0.4	437
: colluvium	>5°	0.1	104
: alluvium	>5°	<0.1	33
Natural stream		0.3	373
Man-made channel		0.2	182
Water storage		2.1	2 331
Pond		2.6	2 878
		100.0	109 029

Approximately 24 ha of reclamation and 22 ha of fill are included in the Man-made channel category.

Table B6 Geology

Geological Unit	% of Total Area	Area (ha)
Alluvium: undifferentiated	13.6	14 847
Colluvium: volcanic	8.4	9 157
: granitic	3.4	3 651
: sedimentary and metasedimentary	1.0	1 124
: mixed	1.6	1 786
Littoral deposits	1.3	1 404
Marine deposits	0.1	110
Reclamation	3.4	3 722
Fill	2.2	2 414
Kat O Formation	<0.1	6
Port Island Formation	1.9	2 039
Repulse Bay Formation: undifferentiated volcanic rocks	2.7	2 968
: sedimentary rocks and waterlaid volcaniclastic rocks	2.0	2 222
: acid lavas	4.9	5 335
: mainly banded acid lavas, some welded tuffs	2.7	2 961
: coarse tuff	6.6	7 204
: agglomerate	0.2	200
: dominantly pyroclastic rocks with some lavas	20.2	21 965
Tai O Formation	0.1	151
Lok Ma Chau Formation	1.1	1 212
Bluff Head Formation	0.7	700
Tolo Harbour Formation	<0.1	8
Undifferentiated Granitic Rocks	1.1	1 229
Granophyric Microgranite	<0.1	39
Needle Hill Granite: fine-grained porphyritic phase	2.2	2 339
: medium-grained porphyritic phase	1.0	1 059
Hong Kong Granite	2.5	2 751
: fine-grained porphyritic phase	0.2	231
: medium-grained porphyritic phase	0.1	114
Quartz Monzonite	0.7	737
Feldspar Porphyry Dyke Swarm	1.8	1 978
Fan Lau Porphyritic Granite	<0.1	41
Ma On Shan Granite	0.6	684
Cheung Chau Granite	7.1	7 710
Sung Kong Granite	2.1	2 241
Sung Kong Granite: medium-grained phase	1.3	1 410
Tai Po Granodiorite	1.2	1 249
Unknown Bedrock	<0.1	31
	100.0	109 029

Approximately 24 ha of reclamation and 22 ha of fill are associated with man-made channels, and approximately 2 323 ha of uncovered reservoirs and 2 875 ha of ponds have been categorised as possessing alluvial deposits.

Table B7 Vegetation

Vegetation	% of Total Area	Area (ha)
Grassland	22.5	24 539
Cultivation	7.7	8 459
Zoological and Botanical Gardens	<0.1	10
Shrubland (<50%)	11.2	12 182
Shrubland (>50%)	12.4	13 563
Mixed broadleaf woodland	20.3	22 112
No vegetation on natural terrain	2.2	2 355
No vegetation due to disturbance of terrain by man	16.2	17 702
No vegetation due to rock outcrop	2.2	2 353
Waterbodies	5.3	5 764
	100.0	109 029

Table B8 Geology and GLUM Class

Geological Unit	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Alluvium: undifferentiated	0	9 245	4	0	5 598
Colluvium: volcanic	0	1 016	5 316	2 825	0
: granitic	0	365	2 098	1 188	0
: sedimentary and metasedimentary	0	335	669	120	0
: mixed	0	375	1 129	282	0
Littoral deposits	0	0	0	0	1 404
Marine deposits	0	0	0	0	110
Reclamation	0	3 610	73	14	25
Fill	0	1 522	846	23	23
Kat O Formation	0	0	0	6	0
Port Island Formation	118	1 182	571	168	0
Repulse Bay Formation: undifferentiated volcanic rocks	49	929	770	1 218	2
: sedimentary rocks and waterlaid volcaniclastic rocks	339	781	455	643	4
: acid lavas	263	2 274	894	1 896	8
: mainly banded acid lavas, some welded tuffs	251	1 345	535	822	8
: coarse tuff	600	3 469	1 935	1 196	4
: agglomerate	10	84	63	43	0
: dominantly pyroclastics rocks with some lavas	1 649	7 976	7 004	5 316	20
Ta O Formation	10	39	39	63	0
Lok Ma Chau Formation	355	377	374	106	0
Bluff Head Formation	8	294	247	151	0
Tolo Harbour Formation	0	0	6	2	0
Undifferentiated Granitic Rocks	63	700	345	113	8
Granophyric Microgranite	0	12	12	13	2
Needle Hill Granite: fine-grained porphyritic phase	112	1 127	584	516	0
: medium-grained porphyritic phase	28	494	329	208	0
Hong Kong Granite	776	804	947	224	0
Hong Kong Granite: fine-grained porphyritic phase	23	71	110	27	0
: medium-grained porphyritic phase	8	25	75	6	0
Quartz Monzonite	37	388	141	169	2
Feldspar Porphyry Dyke Swarm	90	835	784	269	0
Fan Lau Porphyritic Granite	13	10	8	8	2
Ma On Shan Granite	37	188	282	171	6
Cheung Chau Granite	569	2 543	2 976	1 606	16
Sung Kong Granite	159	829	729	503	21
Sung Kong Granite: medium-grained phase	145	667	369	229	0
Tai Po Granodiorite	135	504	461	149	0
Unknown Bedrock	2	4	8	13	4
	5 849	44 419	31 188	20 306	7 267

Table B9 GLUM Class

GLUM Class	% of Total Area	Area (ha)
I	5.4	5 849
II	35.7	38 988
IIS	5.0	5 431
III	28.6	31 188
IV	18.6	20 306
Unclassified	6.7	7 267
	100.0	109 029

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	704	184	6	4	0	0	894	0
		G	1 121	188	4	8	0	0	1 321	0
		S	125	59	0	2	0	0	186	0
		M	110	0	0	0	0	0	110	0
		C	3 259	239	17	314	0	0	3 829	0
		A	14 294	29	0	206	0	0	14 529	0
		L	1 280	6	0	0	0	0	1 286	0
		F	3 910	957	29	10	0	0	4 906	0
5–15°	N	V	271	131	0	8	0	0	410	0
		G	182	86	6	18	2	0	294	<0.01
		S	20	37	0	6	0	0	63	0
		C	376	51	0	141	0	2	570	<0.01
		A	8	0	0	31	0	0	39	0
		L	12	0	0	0	0	0	12	0
		F	35	2	0	0	0	0	37	0
	NE	V	320	176	6	16	0	0	518	0
		G	129	112	4	20	0	0	265	0
		S	20	41	0	10	0	0	71	0
		C	439	61	2	174	0	0	676	0
		A	21	6	0	22	0	0	49	0
		L	4	0	0	0	0	0	4	0
		F	41	6	0	0	0	0	47	0
	E	V	361	149	2	8	0	0	520	0
		G	90	145	4	6	0	0	245	0
		S	27	29	0	8	0	0	64	0
		C	367	63	0	129	0	0	559	0
		A	23	6	0	14	0	0	43	0
		L	18	0	0	0	0	0	18	0
		F	33	2	0	0	0	0	35	0
	SE	V	455	219	4	8	0	0	686	0
		G	149	161	2	17	0	0	329	0
		S	31	37	0	2	0	0	70	0
		C	553	153	0	235	0	8	949	<0.01
		A	39	0	0	18	0	0	57	0
		L	18	0	0	0	0	0	18	0
		F	78	24	0	0	0	0	102	0
	S	V	300	133	0	6	0	0	439	0
		G	204	125	2	8	0	0	339	0
		S	21	14	0	0	0	0	35	0
		C	400	73	0	184	0	0	657	0
		A	21	4	2	10	0	0	37	0
		L	16	0	0	0	0	0	16	0
		F	80	8	0	0	0	0	88	0
	SW	V	343	227	0	8	0	0	578	0
		G	190	129	6	16	2	0	343	<0.01
		S	12	35	0	2	0	0	49	0
		C	422	96	0	176	0	2	696	<0.01
		A	10	4	4	11	0	0	29	0
		L	23	0	0	0	0	0	23	0
		F	100	16	0	0	0	0	116	0
	W	V	245	190	2	10	0	0	447	0
		G	174	108	8	10	0	0	300	0
		S	23	20	0	0	0	0	43	0
		C	323	67	2	143	0	2	537	<0.01
		A	14	2	0	11	0	0	27	0
		L	10	0	0	0	0	0	10	0
		F	49	14	0	0	0	0	63	0
	NW	V	296	206	0	25	0	0	527	0
		G	190	125	2	10	0	0	327	0
		S	43	51	0	0	0	0	94	0
		C	514	109	4	198	0	2	827	<0.01
		A	12	2	0	21	0	0	35	0
		L	16	0	0	0	0	0	16	0
		F	35	18	2	0	0	0	55	0
15–30°	N	V	851	265	0	76	8	500	1 700	0.30
		G	369	219	27	110	8	253	986	0.26
		S	200	90	0	63	0	129	482	0.27
		C	210	16	0	135	0	184	545	0.34
		A	0	0	0	0	0	0	0	—
		F	29	0	2	0	0	0	0	0
	NE	V	1 235	398	6	96	6	610	2 351	0.26
		G	416	284	39	163	8	194	1 104	0.18
		S	106	131	0	29	4	108	378	0.30
		C	294	14	0	188	0	251	747	0.34
		A	0	0	0	2	0	0	2	0
		F	57	2	4	0	0	0	63	0
	E	V	1 115	476	4	122	4	414	2 135	0.20
		G	310	312	27	141	4	127	921	0.14
		S	112	53	0	21	2	51	239	0.22
		C	257	17	2	147	0	153	576	0.27
		A	0	0	0	0	0	0	0	—
		F	33	4	2	0	0	0	39	0
	SE	V	1 694	831	12	125	12	508	3 182	0.16
		G	553	584	59	233	10	118	1 557	0.08
		S	102	66	0	10	6	49	233	0.24
		C	278	18	2	241	0	227	766	0.30
		A	0	0	0	2	0	0	2	0
		F	55	12	2	0	0	0	69	0
	S	V	996	484	4	131	4	255	1 874	0.19
		G	387	347	45	196	10	78	1 063	0.08
		S	88	43	0	10	2	31	174	0.19
		C	165	19	0	165	4	133	486	0.28
		A	0	0	0	0	0	0	0	—
		F	49	8	8	2	0	0	67	0
	SW	V	1 651	955	12	125	8	453	3 204	0.14
		G	480	484	71	202	16	108	1 61	0.09
		S	76	51	0	14	0	35	176	0.20
		C	259	24	0	184	2	182	651	0.28
		A	0	0	0	0	0	0	0	—
		F	69	25	6	2	2	0	104	0

* For legend see Table B10 (Continued) on next page.

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*		
15–30°	W	V	1 061	551	0	139	4	361	2 116	0.17
		G	420	339	88	176	12	133	1 168	0.12
		S	98	29	0	18	0	22	167	0.13
		C	229	22	0	100	0	167	518	0.32
		A	0	0	0	0	0	0	0	—
		F	25	20	8	0	0	0	53	0
	NW	V	1 221	488	4	116	4	712	2 545	0.28
		G	514	388	90	245	4	290	1 531	0.19
		S	161	116	2	29	4	80	392	0.21
		C	271	8	0	173	0	277	729	0.38
		A	0	0	0	0	0	0	0	—
		F	55	17	4	0	0	0	76	0
30–40°	N	V	619	41	4	37	16	1 016	1 733	0.60
		G	353	124	53	80	12	439	1 016	0.44
		S	63	6	0	17	8	51	145	0.41
		C	45	0	0	6	2	200	253	0.80
		F	17	10	2	0	0	2	31	0.06
	NE	V	859	88	8	29	41	1 429	2 454	0.60
		G	457	149	55	118	25	416	1 220	0.36
		S	70	6	0	16	4	43	139	0.39
		C	53	0	2	10	2	157	224	0.71
		F	14	2	0	4	0	0	20	0
	E	V	598	173	2	51	51	1 025	1 900	0.57
		G	267	184	45	106	20	339	961	0.37
		S	63	6	0	2	8	25	104	0.32
		C	16	2	0	12	0	82	112	0.73
		F	6	4	0	0	0	0	10	0
	SE	V	859	239	2	67	43	1 408	2 618	0.55
		G	369	192	25	120	49	457	196	0.38
		S	80	21	0	20	12	63	196	0.38
		C	22	2	0	31	0	94	149	0.63
		F	18	2	2	0	2	0	24	0.08
	S	V	498	163	4	55	27	608	1 355	0.47
		G	212	190	33	96	27	294	851	0.38
		S	55	10	0	12	2	31	110	0.30
		C	25	0	2	14	0	65	106	0.61
		F	8	0	0	0	0	2	10	0.20
	SW	V	808	306	2	57	33	1 108	2 314	0.49
		G	333	298	53	141	33	365	1 223	0.33
		S	33	12	0	2	6	20	73	0.36
		C	16	4	0	23	0	116	159	0.73
		F	35	4	2	4	0	4	49	0.08
	W	V	620	178	2	45	31	902	1 778	0.52
		G	367	239	71	182	31	347	1 237	0.31
		S	67	14	0	6	0	29	116	0.25
		C	20	2	0	29	2	100	153	0.67
		F	14	2	6	0	0	0	22	0
	NW	V	743	90	0	35	29	1 480	2 377	0.63
		G	390	176	41	180	27	584	1 398	0.44
		S	82	10	0	4	8	67	171	0.44
		C	51	2	0	27	6	161	247	0.68
		F	6	6	2	0	2	2	18	0.22
>40°	N	V	39	6	2	6	27	161	241	0.78
		G	31	21	2	2	12	20	88	0.36
		S	0	0	0	0	6	6	12	1.00
	NE	V	92	16	0	2	53	202	365	0.70
		G	63	16	0	2	29	49	159	0.49
		S	4	0	0	2	6	8	20	0.70
	E	V	84	51	0	0	59	90	284	0.52
		G	45	27	0	0	24	37	133	0.46
		S	4	4	0	0	6	40	20	0.50
	SE	V	92	29	0	0	112	131	362	0.67
		G	66	16	0	6	22	49	159	0.45
		S	8	2	0	2	21	12	45	0.73
	S	V	70	18	0	2	61	82	231	0.62
		G	55	6	2	2	12	47	124	0.48
		S	4	0	0	0	6	4	14	0.71
	SW	V	69	25	0	10	51	100	255	0.59
		G	88	31	2	0	25	44	190	0.36
		S	0	4	0	0	2	8	14	0.71
	W	V	53	23	0	4	22	106	208	0.62
		G	45	51	2	4	14	41	158	0.35
		S	0	2	0	0	0	0	2	0
	NW	V	51	14	2	4	31	180	282	0.75
		G	62	47	2	6	8	61	186	0.37
		S	0	0	0	0	12	8	20	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; U=unknown bedrocks; M=marine sediments; GI=general instability; S=sedimentary and metasedimentary rocks

Table B11 Geology, Erosion and Instability

	No Apprecia-able Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)				Total Area (ha)	Area Instability Index
		Sheet	Rill	Gully	WDL	CI	General Instability			
							Recent	Relict		
Alluvium:										
—undifferentiated	14 441	53	6	347	0	0	0	0	14 847	0
Colluvium:										
—volcanic	5 065	620	20	1 688	15	0	1 284	465	9 157	0.19
—granitic	1 925	202	13	967	4	0	518	22	3 651	0.15
—sedimentary and metasedimentary	672	151	0	230	0	0	43	28	1 124	0.06
—mixed	1 204	90	0	290	0	0	173	29	1 786	0.11
Littoral deposits	1 398	6	0	0	0	0	0	0	1 404	0
Marine deposits	110	0	0	0	0	0	0	0	110	0
Reclamation	2 986	679	45	10	2	0	0	0	3 722	<0.01
Fill	1 863	488	37	12	4	0	10	0	2 414	<0.01
Kat O Formation	0	0	0	0	0	4	2	0	6	1.00
Port Island Formation	624	676	0	188	0	28	343	180	2 039	0.27
Repulse Bay Formation:										
—undifferentiated volcanic rocks	623	782	12	49	2	20	1 029	451	2 968	0.51
—sedimentary rocks and waterlaid volcaniclastic rocks	1 074	310	10	69	8	23	514	214	2 222	0.34
—acid lavas	1 744	1 245	21	145	0	298	1 194	688	5 335	0.41
—mainly banded acid lavas, some welded tuffs	1 661	306	4	16	0	55	570	349	2 961	0.33
—coarse tuff	3 777	841	10	535	6	88	1 349	598	7 204	0.28
—agglomerate	126	12	0	13	0	0	43	6	200	0.25
—dominantly pyroclastic rocks with some lavas	10 251	4 022	35	600	43	177	4 504	2 333	21 965	0.32
Tai O Formation	47	6	0	2	0	41	24	31	151	0.64
Lok Ma Chau Formation	751	259	2	18	8	0	86	88	1 212	0.15
Bluff Head Formation	369	57	0	100	6	37	53	78	700	0.25
Tolo Harbour Formation	6	0	0	0	2	0	0	0	8	0.25
Undifferentiated Granitic Rocks	106	831	2	29	0	43	212	6	1 229	0.21
Granophyric Microgranite	25	0	0	2	0	0	12	0	39	0.31
Needle Hill Granite (fine-grained porphyritic phase)	735	418	55	414	0	0	690	27	2 339	0.31
Needle Hill Granite (medium-grained porphyritic phase)	212	210	108	286	0	0	233	10	1 059	0.23
Hong Kong Granite	2 147	325	6	118	0	8	131	16	2 751	0.06
Hong Kong Granite (fine-grained porphyritic phase)	192	17	0	6	0	0	16	0	231	0.07
Hong Kong Granite (medium-grained porphyritic phase)	49	45	0	18	0	0	2	0	114	0.02
Quartz Monzonite	314	233	4	8	0	29	67	82	737	0.24
Feldspar Porphyry Dyke Swarm	420	937	6	31	0	16	419	149	1 978	0.30
Fau Lau Porphyritic Granite	25	2	0	0	0	14	0	0	41	0.34
Ma On Shan Granite	300	120	4	23	2	25	161	49	684	0.35
Cheung Chau Granite	2 000	2 061	586	1 241	0	188	1 183	451	7 710	0.24
Sung Kong Granite	1 239	292	37	66	0	120	367	120	2 241	0.27
Sung Kong Granite (medium-grained phase)	388	324	49	322	0	0	327	0	1 410	0.23
Tai Po Granodiorite	929	86	12	61	0	2	149	10	1 249	0.13
Unknown Bedrock	14	0	0	0	0	17	0	0	31	0.55
Total	59 812	16 706	1 084	7 904	102	1 233	15 708	6 480	109 029	0.22
					23 523					

Note: WDL=Well-defined Landslips CI=Coastal Instability

Table B12 Existing Land Use (From aerial photograph interpretation by the Geotechnical Control Office, 1981–86)

Existing Land Use	Area (ha)	Existing Land Use	Area (ha)
Government housing estate	1 047	Quarries-private	204
Private development	1 720	Quarries-borrow	296
2 Storey development	2 208	Oil storage	45
1 Storey development	1 073	Power station	180
Temporary resettlement area	229	Cemetery	331
Intermixed	320	Prison	90
Industrial	551	Service reservoir	104
Commercial	176	Incinerator	12
Commercial/residential	329	Horticulture	5 616
Park	365	Undefined agriculture	2 876
Sports complex	204	Fish or duck ponds	2 875
Golf course	346	Dairy farm	8
Race course	102	Poultry or pigs	45
Zoological & botanical gardens	10	Undisturbed areas	33 478
School or University	180	Country Park	40 143
Hospital	94	Water storage	2 331
Temple or Church	39	Natural stream	373
Police/Fire Station	92	Man-made channel	178
Airport runway	116	Squatters–low intensity	1 496
Airport facilities	182	Squatters–medium intensity	782
Wharves	253	Squatters–high intensity	557
Railways	90	Construction	1 373
Roads	676	Reclamation	663
Sewerage works	92	Temporary land fill	116
Military – unspecified	594	Temporary land use	424
Military – firing range	2 314	Artificial slopes	996
Quarries – government	35		
		Total	109 029

Table B13 Existing Land Use and GLUM Class

Existing Land Use	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Government housing estate	123	759	157	8	0
Private development	271	1 031	373	45	0
2 Storey development	369	1 355	447	37	0
1 Storey development	92	569	373	39	0
Temporary resettlement area	27	188	12	2	0
Intermixed	28	292	0	0	0
Industrial	51	459	41	0	0
Commercial	21	145	10	0	0
Commercial/residential	43	253	33	0	0
Park	84	218	47	16	0
Sports complex	35	147	22	0	0
Golf course	71	190	71	14	0
Race course	0	100	2	0	0
Zoological and botanical gardens	0	4	6	0	0
School or University	47	84	49	0	0
Hospital	18	72	4	0	0
Temple or Church	8	19	10	2	0
Police/Fire Station	14	63	13	2	0
Airport runway	4	112	0	0	0
Airport facilities	0	182	0	0	0
Wharves	31	218	0	0	4
Railways	10	55	25	0	0
Roads	78	433	141	24	0
Sewerage works	25	63	4	0	0
Military – unspecified	116	373	84	21	0
Military – firing range	33	663	1 169	445	4
Quarries – government	0	6	21	8	0
Quarries – private	16	29	114	45	0
Quarries – borrow	96	129	61	10	0
Oil storage	10	35	0	0	0
Power station	51	125	2	2	0
Cemetery	14	196	98	23	0
Prison	14	59	17	0	0
Service reservoir	6	18	80	0	0
Incinerator	0	12	0	0	0
Horticulture	261	4 149	1 114	92	0
Undefined agriculture	119	2 312	431	14	0
Fish or duck ponds	0	0	0	0	2 875
Dairy farm	0	4	2	2	0
Poultry or pigs	10	27	8	0	0
Undisturbed areas	1 794	10 833	11 939	7 410	1 502
Country Park	1 361	14 704	12 400	11 678	0
Water storage	0	0	0	0	2 331
Natural stream	0	0	0	0	373
Man-made channels	0	0	0	0	178
Squatters – low intensity	106	994	331	65	0
Squatters – medium intensity	65	451	225	41	0
Squatters – high intensity	59	269	192	37	0
Construction	190	973	198	12	0
Reclamation	0	647	16	0	0
Temporary land fill	0	43	65	8	0
Temporary land use	78	320	24	2	0
Artificial slopes	0	37	757	202	0
Total 109 029	5 849	44 419	31 188	20 306	7 267

Table B14 GLUM Class and Instability for the Regional Studies

Study Area	GASP Report No.	Geotechnical Limitations										Total	Instability			Area Instab. Index For Total Area	Area Instab. Index For Glum III & IV
		I		II		IIS		III		IV							
		Area	%	Area	%	Area	%	Area	%	Area	%		WDL	C	GI		
Hong Kong & Kowloon	I	1 092	8.7	4 859	38.6	—	—	4 441	35.2	2 097	16.7	12 587	55	0	1 473	0.12	0.23
Central New Territories	II	414	3.1	4 923	36.8	73	0.5	4 225	31.6	3 472	26.0	13 368	27	0	3 323	0.25	0.44
West New Territories	III	492	5.5	3 947	44.1	253	2.8	2 638	29.5	1 367	15.3	8 952	55	0	1 614	0.19	0.42
North West New Territories	IV	761	4.8	4 211	26.8	1 659	10.5	4 090	26.0	1 426	9.1	15 734	4	0	1 522	0.10	0.28
North New Territories	V	889	5.5	5 647	35.1	2 430	15.1	4 803	29.8	1 893	11.8	16 095	41	2	2 775	0.18	0.42
North Lantau	VI	300	4.1	2 530	34.2	320	4.3	2 624	35.4	1 544	20.9	7 403	2	4	1 908	0.26	0.46
Clear Water Bay	VII	583	15.6	1 073	28.7	2	0.1	1 202	32.2	812	21.7	3 735	6	0	706	0.19	0.35
North East New Territories	VIII	329	4.1	2 927	36.7	202	2.5	2 211	27.8	1 062	13.3	7 968	0	169	1 934	0.26	0.64
East New Territories	IX	528	4.3	4 825	39.2	294	2.4	2 503	20.3	3 286	26.7	12 303	4	359	3 696	0.33	0.70
Island	X	173	5.4	1 298	40.8	33	1.0	851	26.7	753	23.7	3 184	0	296	688	0.31	0.61
South Lantau	XI	204	2.7	2 472	32.6	141	1.9	1 814	23.9	2 666	35.1	7 589	0	202	2 748	0.39	0.66
Unclassified		5 765		38 712		5 407		31 402		20 378		108 918*	194	1 032	22 387	0.22	0.47
		49 884						51 780 (47.5%)					23 613				
7 254		101 664															

*Note: The data contained in this table is extracted from GASP Reports I to XI. The data contained in this Report uses a slightly modified database. Most of the increase results from additional reclamation.

Table B15 Data Collection in the Regional Geotechnical Area Studies

GASP Report No.	Title	Original Survey	Minor Modifications & Editing GEOTECS
I	Hong Kong and Kowloon	1981/82	1986/87
II	Central New Territories	1982/83	1987
III	West New Territories	1982/83	1987
IV	North West New Territories	1981	1987
V	North New Territories	1981	1987
VI	North Lantau	1981	1987
VII	Clear Water Bay	1983	1987
VIII	North East New Territories	1983/84	1987
IX	East New Territories	1984	1987
X	Islands	1983/84	1987
XI	South Lantau	1984/85	1987

APPENDIX C

SUPPLEMENTARY INFORMATION

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APPENDIX C

SUPPLEMENTARY INFORMATION

C.1 Geological Remapping of the Territory

During 1980, a case for a revised geological Survey of the Territory was prepared within the Geotechnical Control Office (GCO). This culminated in 1982 with the appointment of two consultants from the British Geological Survey (BGS) to initiate the remapping programme.

Burnett (1988) states that the justification for the remapping programme was based on the need for more reliable large-scale geological data for engineering, planning and land management purposes. The 1:50 000 scale map of Allen & Stephens (1971) no longer provided the geological detail required to satisfy the needs of government and industry. In particular, a need existed for more site specific geological data for civil engineering, natural resource appraisal and inventory purposes. There was almost a complete absence of marine geological data.

Therefore, in 1982, GCO began a three-phase, systematic geological survey of the Territory, based on the 1:20 000 scale topographic base map series. The revised Geological Survey of Hong Kong will result in the publication of fifteen (15 × 12 km) 1:20 000 scale colour map sheets, and six accompanying memoirs. The memoirs describe groups of map sheets as shown in Figure C1. Phase 1 of the nine-year survey is currently nearing completion, and at the end of 1988, 60% of the Territory has been mapped. The map sheets and memoirs already published are described in Section 2. More detailed mapping of some areas is underway and this will result in the publication of large scale (1:5 000) geological maps.

The remapping programme is aimed at providing a general, balanced coverage of the Territory, with assessment of onshore and offshore areas, bedrock and superficial deposits, in a manner suitable for a wide range of users.

The techniques employ traditional geological mapping methods, carried out on 1:5 000 or 1:10 000 topographic base maps or enlarged vertical aerial photographs, primarily by extensive field traversing, detailed field mapping, collection of hand specimens and assessment of site investigation information. To this basic data is added aerial photograph interpretation, borehole log plotting, geophysical data, archival map and photographic information, petrography and rock chemistry. Several 'slice' maps are compiled, usually at 1:10 000 scale, depicting individual facets of the final map, for example bedrock, superficial deposits and structure. These are combined, and a final hand-drawn geologists 'standard' is produced for cartographers to prepare a printers proof.

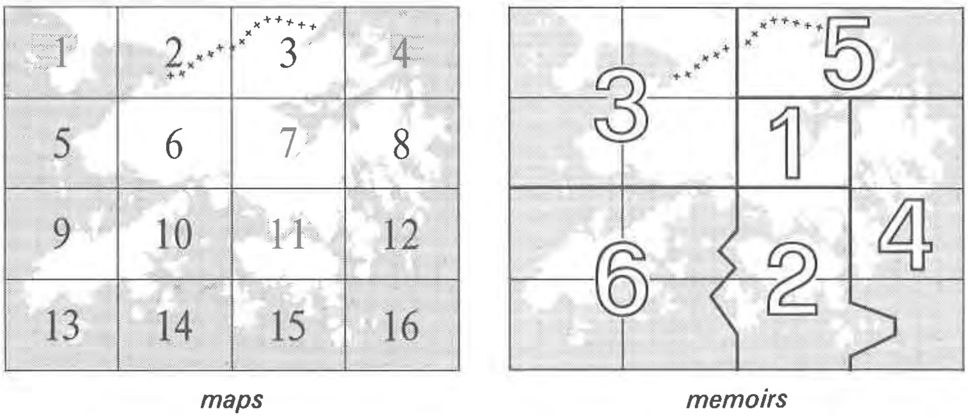


Fig. C1 Maps and Memoirs of the New Geological Survey of the Territory

As a result of the highly developed nature of the Territory, extensive use has been made of the large quantity of archival data. This has proved particularly valuable in the mapping of the urbanised areas of Hong Kong, where field observation is severely restricted because of development. This aspect of the mapping is described by Strange (1986).

A limited amount of seabed mapping is also included in the survey and a general marine stratigraphy has been established for the Territory (Shaw, 1986).

The geological remapping of the Territory is gradually superseding the Allen & Stephens (1971) study, and hence the hardrock geology presented in the GASP Reports. Remapping has led to the confirmation of the existence of cavernous marble in the Yuen Long area, the simplification of the classification of the intrusive igneous rocks (Strange, 1986; Strange & Shaw, 1987), and a restructuring of the volcanic and volcaniclastic units, mapped by Allen & Stephens as the Repulse Bay Formation (Langford, 1986). Burnett (1988) provides a history of geological and terrain mapping within the Territory.

C.2 Site Investigation Data

A large number of site investigations have been conducted by the public and private sectors. Many reports are held by the Geotechnical Information Unit (GIU) and some of these are available to the public in the Civil Engineering Library operated by the Geotechnical Control Office.

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

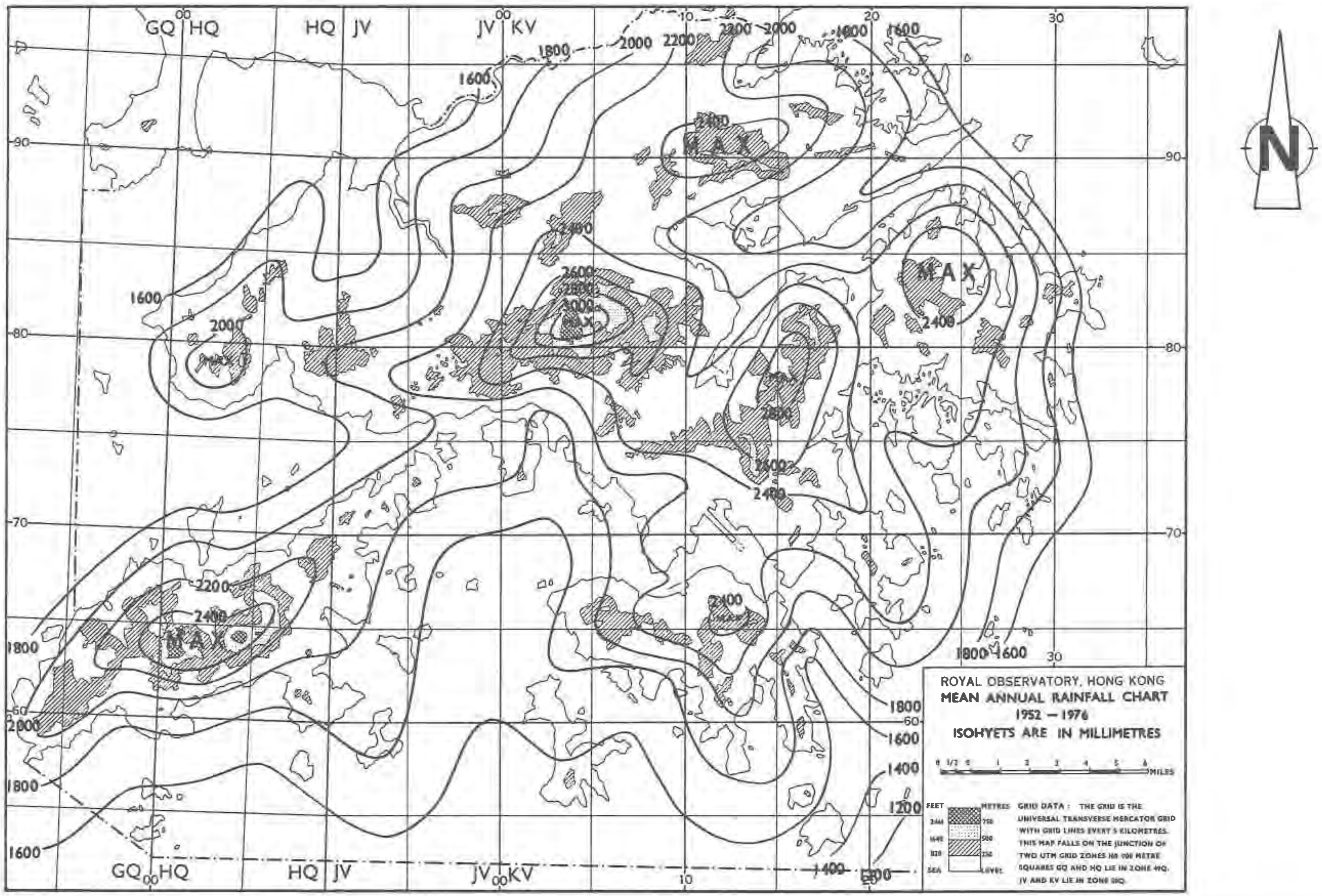
The Territory has been extensively photographed from the air, and many thousands of vertical and oblique aerial photographs are available from the Map Sales Office of the Survey & Mapping Office, Buildings & Lands Department. This office is located on the 14th Floor, Murray Building, Garden Road, Hong Kong.

C.4 Rainfall Data for the Territory

A general appreciation of the annual rainfall distribution for the Territory can be obtained from Figure C2. The average annual rainfall is about 2 250 mm, and occurs between May and September. The range is about 1 500 mm to 3 000 mm. Figure C2 is a reproduction of the mean annual rainfall isohyets for the years 1952 to 1976, published by the Royal Observatory. This information has been included in the GEOTECS data base and is reproduced as a GEOTECS Map of Rainfall. A copy of this Map is in the Map Folder, and an example is at Figure 9.

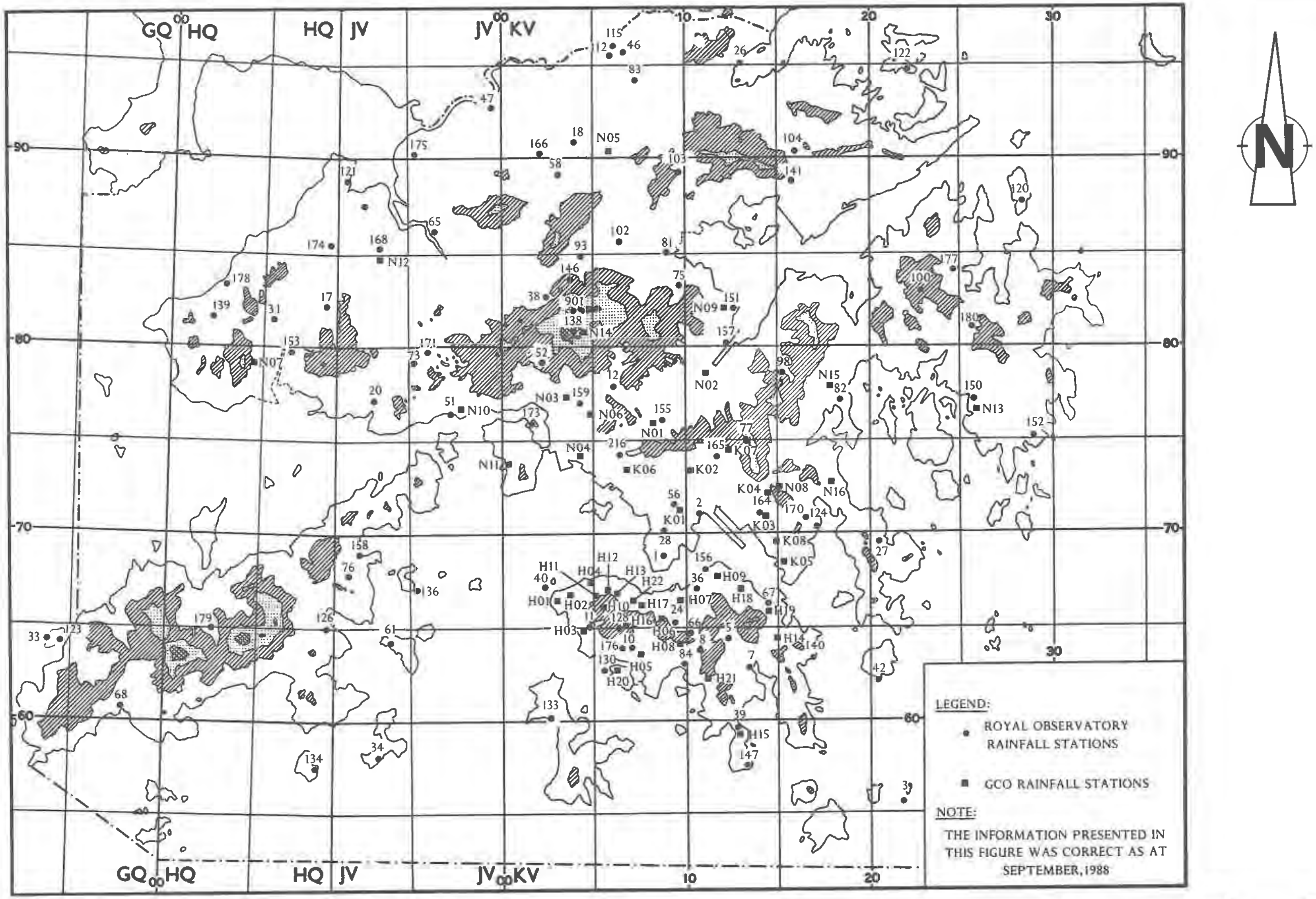
There are approximately 140 rainfall stations within the Territory, the locations of which are indicated on Figure C3 and also on the GEOTECS Map. The eleven regional GASP Reports contain more specific data regarding rainfall in each study area.

A list of rainstorms which have caused landslips and flood damage within the Territory is presented in Peterson & Kwong (1981). They list 64 periods of intensive rainfall for the 21 years between 9.6.1960 and 4.9.1981. The cause and effects of each storm period are summarised. In addition, the Royal Observatory has produced a number of Technical Notes which deal with specific rainstorms or typhoons. Detailed monthly and annual rainfall information for these stations is available from the Royal Observatory.



Mean Annual Rainfall Isohyets (1952–1976)

Fig. C2



Locations of Rainfall Stations

Fig. C3

APPENDIX D

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

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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 the Territory'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 because 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. 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 Territory, 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 with 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 'ravelling'. 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 general in this Report and more specifically in the regional GASP Reports. 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 A4 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 (Zone A) increases 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 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 FEASIBILITY STUDIES. G A S PROVIDES PRELUDE TO SITE SPECIFIC INVESTIGATION.

INFLUENCES ON LAND USE :

POTENTIAL, CONSTRAINT, DEVELOPMENT REQUIREMENTS.

LAND USE CHART :

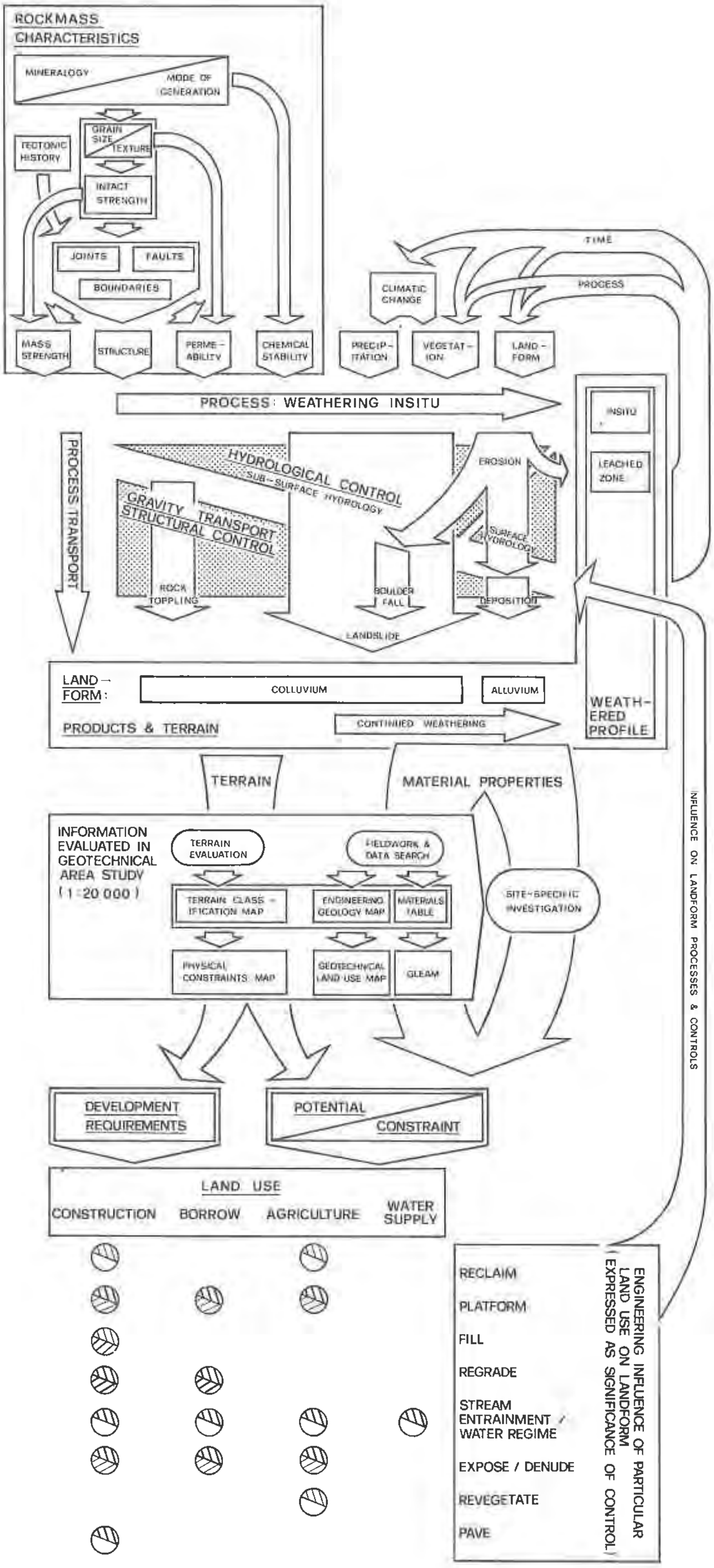
INTENSITY OF SHADING INDICATES ENGINEERING INFLUENCE OF PARTICULAR LAND USE ON

HYDROLOGICAL CONTROL / STRUCTURAL CONTROL THROUGH MODIFICATION OF LANDFORM :

SLIGHT

MODERATE

SIGNIFICANT



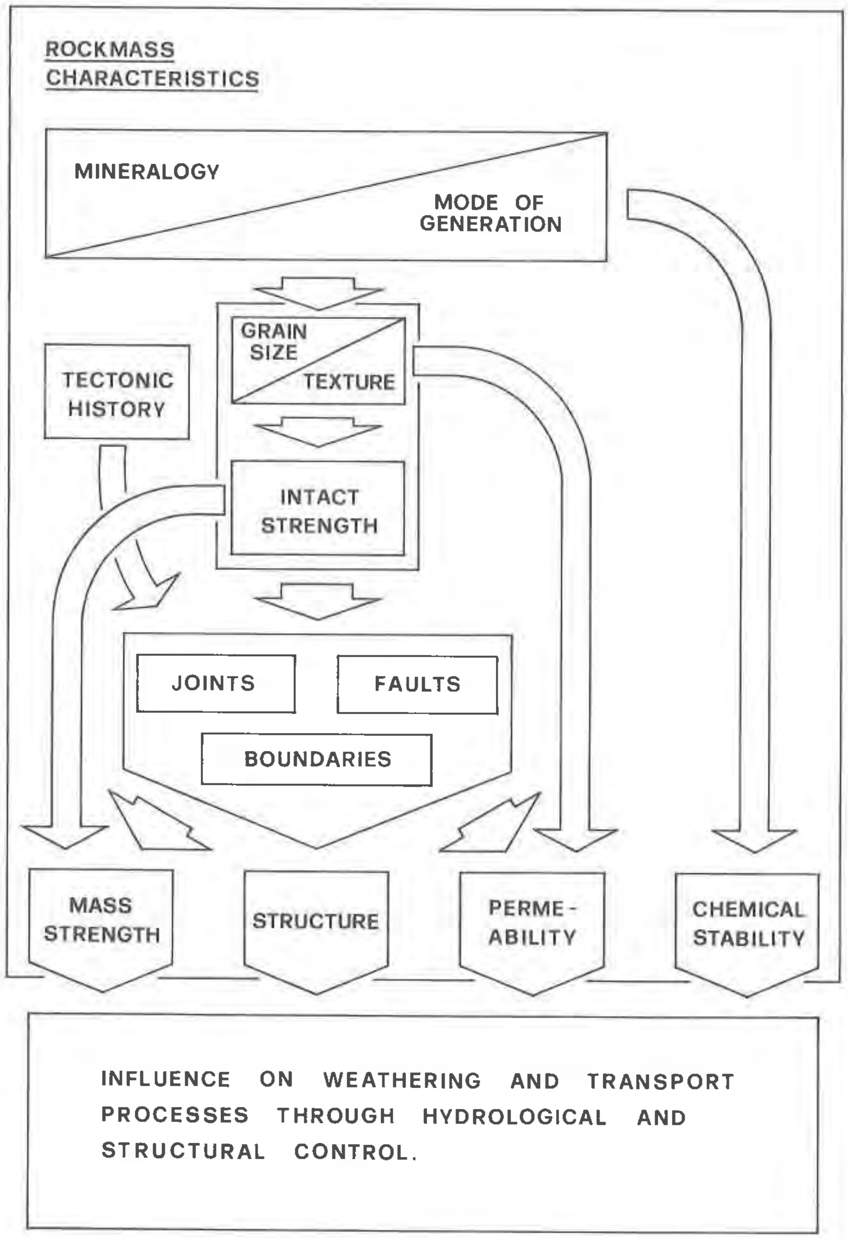
LEGEND :

BOXES INDICATE : CAUSE OR PRODUCT

ARROWS INDICATE : INFLUENCE, PROCESS, OR MECHANISM

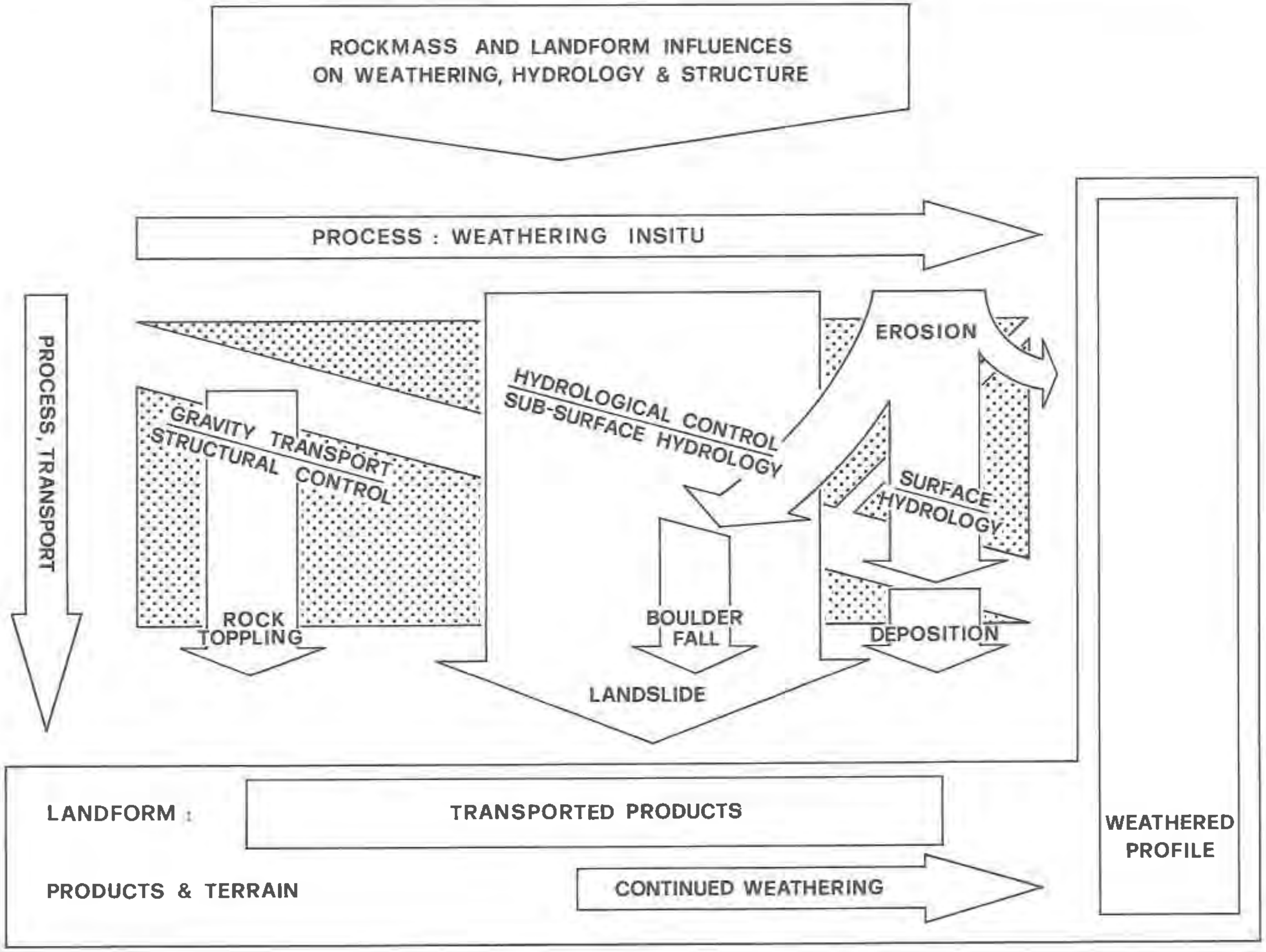
CIRCLES INDICATE : HUMAN INVOLVEMENT

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 photo-geological 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 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 the Territory, 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 Territory 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 Territory, 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 the Territory. 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 controlled by geological structure, 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 create site formation platforms 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 eleven regional Engineering Geology Maps and the Physical Contraints Maps which accompany GASP Reports I to XI.

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 the Territory to provide level building platforms on otherwise steep terrain. Since the disastrous fill slope failures at Sau Mau Ping in 1972 and 1976 (Government of Hong Kong, 1972a & b, 1977), fill has been recognised 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'. In this common practice, fill material was dumped at the crest of a slope and allowed to move downslope, coming to rest at its angle of repose. This results in:

(*a*) Poor compaction—a generally loose structure makes the fills susceptible to liquification resulting from infiltration of rainwater, movement of groundwater, throughflow 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 saturation 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.

(ii) *Fill on Low-lying Terrain*
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*
Some of the coastal areas are modified by reclamation and considerable recent and proposed development is based on these areas.

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 areas 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 an 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, colluvial 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.

(*h*) Sea level rise—in recent years, measurements taken in various countries suggest that the world is gradually becoming warmer. If this trend is real, many scientists agree that global sea levels will rise. Some estimates for such a rise range from 0.5 m to more than 1 m over the next 100 years. In some countries, there is already data to indicate that relative sea level is very slowly rising.

In Hong Kong, there is no definite evidence that local sea level is rising. However, if the global sea level is increasing, then it is expected that Hong Kong may also experience the effect. Any such rise would not be sudden, but would occur very slowly. This should be taken into account when planning new reclamations. In most cases, this may not entail additional works beyond those considered desirable for other engineering and planning reasons.

(iv) *Sanitary Landfill*
Sanitary landfills are used for the disposal of domestic refuse. 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 eleven regional Engineering Geology Maps for the Territory. 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 geological 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.

Although many photolineaments are major features which are continuous for hundreds of metres or even kilometres, they tend to be narrow and therefore they may often be avoided or catered for 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. Foundation difficulties may occur due to rapidly changing ground conditions.

(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, photolineaments may be associated with anomalies in the general pattern of weathering depth which may cause differential settlements of raft foundations.

Regular patterns of lineaments are evidence of the regional pattern of structure present at smaller scale. Engineering works 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.

Boundaries between rock types may or may not form photolineaments, partly depending on whether they are faulted or not. Identified rock boundaries are shown on the regional Engineering Geology Maps. 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 photolineaments 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 photolineaments are identified on the regional Engineering Geology Maps (after Allen & Stephens, 1971) as faults, and other major photolineaments may also indicate faults. Faults may extend laterally for short distances or many hundreds of kilometres. The Government of the People's Republic of China has published a national seismic map which shows extensive fault-zones of NE or ENE trend in Guangdong Province and western Fujian Province. One of these fault-zones lies along the northern boundary of the Territory of Hong Kong, while others intersect the coast of Guangdong Province to the east of Hong Kong. Sources in China regard many of the faults of the region as active, the degree of activity being inferred from recent earthquake data and that derived from the historical geological record.

Throughout the world, even in seismically 'quiet' areas, many major faults are active to some extent. For example, in the UK, which is classified as an area of low to moderate seismicity, a few hundred earthquakes occur every year, although they are rarely felt by individuals. Most of the earthquakes recorded by the Royal Observatory short-period seismograph network originated elsewhere in the Southeast Asian region. The few which actually have been felt by individuals in Hong Kong were mostly related to earthquakes in various parts of China. Nevertheless, minor seismic events originating within the Territory have also been recorded by the Royal Observatory, and these events may be attributed to minor movements on faults at depth giving rise to shock waves but no apparent ground displacement. To date, no clear relationship is obvious between these local seismic events and known faults within the Territory.

On the basis of observations of the historical geological record and mapping work undertaken to date, it appears that, although minor crustal readjustments have been occurring in Hong Kong, the Territory is not characterised by local major fault movements or related severe seismic events.

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 in the Territory, and their location, nature and material properties are discussed in Sections 2.3, 2.4 and 3.1.4. The extent of colluvium as identified by terrain classification is shown on the eleven Engineering Geology Maps produced in the GASP.

Colluvium need not necessarily be regarded as a constraint for engineering. Relict colluvium in a completely weathered state 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 (Government of Hong Kong, 1972 a & b).

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 where 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 often require the use of hand dug caissons. As discussed for boulder colluvium in Section 3.1.4, 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 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 on footslope terrain 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 the Territory 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 an 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 necessarily a major contributing factor. 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. Boulders may also exist in drainage lines where they are likely to be restrained and interlocked. However, high flows caused by torrential rain are 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 regional Generalised Limitations and Engineering Appraisal Maps (GLEAM) where they are obvious in aerial photographs. In many situations, boulders now hidden from view by dense vegetation can be identified by reference to old aerial and sometimes terrestrial photographs.

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 or energy absorbing 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.

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 Section 2.

D.3.9 *Cut Slopes*

Cut slopes and/or slope support structures are an aspect of most large-scale developments in the Territory. 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 are 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 regional Engineering Geology Maps 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 Maps. 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 ravelling, 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) *Granitic Terrain*
Considerable depths of various grades of weathering can be encountered in the granitic areas. 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 (greater 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 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 this material affecting stability are noted in Section 3.1.4. Colluvium overlies the insitu rocks in many of the potential development areas outlined in the regional GLEAM maps. 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 Territory carry large amounts of silt from surface wash, which is often deposited on bends or flatter sections of entrainment schemes.

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 (Government of Hong Kong, 1972 a & b, 1977) 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. Flooding and infiltration of slopes may become a problem in developed areas even though, in the predevelopment terrain, it may not be 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 Reports summarise, interpret and present much of the information which would be reviewed in a desk study and, in addition, is reinforced by field reconnaissance.

The 1:20 000 scale regional GASP Reports are 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 the classes are 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 produced for the regional studies. Only in determining the engineering feasibility of a large uninvestigated area should a preliminary site investigation be based only on a 1:20 000 scale regional GASP Report.

When interpreting the regional GLUM at a scale of 1:20 000 with regard to site investigation, the following points should be considered:

(*a*) In each 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.

(*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.

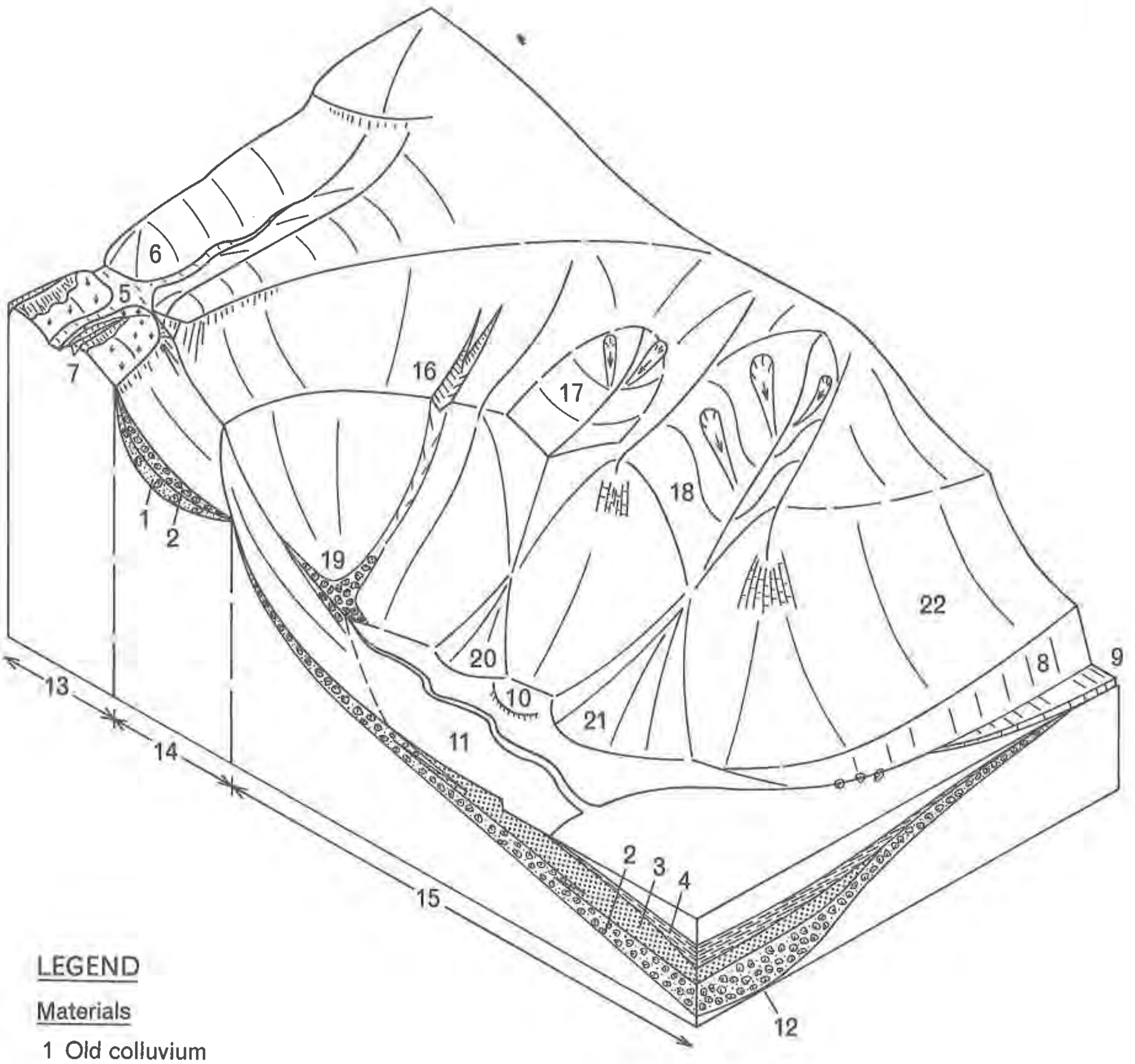
(*c*) The site investigation should be designed to highlight the scope of any available information, the anticipated material, its nature and variability, and the type and form of the engineering project.

D.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 Territory. 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.

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 the Territory lies in the consequences of the fall in sea level that resulted from the growth of the ice sheets during the Pleistocene. 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 geological structure. Incision and removal of material creates oversteepened 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 both recent and relict features, as well as rock outcrops protruding through the thin soils. Above the level of slope oversteepening,



LEGEND

Materials

1 Old colluvium
2 Young colluvium
3 Alluvium
4 Marine deposits

Landforms

5 Upland valley
6 Deeply weathered hills
7 Ridge crest gully erosion
8 Coastal cliffs
9 Wave cut platform
10 Alluvial terrace
11 Floodplain
12 Submarine buried valley
13 Relict landforms on uplands
14 Older landforms
15 Younger landforms
16 Stream incising into superficial deposits
17 Initial incision has widened to a small valley, landslips active at margins
18 Deep, bowl-shaped valley between spurs, relict and recent instability on sides
19 Boulders in stream channel
20 Small colluvial fan
21 Large colluvial fan
22 Coastal slope (thin soils)

Hillslope Model	Fig. D4

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.

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 intercalated with, marine sediments.

APPENDIX E

GLOSSARY OF TERMS

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.

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 just below its point of origin and thereafter thins rapidly in a downstream direction.

ALLUVIUM

Sediment transported and deposited by a river or stream.

APHANITE

Rock with microcrystalline or cryptocrystalline texture that is too small to be seen with the naked eye.

AQUIFER

Water-transmitting rock or soil. Type aquifers are those which are normally associated with high transmissivity such as sandstone or limestone and are often used for water supply purposes.

AREA INSTABILITY INDEX

Proportion of a particular area of land which is affected by instability.

ASPECT

Direction in which a slope faces.

BATHOLITH

Large intrusive igneous rock mass.

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 a 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.

DACITE

Extrusive equivalent of quartz diorite. The principal minerals are plagioclase, quartz, pyroxene and hornblende. The rock is glassy or fine-grained with occasional phenocrysts.

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 rock mass (i.e. joints, faults). The description and classification of discontinuities is given in the 'Geotechnical Manual for Slopes' (Geotechnical Control Office, 1984) and in the 'Guide to Rock and Soil Descriptions (Geoguide 3)', (Geotechnical Control Office, 1988k).

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'.

DOLOS

Interlocking precast concrete structures of regular geometric form normally used for protection against marine erosion.

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 forms of INSTABILITY occur.

GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP (GLEAM)

Map which delineates potential development areas in terms of geotechnical and other constraints.

GEOTECHNICAL AREA STUDIES 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.

GRABEN

Downfaulted block between two or more parallel (or subparallel) faults.

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.

HORNFELS

Fine-grained non-schistose metamorphic rock, usually derived from fine-grained sediments.

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.

IMBRICATE STRUCTURE

Tabular or sheet structures that overlap each other in response to uni-directional forces.

INCISED DRAINAGE CHANNEL

Terrain component consisting of the channel and banks of a drainage line. Identification of this feature is largely dependent upon the scale of the survey and scale of the aerial photograph.

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. 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).

LITHOTYPE

Rock defined on the basis of certain selected physical characteristics.

LITTORAL ZONE

Terrain component, defined as the area between the highest and lowest levels of spring tides, e.g. beach.

MANTLE

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.

NICK POINT

Point of interruption of a stream profile at the head of a second-cycle valley, usually as a result of a change in base level.

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.

PHYLLITE

Argillaceous rock of intermediate metamorphic grade.

PHYSICAL LAND RESOURCES

Physical characteristics of land.

PIPE (=SOIL PIPE)

Tubular conduit within the soil mantle, through which groundwater may flow.

POLYCYCLIC

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 or other waterbody.

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 the ground 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 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.

SPHERULITE

Small radiating, and usually concentric arrangement of one or more minerals formed by radial growth of acicular crystals.

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 CLASSIFICATION

Systematic terrain evaluation based on the use of terrain attributes for the production of a landscape model for engineering or other purposes.

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.

TRANSMISSIVITY

The rate at which water is transmitted through a unit width of aquifer, under a unit hydraulic gradient.

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.

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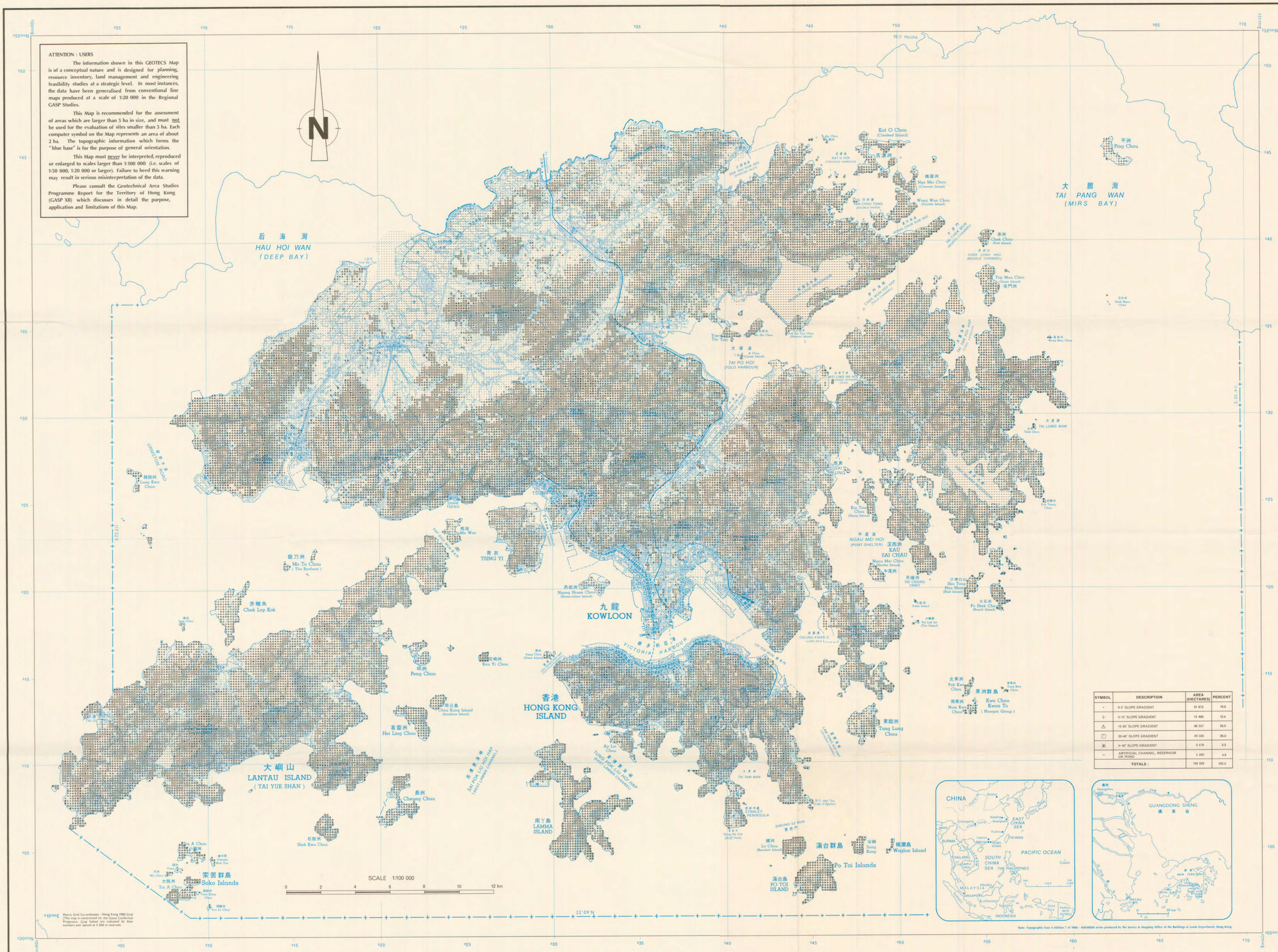

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
·	0-5° SLOPE GRADIENT	21 673	19.9
+	5-15° SLOPE GRADIENT	13 498	12.4
△	15-30° SLOPE GRADIENT	36 557	33.5
⍊	30-40° SLOPE GRADIENT	28 335	26.0
✳	> 40° SLOPE GRADIENT	3 576	3.3
~	ARTIFICIAL CHANNEL, RESERVOIR OR POND	5 390	4.9
TOTALS :		109 029	100.0

810 000E Metric Grid Co-ordinates - Hong Kong 1980 Grid (This map is constructed on the Gauss Conformal Projection. Grid Values are indicated by blue numbers and spaced at 5 000 m intervals.

Note: Topographic base is Edition 7 of 1988 - HM100DB series produced by the Survey & Mapping Office of the Buildings & Lands Department, Hong Kong.

GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECS MAP 1 — SLOPE GRADIENT

TERRITORY OF HONG KONG

Geotechnical Control Office

Civil Engineering Services Department

Title :	GEOTECS MAP 1 — SLOPE GRADIENT
Compiled : K.A. Styles / A. Hansen	Drawn : S.P. Poon / S.S. Ho
Scale : 1 : 100 000	Date : November, 1988
Map Ref. No : GASP / 100 / XII / 16	

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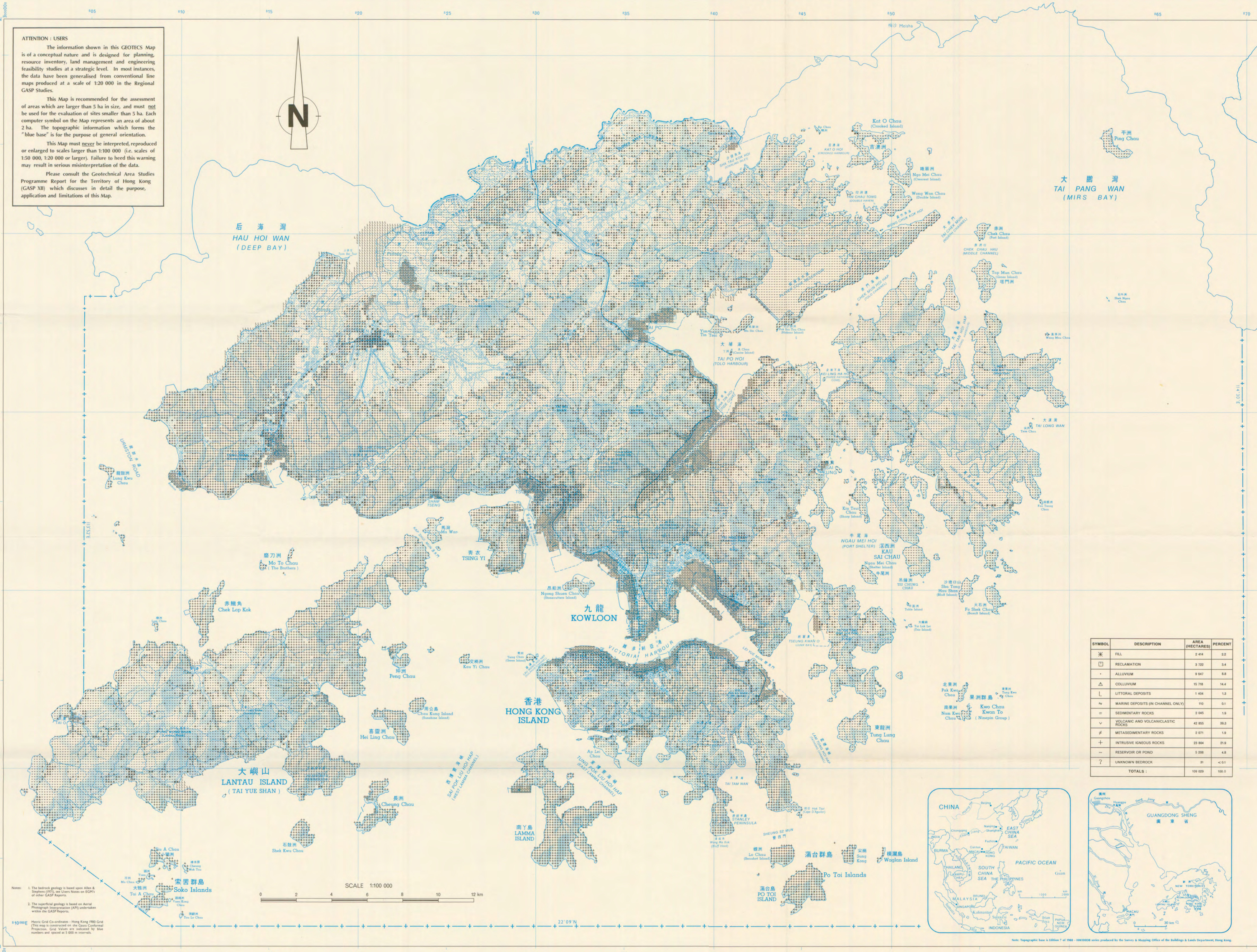


SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
✳	FILL	2 414	2.2
⍑	RECLAMATION	3 722	3.4
·	ALLUVIUM	9 647	8.8
⚠	COLLUVIUM	15 718	14.4
L	LITTORAL DEPOSITS	1 404	1.3
≈	MARINE DEPOSITS (IN CHANNEL ONLY)	110	0.1
=	SEDIMENTARY ROCKS	2 045	1.9
v	VOLCANIC AND VOLCANICLASTIC ROCKS	42 855	39.3
≠	METASEDIMENTARY ROCKS	2 071	1.9
+	INTRUSIVE IGNEOUS ROCKS	23 804	21.9
~	RESERVOIR OR POND	5 208	4.8
?	UNKNOWN BEDROCK	31	< 0.1
TOTALS :		109 029	100.0

Notes:

1. The bedrock geology is based upon Allen & Stephens (1971), see Users Notes on EGM's of other GASP Reports.
2. The superficial geology is based on Aerial Photograph Interpretation (API) undertaken within the GASP Reports.

810000E Metric Grid Co-ordinates - Hong Kong 1980 Grid (This map is constructed on the Gauss Conformal Projection. Grid Values are indicated by blue numbers and spaced at 5 000 m intervals.

Geotechnical Control Office

Civil Engineering Services Department

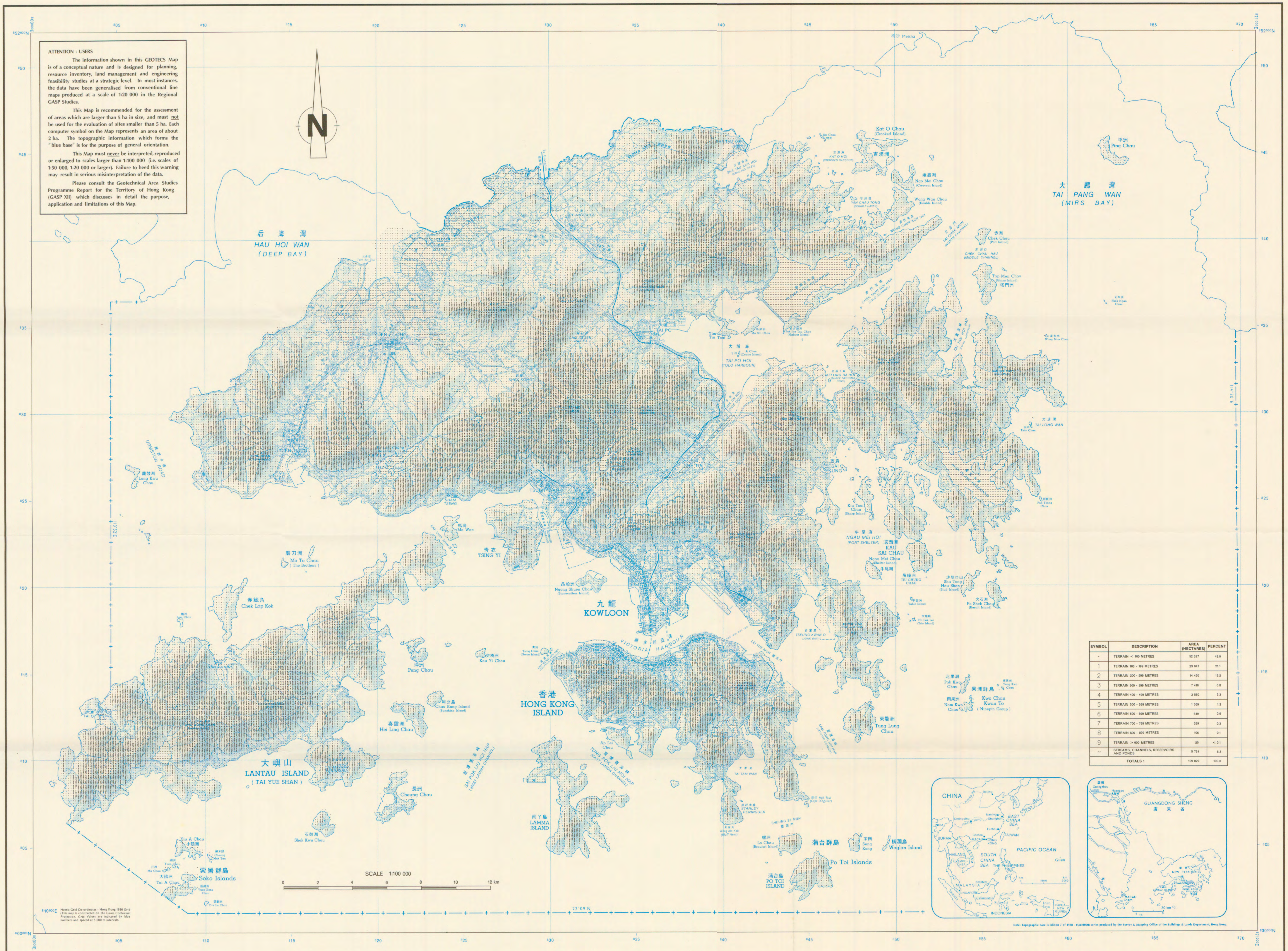
GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECS MAP 2 — GEOLOGY

TERRITORY OF HONG KONG

Title : GEOTECS MAP 2 — GEOLOGY	
Compiled : K.A. Styles / A. Hansen	Drawn : S.P. Poon / S.S. Ho
Scale : 1 : 100 000	Date : November, 1988
Map Ref. No : GASP / 100 / XII / 17	

Published by the Geotechnical Control Office, Civil Engineering Services Department, Hong Kong.



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SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
·	TERRAIN < 100 METRES	52 327	48.0
1	TERRAIN 100 - 199 METRES	23 047	21.1
2	TERRAIN 200 - 299 METRES	14 420	13.2
3	TERRAIN 300 - 399 METRES	7 418	6.8
4	TERRAIN 400 - 499 METRES	3 580	3.3
5	TERRAIN 500 - 599 METRES	1 369	1.3
6	TERRAIN 600 - 699 METRES	649	0.6
7	TERRAIN 700 - 799 METRES	329	0.3
8	TERRAIN 800 - 899 METRES	106	0.1
9	TERRAIN > 900 METRES	20	< 0.1
~	STREAMS, CHANNELS, RESERVOIRS AND PONDS	5 764	5.3
TOTALS :		109 029	100.0

Geotechnical Control Office

Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECS MAP 3 — RELIEF

TERRITORY OF HONG KONG

Title : GEOTECS MAP 3 — RELIEF

Compiled : K.A. Styles / A. Hansen

Drawn : S.P. Poon / S.S. Ho

Scale : 1 : 100 000

Date : November, 1988

Map Ref. No : GASP / 100 / XII / 18

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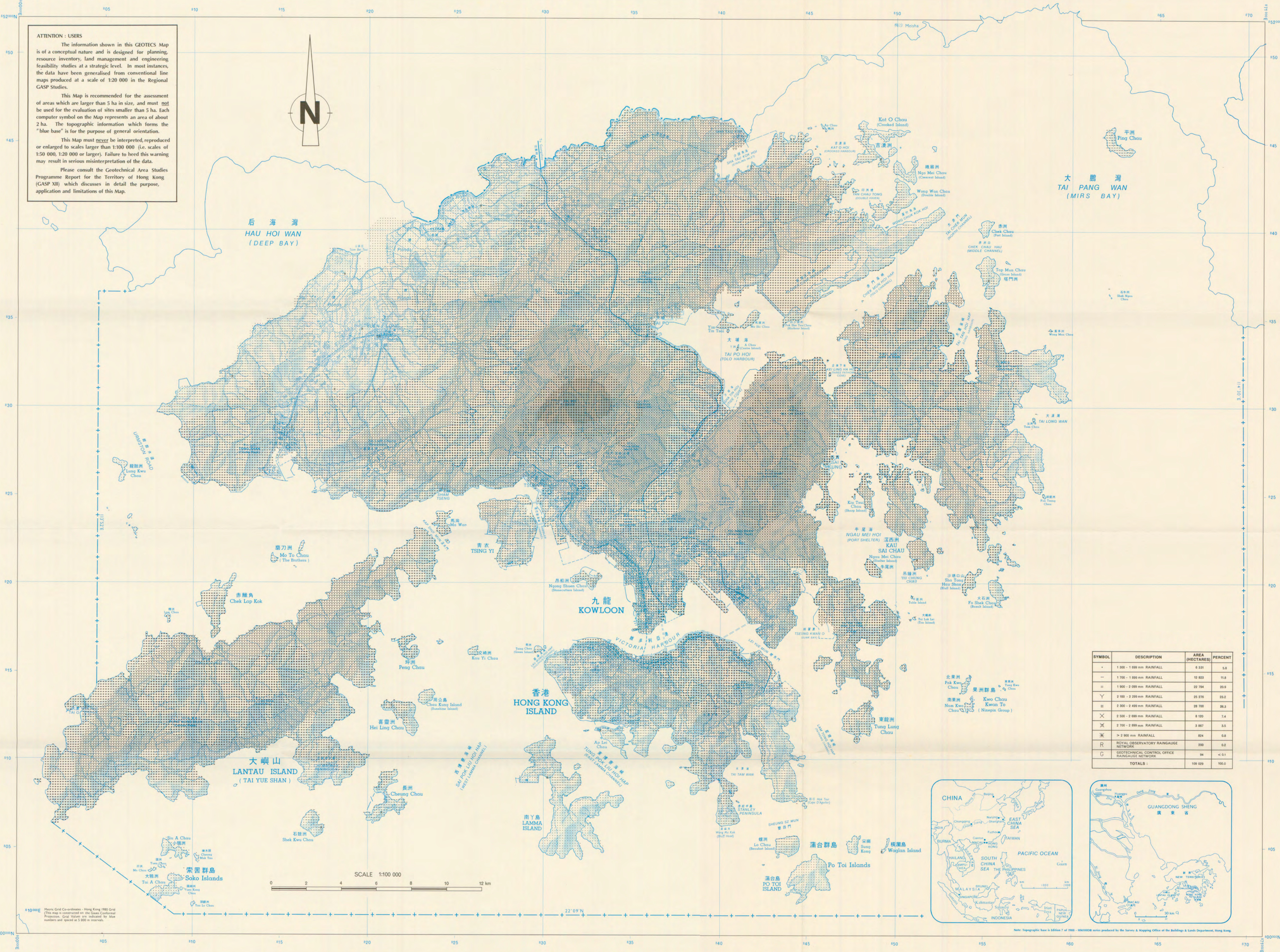

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
·	1 300 - 1 699 mm RAINFALL	6 331	5.8
−	1 700 - 1 899 mm RAINFALL	12 823	11.8
=	1 900 - 2 099 mm RAINFALL	22 794	20.9
Y	2 100 - 2 299 mm RAINFALL	25 276	23.2
≡	2 300 - 2 499 mm RAINFALL	28 700	26.3
X	2 500 - 2 699 mm RAINFALL	8 120	7.4
⌧	2 700 - 2 899 mm RAINFALL	3 867	3.5
✳	> 2 900 mm RAINFALL	824	0.8
R	ROYAL OBSERVATORY RAINGAUGE NETWORK	200	0.2
G	GEOTECHNICAL CONTROL OFFICE RAINGAUGE NETWORK	94	< 0.1
TOTALS :		109 029	100.0

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GEOTECS MAP 4 — RAINFALL
TERRITORY OF HONG KONG

Title : GEOTECS MAP 4 — RAINFALL	
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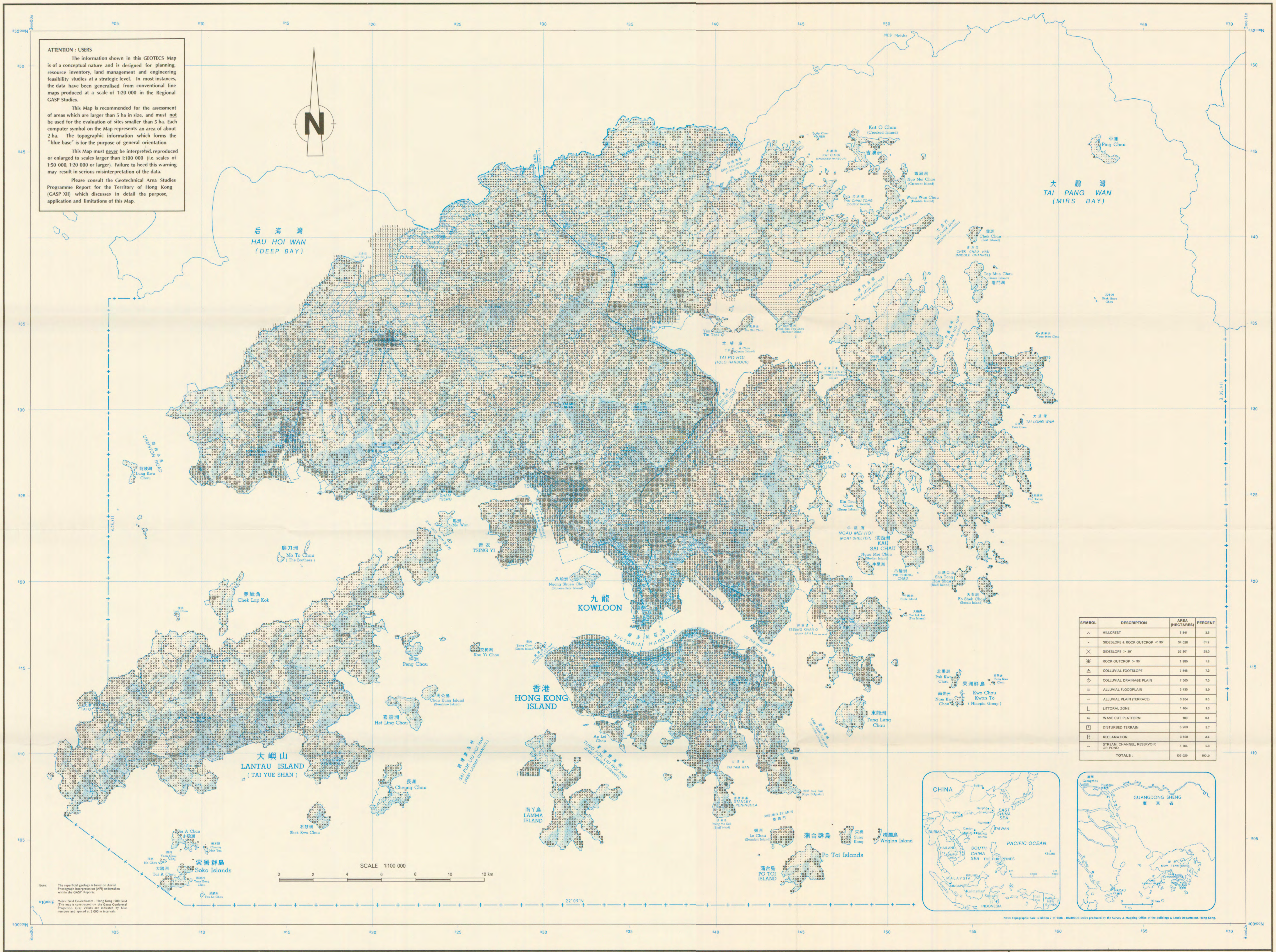

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SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
^	HILLCREST	3 841	3.5
•	SIDESLOPE & ROCK OUTCROP < 30°	34 028	31.2
X	SIDESLOPE > 30°	27 301	25.0
✳	ROCK OUTCROP > 30°	1 980	1.8
△	COLLUVIAL FOOTSLOPE	7 846	7.2
◇	COLLUVIAL DRAINAGE PLAIN	7 565	7.0
≡	ALLUVIAL FLOODPLAIN	5 435	5.0
—	ALLUVIAL PLAIN (TERRACE)	3 804	3.5
L	LITTORAL ZONE	1 404	1.3
≈	WAVE CUT PLATFORM	100	0.1
⊓	DISTURBED TERRAIN	6 263	5.7
R	RECLAMATION	3 698	3.4
~	STREAM, CHANNEL, RESERVOIR OR POND	5 764	5.3
TOTALS :		109 029	100.0

Note: The superficial geology is based on Aerial Photograph Interpretation (API) undertaken within the GASP Reports.

810 000E Metric Grid Co-ordinates - Hong Kong 1980 Grid (This map is constructed on the Gauss Conformal Projection. Grid Values are indicated by blue numbers and spaced at 5 000 m intervals.

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GEOTECS MAP 5 — LANDFORM

TERRITORY OF HONG KONG

Title : GEOTECS MAP 5 — LANDFORM	
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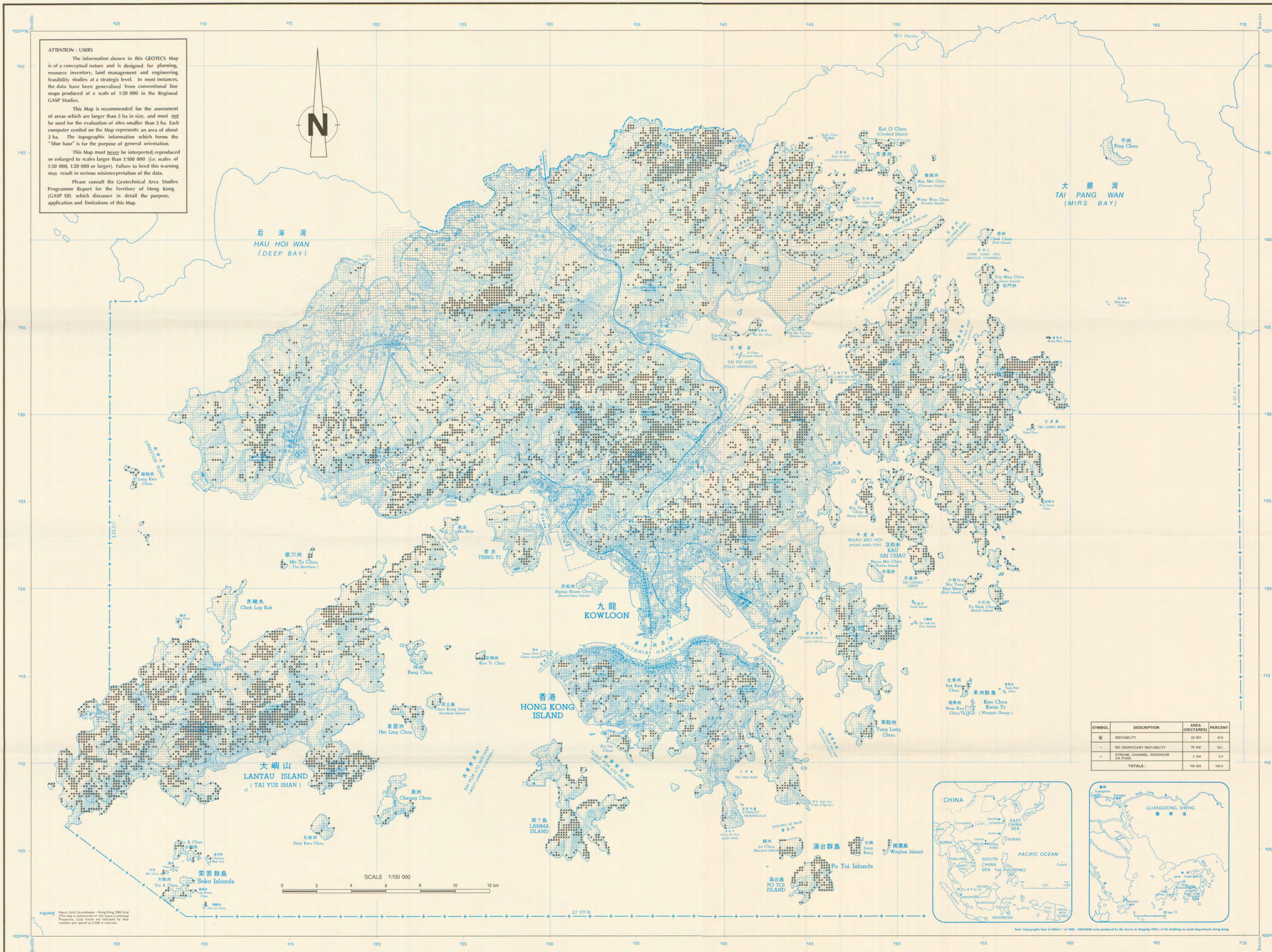

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SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
✳	INSTABILITY	23 523	21.6
·	NO SIGNIFICANT INSTABILITY	79 742	73.1
~	STREAM, CHANNEL, RESERVOIR OR POND	5 764	5.3
TOTALS :		109 029	100.0

Geotechnical Control Office
Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECS MAP 6 — SLOPE INSTABILITY
TERRITORY OF HONG KONG

Title : GEOTECS MAP 6 — SLOPE INSTABILITY	
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Map Ref. No : GASP / 100 / XII / 20	

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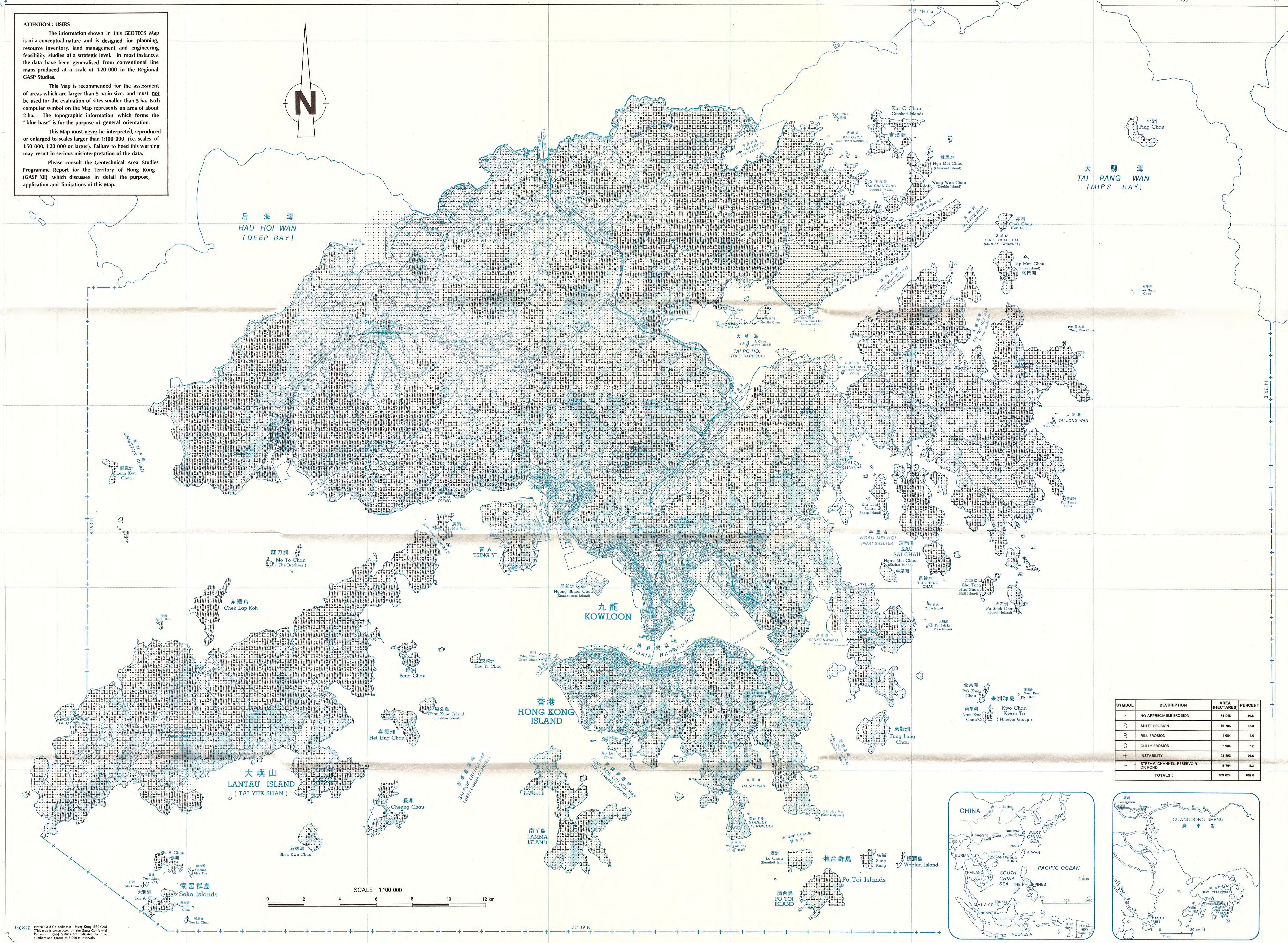

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SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
·	NO APPRECIABLE EROSION	54 048	49.6
S	SHEET EROSION	16 706	15.3
R	RILL EROSION	1 084	1.0
G	GULLY EROSION	7 904	7.2
+	INSTABILITY	23 523	21.6
~	STREAM, CHANNEL, RESERVOIR OR POND	5 764	5.3
TOTALS :		109 029	100.0

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Note: Topographic base is Edition 7 of 1988 - HM100DB series produced by the Survey & Mapping Office of the Buildings & Lands Department, Hong Kong.

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GEOTECS MAP 7 — EROSION
TERRITORY OF HONG KONG

Title : GEOTECS MAP 7 — EROSION	
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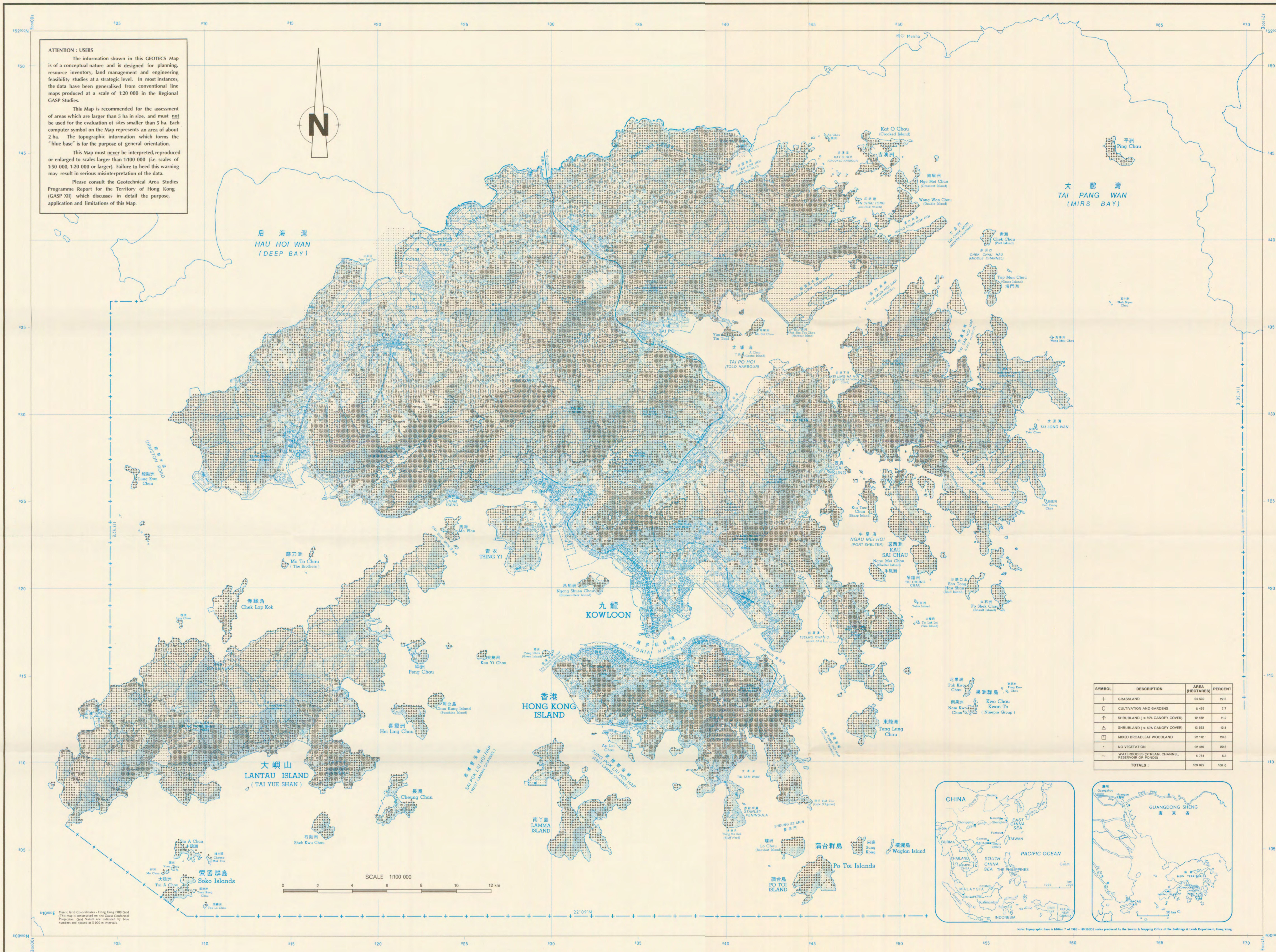

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SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
+	GRASSLAND	24 539	22.5
C	CULTIVATION AND GARDENS	8 459	7.7
个	SHRUBLAND (< 50% CANOPY COVER)	12 182	11.2
△	SHRUBLAND (> 50% CANOPY COVER)	13 563	12.4
⊓	MIXED BROADLEAF WOODLAND	22 112	20.3
•	NO VEGETATION	22 410	20.6
~	WATERBODIES (STREAM, CHANNEL, RESERVOIR OR PONDS)	5 764	5.3
TOTALS :		109 029	100 .0

Geotechnical Control Office

Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECS MAP 8 — VEGETATION

TERRITORY OF HONG KONG

Title : GEOTECS MAP 8 — VEGETATION

Compiled : K.A. Styles / A. Hansen

Drawn : S.P. Poon / S.S. Ho

Scale : 1 : 100 000

Date : November, 1988

Map Ref. No : GASP / 100 / XII / 21

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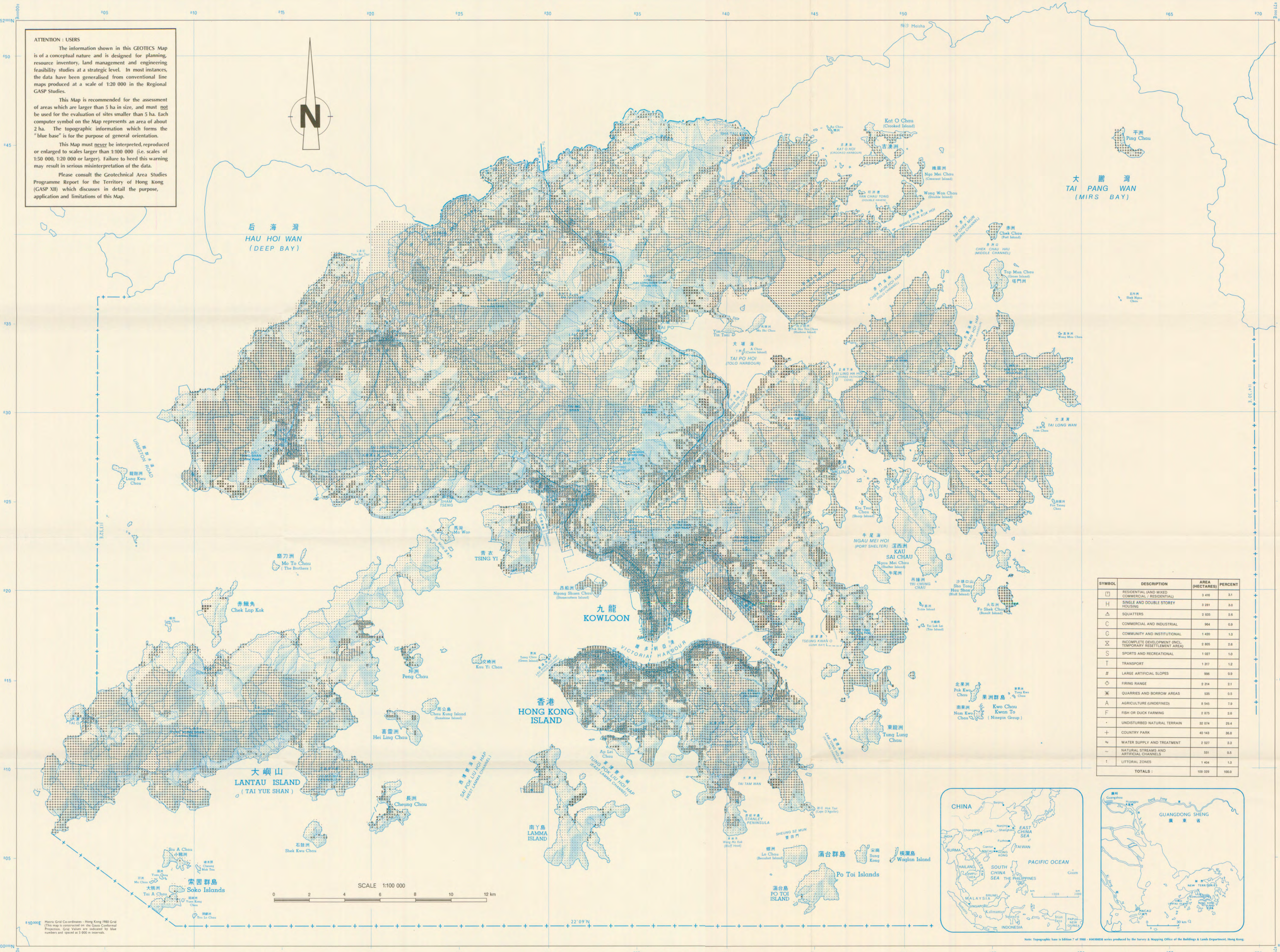


SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
⊡	RESIDENTIAL (AND MIXED COMMERCIAL / RESIDENTIAL)	3 416	3.1
H	SINGLE AND DOUBLE STOREY HOUSING	3 281	3.0
⚠	SQUATTERS	2 835	2.6
C	COMMERCIAL AND INDUSTRIAL	964	0.9
G	COMMUNITY AND INSTITUTIONAL	1 420	1.3
⧖	INCOMPLETE DEVELOPMENT (INCL. TEMPORARY RESETTLEMENT AREA)	2 805	2.6
S	SPORTS AND RECREATIONAL	1 027	1.0
T	TRANSPORT	1 317	1.2
#	LARGE ARTIFICIAL SLOPES	996	0.9
◇	FIRING RANGE	2 314	2.1
✳	QUARRIES AND BORROW AREAS	535	0.5
A	AGRICULTURE (UNDEFINED)	8 545	7.9
F	FISH OR DUCK FARMING	2 875	2.6
·	UNDISTURBED NATURAL TERRAIN	32 074	29.4
+	COUNTRY PARK	40 143	36.8
≈	WATER SUPPLY AND TREATMENT	2 527	2.3
~	NATURAL STREAMS AND ARTIFICIAL CHANNELS	551	0.5
:	LITTORAL ZONES	1 404	1.3
TOTALS :		109 029	100.0

Geotechnical Control Office

Civil Engineering Services Department

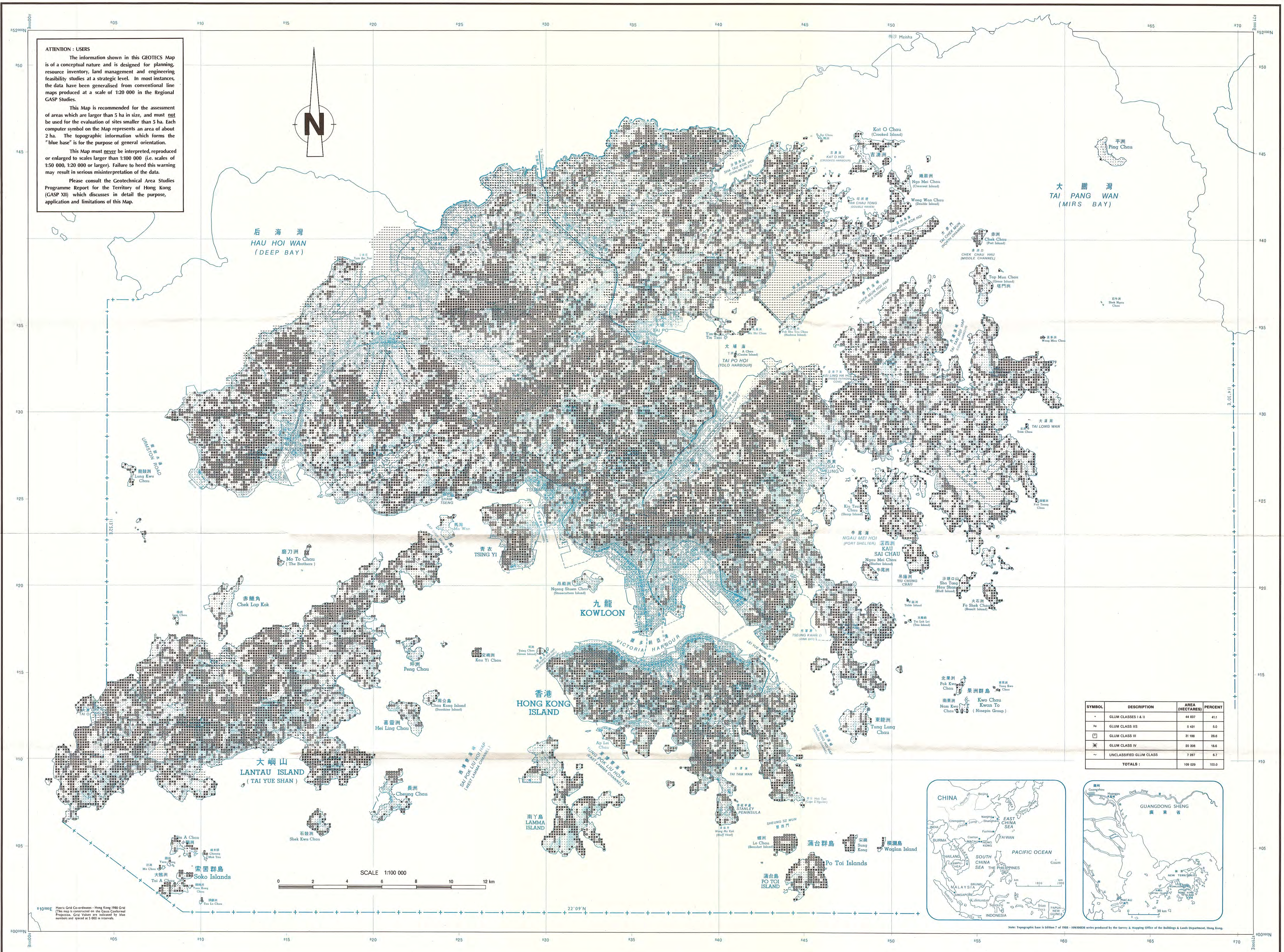
GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECHNICAL MAP 9 — LAND USE

TERRITORY OF HONG KONG

Title : GEOTECS MAP 9 — LAND USE	
Compiled : K.A. Styles / A. Hansen	Drawn : S.P. Poon / S.S. Ho
Scale : 1 : 100 000	Date : November, 1988
Map Ref. No : GASP / 100 / XII / 22	

Published by the Geotechnical Control Office, Civil Engineering Services Department, Hong Kong.



ATTENTION : USERS

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Please consult the Geotechnical Area Studies Programme Report for the Territory of Hong Kong (GASP XII) which discusses in detail the purpose, application and limitations of this Map.

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
•	GLUM CLASSES I & II	44 837	41.1
≈	GLUM CLASS IIS	5 431	5.0
⊡	GLUM CLASS III	31 188	28.6
✳	GLUM CLASS IV	20 306	18.6
~	UNCLASSIFIED GLUM CLASS	7 267	6.7
TOTALS :		109 029	100.0

Geotechnical Control Office

Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECS MAP 10 — GEOTECHNICAL LAND USE MAP

TERRITORY OF HONG KONG

Title : GEOTECS MAP 10 — GEOTECHNICAL LAND USE MAP	
Compiled : K. A. Styles / A. Hansen	Drawn : S.P. Poon / S. S. Ho
Scale : 1 : 100 000	Date : November, 1988
Map Ref. No : GASP / 100 / XII / 1	

Published by the Geotechnical Control Office, Civil Engineering Services Department, Hong Kong.

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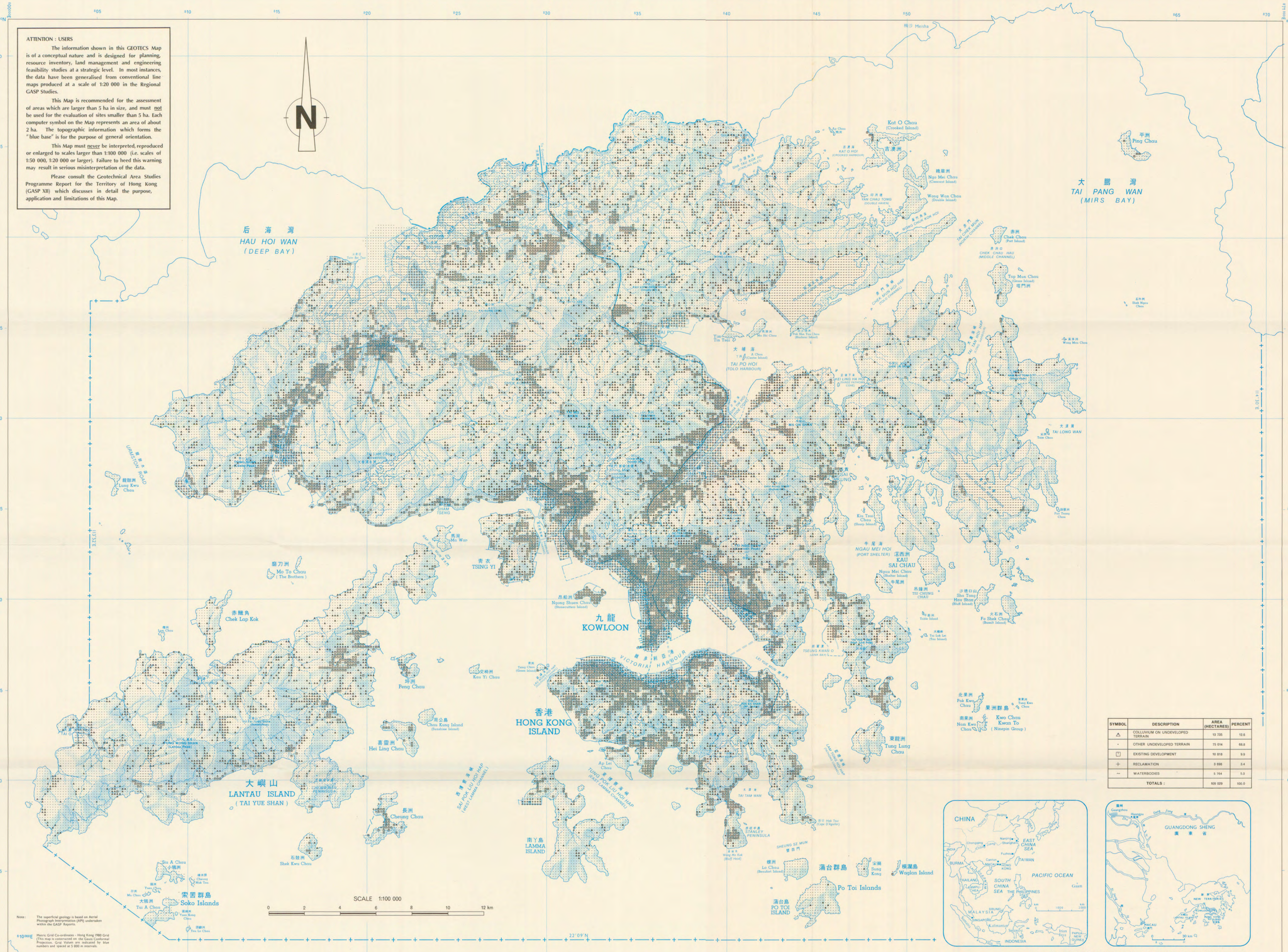

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
⚠	COLLUVIUM ON UNDEVELOPED TERRAIN	13 735	12.6
·	OTHER UNDEVELOPED TERRAIN	75 014	68.8
⍞	EXISTING DEVELOPMENT	10 818	9.9
+	RECLAMATION	3 698	3.4
~	WATERBODIES	5 764	5.3
TOTALS :		109 029	100.0

Note: The superficial geology is based on Aerial Photograph Interpretation (API) undertaken within the GASP Reports.

810000E Metric Grid Co-ordinates - Hong Kong 1980 Grid (This map is constructed on the Gauss Conformal Projection. Grid Values are indicated by blue numbers and spaced at 5 000 m intervals.

Note: Topographic base is Edition 7 of 1988 - HM100DB series produced by the Survey & Mapping Office of the Buildings & Lands Department, Hong Kong.

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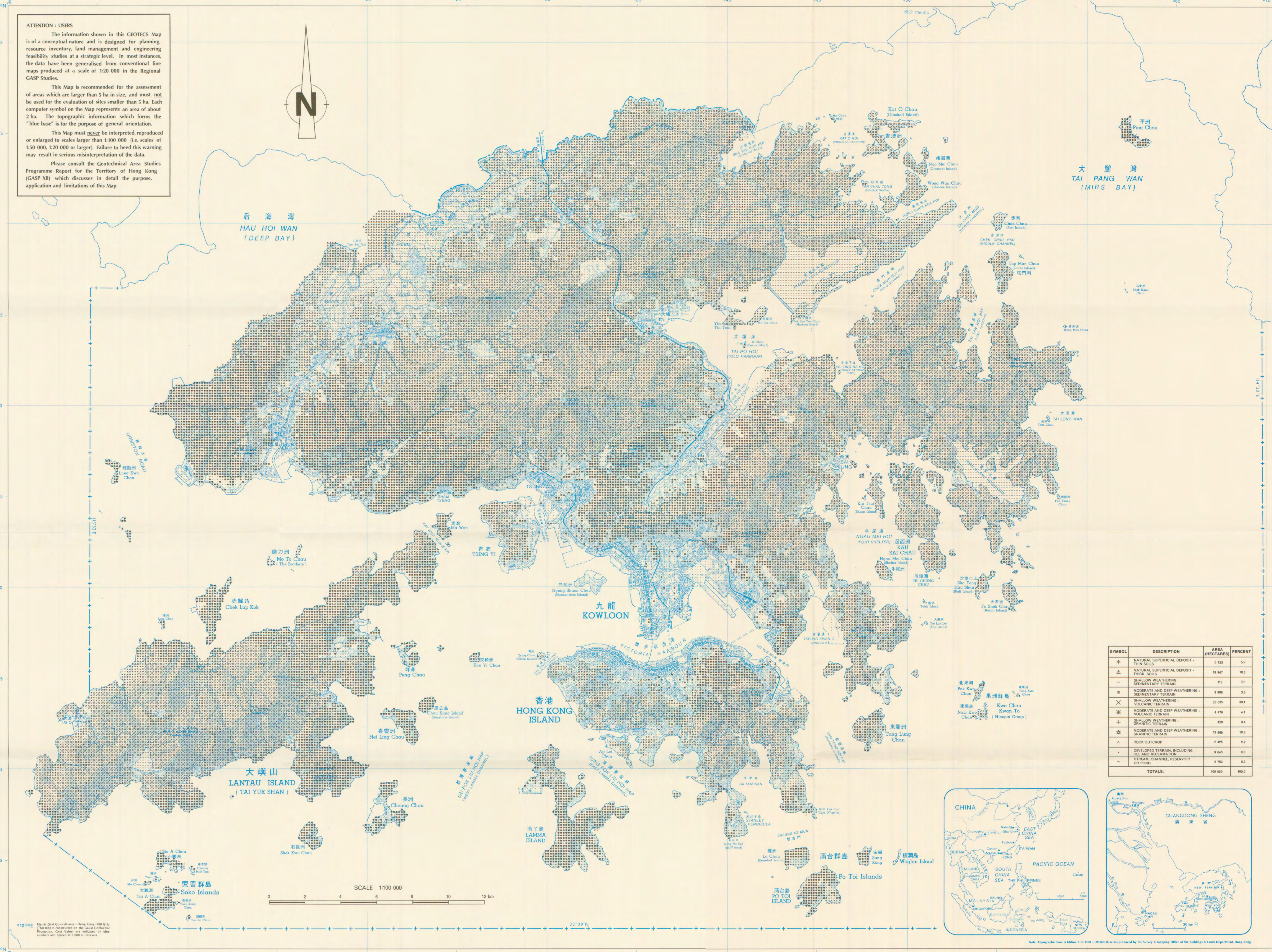
GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECS MAP 11 — COLLUVIUM ON UNDEVELOPED TERRAIN

TERRITORY OF HONG KONG

Title : GEOTECS MAP 11 - COLLUVIUM ON UNDEVELOPED TERRAIN	
Compiled : K.A. Styles / A. Hansen	Drawn : S.P. Poon / S.S. Ho
Scale : 1 : 100 000	Date : November, 1988
Map Ref. No : GASP / 100 / XII / 24	

Published by the Geotechnical Control Office, Civil Engineering Services Department, Hong Kong.



SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
⍏	NATURAL SUPERFICIAL DEPOSIT - THIN SOILS	6 425	5.9
△	NATURAL SUPERFICIAL DEPOSIT - THICK SOILS	19 947	18.3
−	SHALLOW WEATHERING : SEDIMENTARY TERRAIN	118	0.1
≡	MODERATE AND DEEP WEATHERING : SEDIMENTARY TERRAIN	3 906	3.6
×	SHALLOW WEATHERING : VOLCANIC TERRAIN	36 035	33.1
✳	MODERATE AND DEEP WEATHERING : VOLCANIC TERRAIN	4 476	4.1
+	SHALLOW WEATHERING : GRANITIC TERRAIN	420	0.4
✡	MODERATE AND DEEP WEATHERING : GRANITIC TERRAIN	19 869	18.2
^	ROCK OUTCROP	2 425	2.2
·	DEVELOPED TERRAIN, INCLUDING FILL AND RECLAMATION	9 645	8.8
~	STREAM, CHANNEL, RESERVOIR OR POND	5 763	5.3
TOTALS:		109 029	100.0

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Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECS MAP 12 — GENERALISED DEPTH OF WEATHERING ON UNDEVELOPED TERRAIN TERRITORY OF HONG KONG

Title : GEOTECS MAP 12 — GENERALISED DEPTH OF WEATHERING ON UNDEVELOPED TERRAIN	
Compiled : K.A. Styles / A. Hansen	Drawn : S.P. Poon / S.S. Ho
Scale : 1 : 100 000	Date : November, 1988
Map Ref. No : GASP / 100 / XII / 25	

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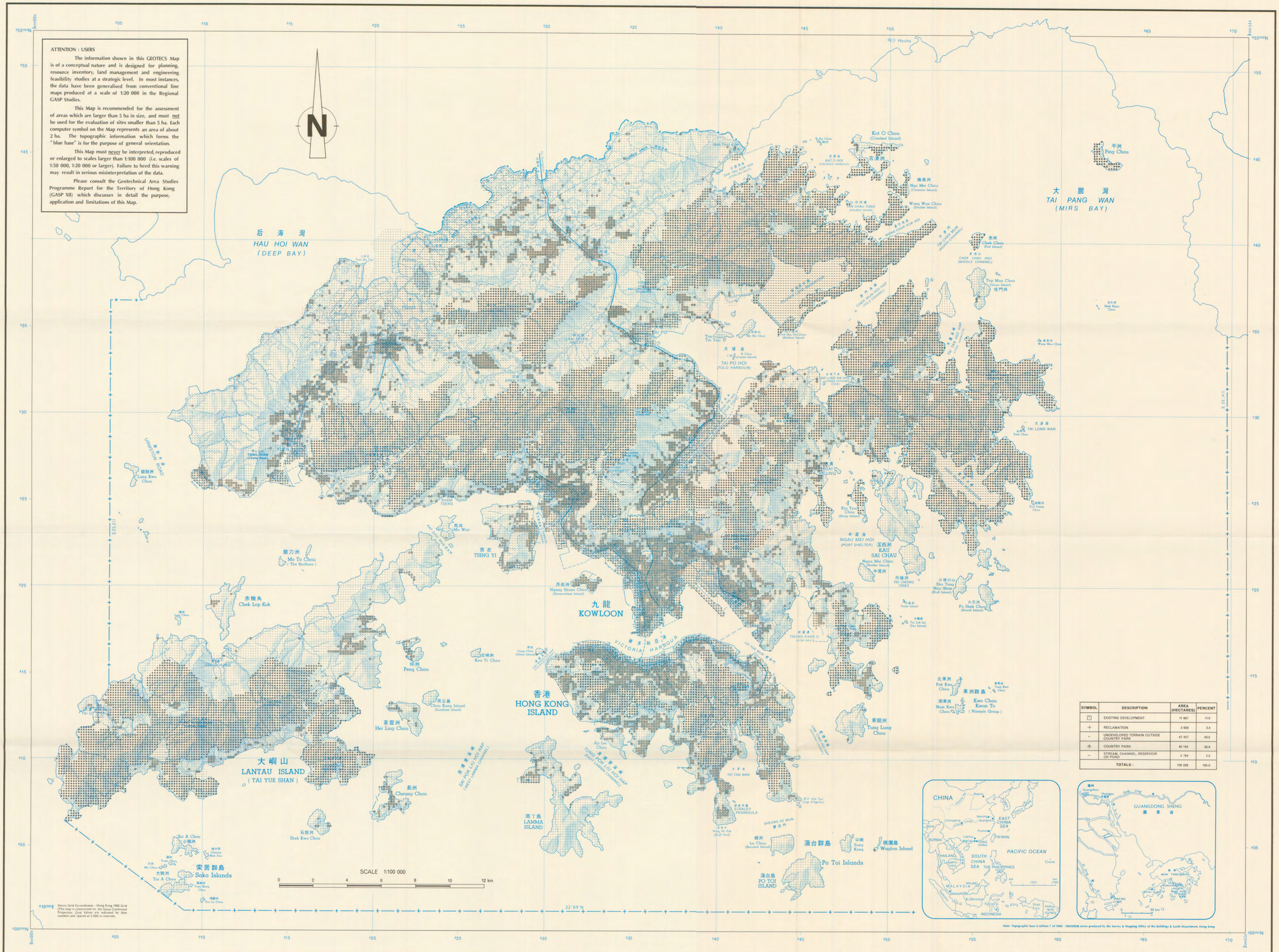

SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
⊓	EXISTING DEVELOPMENT	11 967	11.0
+	RECLAMATION	3 698	3.4
•	UNDEVELOPED TERRAIN OUTSIDE COUNTRY PARK	47 457	43.5
⍏	COUNTRY PARK	40 143	36.8
~	STREAM, CHANNEL, RESERVOIR OR POND	5 764	5.3
TOTALS :		109 029	100.0

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GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECS MAP 13 — EXISTING DEVELOPMENT, RECLAMATION, UNDEVELOPED TERRAIN AND COUNTRY PARK

TERRITORY OF HONG KONG

Title : GEOTECS MAP 13 – EXISTING DEVELOPMENT, RECLAMATION, UNDEVELOPED TERRAIN AND COUNTRY PARK	
Compiled : K. A. Styles / A. Hansen	Drawn : S. P. Poon / S. S. Ho
Scale : 1 : 100 000	Date : November, 1988
Map Ref. No : GASP / 100 / XII / 26	

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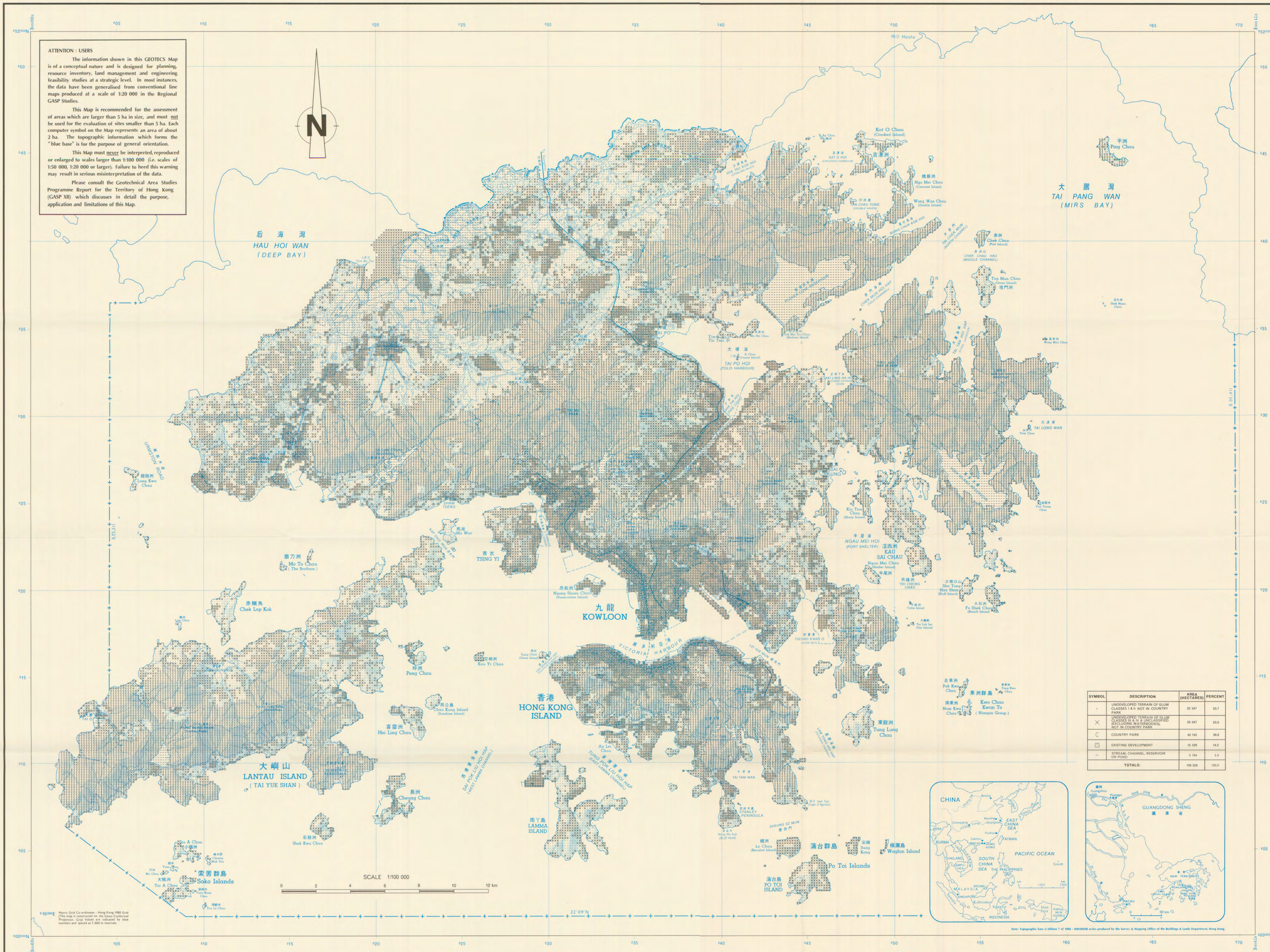

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SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
·	UNDEVELOPED TERRAIN OF GLUM CLASSES I & II NOT IN COUNTRY PARK	22 547	20.7
×	UNDEVELOPED TERRAIN OF GLUM CLASSES III & IV & UNCLASSIFIED (EXCLUDING WATERBODIES), NOT IN COUNTRY PARK	25 047	23.0
C	COUNTRY PARK	40 143	36.8
⊡	EXISTING DEVELOPMENT	15 528	14.2
~	STREAM, CHANNEL, RESERVOIR OR POND	5 764	5.3
TOTALS:		109 029	100.0

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GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECS MAP 14 — GEOTECHNICAL LIMITATIONS ASSOCIATED WITH UNDEVELOPED TERRAIN OUTSIDE COUNTRY PARK

TERRITORY OF HONG KONG

Title : GEOTECS MAP 14 — GEOTECHNICAL LIMITATIONS ASSOCIATED WITH UNDEVELOPED TERRAIN OUTSIDE COUNTRY PARK

Compiled : K.A. Styles / A. Hansen

Drawn : S.P. Poon / S.S. Ho

Scale : 1 : 100 000

Date : November, 1988

Map Ref. No : GASP / 100 / XII / 27

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