GASP Report II

Geotechnical Area Studies Programme

Central New Territories

Geotechnical Control Office
Civil Engineering Services Department
Hong Kong

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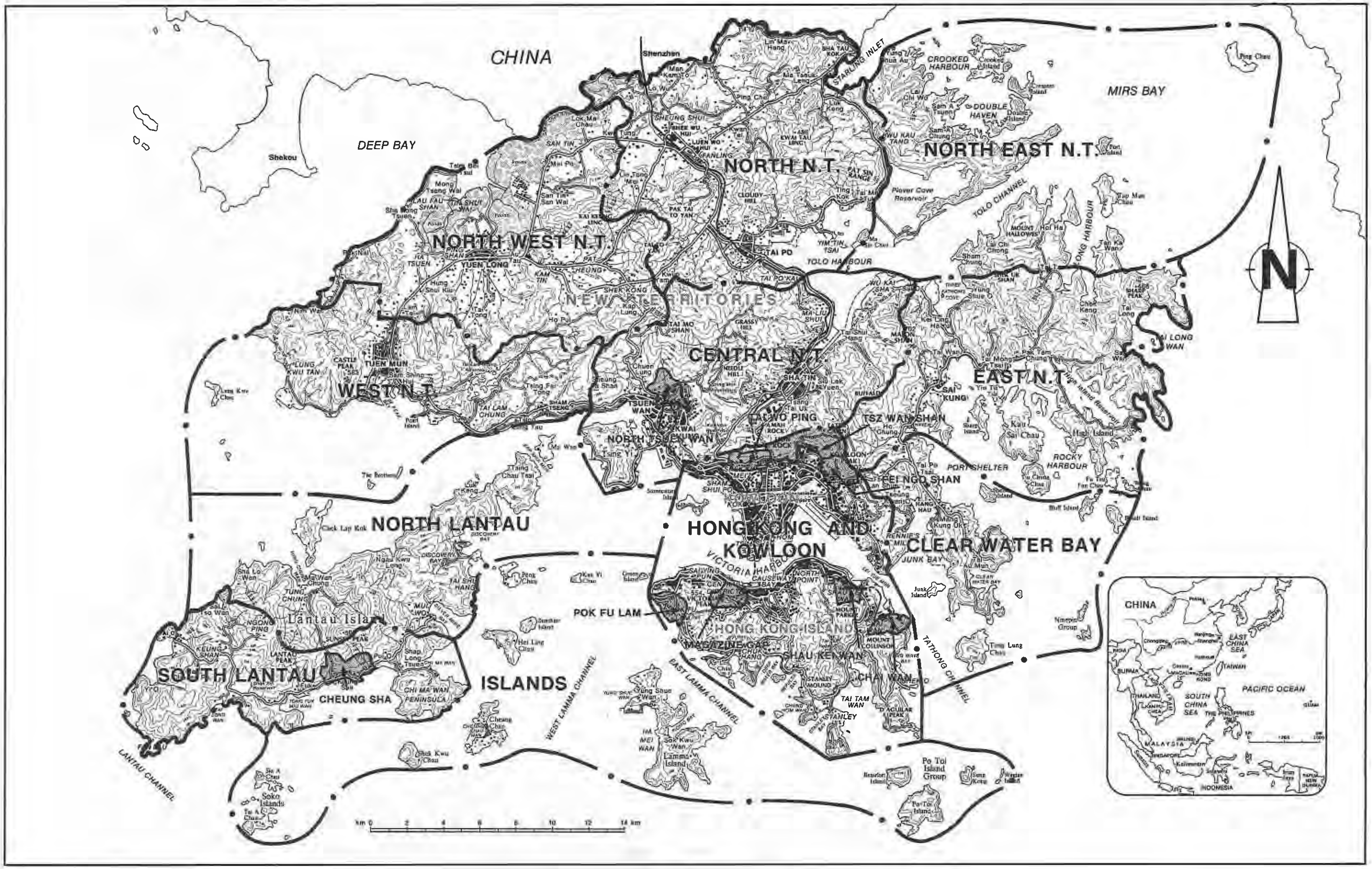

Map of the Territory of Hong Kong Showing the Locations of the Geotechnical Area Studies.
(Boundaries of the Regional Studies are shown by dashed lines and locations of District Studies are indicated by dark screens)

FOREWORD

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

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

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

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

This Report was originally produced in May 1985, for use within the Hong Kong Government on the basis of information assembled during the period March 1980 to October 1984. This fact should be borne in mind by users, who should also note that the contents of the Report have for the most part not been updated. Further, although every effort has been made to ensure the accuracy of the information contained in the Report, this cannot be guaranteed. The Geotechnical Control Office cannot therefore accept any liability for errors in the data or for misinterpretations made during the study.

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

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

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

E. W. Brand
Principal Government Geotechnical Engineer
September 1987

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1. INTRODUCTION

1.1 The Central New Territories Geotechnical Area Study

This Report presents the results of a 1:20 000 scale Regional Geotechnical Area Study of the Sha Tin to Tsuen Wan area which was carried out in the Geotechnical Control Office between March 1980 and October 1984. The area covered by the study, which is designated as GASP II, is shown in Figures 1 to 3.

The study is based primarily on:

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

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

(*c*) Field reconnaissance.

Subsurface investigations were not carried out specifically for this study.

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

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

1.2 The Geotechnical Area Studies Programme

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

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

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

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

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

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

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

1.3 Aims of the Geotechnical Area Studies Programme

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

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

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

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

1.4 Organisation of the Report

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

Section 2 describes the topography, geology, geomorphology, hydrology, vegetation, erosion and land use of the Central New Territories area. A detailed description of the Allen & Stephens (1971) geological units is provided in Appendix C.

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

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

The figures are designed to explain and demonstrate the system used for compiling the maps from the data. Figure 14 illustrates the system, and Figures 15 to 21 are extracts from the set of maps. The full size originals of these maps are held by the Geotechnical Control Office.

A selection of maps, plans, stereopairs and photographs follow the example figures in the report, and these are presented as Plates 1 to 19. These plates, together with Figure 2, provide a visual impression of the study area.

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

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

1.5 Maps Produced within the Regional Study

1.5.1 *General*

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

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

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

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

1.5.2 *Terrain Classification Map (TCM)*

This map records the general nature of the geological material (insitu, colluvial, alluvial, etc), slope angle, terrain component, erosion and instability. It forms the basis of the mapping system and is not designed for general distribution. The map is produced by aerial photograph interpretation and field work. An example is provided in Figure 15b.

1.5.3 *Landform Map (LM)*

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

1.5.4 *Erosion Map (EM)*

This map is totally derived from the Terrain Classification Map, and it delineates the broad pattern of erosion and instability at a scale of 1:20 000. It is designed for technical or non-technical users who require information regarding the general nature, degree and intensity of erosion and instability for planning and/or engineering purposes. An example is presented in Figure 21a.

1.5.5 *Geotechnical Land Use Map (GLUM)*

This map is totally derived from the Terrain Classification Map, and it delineates the general level of geotechnical limitation associated with the terrain at a scale of 1:20 000. It is designed for non-technical users who require general information relating to geotechnical difficulty of the terrain for development planning. A copy of the GLUM Classification System is presented at Table 1.1, and a detailed discussion is provided in Appendix A.7. An example of the map is provided in Figure 16a, and a copy of the map sheet is located in the Map Folder.

Table 1.1 GLUM Classification System

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

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

1.5.6 *Physical Constraints Map (PCM)*

This map is totally derived from the Terrain Classification Map, and it presents the major physical land resource constraints at a scale of 1:20 000. It is designed for technical or non-technical users who require information relating to the types of physical constraints which affect the terrain. It should be used in conjunction with the GLUM but is designed to stand alone as an assessment of the physical resources for general planning and engineering purposes. An example of this map is presented in Figure 17a and is discussed in detail in Appendix A.6. A copy of the map sheet is located in the Map Folder.

1.5.7 *Engineering Geology Map (EGM)*

Some of the information in this map is derived from the Terrain Classification Map, and some is compiled from other geological sources. This map displays the broad pattern of geological materials at a scale of 1:20 000. It is designed for technical users who require engineering geological information for strategic planning and engineering purposes. An example is presented in Figure 18a and is discussed in detail in Appendix A.8. A copy of the map is located in the Map Folder.

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

This map is prepared by an assessment of the terrain information recorded in the Terrain Classification Map, GLUM, PCM, EGM and current land management. This map evaluates the engineering-related factors which influence the potential of the terrain for future development. Areas with potential are identified at a scale of 1:20 000. The GLEAM is designed for technical and non-technical users who require information relating to the engineering suitability of the terrain for development. An example of the map is presented in Figure 19a, and a detailed discussion is provided in Section 4.2 and in Appendix A.9. A copy of the map is located in the Map Folder.

1.5.9 *Computer-generated Maps*

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

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

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

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

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

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

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

* Located in the Map Folder accompanying this Report.

1.7 GASP District Studies Relevant to the Study Area

One GASP District Study: Stage 1 has been undertaken within the study area at a scale of 1:2 500. The area covered is shown in Figure 3. Approximately 243 ha of the geotechnically problematical terrain within the Tsuen Wan area have been assessed, and the results are summarised in a general form in Table 1.3. Some 50% 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 160 landslips were recorded during the District Study.

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

Table 1.3 GLUM Classes and Landslips within the GASP District Study Located in the Central New Territories Regional Study Area

Study Area	District Stage 1 GASP Report No.	Geotechnical Limitation (GLUM Class—ha)				No. of Landslips	Total Area (ha)
		Low I	Moderate II	High III	Extreme IV		
North Tsuen Wan	11	45.8	76.2	96.1	24.8	163	242.9

1.8 Access to GASP Data

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

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

2. DESCRIPTION OF THE CENTRAL NEW TERRITORIES STUDY AREA

2.1 Geographical Location

The study area occupies approximately 13 368 ha situated in the central part of the New Territories as shown in Figure 1 and 2. It includes the major New Towns of Sha Tin and Tsuen Wan and, in addition, Kwai Chung and Tsing Yi Island.

The study area has common boundaries with the following Regional 1:20 000 Geotechnical Area Studies; West New Territories (GASP III), North West New Territories (GASP IV), North New Territories (GASP V), East New Territories (GASP IX) and Hong Kong and Kowloon (GASP I).

The eastern boundary is formed by the Ma On Shan to Tate's Cairn ridgecrest and the southern boundary is formed by the ridgecrest extending from Tate's Cairn through Lion Rock and Beacon Hill to the sea at Lai Chi Kok. The western boundary follows the ridgecrest from Approach Beach, north through Shek Lung Kung and Lin Fa Shan and eastwards to Tai Mo Shan. The boundary runs north from Tai Mo Shan to Ng Tung Chai and then continues eastwards following irregular ridgelines to the sea to the north of Tsiu Hang. The island of Tsing Yi is included in this study.

2.2 Topography

The majority of the area consists of two large basins, with the slopes of Tai Mo Shan draining southwards, and the Sha Tin valley generally draining to the northeast. Tai Mo Shan (957 m) dominates the landscape in the Central New Territories. Gently convex upper slopes on this mountain give way to steep upper sideslopes on both the northern and southern sides. Irregular ridges extend to the east and southwest of the main summit. Several parts of the southwest ridge exceed 500 m in elevation but still possess gently to moderately steep (15 to 30°) sideslopes with extensive midslope benches. The eastern ridge is offset approximately 700 m to the north from the southwest ridge and dips in the direction of Lead Mine Pass. Several major spurs trend approximately north to south under the influence of the drainage pattern.

Shing Mun (Jubilee) Reservoir lies along the fault controlled valley that continues through Lead Mine Pass. Needle Hill (532 m), forms the summit of the ridgeline to the east of the Shing Mun Reservoir. The Lower Shing Mun Reservoir separates Needle Hill from the low, undulating relief of the Kam Shan Country Park. Kam Shan (369 m), forms the summit of a minor southwest trending ridge, parallel to the Needle Hill ridgeline.

To the north of Sha Tin, up to and including the Tai Po Kau Nature Reserve, the relief extends to 647 m at Grassy Hill as long, moderately steep to gentle slopes (up to 35°). Many wide drainage plains exist within the upper parts of the valleys which have been extensively used for cultivation.

On the southeast side of the Sha Tin valley, the Ma On Shan to Tate's Cairn ridge has many steep-sided northwest spurs extending from the main northeast trending irregular ridgeline. The main peaks are Ma On Shan (702 m), the Hunch Backs, Ngong Ping Shan (536 m), Wong Ngau Shan (604 m), and Tate's Cairn with an elevation of 577 m.

The main summits along the Tate's Cairn to Eagle's Nest ridgeline are Lion Rock (495 m) and Beacon Hill (452 m).

2.3 Geology

2.3.1 *General*

The regional geology can be described simply as a sequence of faulted, folded, mildly metamorphosed volcaniclastic rocks (Repulse Bay Formation) that are extensively intruded by younger igneous rocks and partially overlain by a variety of superficial deposits. The volcanic rocks occur as roof pendants punctured locally and regionally by the underlying granitic batholith. The granitic rocks occupy a broad band trending northeast to southwest in the Sha Tin valley and around Tsuen Wan and Tsing Yi Island. The Repulse Bay Formation occurs principally on the upper slopes of this valley in the northwest quadrant of the study area. These relationships are illustrated in the geological cross-sections presented in Figure C1 in Appendix C.

The locations of the various geological materials are presented in the Engineering Geology Map located in the Map Folder of this Report. The general distribution of the major geological units is summarised in the GEOTECS Plot in Figure 6.

The geological boundaries for the bedrock geology are based on those mapped by Allen & Stephens (1971). The boundaries for the superficial deposits are drawn from aerial photograph interpretation, fieldwork and a review of borehole information carried out for this study (Styles, 1983).

The Geotechnical Control Office is currently preparing a new series of geological maps at a scale of 1:20 000 which will result in a more precise definition of the distribution of the geological units within the Territory. A considerable portion of the study area has been remapped as part of the revised Geological Survey of Hong Kong (Geotechnical Control Office, 1986; Addison, 1986).

As a precursor to the geological remapping programme Bennett (1984 a, b, c) reviewed the superficial deposits, weathering, stratigraphy, tectonic history and metamorphism in the Territory. Further general geological information is presented by Atherton & Burnett (1986) and Brand (1985). From an historical viewpoint Davis (1952) is still of considerable interest.

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

The bedrock materials have generally been subjected to severe weathering. The depth of decomposition is determined by the relative resistance of the individual lithological units and groundwater regimes in association with the local geological structure. The Tolo Harbour Formation appears to be the most deeply weathered and weathering fronts, in excess of 90 m below sea level, have been reported in Tide Cove.

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

2.3.2 *Metamorphic Units—Tolo Harbour Formation*

Although this formation does not outcrop on land within the study area, it has been encountered under areas of recent or proposed reclamation in the northeast of Tide Cove adjacent to the Ma On Shan New Town Development. From the limited information obtained from site investigation it appears to consist of very deeply weathered black shales and quartzites. The weathered products are generally overconsolidated black sulphurous clays and silts.

2.3.3 *Volcanic Units—Repulse Bay Formation*

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

(i) *Undifferentiated Volcanic Rocks (RB)*
A small area (159 ha) north of Buffalo Hill has been designated as Undifferentiated Volcanic Rocks. Weathering and material properties are expected to be similar to the rocks in the 'Dominantly Pyroclastic Rocks with Some Lavas' unit.

(ii) *Sedimentary Rocks and Water-laid Volcaniclastic Rocks (RBs)*
This unit occupies 2.7% (357 ha) of the study area principally in the north and northeast region around Tide Cove, with small outcrops on Tsing Yi Island and at Tsuen Wan. A wide variety of sedimentary rocks have been noted including orthoquartzites and cleaved grey shales. Weathering and jointing vary considerably within the rock type; the quartzites having the thinnest soils and the widest joint spacing.

(iii) *Acid Lavas (RBv)*
Horizons of dense, dark, columnar jointed rhyodacitic lava flows occur in the eastern part of the study area near Shek Na Shan. Only 0.8% (104 ha) of the study area is underlain by this rock unit. The rock is subject to shallow weathering and has moderately close, smooth joints.

(iv) *Mainly Banded Acid Lavas, some Welded Tuff (RBvb)*
This very minor rock unit occupies only 0.2% (20 ha) and occurs to the north of Pyramid Hill. It is a dark, finely banded rhyodacitic lava similar to the above unit.

(v) *Coarse Tuff (RBc)*
This rock unit occupies 11.7% (1 571 ha) of the study area and is mainly located around Tai Mo Shan and in a broad belt west of Tsuen Wan. The rock is generally a coarse tuff with light euhedral crystals of feldspar set in a fine dark matrix with occasional bombs. The rock usually occurs in thick, unstratified deposits. Weathering is moderately deep and joints are generally smooth.

(vi) *Agglomerate (RBag)*
This rock unit occupies 1.2% (155 ha) of the study area to the north of Tsuen Wan. It has a typically light greenish-grey fine matrix containing blocks and lapilli of a variety of different rock types. Jointing tends to be widely spaced and smooth and the rock is subject to moderately deep weathering with corestones.

(vii) *Pyroclastic Rocks with Some Lavas (RBp)*
Approximately 15.3% (2 050 ha) of the study area is underlain by this rock unit, with the principal occurrences in the north and west. The most common rock type is a fine-grained, grey to dark grey rhyodacitic tuff. Weathering tends to be shallow compared with the granitic rocks and jointing is smooth and closely spaced.

2.3.4 *Intrusive Igneous Units*

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

(i) *Tai Po Granodiorite (XT)*
This is considered to be the oldest of the intrusive rocks and occurs northeast of Tsuen Wan and on Tsing Yi Island. It occupies approximately 1.9% (253 ha) of the study area. The rock is a dark, coarse-grained, grey intrusive igneous rock that exhibits moderate to deep weathering, has widely spaced tectonic joints and rough sheeting joints.

(ii) *Sung Kong Granite (SK)*
This rock unit outcrops over a large area (11.3%, 1 514 ha) in the southern and central portions of the district and is centred on Sha Tin. Coarse and medium-grained phases are present. It consists of a pale grey to pink, porphyritic granite subject to deep weathering with widely spaced, smooth tectonic joints and rough sheeting joints.

(iii) *Cheung Chau Granite (CC)*
This rock unit occupies a large proportion (8.1%, 1 081 ha) of the northern shore of Tide Cove, Tsing Yi Island and the headland at Wu Kwai Sha Tsui. It consists of a pale grey to pink, coarse-grained, porphyritic granite that is subject to deep weathering and contains moderately to widely spaced, smooth tectonic joints and rough sheeting joints.

(iv) *Ma On Shan Granite (MS)*
This rock unit occupies 2.6% (351 ha) of the study area, principally around Ma On Shan. It consists of a grey, fine-grained, porphyritic granite subject to deep weathering and contains moderately to widely spaced smooth tectonic joints and rough sheeting joints.

(v) *Feldspar Porphyry (La)*
This rock unit, underlying 2.6% (351 ha) of the study area, can be found on Tsing Yi Island and in Tsuen Wan. It generally consists of a dark, fine-grained rock with numerous large, well-formed crystals of feldspar. The rock usually occurs in a complex swarm of separate dykes. Weathering is normally less deep than the granites and jointing is more closely spaced.

(vi) *Quartz Monzonite (Mo)*
This rock unit is rare in the study area, occupying 0.1% (16 ha). It is present in the form of elongate dyke-like bodies that trend northeast. It is a grey, medium-grained, feldspathic igneous rock subject to moderately deep weathering, extensive boulder development with moderately spaced smooth tectonic joints and rough sheeting joints.

(vii) *Needle Hill Granite—Fine-grained Porphyritic Phase (NH)*
This extensively exposed rock unit occurs in the southwest near Tsuen Wan and occupies 5.2% (698 ha) of the study area. It consists of a pink, porphyritic, fine to medium-grained granite that is subject to deep weathering and contains moderately to widely spaced smooth tectonic joints.

(viii) *Dolerite (D)*
This rock type is rare (less than 0.1%) within the study area and occurs in dykes near the Jubilee Reservoir, south of Shek Lau Tung and on Tsing Yi Island. It is a dark, strong, basic igneous rock that weathers to a red clay. Jointing tends to be closely spaced and normal to the dyke walls.

In total the intrusive igneous rocks outcrop across 4 021 ha and cover approximately 30.1% of the area.

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.

2.3.5 *Superficial Units*

In addition to the solid geology, both natural and man-made superficial deposits constitute some 32.8% (4 931 ha) of the land surface. These superficial deposits are classified as follows:

(i) *Colluvium*
The colluvial materials occur over 2 591 ha or 19.4% of the study area. These deposits are formed by gravity transport of rock and soil debris down slope, and occur as recent or relict deposits. They are very heterogeneous in their physical properties and, in this Report, are subdivided only on the basis of the parent rock type as follows:

(*a*) Volcanic colluvium (Cv)—This material occupies 10.1% (1 353 ha) of the study area, mainly in the northwest.

(*b*) Granitic colluvium (Cg)—The largest deposits of this material occur in the Sha Tin Valley. It covers some 5.5% (738 ha) of the study area.

(*c*) Sedimentary colluvium (Cs)—This material covers some 106 ha (0.8%) of the study area and is most common on the sideslopes of the Hunchbacks.

(*d*) Mixed colluvium (Cm)—This category contains all colluvium of mixed geological origin and makes no distinction between relative proportions of the parent materials. It occupies 3% (394 ha) of the study area.

(ii) *Alluvium*
An extensive area of alluvium is present to the southwest of Sha Tin and northwest of Tsuen Wan. These deposits contain recent sandy gravelly alluvium overlying older alluvial clays, silts and sands. A total of 216 ha (1.6%) of the area is covered by these materials.

Beneath Tide Cove and, to a lesser extent, beneath Rambler Channel, older alluvium is present under the marine deposits. The old alluvium is stratified and contains beds of silt, clay and sandy gravel.

(iii) *Marine Deposits*
On the sea bed and beneath reclamation, deposits of soft marine muds and shelly sands may be found.

(iv) *Littoral Deposits*
Littoral deposits of medium dense sand and gravel may be found near Wu Kwai Sha Tsui, Pak Shek Kok and beneath some areas of reclamation. These deposits form only 0.1% (14 ha) of the surface of the study area.

(v) *Reclamation*
Along the coastal areas of Tsing Yi Island, Tsuen Wan and Sha Tin extensive reclamation has taken place, Approximately 7.6% (1 022 ha) of surface of the study area is covered by reclamation. The material used for reclamation is highly variable in nature and may contain weathered and fresh rocks, old sea walls, mine waste and or refuse.

(vi) *Fill*
Associated with site formation and other engineering construction practices, fill has been placed over a total of 7.6% (1 010 ha) of the study area. The engineering behaviour of the material depends to a great extent on the degree of compaction at the time of emplacement.

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

A description of the geology of the entire Territory is available in the Report of the Geological Survey of Hong Kong (Allen & Stephens, 1971). This work is, of course, updated by the revised geological mapping (Geotechnical Control Office, 1986; Addison, 1986). A detailed description of the rock units is presented in Appendix C.

2.4 Geomorphology

2.4.1 *General*

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

Table B5 in Appendix B provides data on the distribution of the major landform units. The distribution of slope gradients is illustrated in the GEOTECS Plot Figure 5.

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

2.4.2 *Granitic Terrain*

Much of this consists of deeply dissected terrain, particularly on the slopes to the east and south of Sha Tin. Stream incision has produced long straight sideslopes with small basal concavities and narrow ridge convexities. In the areas of lower relief associated with the Kam Shan Country Park, the ridgecrests are more rounded, possibly as an indication of deeper weathering, but the major fault controlled valleys are still deeply incised and possess only shallow weathering mantles.

Many of the ridgecrests are subject to gullying of the granular soils, and in some cases incision may have originated along footpaths. Many large, rounded corestones exist on the slopes, particularly along ridgecrests. Although rock outcrops occur sporadically across the terrain, more continuous outcrops are found along the steeper drainage lines and as small cliffs on the steepest slopes. The distribution of slopes steeper than 30 degrees is shown on the Physical Constraints Map.

Granitic terrain also exists on the southern and eastern sides of Tsing Yi Island. The volcanic rocks that form the rest of the island have been extensively intruded by feldspar porphyry dykes with the result that parts of the terrain have a morphology similar to the rounded morphology of granitic areas of low relief. Deep weathering of ridgecrests is common and many boulders occur on sideslopes.

The terrain formed on the outcrops of Tai Po Granodiorite is characterised by steep slopes and narrow ridgecrests due to deep dissection. Weathering depths decrease markedly from the ridgecrest to the drainage lines.

2.4.3 *Volcanic Terrain*

Although many areas of steep, dissected volcanic terrain exist, small upland catchments occur above the level of slope oversteepening. These contain shorter, gentle slopes on the valley-sides, with colluvial infill in the valley floors and larger sideslope depressions. However, over much of the terrain, active erosion is occurring in the form of landslips including rockfalls, soil creep and slopewash, as the slopes are steep, often in excess of 35 degrees. The terrain is typically irregular in morphology with large rock exposures through a generally thin veneer of boulder scree deposits and clayey soil with a high percentage of rock fragments. Large boulders of volcanic rock are scattered over these upper slopes.

The area to the south of the summit of Tai Mo Shan and its southwest trending ridge contains the largest area with moderate slope angles, as shown in the GEOTECS Plot at Figure 5.

2.4.4 *Colluvial Terrain*

Colluvial deposits exist over approximately 19.4% of the terrain in the study area. Deposits are delineated if they are of significance to engineering at a scale of 1:20 000 (Styles, 1983). The mapped distribution is shown on the Physical Constraints Map and, the Engineering Geology Map, and is summarised on the GEOTECS Plot in Figure 6. A breakdown of the 2 591 ha of colluvial terrain according to slope angle is also summarised in Table B5 in Appendix B. Approximately 1 113 ha is less than 15° in slope angle and 275 ha is steeper than 30°. There is 1 203 ha within the 15 to 30° slope range. Almost 30% of the deposits which occur within the latter slope range are located on terrain which is subject to possible groundwater flow.

Colluvial deposits exist over much of the footslope terrain in the study area and occur as extensive blankets, such as at Wu Kai Sha and Wong Nai Tau. Some of the colluvial deposits may reach 30 m in thickness but they are often deeply dissected by valleys which contain many boulders. These boulders have been exhumed by erosion of the colluvial mass or may have been deposited by recent landslip activity. The amount of incision into the colluvial fans is dependent on the gradient and catchment area of the drainage system. Boulders are common on the surface of the majority of colluvial deposits.

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

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

2.4.5 *Alluvial Terrain*

The alluvial terrain is usually flat or gently sloping. There is a complex interrelationship between colluvium and alluvium and lobes of colluvium frequently interdigitate within the alluvial plain.

Some alluvium is obscured by disturbed terrain, and this is reflected separately in the area calculations (Table B5 in Appendix B). The terrain in these areas is usually flat or gently sloping but may also have a veneer of fill. Colluvial lenses or more extensive detrital bodies may also exist within the alluvial sequence, and both deposits may extend below the marine deposits.

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

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

The most common occurrence of this terrain is as the broad flat base to large valleys such as at Sha Tin. However, some areas of alluvium occur as small, isolated plains drained by streams with restricted outlets. An example of this type of terrain occurs on the high plateau below the Hunch Backs.

2.5 Surface Hydrology

The natural drainage regime has been greatly modified by development and the need to provide water supplies to the urban areas. From the mean annual rainfall data incorporated in the GEOTECS data base it is estimated that an average of 329 million m^3 of water falls within the Central New Territories study area per annum. Major modifications to the drainage system have included the creation of six large reservoirs, the construction of extensive catchwaters, development on footslope terrain and the formation of large areas of reclamation.

The main modification to the drainage system that is associated with development involves the covering of large areas with effectively impermeable materials. This has resulted in larger volumes of surface runoff as infiltration is reduced, and a shorter time to peak discharge following the onset of rainfall. A high density of drains to remove the large volumes of storm runoff are provided within the area. In addition, some natural drainage paths are channelised to improve their efficiency of discharge beyond the developed areas.

There are six reservoirs in the study area, the Shing Mun (Jubilee), the Lower Shing Mun and four smaller reservoirs in the Kam Shan Country Park. These are supplied by an extensive network of catchwaters and with the aid of several water tunnels form part of a complex water management system.

The boundaries of the major natural catchments are indicated on the Engineering Geology Map and are classified in accordance with the method devised by Strahler (1952) which is described in Appendix A. 8.

The largest catchment is formed by the Shing Mun and Sha Tin valleys. The southeastern slopes of Tai Mo Shan, the southwestern slopes of Grassy Hill and the western slopes of Needle Hill form the natural catchment for the Shing Mun (Jubilee) Reservoir. Apart from the upper valley, the Lower Shing Mun Reservoir has only a small natural catchment. The majority of streams that flow into the lower reaches of the Shing Mun River are subparallel, with long elongate catchments which drain moderately steep sideslopes.

Two fifth order catchments exist in the Sha Tin valley, one draining the eastern slopes of Grassy Hill and the other draining the slopes from Tate's Cairn to Turret Hill. Another fifth order catchment drains the slopes from Turret Hill to Ma On Shan and currently discharges into Tide Cove, however further reclamation will result in this stream discharging into an extension of the Shing Mun River Channel. These three catchments are approximately equal in size and shape with a well developed pattern of dendritic drainage. Runoff is concentrated along the lower reaches of the streams with resultant high peak discharges.

The Kam Shan Country Park has a very high drainage density, producing a fifth order catchment within a comparatively small area. However, the resultant discharge within the natural drainage system through Butterfly Valley has been modified by the presence of the four reservoirs within the drainage basin.

Directly south of the summit of Tai Mo Shan an elongate fourth order basin drains through Lo Wai. Steep slopes and the high annual rainfall on Tai Mo Shan (Appendix C.4) result in high discharges from this catchment. The catchments which drain the ridge that trends southwest from Tai Mo Shan have more gentle slope angles and longer drainage paths. Times to peak discharge are expected to be longer. The drainage pattern is slightly elongate in nature resulting in a spreading of the times to peak discharge in the main channel and nullah that carries the flow through Tsuen Wan.

For the most part, Tsing Yi Island has a radial drainage pattern. However, one small fifth order catchment exists which drains the northeast of the island and discharges into Tsing Yi Bay.

Two subcatchments exist on the northern slopes of Tai Mo Shan and Grassy Hill. These catchments ultimately drain through Tai Po. Slopes are steep, with a moderately dense drainage pattern. The remainder of these catchment areas are contained with in the North New Territories (GASP V) Study Area.

2.6 Vegetation

The vegetation of the study area is considerably affected by human activities and the present pattern represents significant variation from the natural regime. In this Report, a nine class classification system is used to distinguish broad categories of vegetation type. The spatial distribution of these groups is illustrated in the GEOTECS Plot in Figure 7 whilst Figure 4 shows their relative proportions. About 25.9% (3 458 ha) of the study area is devoid of vegetation due to man's disturbance. Denudation within the study area is generally the result of site formation and, to a lesser extent, man induced soil erosion. The data is presented in Table B7 at Appendix B.

The vegetation classes are as follows:

(i) *Grassland*
This class generally consists of indigenous or introduced grass species which occur naturally or after the clearing of shrubland or woodland. Grassland occupies 3 696 ha (27.6%) of the study area and occurs on the slopes of Tai Mo Shan, Ma On Shan and Pyramid Hill. However, scattered areas of grassland occur throughout the undeveloped areas of the district.

(ii) *Cultivation*
This class occupies 453 ha (3.4%) of the study area. Most of the agricultural activity has now ceased but some horticulture remains around Chuen Lung, Yuen Tun Ha and Wo Sheung Tun.

(iii) *Mixed Broadleaf Woodland*
This class may contain a wide variety of native and exotic species. Extensive areas of woodland occur on the hills above Tsuen Wan and to the west of the Jubilee Reservoir. Other large areas of woodland occur on the Hunch Backs and in the Tai Po Kau Nature Reserve. A total of 2 383 ha (17.8%) is covered by this class.

(iv) *Shrubland (Less than 50% Ground Cover)*
Shrubland occurs as regrowth on areas which have been affected by disturbance of one form or other. Shrubland generally develops after grassland, particularly in areas protected from hill fires. This class occupies 1 467 ha (11.0%) and is most common near Tai Shui Hang and above the Turret Hill quarry.

(v) *Shrubland (Greater than 50% Ground Cover)*
This class is similar to the above but is characterised by denser growth. It covers 1 377 ha (10.3%) and is scattered throughout the undeveloped land. Along the western shoreline of the Jubilee Reservoir and the southern shoreline of the Lower Shing Mun Reservoir there are extensive areas of this class.

(vi) *No Vegetation on Natural Terrain*
Predominantly bare soil which is presently, or has in the recent past, been affected by moderate or severe soil erosion is usually marked by an absence of vegetation. This terrain occupies 171 ha (1.3%) of the study area, mainly on ridge and spur crests and upper sideslopes.

(vii) *No Vegetation due to Man's Disturbance*
Approximately 3 458 ha (25.9%) of the study area is affected by development and associated activities. Existing development is discussed in Section 2.8.1.

(viii) *Rock Outcrop*
Areas of rock outcrop may contain sparse intermittent grass and shrubland vegetation but the terrain is predominantly rock with little soil. Rock outcrop is not a common class in this area and is restricted to the hills such as Ma On Shan and Pyramid Hill. A total of 116 ha (0.9%) is mapped.

(ix) *Waterbodies*
Natural streams, man-made channels and reservoirs occupy some 247 ha of the study 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 hazard of shallow slope failures (Carson & Kirkby, 1972). One significant effect of a substantial vegetation cover is that it reduces the degree of erosion on undisturbed natural terrain. The majority of the erosion observed on the natural terrain is associated either with minor disturbance by man (footpaths triggering gullying) or with minor gullying associated with the headward extension of drainage lines.

The variation in the vegetation pattern across the area is a product of the relationship between the soils, the microclimate (aspect, exposure and elevation) and human influence. Hill fires have reduced woodland vegetation to shrubland or grassland over much of the terrain. Even the low broadleaf woodland which does exist often has a high density of thin young trees, with a dense shrub ground cover associated with regrowth rather than the more open woodland associated with native stands.

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

2.7 Erosion and Instability

2.7.1 *General*

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

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

The areas affected by the severe forms of erosion and slope instability are shown on the Physical Constraints Map and the latter on the Engineering Geology Map. A summary of the distribution of erosion and instability is given in the pie charts in Figure 4, tabulated in Table B2 at Appendix B, and illustrated in the GEOTECS Plot in Figure 8.

Erosion and instability affect 40.8% (5 449 ha) of the study area. However, approximately 27.9% (3 724 ha) of the study area is currently developed, within which erosion is restricted to unprotected platforms and slopes. In addition to this, approximately 171 ha of natural terrain is subject to erosion.

2.7.2 *Erosion*

(i) *Sheet Erosion*
This form of erosion produces extensive areas of bare ground devoid of vegetation. Within the study area, sheet erosion occurs around Needle Hill and along the hills northwest of Sha Tin and, to a lesser extent, on Turret Hill. A total of 963 ha (7.2%) of the study area is affected.

(ii) *Rill Erosion*
This form of erosion is usually associated with cut and fill batters but may also occur on natural terrain. It is characterised by numerous subparallel drainage rivulets, which produce a striated appearance and result in significant soil loss. Within the study area, it is a minor class affecting less than 0.5% (63 ha) of the terrain. No geographic pattern is discernible.

(iii) *Gully Erosion*
This form of erosion produces deep dissection of the surface with consequent disruption of drainage and may precipitate slope instability. It is commonly associated with drainage lines and affects 8.0% (1 073 ha) of the study area.

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

2.7.3 *Instability*

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

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

Slope instability of some form or other is relatively common within the study area. Approximately 3 350 ha of the terrain displays some form of instability, and this represents 25.1% of the study area.

(i) *Well-defined Landslips*
Within the study area, 'well-defined landslips' occupy only 18 ha (0.1%) of the land surface. The largest landslips are located near the now abandoned Ma On Shan Mine.

(ii) *Coastal Instability*
This form of instability is usually associated with marine erosion and undercutting of coastal slopes. There is extensive reclamation along the coastal margins within the study area and therefore, this form of instability is not common, only 8 ha are affected. Evidence of this form of instability occurs along the north coast of Tsing Yi Island.

(iii) *General Instability—Recent*
This form of instability relates to colluvial and insitu terrain where many failures and other evidence of instability occur, but it is not possible to show them as discrete units on a 1:20 000 scale map due to their small size. This class occupies 3 229 ha (24.2%) of the study area and is common in the Shing Mun Country Park, around the Hunch Backs and on Tsing Yi Island.

(iv) *General Instability—Relict*
This form of instability occupies 0.7% (94 ha) of the area, but it does not appear to follow any particular geographical pattern. This class is no less important in terms of constraints upon development than general instability-recent, as it may be reactivated by construction or earthworks.

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

2.8 Land Use

2.8.1 *Existing Development*

Within the Central New Territories study area there are a number of areas where large scale 'New Town Development' is occurring or is planned. It also contains very large areas of essentially undisturbed terrain within the bounds of Country Parks or Nature Reserves. Existing land use has been mapped using aerial photographs in combination with other sources within this Report and is stored in the GEOTECS inventory. Linear features such as roads, railways and streams tend to be under-estimated in the inventory because they rarely occupy the largest proportion of the 2 ha grid cell which forms the basic unit of the data bank. The GEOTECS Plot in Figure 9 shows the approximate distribution of existing land use groups within the study area. The distribution of existing land use with respect to geotechnical limitations (GLUM class) is discussed in Section 2.8.2. The distribution of broad land use groupings is shown in the pie chart at Figure 4 and is summarised in Table B12 in Appendix B.

To ease population pressure on the older urban areas New Towns have been established with a high proportion of residential development. Public housing estates occupy approximately 261 ha (2.0%) and multi-storey private residential development and mixed commercial and residential development occupies a further 189 ha (1.4%). Low intensity residential development occupies a further 549 ha (4.1%). In total, residential classes form 7.5% of the study area and comprise the largest group of the 'developed' classes.

Industrial development covers 218 ha (1.6%) and is primarily concentrated around Kwai Chung and Tsing Yi Island with smaller but rapidly expanding areas in Sha Tin. The extensive container wharf facilities at Kwai Chung and Tsing Yi occupy some 127 ha of study area and are associated with industrial activity. The exclusively commercial development occurs in the older parts of Tsuen Wan and Tai Wai and is associated with 10 ha of land.

Squatters occur around the east of Sheung Kwai Chung below Ma Tsz Keng and north of Tsuen Wan. A total of 104 ha is occupied by squatters and this represents 0.8% of the study area. There are difficulties in distinguishing squatters from other single storey village development using aerial photographic interpretation, therefore the actual area occupied by squatters is probably somewhat higher.

The largest recreational facility within the study area is the Sha Tin Racecourse. Smaller recreational facilities are scattered throughout the urban area. A total of 179 ha of recreation facilities are mapped in the study area.

Small areas devoted to horticulture remain at Lok Wu Sha, Ngau Wu Tok, Chuen Lung and Ta Tit Yan. Many of these cultivated area are sites of potential or planned development and may disappear in the future. At the time of data collection, approximately 465 ha (3.5%) was under cultivation.

The extent of current land development and the area under temporary use provides an indication of the current level of construction activity. A total of 432 ha (3.2%) is subject to site formation or is allocated to temporary use pending construction. Most of this development and temporary allocations are in the Sha Tin New Town area but a large portion of Tsing Yi Island is also included.

Land used for water storage and treatment covers 147 ha (1.1%) and this principally represents the large storage areas of the Jubilee Reservoir, the Lower Shing Mun Reservoir and the smaller reservoirs in the Kam Shan Country Park.

Outside the developed areas there are 5 370 ha (40.2%) of Country Park and 3 760 ha (28.1%) of undesignated undeveloped land. These two classes constitute the largest proportion of the study area and their development potential is discussed in Section 4.2.2. Their distribution is shown in the GEOTECS Plot in Figure 9.

2.8.2 *GLUM Class and Existing Land Use*

The distribution of GLUM classes is shown in the Geotechnical Land Use Map contained in the Map Folder. The general distribution of the four classes is shown in the pie chart in Figure 4. The relationship between existing land use and GLUM class is tabulated in Table B13 in Appendix B. The following is a summary of the geotechnical characteristics of the terrain associated with the current principal land uses.

(i) *Natural and Undeveloped Areas*
Some 9 644 ha (72.1%) of the area is undeveloped, and of this some 33.7% is subject to high geotechnical limitations (GLUM Class III), 34.9% is affected by extreme geotechnical limitations (GLUM Class IV), 29.0% is influenced by moderate geotechnical limitations (GLUM Class II) and 2.2% has low geotechnical limitations (GLUM Class I).

(ii) *Squatters*
Squatters appear to be located on 104 ha and this represents only 0.8% of the study area. Approximately 58.7% of the terrain occupied by squatters is classified as subject to high to extreme geotechnical limitations. The distribution of squatters on land with potential for development, within the Central New Territories study area, is illustrated in the GEOTECS Plot in Figure 12. In the study area, it is difficult to distinguish between squatters and single storey village developments using aerial photograph interpretative techniques. There are an additional 333 ha occupied by single storey residences which, in fact, may be squatters. When both land uses are combined the distribution of GLUM classes is as follows; 0.9% GLUM Class 1, 40.3% GLUM Class II, 48.1% GLUM Class III and 10.7% GLUM Class IV.

(iii) *Residential*
Excluding squatters and single storey development approximately 4.0% of the area is occupied by residential development. This development is concentrated on the lower footslope terrain and reclamation and is associated with the New Towns. Consequently, a high proportion of land occupied by residential development occurs on GLUM Classes I & II. The GLUM class distribution is 4.1% in GLUM Class I, 63.4% in GLUM Class 11, 31.8% in GLUM Class III and 0.7% in GLUM Class IV.

Two storey village houses in remote locations account for some 60.6% of the residential land in GLUM Classes III & IV.

(iv) *Commercial and Industrial*
Within the area there are 346 ha used for commercial or industrial purposes (2.6%). The GLUM class distribution is 7.8% in GLUM Class I, 75.7% in GLUM Class II, and 16.5% in GLUM Class III. The location of industrial and commercial activities on reclamation in Tsuen Wan and Sha Tin is reflected by the high proportion of GLUM Class II terrain.

(v) *Recreational*
Sporting facilities and urban recreational areas occupy 179 ha. These areas tend to be concentrated on reclamation and this is reflected in the high proportion of GLUM Class II terrain. The GLUM class distribution is 1.1% GLUM Class I, 87.7% GLUM Class II, and 11.2% GLUM Class III.

(vi) *Community and Institutional*
Community institutions, such as schools and hospitals, occupy only 0.5% (63 ha). The location of the Chinese University on steep terrain results in a relatively high incidence of GLUM Class III terrain in this group. GLUM Class II terrain occupies 71.4% and GLUM Class III terrain occupies 28.6% of the useful area. Large artificial slopes have been assigned to a separate Land Use category.

(vii) *Cemeteries*
These only occupy a small proportion of the study area (0.2%). They involve little disturbance to the natural terrain and generally occur on GLUM Class III terrain.

(viii) *Transportation*
Roads and railways occupy a significant proportion of the urbanised area but are rarely mapped as discrete units, because, they usually occupy only a small proportion of the basic 2 ha grid cell. A total of 396 ha is mapped for transportation services. The GLUM class distribution is 10.9% in GLUM Class I, 69.2% in GLUM Class II, 19.4% in GLUM Class III, and 0.5% in GLUM Class IV.

(ix) *Service Facilities*
This group includes service reservoirs and sewage treatment works, however, the large water supply reservoirs are unclassified within the GLUM system. One large sewage treatment plant is located on reclamation and is therefore classified as GLUM Class II, another is located on a cut and fill platform at the southwestern end of the Sha Tin valley. The service reservoirs have been designated as GLUM Class III.

(x) *Quarries and Borrow Areas*
This land use group occupies approximately 105 ha, although some former borrow areas are now used for construction purposes or are classified as incomplete development, or artificial slopes. The borrow areas are mainly on GLUM Classes II and III terrain whereas the quarry floors are principally classified as GLUM Class II terrain.

(xi) *Incomplete Development*
Construction zones, areas of vacant reclamation and other temporary uses occupy approximately 955 ha (7.1%) of the area. The intensive construction activity with in the New Town areas is reflected by this figure. The GLUM Class distribution is 7.9% in GLUM Class I, 79.0% in GLUM Class II, 12.0% in GLUM Class III, and 1.1% in GLUM Class IV.

2.8.3 *Future Development*

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

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

Statutory restrictions on development, as in Country Parks and designated 'green belt' areas, together with the natural constraints of the terrain, result in limiting the availability of land for development.

Within the study area there are two large nucleii of current and planned development. These are the Sha Tin and Tsuen Wan New Towns. In addition to these major areas, substantial areas of development are located on Tsing Yi Island and near Ma On Shan.

Large reclamations are planned for the north and east of Tsing Yi Island, and across the channel, at Tsuen Wan. Reclamation is also underway near Ma On Shan and northwest of the Chinese University. Once ground settlement has occurred these areas should have few physical restrictions for future development. Adjacent to the reclamation near Ma On Shan, extensive developments are proposed on the terrain that has been extensively altered by borrow activities.

Developments proposed for Tsing Yi Island include extensive cut platforms and reclamation out to Nga Ying Chau. Two bridges are proposed and the north of the island has been considered as a link to North Lantau. A new northeast to southwest road is also planned that will aid access to areas of potential development.

The Ma On Shan New Town will involve major new construction of high and medium density residential development, with associated community facilities.

3. ASSESSMENT OF MATERIAL CHARACTERISTICS

3.1 Description and Evaluation of Natural Materials

3.1.1 *General*

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

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

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

(i) *Weathering*
Within the regional context, it is important to appreciate the influence of local features on determining the actual depth of weathering at a particular location. The descriptions given in column 7 of Table 3.1 are for general guidance only. For example, volcanic rocks normally weather to depths of about 10 m but rock outcrops such as on Ma On Shan or Pyramid Hill 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 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 rock exposed in their beds due to incision 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 remnant from a previous 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 A3 in Appendix A.

(ii) *Erosion, Instability and Geology*
The different geological materials are subject to various degrees of erosion and instability (Randall & Taylor, 1982; Rodin *et al*, 1982; Richards & Cowland, 1986). This is reflected in the relative proportions of the various geological materials present in eroded or unstable areas and, conversely, the proportions of erosion and instability occurring within each geological class. These factors are illustrated in Figures 4 and 8 and tabulated in Appendix B, Table B11. The Area Instability Index presented in the table indicates the percentage of each rock type affected by instability.

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

(iii) *Material Resources*

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

A broad division can be based on whether the material is 'soft' or 'hard', and this relates to the mode of extraction. Soft material can be economically extracted in volume by machine methods. Hard material requires blasting prior to extraction. In Section 4.2.4 of this Report, a method of identifying potential quarry sites is given in the GEOTECS Plot in Figure 13.

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

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

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

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

(*c*) Colluvium.

(*d*) Intrusive igneous rocks.

(*e*) Volcanic and volcaniclastic rocks.

(*f*) Metamorphic 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 study area. 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.

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

Within this study, a large area of reclamation consists of sanitary landfill. This material, mixed with layers of natural borrow may be subject to large and unpredictable settlements.

Fill is a natural material that provides site formation above the general level of the terrain. The location of fill is shown on the Engineering Geology Map 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 down slope and allowed to accumulate at its angle of repose, in much the same way as natural colluvium. The resultant poor compaction and loose structure resulting from this practise 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 advisable 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.

3.1.3 *Characteristics of Alluvium, Littoral and Marine Deposits*

In the study area, these natural materials occur as thin, flat-lying recent deposits that have 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 study area 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 was evident on the terrestrial deposits but alluvium is erodible if hydrological conditions are adversely altered by construction activity.

All steep-sided excavations require strutting as these superficial materials have little 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 appropriate piling technique used to transfer high loads will be dependent on the overall stratigraphy but nearly all members of this group are amenable to driven piles. The materials in this group are easily excavated by machine methods. Marine deposits of sand, such as those in Tide Cove, have been extracted or covered by reclamation and the marine silts and clays are generally unsuitable as hydraulic fill. The siting of villages and proposed large scale developments such as the Ma On Shan New Town 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, with the exception of littoral deposits which are subject to marine erosion.

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 and in Appendix C.1.3.

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

Relict colluvium may be considerably weathered but recent colluvial deposits, especially those occurring in the beds of fast flowing streams, may contain very little weathered material. Relict colluvium, in a lobe near Wu Kai Sha, is considerably weathered and has significantly different geotechnical properties compared to the fresh bouldery colluvium found in streambeds on Tsing Yi Island.

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

From an examination of Tables B10 and B12 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 are generally subject to a high water table. There does not appear to be any difference in the susceptibility to erosion of granitic colluvium as compared to colluvium derived from volcanic rocks.

Table 3.1 Description and Evaluation of Geological Materials

MATERIAL DESCRIPTION							EVALUATION OF MATERIAL		
Type	Age	Symbol	Map Unit	General Lithological Description	Topographic Form	Weathering and Soil Development	Material Properties	Engineering Comment (Stability, Foundation, Hydrogeology)	Material Uses and Excavation Characteristics
SUPERFICIAL DEPOSITS	QUATERNARY – RECENT?	R	RECLAMATION/FILL	Generally local or imported borrow of colluvium, decomposed volcanics or plutonics and crushed quarry rock. Often a mixture of silt, sand, gravel and cobbles. Some building waste, mine waste or sanitary fill also included.	Extensive planar deposits adjacent to coast (reclamation) or as platforms and adjacent slope (fill) in otherwise undulating terrain.	These materials placed by man have no soil (pedogenic) or weathering profile but may contain weathered rocks or be underlain by natural superficial deposits and/or a pre-existing weathered profile.	These materials are highly variable dependent on source of fill. Generally they can be described as low fines, low plasticity granular cobbly soils. Relative density is dependent on method and degree of compactive effort. Ø ≅ 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 pile foundations. Settlement problems minor except in sanitary fill, which may have associated leachate and gas problems.	These areas, when properly formed, provide platforms with high development potential. Care should be taken in excavation of sanitary landfill when biodegradation is incomplete.
SUPERFICIAL DEPOSITS	QUATERNARY – RECENT?	L	LITTORAL DEPOSITS	Essentially beach and dune sand with occasional gravel horizons.	Deposits are very local in nature and generally confined to the intertidal zone, forming beaches and sandbars. Occasionally raised beaches may occur.	Nil	Generally sand sized granular material, often uniformly graded and well rounded.	Too restricted in size and distribution to be of significance.	Main development potential is as beaches for recreational purposes. Excavation of these materials usually prohibited.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	A	ALLUVIAL DEPOSITS	Generally brownish-grey silty sand with subangular gravel. Occasionally contains cobble and boulder horizons.	Material forms broad floodplains with local fan deposits upslope. May be present more continuously as horizons interdigitated with marine muds or forming channel infill deposits.	In subaerial locations very minor development of soil 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' ≅ 0 - 10 kPa, Ø' ≅ 20 - 25°.	Materials are usually saturated and of a low density - clay layers are normally consolidated. Buried channels may pose local problems of high water flows into tunnels or excavations. Steep excavations require support.	Land deposits easily excavated. Marine deposits often form reasonable hydraulic fill. Excavation by cutter, suction or bucket dredger.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	M	MARINE SEDIMENTS	Usually dark grey silty sand or clay with traces of shell fragments, and some sand horizons, especially near shore.	Seabed sediments of variable thickness (0-10's of metres) below low tide mark.	Nil	Usually a soft to very soft normally consolidated soil with a high moisture content and high plasticity (LL > 50%), clay content ranges from 20 - 35%, silt content from 50 - 70%. Cu < 10 kPa, c' ≅ 0 - 5 kPa, Ø' ≅ 25°. SPT < 10 but increases with depth.	Material is poor to unsatisfactory for hydraulic fill. It is also poor as a foundation because of settlement and bearing capacity problems. May be susceptible to mud wave if fill is end-tipped onto it. Consolidation may be aided by wick drains and/or surcharge loading.	Easily excavated using bucket or possibly suction dredger where necessary. Sandy deposits may be used in construction but silt and clay may pose problems of disposal.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	C	COLLUVIUM: VOLCANIC DERIVED; GRANITIC DERIVED; MIXED	Composed of a range of materials which vary from boulder colluvium, to gravelly colluvium with clay and sand, to finer textured gravelly sands and clay slopewash. The boulder colluvium with sand and gravel occurs on the higher sideslopes, while the gravelly sands, sandy silts and clays are to be found on the middle to lower sideslopes and on footslopes.	Mainly occupies the lower sideslope and footslope terrain and may underlie much of the alluvial floodplain. Generally gentle to moderately steep, broad, low, rounded, dissected outwash-fans and interfluves with undulating and hummocky surfaces; elsewhere irregular planar to shallow concave colluvial footslopes, leading upslope to gentle to moderately steep outwash slopes.	Colluvium can occur as independent deposits of a unique age such that one deposit overlies another. The older deposits may be subject to severe weathering and may be completely decomposed to a mottled, coloured sand 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/m^3. 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' ≅ 0 - 5 kPa, Ø' ≅ 29 - 42°. Standard compaction values : OMC ≅ 17 - 20%, MDD ≅ 1 630 - 1 750 kg/m^3. CBR ≅ 3 - 8%.	Material that 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. SI difficult and expensive.	May be used for borrow due to its ease of excavation by machine, broad grading characteristics and relative ease of access on hillsides. Some stream fill bouldery deposits will be of limited use. Large boulders may require blasting or splitting.
	CRETACEOUS TERTIARY	D	INTRUSIVE IGNEOUS ROCKS – DYKE ROCKS: DOLERITE	Black to very dark grey, fine to medium grained rock. Smooth joints normal to boundaries result from cooling.	Forms linear shallow depressions or ridges due to differential weathering compared to country rocks.	Weathers deeply to a dark red silty clay.	No laboratory information available. Weathered mantle will contain a high proportion of clay and iron oxides leading to low Ø' values. Intact rock strength will be very high.	Restricted extent precludes detailed comment. Weathered mantle will have low relative permeability and will affect near-surface groundwater hydrology. Sub-vertical dykes may dam groundwater leading to unnaturately high groundwater levels.	Restricted extent precludes deliberate borrow or quarry activities - weathered material would make poor fill but fresh rock would make suitable high density aggregate or railway ballast.
BEDROCK	UPPER JURASSIC	NH	INTRUSIVE IGNEOUS ROCK (PLUTONIC) – NEEDLE HILL GRANITE: FINE GRAINED PORPHYRITIC PHASE	Fine grained, pink, with phenocrysts of quartz and potassium feldspar in varying proportions. Pyrite is a common accessory mineral. Jointing is similar to other granites.	Occurs as strongly dissected midslope plateau of extensively eroded granite ridges and spurs. Narrow but rounded ridge and spurcrest. Moderate to steep planar dissection slopes.	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 x 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.
BEDROCK	UPPER JURASSIC	Mo	INTRUSIVE IGNEOUS ROCK (PLUTONIC): QUARTZ MONZONITE	Grey to pinkish-grey, fine to medium grained, porphyritic, strong acid plutonic igneous rock. Phenocrysts are plagioclase. Generally displays wide rough joints.	Dissected essentially planar-concave terrain forming strong relief.	Shallow to deep residual soil over moderately weathered rock. Corestones extensive.	Coarser grained fresh rock has an unconfined uniaxial compressive strength of 100 - 150 MPa and a DD of 2 600 - 2 750 kg/m^3. Point Load, Is(50) ≅ 5 - 8 MPa.	Relatively unknown rock type, comments as for granites but more care required with weathered materials because likely to be slightly more clayey. Several troublesome case histories noted.	Material can be 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.
BEDROCK	UPPER JURASSIC	Pq	INTRUSIVE IGNEOUS ROCK – DYKE ROCKS: QUARTZ PORPHYRY	Grey to greenish-grey when fresh, weathers to a pale pink. Fine groundmass with up to 20% large phenocrysts of quartz and minor feldspar.	Generally occur as linear structural features transecting the volcanic and granite units. May be of slightly depressed or elevated topographic form due to variable resistance to erosion compared to country rocks. This geological structure often controls local surface runoff and may act as loci for subsurface water concentration.	Weathers more rapidly than country rocks. Develops a thick reddish soil. Weathering depths are generally in the range 7 - 15 m.	No laboratory information available. Weathered mantle should contain coarse quartz sand along with silt and clay. Fresh rock parameters should be similar to granites.	Due to restricted outcrop, these rocks are unlikely to affect engineering activity to any great extent. The surface hydrology can be affected by these rocks with drainage network aligning with the strike of the dykes. Subsurface hydrology and foundation levels will be affected by the variable rockhead.	Restricted extent precludes deliberate borrow or quarry activities. May be suitable as aggregate when fresh. Excavation conditions may be difficult and expensive.
BEDROCK	UPPER JURASSIC	La	INTRUSIVE IGNEOUS ROCK – DYKE ROCKS: FELDSPAR PORPHYRY	Grey to greenish-grey. Fine grained groundmass with up to 20% large (8-10 mm) phenocrysts of feldspar.			Little laboratory information available. Parameters should be similar to granite but with a higher proportion of clay.		

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	MS	INTRUSIVE IGNEOUS ROCKS (PLUTONIC)		MA ON SHAN GRANITE	Grey to pinkish-grey fine grained porphyritic strong granite. Phenocrysts are quartz and feldspar. Generally displays smooth tectonic joints.	Forms extensive areas of moderate relief, broad convex hillcrests are common with high level infilled valleys. Occasionally occurs as steep to precipitous terrain. Drainage is dendritic in nature although structural control does dislocate the general pattern. Sheet and gully erosion is common on hillcrest and sideslope terrain.	Rock sometimes produces a poor, thin (< 1 m) soil (pedogenic) horizon. 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 an average of 18 m has been quoted. Weathering to produce corestones is common.	The near surface completely decomposed material has a DD ≅ 1 200 - 1 400 kg/m^3 and is usually only 35 - 50% saturated. The material is a silty sand containing up to 20% silt with some fine gravel. Typical shear strength values are c' ≅ 0 - 10 kPa, Ø' ≅ 32 - 40°. Strength characteristics of fresh rock are dependent on joint strength as unconfined compressive strength in order of 100 - 150 MPa. DD ≅ 2 500 - 2 600 kg/m^3, tangent modulus ≅ 30 000 - 60 000 MPa. Point Load Is(50) ≅ 5 - 8 MPa. Joint c' ≅ 0 kPa, Ø' ≅ 40°, roughness angles 5 - 10° (tectonic joints), 10 - 15° (sheet joints).	Stability of the weathered material can be suspect, i.e. Zones A & B, where soil type failures may occasionally occur. Insitu material is subject to severe erosion. 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.
		CC			CHEUNG CHAU GRANITE	Pale grey or pink, medium to coarse grained, sparingly porphyritic granite. Potassium feldspar is prevalent in this widely spaced rough jointed rock which is difficult to distinguish from Hong Kong Granite.					
		SK			SUNG KONG GRANITE	Pale grey or pink, coarse grained porphyritic granite. Medium grained and non-porphyritic phases exist. Generally displays widely spaced joints. Quartz is often very abundant.					
		XT			TAI PO GRANODIORITE	Grey to dark grey, coarse to medium grained, porphyritic granitoid rock. Large well formed crystals of white feldspar up to 15 mm are present in 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.	Forms extensive areas of moderate relief with colluvial and boulder cover. Broad convex hillcrests and well vegetated slopes.	Average depth to Zone C is approximately 15 m but can be over 40 m. Boulders and corestones are common in weathered zones. Weathering product is subangular silty sand.	Little test data available for study area but decomposed granodiorite 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) ≅ 6 - 9 MPa.	Relatively unknown rock type in study area, comments as for granites but a little more care required with weathered materials because they are likely to be slightly more clayey. Special care must be taken in establishing adequate surface protection on newly formed slopes.	Because of the low to moderate content of quartz in the clay, weathered zone could be used for making bricks. Weathered zone material may be used for fill.. Fresh rock is suitable for aggregate. Lower quartz content makes this material suitable for ashphaltic concrete.
	LOWER TO MIDDLE JURASSIC	RB	SEDIMENTARY, VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS	REPULSE BAY FORMATION	UNDIFFERENTIATED VOLCANICS	Rock types uncertain but probably similar to RBp.	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 a thin soil or thin weathering occurs.	The near surface completely decomposed material has a DD ≅ 1 500 kg/m^3 and a saturation greater than 70%. Gradings are variable but 20 - 40% silt, 10 - 20% clay and 40 - 60% fine sand is common. Plasticity varies from PL 22 - 32%, LL 35 - 60%. Typical shear strength values are : c' ≅ 0 - 10 kPa, Ø' ≅ 30 - 35°. Fresh rock properties are approximately as follows : unconfined compressive strength ≅ 150-250 MPa. Joint strength parameters are c' ≅ 0 kPa, Ø' ≅ 30°, roughness angles ≅ 5 - 10°. DD ≅ 2 500 - 2 700 kg/m^3. Point Load Is(50) ≅ 6 - 12 MPa. Tangent modulus ≅ 30 000 - 60 000 MPa.	Stability of weathered material and also of highly jointed rock masses may be suspect, especially during or immediately after prolonged heavy rainfall. Failures are quite common, especially in over-steepened slopes. Rapid surface runoff is common. Stability of rock slopes controlled by relatively close spaced discontinuities in moderately weathered to fresh rock mass. - Few opportunities for creation of platforms; usable sites may be small and fragmented. - Access route selection hampered by terrain. - Tunnelling probably easier than in granitoids. Deep weathering and close jointing should be anticipated near structural geological lineaments.	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.
		RBs			SEDIMENTS AND WATER-LAID VOLCANICLASTICS	Generally a hard, thinly banded black and grey siltstone and black shale, interbedded with volcanic sandstones and tuffs, sometimes cherty. Very closely spaced joints in some units. Some areas of orthoquartzite and dolomite, altered by hydrothermal activity.	Forms areas of moderate to low relief.	Shallow to moderately deep, reddish to brown, fine, sandy to silty clay, i.e. residual soil sometimes with ferrugineous 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.	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 steep narrow ridges with deep structurally controlled gullies. Rock outcrop common.	Rock usually develops a thin (< 1 m) soil horizon and a thin (< 10 m) weathered zone before passing rapidly into moderately to slightly weathered bedrock.	No laboratory results available but should be similar to other volcanics as below.	Stability of weathered material and also of highly jointed rock masses may be suspect, especially during or immediately after prolonged heavy rainfall. Failures are quite common, especially in over-steepened slopes. Rapid surface runoff is common. Stability of rock slopes controlled by relatively close spaced discontinuities in moderately weathered to fresh rock mass. - Few opportunities for creation of platforms; usable sites may be small and fragmented. - Access route selection hampered by terrain. - Tunnelling probably easier than in granitoids. Deep weathering and close jointing should be anticipated near structural geological lineaments.	Very hard and abrasive when fresh, will require blasting which may result in brittle fracture. Inadvisable for aggregate unless tested for silica/cement reaction.
		RBvb			MAINLY BANDED ACID LAVAS, SOME WELDED TUFFS	Amygdaloidal banded rhyolite, banded trachy-andesite, spherulitic rhyolite and ignimbrite. Displays closely spaced smooth joints.	Massive volcanic peaks with deeply dissected slopes forming a system of subparallel ridges and spurs. Crests are narrow and sharply convex with steep to very steep valley slopes. Rock outcrops are common on the upper slopes.	Rock usually produces a thin (< 1 m) soil horizon, followed downwards, especially on lower slopes, by yellowish brown sandy completely weathered material overlying less weathered, locally strongly jointed rock below an average depth of 11 m. On steep, high slopes considerable rock exposure, with thin soil or thin weathered zone.	The near surface completely decomposed material has a DD ≅ 1:500 kg/m^3 and a saturation greater than 70%. Gradings are variable but 20 - 40% silt, 10 - 20% clay and 40 - 60% fine sand is common. Plasticity varies from PL 22 - 32%, LL 35 - 60%. Typical shear strength values are : c' ≅ 0 - 10 kPa, Ø' ≅ 30 - 35°. Fresh rock properties are approximately as follows : unconfined compressive strength ≅ 150 - 250 MPa. Joint strength parameters are c' ≅ 0 kPa, Ø' ≅ 30°, roughness angles ≅ 5 - 10°. DD ≅ 2 500 - 2 700 kg/m^3. Point Load Is(50) ≅ 6 - 12 MPa. Tangent modulus ≅ 30 000 - 60 000 MPa.		Material can be used for fill if it is weathered locally. It is possible to quarry, although very hard and not generally favoured. Coarse crystal tuff horizons may provide good aggregate.
		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.					
		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.					
		RBp			DOMINANTLY PYROCLASTICS	The principal rock type is grey to dark grey fine grained rhyodacitic tuff but welded tuffs, coarse tuffs, lavas and sedimentary rocks may also be found in this unit. Jointing is usually smooth and closely spaced.					
	PERMIAN	TH	METASEDIMENT		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.	Does not occur on the surface in this study. It has been encountered beneath Tide Cove.	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.

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

Abbreviations

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

Erosion in colluvium may sometimes result in the undercutting of contained boulders which subsequently move down slope. Internal erosion may also take place within the deposits, and voids may pose a hazard to earthworks and engineering design. These voids may occur as tunnels which act as major subsurface conduits for water movement (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. From the GEOTECS data presented in Table B12 and in Figures 4 and 8, volcanic colluvium appears to have a higher proportion of instability compared to other colluvial materials. This is possibly a result of the steeper slope angles associated with both the parent rock type and the volcanic colluvial terrain.

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

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

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 these 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 subterranean pipes are present.

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. An area north of Wu Kwai Sha has 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, 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 Intrusive Igneous Rocks*

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

Amongst these rocks, a division can be made between dyke rocks and those occurring in large intrusive bodies. The dyke rocks generally are of limited width although they may cause localised variations in weathering depths and groundwater conditions. Usually they are not of great engineering significance except when they occur as a dyke swarm, as on Tsing Yi Island. 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 surface. Tectonic joints are generally orientated normal to the sheeting joints, smooth to moderately rough and spaced in the order of 1 m apart. On weathering, both joint groups are often preserved as relict features with coatings of limonite, manganese dioxide or thin layers of clay.

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

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

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

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

The completely decomposed rock disintegrates into a silty clayey sand, with the grading depending on the original rock type. Weathered monzonite and Tai Po Granodiorite have higher concentrations of clay compared to other members of this group with the exception of dolerite. This is 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 Figures 4 and 8 and in Tables B10 and B11 indicate relatively high levels of erosion within the intrusive igneous rocks when compared to the other rock types, although there appear to be significant differences between the individual intrusive rocks. 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.

In general, instability in these rocks is not as extensive as in colluvium or volcanic materials. Landslips do not appear to have the same impact on the terrain and tend to form small rotational or joint-controlled failures associated with natural terrain or cut slopes. Length to width ratios are generally 1 to 2:1.

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

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

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

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

This group of rocks is extensively used for construction materials. The deeply weathered material is easily extracted by machine methods for use as soft borrow, and the underlying rock is highly favoured for the production of crushed aggregate. In the Sha Tin area a number of site formation excavations have produced large volumes of fill for reclamation work. A quarry at Turret Hill was used as a source of rip-rap for the Plover Cove Reservoir and as a source of aggregate. At Lok Wo Sha (White Head) quarrying and site formation work produced rock fill for the Sha Tin to Tai Po Road reclamation work. Approximately 160 000 tonnes were extracted during 1982.

No other quarries are active within the study area, although a number of abandoned sites exist. A former large quarry at Kwai Chung is being developed for use as a public housing estate.

Granitic rocks are generally favoured 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 monzonite and the Tai Po Granodiorite, which have a significantly lower quartz content and similar crushing characteristics, may be more suitable for this purpose and should be considered for quarrying.

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

3.1.6 *Characteristics of the Volcanic Rocks*

The location and type of volcanic and volcaniclastic rocks found in the study area are discussed in Section 2.3.3 and in Appendix C.1.1. Excluding the minor sedimentary member, these rocks tend to have similar material characteristics.

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

The volcanic rocks of the Repulse Bay Formation are generally well jointed. Joint spacing (Geological Society of London, 1977) commonly ranges from 'moderately narrow' (20 to 60 mm) to 'wide' (200 to 600 mm) or, more rarely, 'very widely' spaced (600 to 2 000 mm). Small outcrops that have a joint spacing of greater than 2 m tend to stand out on hillsides and ridges as tors. Locally, the joint spacing is very variable, often ranging from wide to narrow over distances of less than 10 m. Most exposures contain several sets of joints, each set exhibiting a range of orientations. This range is generally related to the persistence of the joints, with less persistent joints being the most variable in orientation. Joints can sometimes be seen to curve in larger exposures. 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 the Tsing Yi Road. Site investigations for projects involving rock cut slopes should be designed to identify and define the dominant joint sets prior to engineering design.

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 (shown on the Engineering Geology Map), 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. A major lineament in this study area passes through Tide Cove from Lai Chi Kok and corresponds with a major valley, now filled with alluvium and marine deposits. 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, 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 the product of 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 B10 and B11 and Figures 4 and 8 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. Due to 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 to the mean for the insitu terrain in the study area. The morphological forms associated with slope failure in volcanics are similar to those in colluvium, in that they are characterised by small landslip scars with extensive debris deposits. That is, they are characterised by large length to width ratios (4 or 5:1).

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

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

3.1.7 *Characteristics of the Metamorphic Rocks*

Very little is known about these rocks within the study area. Dark metamorphosed sulphurous shales and quartzites occur offshore in an area planned for reclamation. These rocks are deeply weathered and occur beneath, up to 40 m of marine deposits and old alluvium. They decompose to a very dense clayey silt that has SPT values ranging from 20 up to 120. The upper value indicates that driven piles may terminate within it. It should be noted that the sulphur derived from pyrites may produce an acid groundwater that could react with steel piles or concrete. Chemical analysis of the groundwater may indicate the nature and extent of this potential problem.

4. GEOTECHNICAL ASSESSMENT FOR PLANNING PURPOSES

4.1 Geotechnical Limitations and Suitability for Development

4.1.1 *Introduction*

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

The distribution of the four GLUM classes is summarised in the pie diagram presented in Figure 4 and at Table B9 in Appendix B.

The Generalised Limitations and Engineering Appraisal Map (GLEAM) identifies parcels of land with potential for development from a geotechnical point of view. The geotechnical limitations and other planning constraints such as, provision of access, presence of Country Parks and designated Green Belt are highlighted.

4.1.2 *Land with Low to Moderate Geotechnical Limitations*

Within the study area, there exists a relatively small area (414 ha) with low geotechnical limitations and approximately 4 996 ha with moderate geotechnical limitations. Terrain with low to moderate limitations (GLUM Classes I & II) forms 40.4% of the study area. Some 1 901 ha of the GLUM Class I & II terrain is developed and 3 509 ha of the GLUM Classes I & II terrain is substantially undeveloped.

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

The major areas of GLUM Classes I & II terrain outside of the developed parts of the Central New Territories study area are discussed in the description of potential development areas in Section 4.2. There are extensive areas of these classes north of Tsuen Wan and Kwai Chung, in the Shing Mun and Tai Mo Shan Country Parks, around the Kowloon Reservoir and northwest of Ma On Shan.

4.1.3 *Land with High Geotechnical Limitations*

Approximately 31.6% (4 225 ha) of the study area has a high level of geotechnical limitation (GLUM Class III) and of this, some 855 ha is currently developed.

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

Small areas of GLUM Class III terrain may be included within the Potential Development Areas (PDA) shown on the GLEAM if they are unlikely to adversely affect the overall development opportunities of the area.

4.1.4 *Land with Extreme Geotechnical Limitations*

Approximately 26% (3 472 ha) of the area is classified as GLUM Class IV. This terrain should not be developed if alternatives exist. Only 84 ha (2.4%) of this class occurs within areas of existing development.

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

Terrain attributes which contribute to the designation of GLUM Class IV include steep insitu and colluvial terrain and areas with evidence of instability. Extensive areas of this terrain are present to the north of Ma On Shan, northwest of the Shing Mun Reservoir and to the east of Sha Tin.

In most cases, it will be obvious from the topography alone that GLUM Class IV terrain would present extreme geotechnical difficulties. The steep to precipitous slopes of the Hunch Backs, Southern Tsing Yi and northern Tai Mo Shan are examples.

Isolated GLUM Class IV terrain within the developed area is usually associated with locally steep slopes produced during site formation or road construction.

Other areas of GLUM Class IV are due to natural drainage lines crossing colluvium or the presence of instability. These features are highlighted on the Physical Constraints Map (PCM).

4.2 Potential Development Areas

4.2.1 *General Planning Considerations*

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

From a geotechnical viewpoint, land with potential for development should generally be free of constraints. Engineering design, ideally should be unhindered by geotechnical limitations. Within the Central New Territories study area, there are many natural areas with potential for development, but a significant proportion occur within the bounds of designated Country Park, Green Belt and Water Supply Catchment. These artificial constraints are noted but are not used to exclude areas that have potential from a geotechnical point of view based on their natural terrain attributes.

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

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

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

The GLEAM identifies 28 areas within the study area which have potential for development from a geotechnical point of view. This represents approximately 3 300 ha or 25% of the total area. The areas range in size from about 50 ha up to 250 ha. They occur on different types of terrain, which are not necessarily suitable for the same type of development.

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

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

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

Each area with potential for development is numbered and presented on the GLEAM. They are summarised in the GEOTECS Plot in Figure 11.

The comments for each area reflect the general strategic considerations which influence planning and engineering feasibility. In the main, they relate to the suitability of the areas for intensive development.

Reference should be made to the Geotechnical Land Use Map, Engineering Geology Map and Physical Constraints Map (PCM) for identification of factors influencing development opportunities. In particular, the PCM shows the nature of any constraint. If a constraint is identified on the PCM and the constraint occurs within a potential development area, then the area of constraint is also shown on the GLEAM.

4.2.3 *Development Opportunities*

There are 28 areas within the study area which have potential for development from a geotechnical point of view. These areas constitute approximately 3 300 ha of land.

Area 1 *Tsing Yi Island* (140 ha approx.) Within the undeveloped parts of this Island, a number of sites exist that have development potential from a geotechnical of view. These sites occur in the north near Shek Wan, Yim Tin Kok, Sai So Wan, Tai Shan Ha and Lam Tin.

These sites are 65% underlain by volcanic rocks and the remaining 35% are underlain by granitic rocks. The localised depth of weathering at these sites largely depends on the geology, the presence of structural geological discontinuities and the rate of erosion. As a generalisation, the volcanic rocks are less deeply weathered than the granitic rocks for any given geormorphological situation. There are exceptions, such as the porphyry dyke swarm south of Ng Kok Wan, where the rocks, although granitic, have a weathering thickness similar to the volcanics. There are some small deposits of colluvium which account for about 6% of the PDA. These deposits have slope angles generally less than 15° and slope instability should not be a problem, but unusual groundwater conditions should be anticipated. Care is also required not to destabilise adjacent steep colluvial terrain such as at Kan Chuk Kok.

The majority of the area is classified as GLUM Class I or II terrain with the colluvial deposits being designated GLUM Class III.

Much of the land defined on the GLEAM as Area 1 is already planned for future use.

Area 2 *Ha Fa Shan* (110 ha approx.) This area occupies the hillsides and ridgecrests above Yau Kom Tau, Shek Lung Kung and the valley floor to the north of Ha Fa Shan.

It is entirely underlain by rocks of the Repulse Bay Formation but includes a sedimentary unit. The volcanic rocks are generally coarse-grained with some very coarse agglomerates. The weathering depths in each of the different units of the Repulse Bay Formation vary considerably, with the sedimentary unit being the deepest. South of Yau Kom Tau, an extensive deposit of colluvium has slope angles mainly in the range of 5 to 15°. This area has some existing development in the form of two and three storey residences.

South of Ha Fa Shan, large boulders are present on upper slopes that may affect the PDA. The areas underlain by agglomeratic rocks tend to have a high incidence of boulders at the surface. The presence of structural geological discontinuities, shown as photogeological lineaments on the GLEAM, will locally depress the weathered profile in these rocks which is normally in the range of 5 to 10 m. Some corestones should be anticipated. The relatively shallow weathering of the volcanic rocks in this area may result in only minor amounts of soft fill in excess of local site formation requirements.

To the north of Ha Fa Shan, a valley is infilled with colluvium and may have high groundwater levels.

The development of this PDA could be assisted by the construction of a road along the ridgeline which forms the western boundary of the study area, connecting with Tsuen Wan by way of Shek Lung Kung and Ha Fa Shan. This would also aid the development of PDA's in the adjacent West New Territories Geotechnical Area Study (GASP III).

Area 2 could be developed with narrow stepped platforms in order to minimise the amount of hard rock excavation and to reduce the height of steep cut slopes.

About 60% of the PDA is within Country Park and the south facing slopes, above the Castle Peak Road are upslope of a catchwater.

Area 3 *Pak Shek—Sheung Fa Shan* (105 ha approx.) This site is consists of hillcrest and sideslope terrain and an extensive valley floor that extends from Sheung Fa Shan to a catchwater to the west of Tso Kung Tam. Overall, the slopes are moderately steep with about 70% having gradients in the range of 15 to 30°. Approximately 20% of the slope angles are in the range of 5 to 15° and the remaining 10% are in the 0 to 5° range. The GLUM class distribution is 10% in GLUM Class I, 70% in GLUM Class II and 20% in GLUM Class III. The GLUM Class III terrain corresponds to the colluvial deposits on the valley floor.

About 20% of the area is underlain by granitic rocks and the balance is underlain by volcanic rocks. The areas of granitic terrain are likely to be more deeply weathered and may have potential for soft fill. In the granitic areas near Pak Shek Kiu, old mines are present. Abandoned tunnels and shafts may pose a hazard in this area. The ore mined in this area was molybdenum sulphide and therefore acidic groundwater is likely.

An additional constraint in this area is the presence of high voltage transmission lines and associated pylons.

There is a risk of flooding of the valley floor during high intensity rainfall. The development of this part of the PDA may be aided by the entrainment of the stream and the use of soft fill from the granitic areas to raise the general ground level.

The eastern part of the PDA is adjacent to Route TWISK and access is not difficult. In the west, there is a sealed single lane restricted road that follows a ridgeline. This could enable access to the western portion as well as providing a road link to Area 2.

About 80% of the PDA is within Country Park and the remainder is unused. All parts of this area are within a water catchment.

Large platforms could be constructed in granitic terrain and developed in conjunction with the large PDA's occurring in West New Territories area. A less dramatic method for the development of volcanic terrain could involve the construction of narrow terraces conformable with the terrain.

Area 4 *Chuen Lung* (245 ha approx.) This very large area of land, that is generally geotechnically suitable for development, is bounded to the north by the boundary of the study area. The natural extension of this PDA is within the North West New Territories 1:20 000 Geotechnical Area Study (GASP IV).

About 80% of Area 4 is within Country Park and the remainder is used as a village site, with associated agriculture around Chuen Lung.

The PDA ranges in elevation from about 200 m in the south up to 780 m in the north near Tai Mo Shan. The slope angles are generally moderately steep with about 86% in the 15 to 30° range, 12% in the 5 to 15° range and only 2% in the 0 to 5° range.

The entire site is underlain by volcanic rocks and therefore weathering depths are expected to be shallow and the potential for soft borrow is low. The occurrence of coarse tuff near Tai Mo Shan accounts for a number of large core boulders that may threaten any development down slope. In the valley around Chuen Lung there are extensive deposits of colluvium and these occupy about 15% of the PDA. These areas of colluvium require care during site formation due to possible high water tables and the potential for flooding.

There is no apparent instability within this PDA, however, some instability is present to the south of Ngau Liu which may endanger development in the valley below. Erosion is limited to minor gullying in the streambeds. The GLUM class distribution is 5% GLUM Class I, 85% GLUM Class II and 10% GLUM Class III. The overall development opportunities of this site would require an integrated approach that carefully balances cut and fill volumes, as the latter is scarce. Access is currently available by way of Route TWISK and a number of minor restricted roads. As well as upgrading of restricted roads, new road construction would be required in order to gain access to Ngau Liu.

Area 5 *North of Kwong Pak Tin* (100 ha approx.) This area is to the east and south of Area 4 and consists mainly of sideslope and hillcrest terrain. It is well wooded and about 70% lies within Country Park. The PDA contains a cemetery and some squatters exist in the southern part of the area. High voltage electrical transmission lines and a catchwater pass through the south of the area.

The elevation ranges from a low of 100 m near Lo Wai up to a maximum of 740 m near Tai Mo Shan.

The site is underlain entirely by volcanics and minor colluvium. Some boulders occur in the north but are less common in the south. There is no apparent instability within the area and adjacent instability should not be a problem, as it is down slope of the site.

Slope angles are generally moderately steep with approximately 91% in the range of 15 to 30°, 7% in the range of 5 to 15° and only 2% in the 0 to 5° range. The GLUM class distribution is: 3% in GLUM Class I, 94% in GLUM Class II, and 3% in GLUM Class III.

Access is already available in the south around Lo Wai, but the northern areas are served only by a narrow restricted road that would require upgrading to permit development. The area could be developed in conjunction with Area 4, with low density housing on large plots. This would also minimise the detrimental effects caused by development on the vegetation within the PDA.

Area 6 *Tai Mo Shan* (135 ha approx.) Despite the high elevation of this site, the terrain is favourable for development from a geotechnical point of view. It consists of mainly grass covered ridgecrest and sideslope terrain, underlain by volcanic rocks. About 5% of the area is covered by colluvium which occurs mainly along the drainage lines. The elevation varies from a low of 500 m rising to 957 m at Tai Mo Shan (the highest point in the Territory).

A wireless station is situated on the summit of Tai Mo Shan but otherwise the terrain is undeveloped Country Park.

Slope angles are moderately steep with 40% between 5 to 15° and the balance of 60% in the range of 15 to 30°. The GLUM classes distribution is: 11% in GLUM Class I, 81% in GLUM Class II and 8% in GLUM Class III. There is no instability apparent within the PDA but the terrain to the west is very steep and unstable. On the slopes of Tai Mo Shan, there are large boulders of coarse tuff which may influence future development.

Existing vehicular access consists of a narrow restricted road that joins Route TWISK.

Area 7 *Tai Mo Shan Country Park* (240 ha approx.) This is a very large PDA which coincides with a major east to west trending ridgeline in the Tai Mo Shan and Shing Mun Country Parks. The underlying geology consists entirely of volcanics and only about 5% of the PDA is covered by colluvium. Access will be difficult, but despite the remote location, this area has a high potential for development because it is generally free from geotechnical constraint. Vegetation consists mostly of grassland but some woodland occurs in the south. Some minor gully erosion is present but no natural instability is apparent.

A number of structural discontinuities dissect the area and these are shown as photogeological lineaments on the GLEAM. These features are likely to be associated with more intense weathering and groundwater concentration. Normal weathering is expected to be in the order of 10 to 15 m. Slope gradients are mostly in the range of 15 to 30° (85% of the PDA). Approximately 7% is in GLUM Class I, 90% in GLUM Class II and only 3% in GLUM Class III.

Access would need to be improved by upgrading either the Tai Mo Shan road or the restricted road from Tai Po Kau to Lead Mine Pass. Within the area, a major route could be developed along the ridgecrest with spur roads to serve the northern and southern ridges and sideslope terrain. Many alternative layouts of terraced platforms are possible, but narrow elongate sites, constructed by excavations that blend with the natural terrain, should be considered. There is likely to be an excess of soft fill if a linear layout were to be adopted.

Area 8 *North of Wo Yi Hop* (160 ha approx.) This is a fragmented area that geotechnically has some potential for development. It consists of a number of discrete sites on upland and lowland terrain separated by land with high to extreme geotechnical limitations. Any development of the ridgecrest and upper sideslopes will have problems associated with access. The upland sites mainly consist of elongate sections of ridgecrest terrain trending north to northwest. Access could be developed by following these ridges.

The lowland sites form a broad colluvial valley floor with some low angle insitu sideslopes at the margins of the PDA. The area below the catchwater has been studied in greater detail in the North Tsuen Wan District Stage I study.

Approximately 80% of the PDA lies within the Shing Mun Country Park, with the southern region containing some village development and associated agriculture. The sites in the valley at Lo Wai may be subject to flooding as the catchment of the established stream is quite large.

The major rock type underlying these sites is volcanic, although some dykes of feldspar porphyry occur north of Wo Yi Hop. Recent geological mapping indicates that some isolated bodies of granodiorite may also be present. Approximately 10% of the area is covered by colluvium which principally occurs in the stream channels. There is also a large fan deposit of colluvium at San Tsuen.

No natural instability is apparent within the sites but much of the adjacent terrain is potentially unstable. The only erosion noted is minor gullying along the stream courses.

Area 9 *North of Yin Ngam* (55 ha approx.) The northern limit of this PDA is formed by the boundary of the study area and its natural extension occurs within the North New Territories (GASP V) area. The PDA is composed essentially of grass covered hillcrest and sideslope terrain and the floor of an east to west trending valley filled with colluvium.

The underlying rocks are volcanic and the general depth of weathering is expected to be in the range of 5 to 10 m. A structural geological discontinuity occurs along the axis of the valley floor and locally, deeper weathering can be expected.

Within the area, 85% is in the slope range of 15 to 30%, 10% is in the range of 5 to 15° and 5% varies from 0 to 5°. The GLUM class distribution is: 4% in GLUM Class I, 88% GLUM Class II and 8% GLUM Class III.

The southern slopes above the valley exhibit evidence of instability and slope failure could influence development down slope.

Access to this area would be difficult as the only practical route is along the valley floor from Lo Lau Uk. Instability and the risk of flooding may reduce the suitability of this route.

The PDA is currently undeveloped but some 70% is within the bounds of the Tai Mo Shan Country Park.

Area 10 *Ta Tit Yan* (55 ha approx.) This PDA is close to Area 9 but mainly consists of valley floor terrain. The small villages of Ta Tit Yan and Yuen Tun Ha area located within this PDA. The area is entirely underlain by volcanics and about 25% is covered by colluvium. The valley floor is expected to be subject to short duration flooding and any development in this area will require the entrainment of the stream and the raising of the general ground level.

The slope angle distribution is 75% in the 15 to 30° range and the remaining 25% is in the range of 5 to 15°. Colluvium accounts for the 25% of 5 to 15° range of slope angles and thus the GLUM classes are 25% in GLUM Class III and 75% in GLUM Class II. The areas of colluvium will require extra care during site formation as the groundwater table is expected to be high.

A large diameter water tunnel occurs in the north and there is also a high voltage transmission line in the same region.

Existing vehicular access is in the form of a minor road to Lo Lau Uk which would require upgrading to facilitate further development.

Area 11 *Shing Mun Country Park* (120 ha approx.) The area around the Shing Mun Reservoir mostly consists of steep, unstable terrain. However, within the reservoir catchment there are some isolated sites that could be developed. Area 11 is composed of numerous small units of a variety of terrain types, each suitable for development from a geotechnical point of view. The larger parcels occur in the northwest and are mainly covered by colluvium with slopes in the range of 5 to 15°. They are classified as GLUM Class III terrain and would require careful investigation and design in order to minimise the hazard of slope failure associated with the adjoining steep colluvial deposits. The majority of the small sites are underlain by volcanic rocks and therefore weathering depths are expected to be relatively shallow.

All of the sites are within the Shing Mun Country Park and have a thick cover of woodland vegetation.

The existing vehicular access consists of a number of sealed single lane restricted roads.

Area 12 *Tai Po Kau Nature Reserve* (75 ha approx.) This PDA is comprised of mainly ridgecrest and sideslope terrain that has a thick cover of woodland vegetation. A colluvium filled valley occurs in the east. The PDA is entirely underlain by volcanic rocks and approximately 5% of the area is covered by colluvium.

The slope angle distribution is: 15% in the 5 to 15° range and 85% in the 15 to 30° range. About 95% of the area is classified as GLUM Class II with the remaining 5% as GLUM Class III. The GLUM Class III terrain corresponds to the colluvial deposits in the valley. These deposits are expected to be subject to high groundwater tables and periodic flooding.

Although no natural instability is evident within the PDA, the surrounding terrain is steep and exhibits slope failure.

The existing vehicular access consists of a narrow restricted road that connects with Tai Po Kau. Part of the existing route passes over unstable terrain and any upgrading may require partial realignment. Two large diameter water tunnels are present within the PDA but these are located at considerable depth.

The PDA is currently undeveloped but about 80% occurs within the Tai Po Kau Nature Reserve.

Area 13 *North of Cheung Lek Mei* (60 ha approx.) This area consists of two ridgecrests in the east of the Tai Po Kau Nature Reserve that extend eastwards toward Sha Tin New Town. The PDA has a thick cover of woodland vegetation and no appreciable erosion is evident. The elevation of the site ranges from about 100 m near Hang Hau up to 408 m on the northern ridge. The northern boundary is formed by the limit of the study area and the natural extension of this PDA is within the North New Territories (GASP V) study area.

The area is entirely underlain by volcanic rocks and a number of major structural geological discontinuities occur within the PDA.

Within the area 17% occurs in the slope range of 5 to 15° and 83% occurs in the 15 to 30° range. The GLUM class distribution is: 10% in GLUM Class III and 90% in GLUM Class II. The GLUM Class III terrain is represented by colluvium in the valley between the two major ridges and the area around the village of Nim Au.

Access to this PDA would provide geotechnical problems as the surrounding hillsides are steep and unstable. The nearest major road is the Tai Po Road at Tai Po Mei and a minor restricted road extends to the western edge of the PDA.

Area 14 *Tai Po Mei* (30 ha approx.) Northwest of the Chinese University and east of the Tai Po Road, a number of small areas with potential for development combine to form this PDA. These sites are currently used for low density village type housing or agriculture.

All the individual sites are underlain by volcanic rocks and a high proportion are covered by colluvium or alluvium. The sites with a mantle of superficial deposits are likely to have complex subsurface geology and high groundwater levels.

The individual sites range in elevation from sea level up to 200 m. Slope angles occur as follows: 75% in the 15 to 30° range and the remaining 25% in the 5 to 15° range. Approximately 80% of the PDA is classified as GLUM Class II and 20% is classified as GLUM Class III terrain.

There is some likelihood of flooding in the low-lying alluvial areas.

Area 15 *Grassy Hill—Needle Hill* (210 ha approx.) This large area primarily consists of the long narrow ridgecrest extending from the Lower Shing Mun Reservoir to Grassy Hill. Much of this PDA may be suitable for use only as a transport corridor due to its elongate nature. There are some large areas free of major geotechnical constraint in the north around Grassy Hill that are suitable for large scale intensive development. These areas are underlain by volcanics whereas the narrow ridgecrest to the south is underlain by granitic rocks. The steep sideslopes exhibit evidence of instability. A number of major structural geological discontinuities pass through the PDA. The largest of these features represents the contact between the volcanic and granitic rocks. The granitic terrain is commonly subject to moderate gully and sheet erosion but this should not inhibit development if adequate provision is made for drainage.

Slope angles are mostly in the range of 15 to 30° with only 5% between 5 and 15°. This 5% represents scattered deposits of colluvium which are classified as GLUM Class III terrain with the remaining 95% classified as GLUM Class II occurring on the moderately sloping insitu terrain.

Approximately half of the PDA lies within a Country Park and the remainder is undeveloped except for some minor agriculture.

The existing vehicular access consists of a single lane restricted road that terminates at Needle Hill.

Area 16 *Kau To Shan* (60 ha approx.) This PDA is adjacent to large scale development in the Sha Tin New Town and consists largely of ridgecrest terrain, including Cove Hill and a drainage plain near the villages of Kau To and Lok Lo Ha. A small proportion is used for low density village type residential development but the majority is unused land partly zoned as a Green Belt.

The area around Ho Tung is underlain by granitic rocks but most of the northern part of the PDA is underlain by volcanic rocks. The contact between the two rock types is marked by a major structural geological lineament that is deeply weathered and hydrothermally altered. Valley bottoms are commonly filled with colluvium and alluvium and probably exhibit high groundwater levels and are subject to flooding. The PDA ranges in elevation from about 10 m adjacent to the reclamation near the Sha Tin Race Course up to 400 m at Cove Hill. Slope angle distribution is: 10% in the range of 5 to 15° and 90% in the range of 15 to 30°. Approximately 95% of the area is classified as GLUM Class II terrain with only 5% as GLUM Class III.

There is no apparent natural instability within the PDA but adjacent southern slopes do show evidence of past instability. Moderate to severe sheet erosion affects the granitic terrain but this is unlikely to affect development provided that adequate drainage is provided.

This PDA has considerable potential as it is close to existing development at Fo Tan Heights and Kau To. Access is already established and development of the PDA could be assisted by an additional road along the ridgecrest to Cove Hill.

Area 17 *East of Sha Tin* (155 ha approx.) A number of parcels of land comprise this area and are scattered on hills and in valleys to the east of Sha Tin. The largest areas are south of Wong Chuk Yeung, north of Tung Lo Wan and west of Pak Tin. Both narrow ridgecrest terrain and confined areas of valley floor terrain are included in this PDA.

These parcels are all underlain by granitic rocks which are subject to deep weathering and varying degrees of sheet erosion. If these sites are considered as a whole, about 25% of their surface area is covered by colluvium. The largest deposits of colluvium occur west of Pak Tin near the village of Heung Fan Liu. This area will require careful development to avoid destabilisation of adjacent steep colluvial slopes. Cut slopes in the area will also require modest slope angles to avoid problems of instability.

Within the PDA slope angles are: 22% in the range of 5 to 15° and 78% in the range of 15 to 30°. Approximately 30% of the PDA is classified as GLUM Class III terrain due to the presence of large areas of colluvium with the remaining 70% classified as GLUM Class II.

Most of the adjacent terrain is potentially unstable and access to many of the smaller sites would be difficult. The larger parcels, as listed above, are near existing developments and could be developed without construction of extensive access links. The narrow ridgecrest and valley floor sites could be used as transport corridors. As all the sites in this PDA are underlain by granitic rocks, the anticipated depth of weathering suggests that there is some potential for soft fill.

Area 18 *Kam Shan Country Park* (250 ha approx.) This large area to the southeast of Kwai Chung has considerable potential for development with a minimum of geotechnical limitations. However, large parts of this PDA are within Country Park or water supply catchments.

The area is entirely underlain by granitic rocks and weathering depths will probably be in the order of 15 to 30 m on hillcrests and sideslopes. Approximately 5% of the area is covered by colluvium which principally occurs along stream courses. These is also a deposit of alluvium at Kau Wa Keng.

Approximately 15% of the PDA has slope angles in the range of 5 to 15° and the remaining 85% is in the range of 15 to 30°. The GLUM class distribution is: 10% in GLUM Class I, 80% in GLUM Class II and 10% in GLUM Class III.

The area is dissected by closely spaced drainage lines that follow structural geological discontinuities, and subdivide the PDA into separate sections. The terrain that divides these sections is mainly GLUM Class III and, as the PDA consists of granitic rocks, these ridges could provide soft borrow for site formation. Very little natural instability is evident in this part of the study area. Thick woodland vegetation has prevented any extensive erosion.

The existing vehicular access consists of a major highway along the southern boundary (Tai Po Road) and a minor restricted road from the Tai Po Road to Smugglers' Pass. A high voltage electrical transmission line crosses the PDA and a number of large diameter water tunnels are also present.

Four water supply reservoirs and their associated catchments occur within the PDA.

Area 19 *South of the Byewash Reservoir* (100 ha approx.) This area, immediately to the south of Area 18, consists of granitic ridgecrest and sideslope terrain and colluvium filled valley floor terrain. Approximately 15% of the area is covered by colluvium with the largest deposit occurring west of the Sha Tin Water Treatment Works. These areas of colluvium may have high water tables and cut slopes would require careful investigation and design.

The vegetation in the PDA is thick woodland and this has prevented the development of any significant soil erosion.

Approximately 20% of the slopes in the area are in the range of 5 to 15° and the remaining 80% are in the range of 15 to 30°. GLUM Class I occupies 5% of the area, GLUM Class II some 80% and GLUM Class III a further 10%.

Weathering is expected to be relatively deep on the hillcrest and sideslopes and consequently the PDA has some potential as a source of soft fill.

The Tai Po Road passes through this PDA. A high voltage electrical transmission line is present west of the Sha Tin Water Treatment Works.

Approximately half of the PDA is within the Kam Shan Country Park but otherwise the area is unused, except for squatters in Butterfly Valley.

Area 20 *Sheung Kwai Chung* (55 ha approx.) To the west of Sheung Kwai Chung and Kwai Chung there are a number of small sites with potential for development from a geotechnical point of view. Included in this PDA is Smugglers' Ridge, adjacent ridgecrest terrain, and a number of isolated parcels of moderately sloping sideslope terrain and small valleys.

All of these sites are underlain by granitic rocks and about 5% of the area is covered by colluvium. A number of major structural geological discontinuities pass through the area and these are probably associated with zones of deep weathering.

Approximately 5% of the terrain has slope angles within the range of 0 to 5°, 10% are in the range of 5 to 15° and 85% are in the range of 15 to 30°. GLUM Class occupies 10% of the area, Class II, 85%, and the remaining 5% is GLUM Class III. Much of the adjacent terrain is unstable and the provision of access would be difficult due to geotechnical constraints. The only existing vehicular access in the area consists of a narrow restricted road from Lei Muk Shue to the Shing Mun Reservoir. Some of the small parcels of land in the PDA are adjacent to existing development in the Kwai Chung district.

A high voltage transmission line passes through the area as does a large diameter water tunnel. About 30% of the area is within Country Park.

Area 21 *Lion Rock Country Park* (100 ha approx.) This PDA consists of a number of parcels of terrain geotechnically suitable for development which are separated by steep unstable land. Most of the potential sites occur on ridgecrests, although some colluvial valley terrain near Shap Yi Wat and San Tin Wai is included.

This PDA is underlain by granitic rocks and about 10% of the surface is covered by colluvium. There are a number of quartz monzonite dykes and structural geological discontinuities occur along the valley floors.

Approximately 5% of the slopes in the area range from 0 to 5°, 15% range from 5 to 15° and 80% range from 15 to 30°. Some 7% of the terrain is classified as GLUM Class I, 83% as GLUM Class II and 10% as GLUM Class III. The areas of GLUM Class III correspond to colluvial terrain. These areas may be subject to high groundwater levels, flood risk and possibly lower strength of the colluvium in comparison with the insitu weathered materials.

Those parts of the PDA that are adjacent to existing development in the Sha Tin New Town area could be developed with a minimum of access construction. The terrain near Shap Yi Wat could be reached from the Sha Tin Pass Road and the north trending valley could form a transport corridor to connect this site with Sha Tin New Town.

Area 22 *West of Tai Wai* (50 ha approx.) Most of this area is already developed and comprises ridgecrest terrain such as Sha Tin Heights, the colluvial terrain west of Mei Lam, and land adjacent to the Kowloon-Canton Railway line. There are also some formed, but unused cut platforms within the bounds of this PDA. The area is underlain by granitic rocks and approximately 20% is covered by colluvium. There are also small fill slopes associated with the existing development. Extensive areas of fill occur on alluvium. A feldspar porphyry dyke occurs in the PDA and possibly has a thinner weathering profile than the host granite.

Approximately 50% of the slopes in the area range from 0 to 5°, 30% range from 5 to 15° and 20% range from 15 to 30°. The GLUM class distribution is: 15% GLUM Class I, 75% GLUM Class II and 10% GLUM Class III terrain. Some instability is apparent on the slopes south of Sha Tin Heights and to the east of the Lower Shing Mun Reservoir Dam. Debris flows from these areas may influence future construction down slope.

Area 23 *Ngau Au Shan* (120 ha approx.) Although a large proportion of the land in this PDA is covered by colluvium and is GLUM Class III terrain, development should be feasible. The area consists of a small portion of ridgecrest and sideslope terrain to the north of Ngau Au Shan and extensive valley floor terrain to the southwest.

Approximately 10% of the PDA is underlain by volcanics which principally occur in the south. The remainder is underlain by granitic rocks. Structural geological discontinuities correspond with most of the larger streams. Approximately 10% of the slope angles are in the range of 0 to 5°, 55% are in the range of 5 to 15° and 35% are between 15 and 30°. The GLUM class distribution is: 10% in GLUM Class I, 55% in GLUM Class II and 35% in GLUM Class III. No major instability is evident but the slopes below Tate's Cairn are unstable and may influence future development near Kwun Yam Shan.

About half of the PDA is within the Lion Rock Country Park and the rest is partly used as village sites and for associated agriculture. The villages of Mau Tso Ngam and Tso Tui Ha are also included.

Existing vehicular access consists of a narrow road from Tate's Cairn which would require substantial reconstruction to permit development of the area. An alternative would be to construct a new road connecting with the Sha Tin New Town by way of the ridgecrest terrain from Lo Shue Tin to Wong Nai Tau.

During development, cut slopes in colluvium should be minimised and advantage could be made of the availability of soft fill in granitic areas. The colluvial deposits may contain erosion tunnels resulting in complex groundwater hydrology.

Area 24 *Shek Kwu Lung* (160 ha approx.) This area consists of mainly colluvial valley floor around Wong Nai Tau and Tai Lam Liu and some sideslope terrain on Turret Hill and near Turret Pass. As the PDA consists mainly of colluvium, considerable care will be required during development due to expected low material strength and complex groundwater conditions. The underlying solid geology consists mainly of granitic rocks although the far eastern portion may be underlain by volcanics. A large structural geological discontinuity coincides with the alignment of the valley floor.

Slope angles are generally gentle within the area, 5% of the terrain lies in the range of 0 to 5°, 80% is in the range of 5 to 15° and 15% is in the range of 15 to 30°. The GLUM class distribution is: 10% in GLUM Class I, 25% GLUM Class II and 65% GLUM III. Approximately 75% of the PDA is covered by colluvium. There are extensive areas of instability to the east of this PDA and care will need to be exercised to prevent destabilisation during any site formation.

Cut slopes in areas of colluvium should be formed with due care, and drainage provision should be designed for the possible presence of erosion tunnels.

The existing access consists of a narrow public road that could be improved without major geotechnical constraint. The PDA is currently used for low density village type residential development with some southern sections extending into Country Park.

The granitic sideslope terrain in the north of the PDA may provide a source of soft fill that could be used to develop platforms in the colluvial areas. This would result in a minimum of disturbance to the colluvium and the formation of platforms on sideslope terrain.

Area 25 *North of Turret Hill* (50 ha approx.) The majority of this PDA consists of hillcrest and sideslope terrain to the north of Turret Hill, although small areas of valley floor terrain are present near Shek Mun and A Kung Kok. A large formed platform is surrounded by this PDA.

The underlying geology is granitic and weathering depths in the order of 15 to 20 m are probable. The natural drainage in the area is dense and streams tend to follow structural geological discontinuities. These lineaments are likely to be accompanied by local areas of intensely fractured and deeply weathered rock. Colluvial deposits are mainly located within stream channels and cover about 10% of the PDA.

The distribution of slope angles in the area is: 5% range from 0 to 5°, 20% range from 5 to 15° and 75% range from 15 to 30°. Approximately 10% of the area is classified as GLUM Class I, 80% GLUM Class II and 10% as GLUM Class III terrain. The PDA ranges in elevation from about 10 m near A Kung Kok up to 400 m on Turret Hill.

Much of the area is subject to moderate to severe sheet erosion and weathered surfaces will need to be protected during construction to minimise soil loss. No natural instability is evident within the PDA but many adjacent slopes exhibit old landslips. This instability may influence access into this PDA.

The existing vehicular access in confined to the haul road used to service the large cut platform. A new route could be constructed in conjunction with the development of the northern sector of Area 24.

This area is currently unused except for a small area in the northwest that is within Country Park.

Area 26 *Mau Ping* (50 ha approx.) This area occupies valley floor terrain around Mui Tsz Lam, Mau Ping and Wong Chuk Shan and ridgecrest terrain near Shek Nga Shan, Buffalo Hill and along the boundary of the study area. The natural extension of this terrain occurs within the East New Territories Geotechnical Area Study (GASP IX).

The section near Mui Tsz Lam is underlain by granitic rocks but most of the area is underlain by volcanics. Approximately 40% of the PDA is covered by colluvium and a further 5% is covered by alluvium. Major structural geological discontinuities cross the PDA and correspond with the axes of the principal valleys. The occurrence of these lineaments suggest that complex groundwater conditions should be expected along the valley floor.

Slope angles are generally gentle within the area, 5% are in the range of 0 to 5°, 50% are in the range of 5 to 15° and 45% are in the range of 15 to 30°. The GLUM Classes range from 10% in GLUM Class I, 50% in GLUM Class II and 40% in GLUM Class III. The areas of GLUM Class III are covered by colluvium and the design of any proposed development should consider the difficulties associated with this material.

A large diameter water tunnel crosses the PDA and an associated catchwater is located in the northwestern sector. There is an existing road to the area near Mui Tsz Lam but access would need to be developed to the eastern portion of the PDA. Access could be constructed along the valley floor connecting the two major areas within this PDA.

Most of the ridgecrest terrain falls within Country Park. Valley terrain is either unused or forms the sites of existing low intensity village-type residential development and associated agriculture.

Area 27 *Ma On Shan Country Park* (215 ha approx.) This large PDA has considerable potential for development from a geotechnical point of view. It consists of a variety of terrain types and ranges in elevation from 120 m up to 500 m. The vegetation is restricted to a grass cover on most of the terrain.

The area is underlain by volcanic rocks in the eastern portion near Pyramid Hill and by granitic rocks northwest of Luk Chau Au. A body of granitic rock is enclosed by volcanic rocks near Ngong Ping, where a dyke of deeply weathered quartz monzonite is present. This site is partly covered by a deposit of alluvium. About 6% of the total area is covered by colluvium which occurs as scattered deposits on the hillsides and along stream courses. To the north of Ma On Shan Tsuen and adjacent to a stream course are large spoil tips, the product of earlier mining operations. These waste tips are unlikely to have been adequately compacted. They may be a source of rockfill for use in any future site formation activity. A number of structural geological discontinuities traverse the PDA and these are probably associated with zones of deeper weathering and groundwater concentration.

Only about 1% of the PDA has slope angles in the range of 0 to 5°, 15% is in the range of 5 to 15° and the remaining 84% is in the range of 15 to 30°. The GLUM class distribution is: 4% in GLUM Class I, 90% in GLUM Class II and 6% in GLUM Class III.

Within the PDA, no evidence of past instability is apparent but some adjacent areas are potentially unstable. To the southeast of Ma On Shan Tsuen, a disused iron ore mine is surrounded by unstable slopes and development is not recommended in its immediate vicinity. The granitic terrain is subject to minor and moderate sheet erosion and some minor gully erosion has been noted in stream courses.

Approximately 85% of the PDA is within the Ma On Shan Country Park and the remainder is unused. A catchwater is present below Pyramid Hill and another is located beneath Luk Chau Au.

The granitic terrain could be developed by way of large cut platforms. This would yield large volumes of soft fill suitable for reclamation. The volcanic areas are not expected to yield an excess of soft materials and would be more amenable to narrow cut platforms conformable with the general trend of the terrain.

Area 28 *Southeast of the Ma On Shan New Town* (95 ha approx.) This area consists of a number of discrete parcels of land that abutt the boundary of the proposed Ma On Shan New Town. They represent areas that could be used to enhance the resources of this major development.

The PDA consists of some ridgecrest and sideslopes and large colluvial deposits on the footslope terrain. The vegetation mainly consists of dense scrubland and woodland which has prevented severe erosion. The underlying rocks are granitic in the west and volcanic rocks underlie the eastern parts of the PDA. The contact between these rock types is frequently obscured by the overlying colluvium. Colluvium covers about 42% of this PDA and has been used for soft fill. Waste from the old Ma On Shan Mine has been dumped in this area. The material may be suitable, however, as a source of rock fill for use in site formation.

The distribution of slope angles is: 4% in the range of 0 to 5°, 43% in the range of 5 to 15° and 53% in the range of 15 to 30°. Approximately 58% of the area is classified as GLUM Class II terrain and the balance of 42% is classified as GLUM Class III. The GLUM Class III terrain corresponds to the colluvial terrain which mainly occurs near Cheung Muk Tau. It should be feasible to develop this land provided that the anticipated problems of high groundwater tables, the presence of erosion tunnels, low material strengths and steep unstable adjacent slopes are considered in the planning and engineering design stages.

About 50% of the area is within the Ma On Shan Country Park and the remainder is unused. To the south of Cheung Muk Tau, there are some areas that were previously used for agriculture but are now abandoned.

When the Ma On Shan New Town is completed, access to the PDA will be relatively easy. At the time of preparation of this report the existing vehicular access consisted of an unsealed road which connects Wu Kwai Sha with Ma On Shan Tsuen.

4.2.4 *Assessment of Planning Strategies Using GEOTECS*

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

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

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

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

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

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

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

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

(i) *Development Potential in Squatter Areas*
An initial assessment of the suitability of the terrain for development is used as the basis for the GLEAM (see Appendix A.9). Using the GLEAM criteria to determine 'potential' terrain and relating it to the presence of squatters, the GEOTECS Plot in Figure 12 has been produced. The squatter areas which could be cleared to provide land suitable for development are shown.

Squatters occur on approximately 131 ha within the study area. Some 38 ha of this terrain has potential for development from a geotechnical point of view. The GEOTECS symbol (+) also shows the general location of 1 400 ha of land with development potential on undesignated natural terrain outside of the Country Parks. Squatters occur on approximately 93 ha of geotechnically difficult terrain (GLUM Classes III & IV).

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

(ii) *Potential Quarry Sites*
The GEOTECS Plot in Figure 13 indicates areas which exhibit quarry potential on the basis of several terrain attributes. The selection criterion for areas without intensive existing land use is primarily those units with convex, straight or cliff slopes less than 40° in gradient. As a secondary criterion, areas are also selected on the basis of slope angle alone. These selection criteria enable quarry potential to be maximised between the existing ground surface and the final quarry face. Thus, groups of several units with optimum potential or with occasional secondary potential may make suitable sites. Bedrock geology is not used in the initial assessment presented in the GEOTECS Plot in Figure 13, although it must be incorporated for advanced planning. Once potential rock types are selected, they can be added to the GEOTECS strategy for the production of a further plot. Hence, the refinement of alternative quarry sites is possible.

Approximately 1 800 ha of undesignated natural terrain has potential for quarry sites. A further 3 230 ha with potential for quarrying occur within existing Country Parks or are under cultivation. These figures indicate that many options exist, but these options would be severely reduced when rock type is specified.

5. CONCLUSIONS

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

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

5.1 Materials and Land Resource Distribution

(*a*) Slope instability of some form or other is relatively common within the study area. Approximately 3 350 ha of the terrain (25.1%) 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*) The geology of the area is complex, and several aspects require careful investigation. Weathering depths are variable, with very deep weathering occurring in some granitic areas. The competition from alternative land uses restricts the future excavation of borrow and rock materials, and the study area is a net importer of borrow materials. There are numerous photolineaments present, many of which are likely to be faults, shear zones, major joint zones or dykes. Surface erosion is more pronounced on the granitic terrain than on the volcanics.

(*c*) Approximately 2 591 ha of the footslope terrain is covered by extensive colluvial deposits; 25.3% 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 39.1% (1 014 ha) of the generally low angle colluvial footslope terrain.

(*d*) The granitic terrain has a slightly lower proportion of GLUM Classes I & II (41.9%) than the volcanics (45.4%). Of the 2 591 ha of colluvial terrain which occurs within the study area, some 96.9% is subject to high to extreme geotechnical constraints (GLUM Classes III & IV).

(*e*) Approximately 30.8% of the study area is characterised by slopes which have gradients between 0 and 15°. A further 65.5% of the terrain has slope gradients between 15 and 40° and 3.7% is steeper than 40:

(*f*) There is approximately 1 000 ha of reclamation (7.5%) within the study area and additional reclamation is associated with the Ma On Shan New Town. The siting of development on extensive reclamation that is underlain by thick compressible marine sediments may give rise to foundation problems and settlement of services. This aspect will require careful design and control during construction.

(*g*) Approximately 27.9% of the study area is currently developed in some form or other. Squatters occupy 0.8% of the area, and 40.2% is allocated to Country Park. The remaining 72.1% consists of undeveloped natural terrain.

5.2 Land Management Associated with Planning and Engineering Feasibility

(*a*) Within the Territory, a number of large landslips during the last 20 years have resulted in considerable loss of life and very substantial property damage (So, 1971; Lumb, 1975; Brand, 1984). Landslips have occurred in developed areas, squatter villages and natural terrain (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 Central New Territories study area, the geotechnical constraints associated with the terrain are important factors for land management purposes and engineering feasibility.

(*b*) Opportunities do exist for urban expansion in the study area, but it is unrealistic to envisage that future development can avoid areas with geotechnical limitations. The Generalised Limitations and Engineering Appraisal Map (GLEAM) recognises this fact and delineates 28 areas which have overall potential for development from a geotechnical point of view. These represent a total of 3 300 ha or 25% 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.

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

(*d*) This study indicates that there is 4 274 ha of currently undisturbed natural terrain, which does not include Country Park. Of this figure, GLUM Classes I & II occur on some 28.1% (1 203 ha) of the terrain, and 3 053 ha is associated with high to extreme geotechnical limitations (GLUM Classes III & IV). There is approximately 5 370 ha of land within the Country Parks and of this figure 1 808 ha is classified as either having low or moderate geotechnical limitation (GLUM Classes I & II).

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

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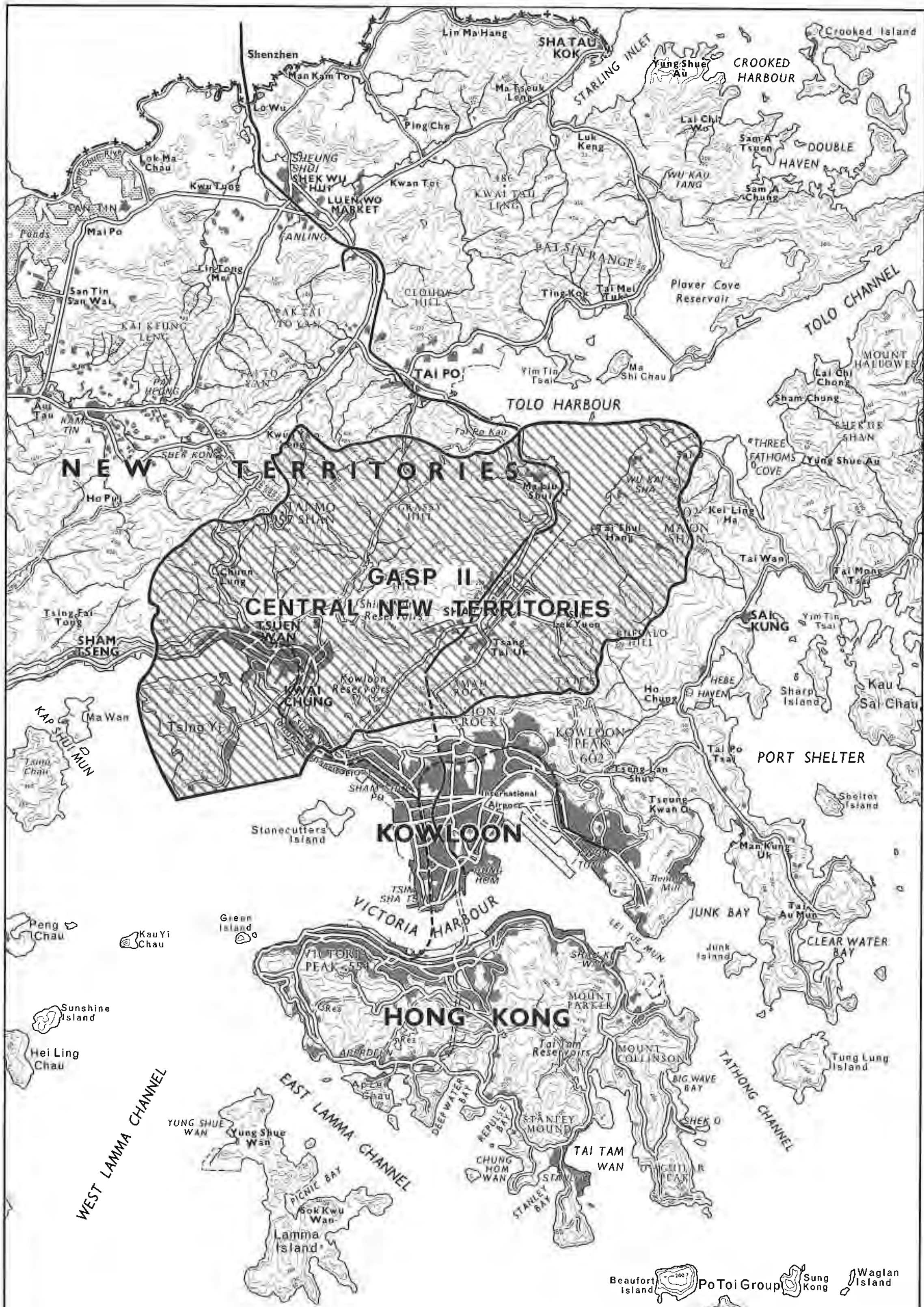
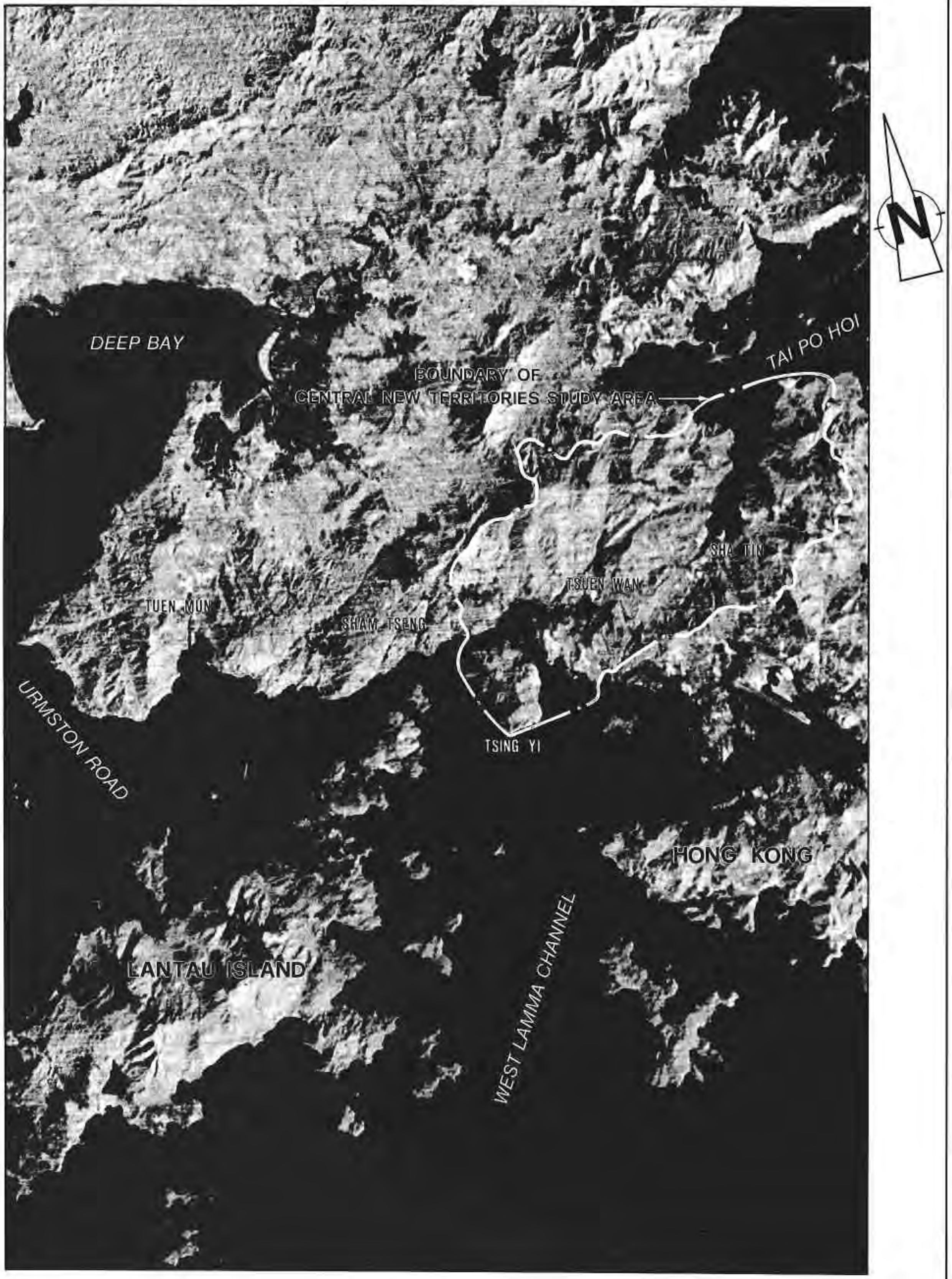
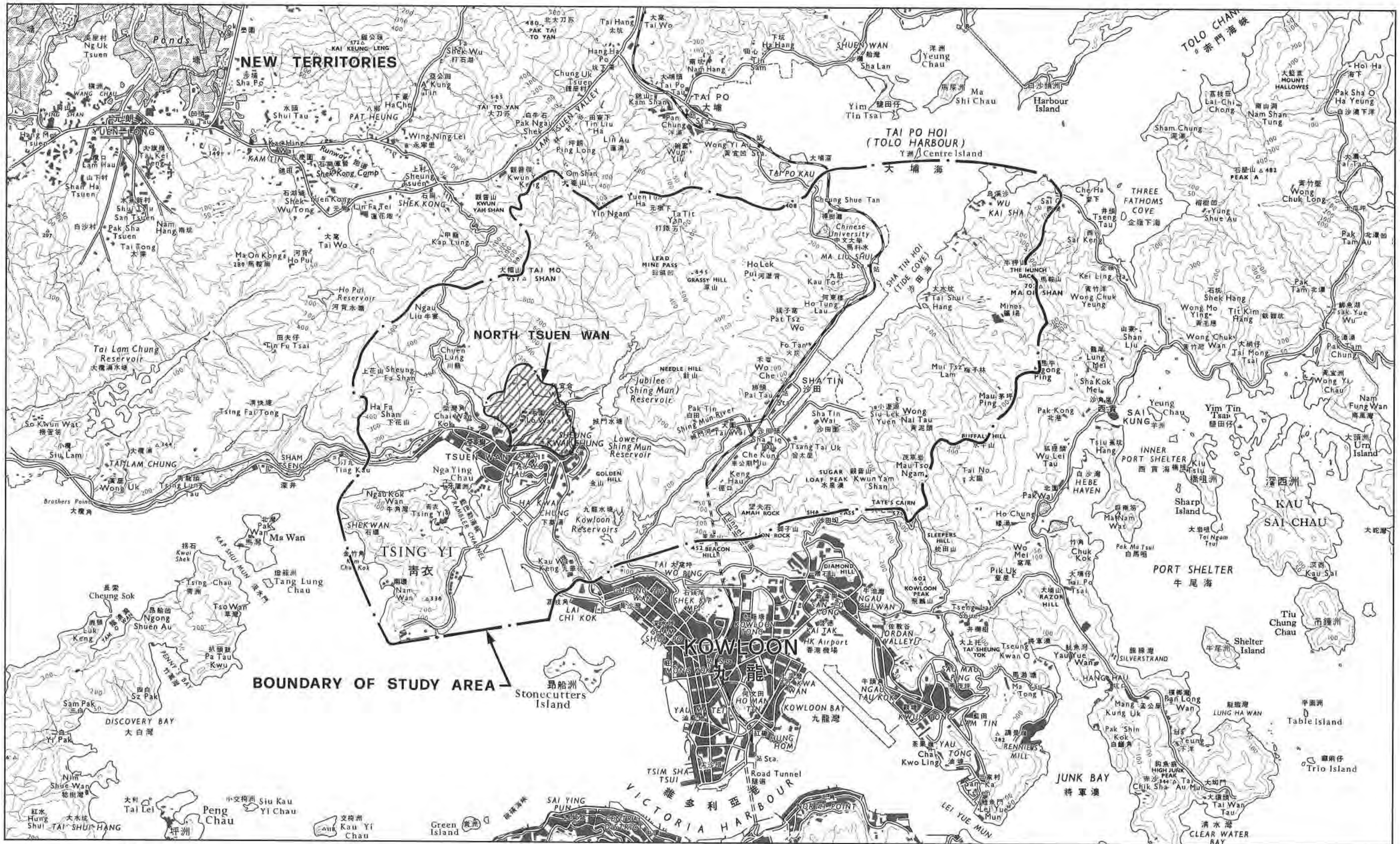


Scale 1:200 000	Location Map of the Central New Territories Study Area	Fig. 1

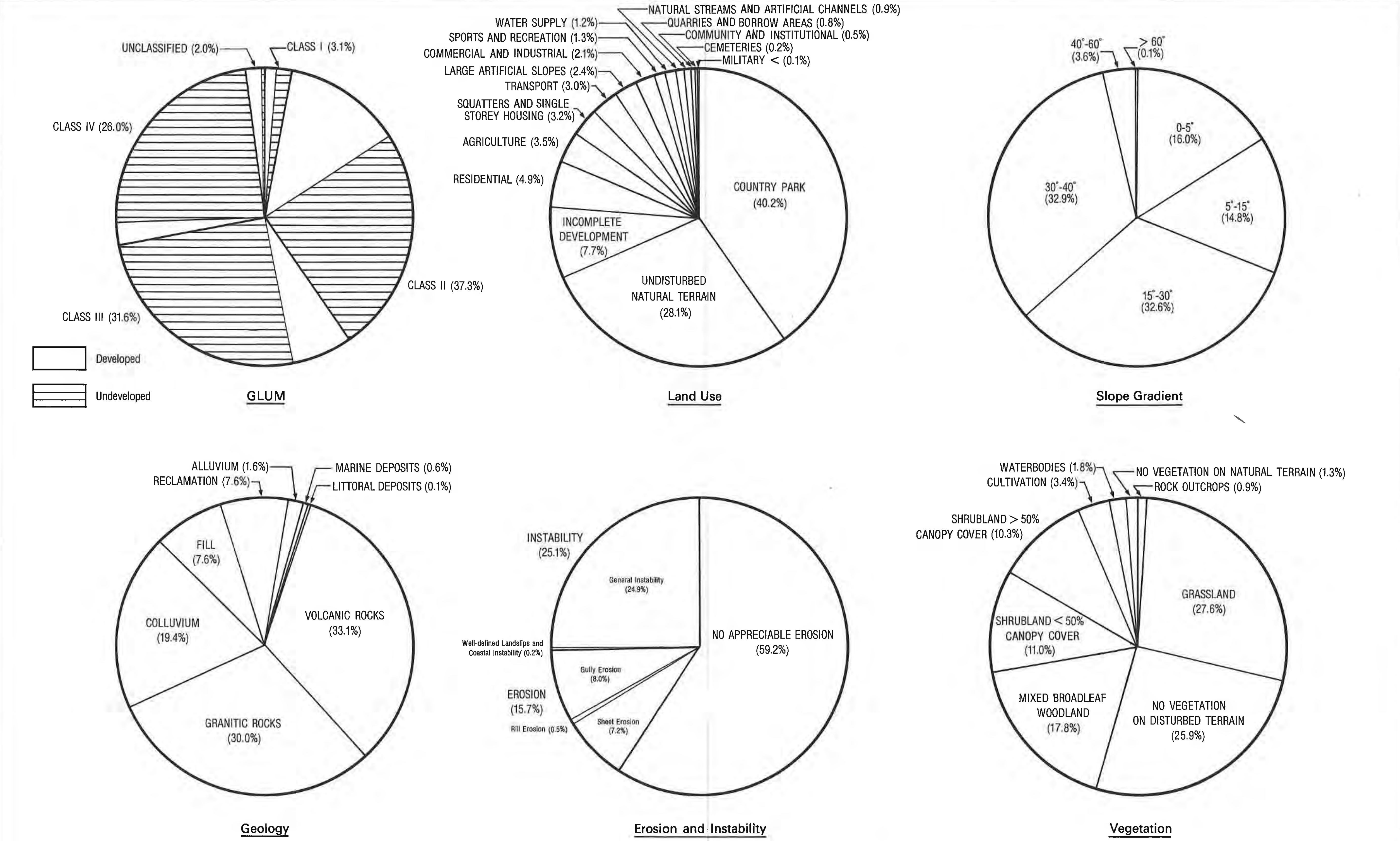


Scale 1:250 000	Satellite Image of the Central New Territories Study Area	Fig. 2



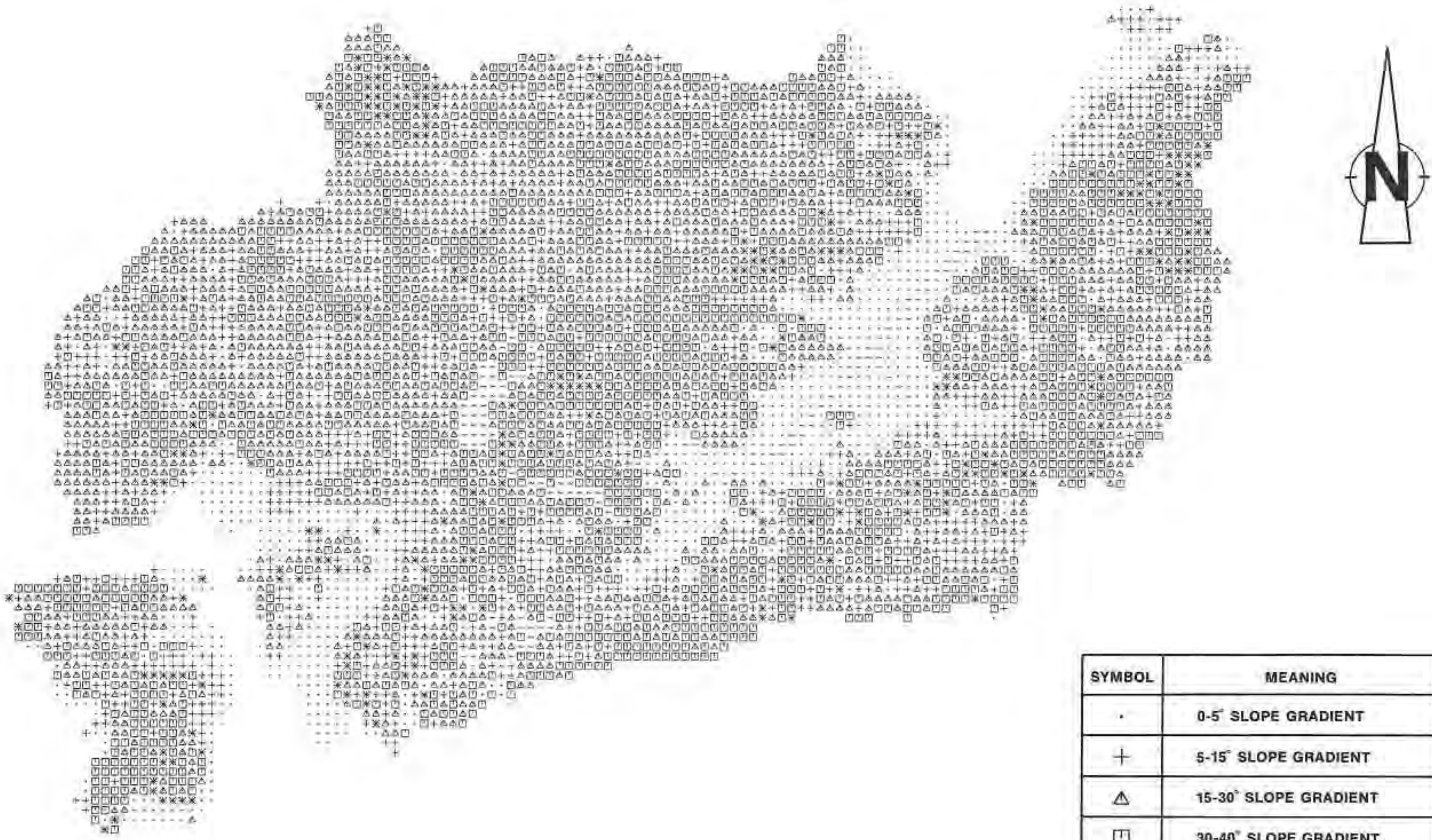
GASP District Studies : Stage 1 (1:2 500 scale)

Scale 1:100 000	Central New Territories Study Area	Fig. 3



Pie Charts of Selected Attributes of the Central New Territories

Fig. 4

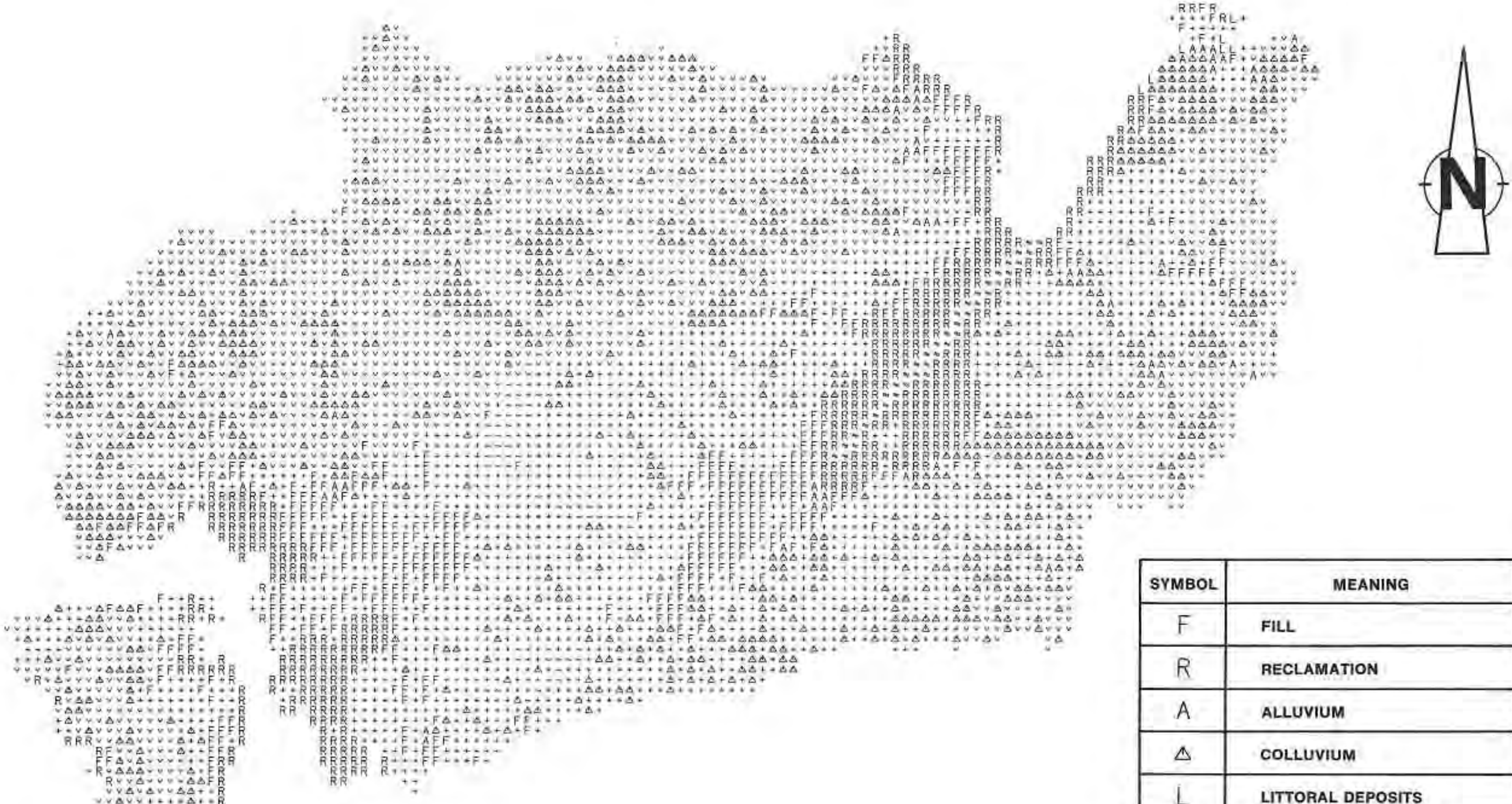


SYMBOL	MEANING	%TOTAL
·	0-5° SLOPE GRADIENT	14.2
+	5-15° SLOPE GRADIENT	14.8
△	15-30° SLOPE GRADIENT	32.6
⊡	30-40° SLOPE GRADIENT	32.9
✳	> 40° SLOPE GRADIENT	3.7
~	ARTIFICIAL CHANNEL, RESERVOIR OR POND	1.8

Scale 1:100 000

GEOTECS Plot - Slope Gradient

Fig. 5

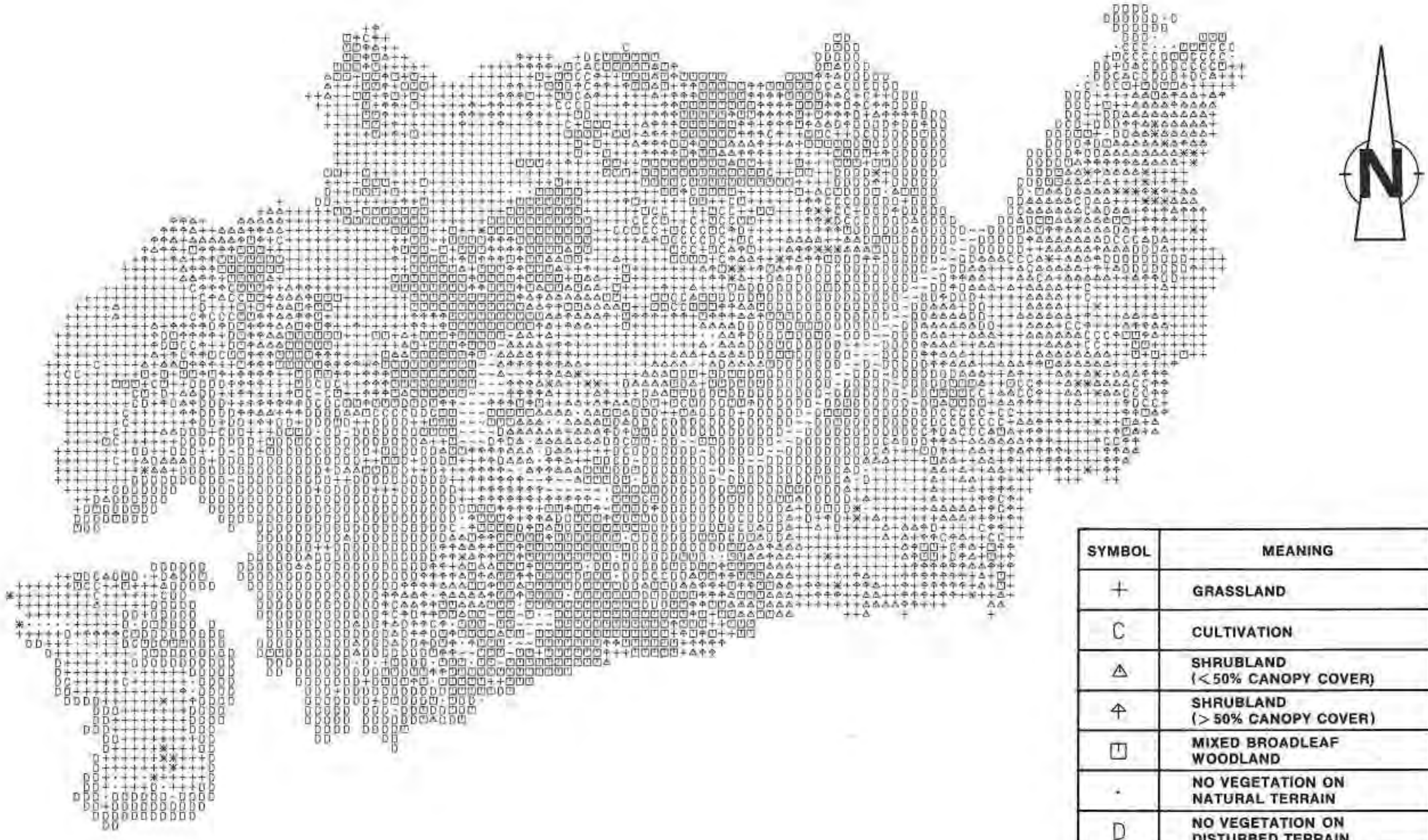


SYMBOL	MEANING	%TOTAL
F	FILL	7.6
R	RECLAMATION	7.6
A	ALLUVIUM	0.7
△	COLLUVIUM	19.4
L	LITTORAL DEPOSITS	0.1
≈	MARINE DEPOSITS (IN CHANNEL ONLY)	0.6
v	VOLCANIC ROCKS	33.1
+	INTRUSIVE IGNEOUS ROCKS	30.0
~	RESERVOIR OR POND	0.9

Scale
1:100 000

GEOTECS Plot - Geology

Fig. 6

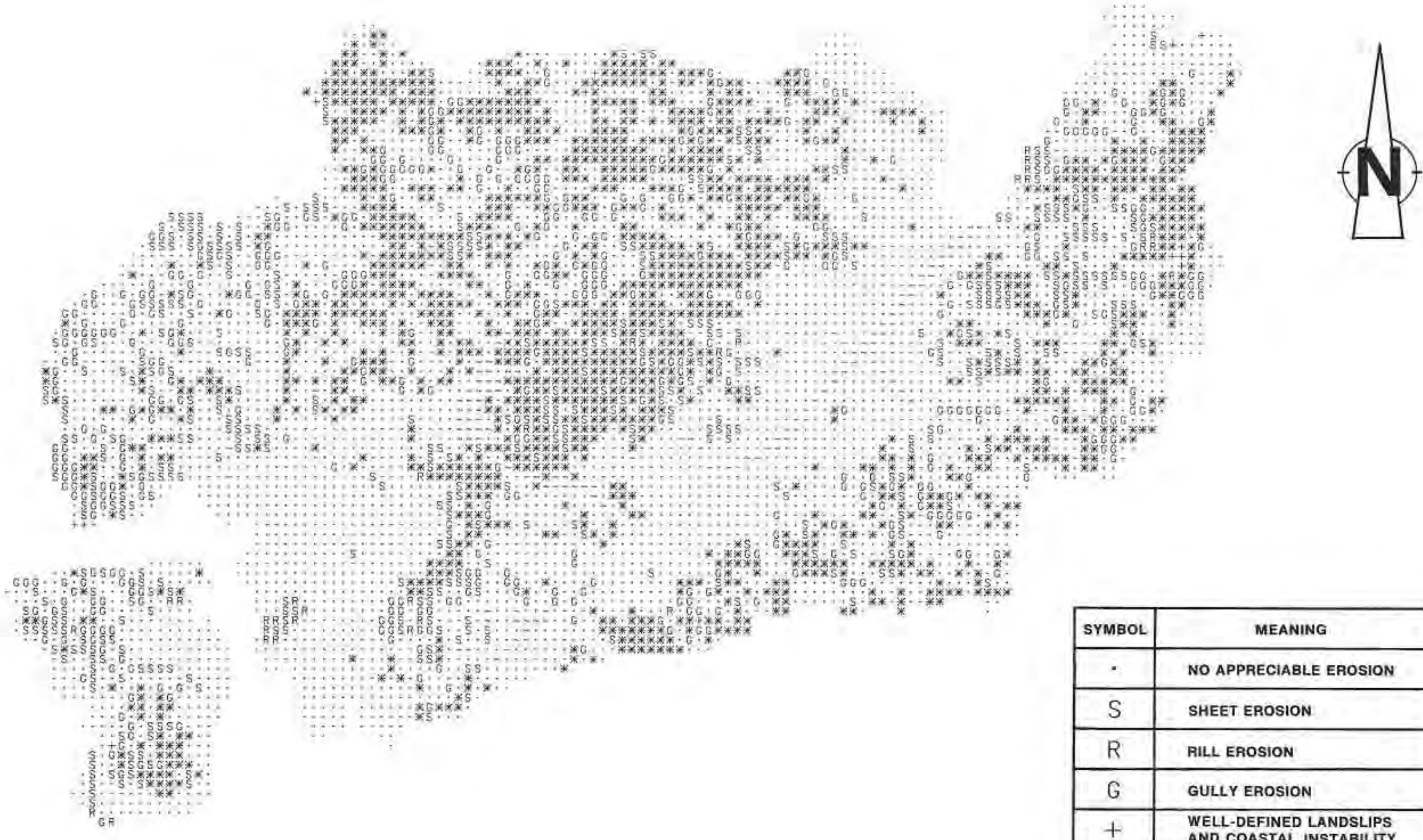


SYMBOL	MEANING	%TOTAL
+	GRASSLAND	27.6
C	CULTIVATION	3.4
△	SHRUBLAND (<50% CANOPY COVER)	11.0
⏆	SHRUBLAND (>50% CANOPY COVER)	10.3
⊡	MIXED BROADLEAF WOODLAND	17.8
·	NO VEGETATION ON NATURAL TERRAIN	1.3
D	NO VEGETATION ON DISTURBED TERRAIN	25.9
✳	NO VEGETATION ON ROCK OUTCROPS	0.9
~	WATERBODIES (STREAM, CHANNEL RESERVOIR, PONDS)	1.8

Scale 1:100 000

GEOTECS Plot - Vegetation

Fig. 7

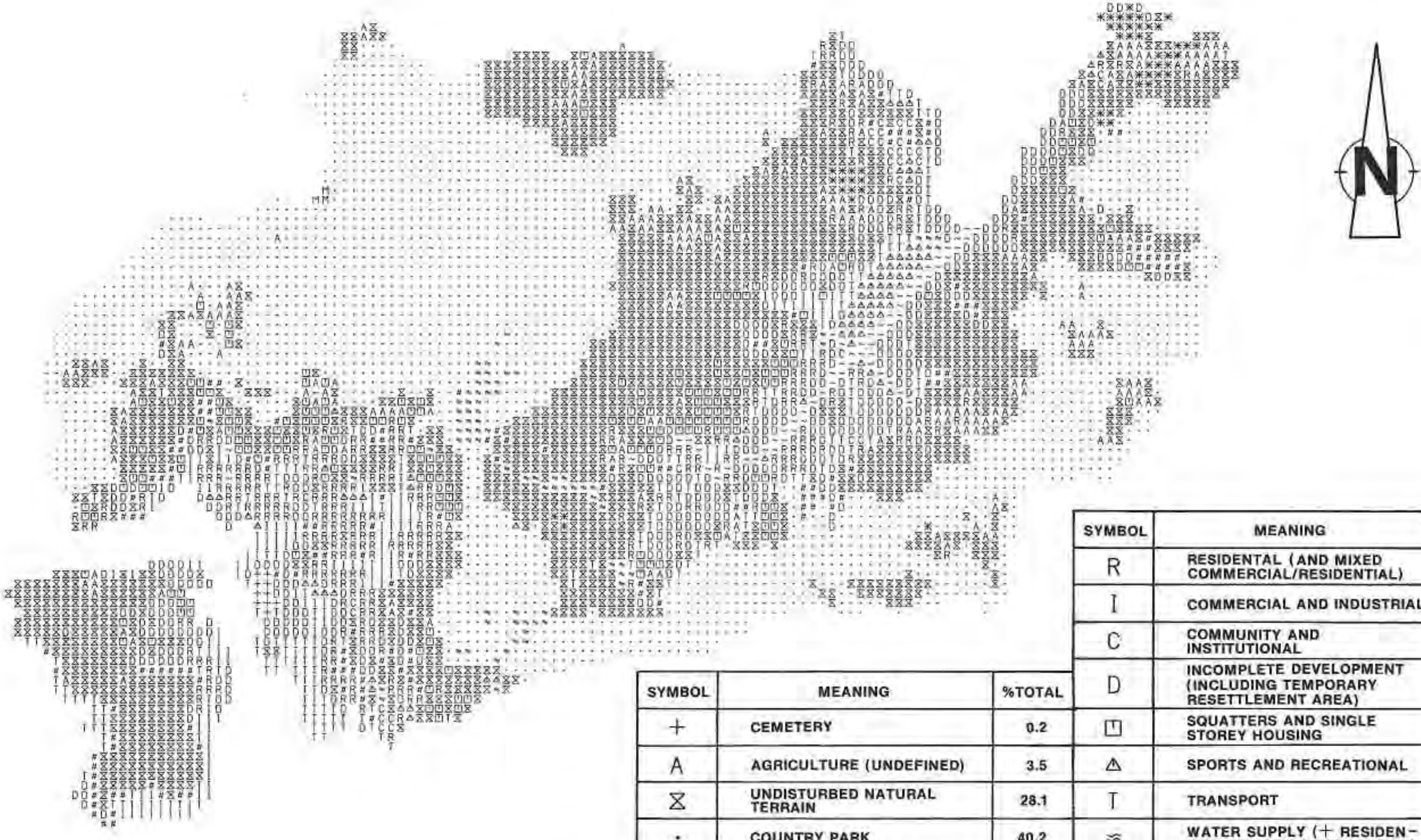


SYMBOL	MEANING	%TOTAL
·	NO APPRECIABLE EROSION	57.4
S	SHEET EROSION	7.2
R	RILL EROSION	0.5
G	GULLY EROSION	8.0
+	WELL-DEFINED LANDSLIPS AND COASTAL INSTABILITY	0.2
*	GENERAL INSTABILITY	24.9
~	STREAM, CHANNEL, RESERVOIR OR POND	1.8

Scale
1:100 000

GEOTECS Plot - Erosion and Instability

Fig. 8



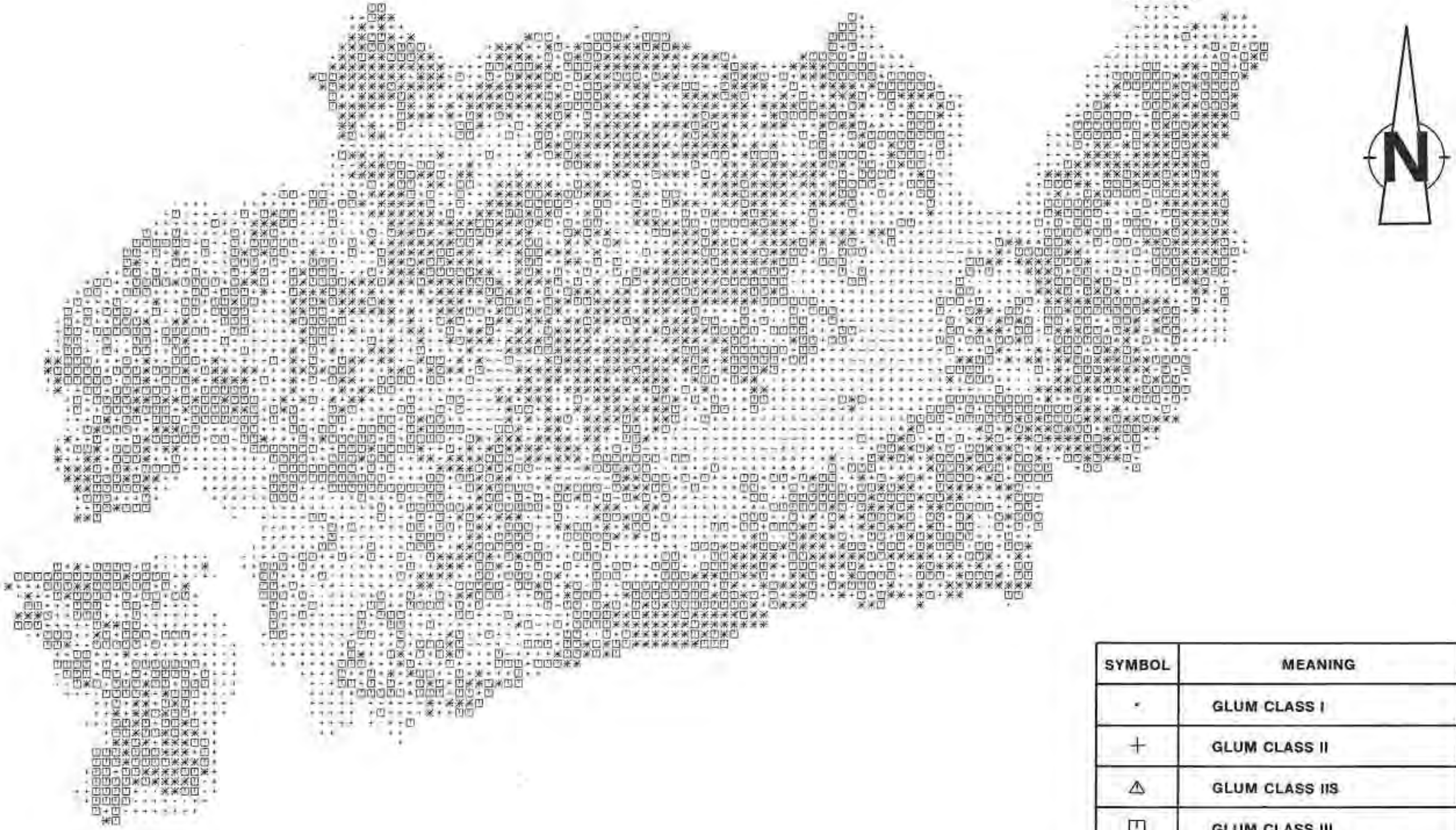
SYMBOL	MEANING	%TOTAL
+	CEMETERY	0.2
A	AGRICULTURE (UNDEFINED)	3.5
⊠	UNDISTURBED NATURAL TERRAIN	28.1
·	COUNTRY PARK	40.2
~	NATURAL STREAMS AND ARTIFICIAL CHANNELS	0.9
#	LARGE ARTIFICIAL SLOPES	2.4

SYMBOL	MEANING	%TOTAL
R	RESIDENTAL (AND MIXED COMMERCIAL/RESIDENTIAL)	4.9
I	COMMERCIAL AND INDUSTRIAL	2.1
C	COMMUNITY AND INSTITUTIONAL	0.5
D	INCOMPLETE DEVELOPMENT (INCLUDING TEMPORARY RESETTLEMENT AREA)	7.7
⊡	SQUATTERS AND SINGLE STOREY HOUSING	3.2
Δ	SPORTS AND RECREATIONAL	1.3
T	TRANSPORT	3.0
≈	WATER SUPPLY (+ RESIDENTIAL, SEWAGE & TREATMENT)	1.2
M	MILITARY (UNSPECIFIED)	<0.1
✳	QUARRIES AND BORROW AREAS	0.8

Scale 1:100 000

GEOTECS Plot - Land Use

Fig. 9

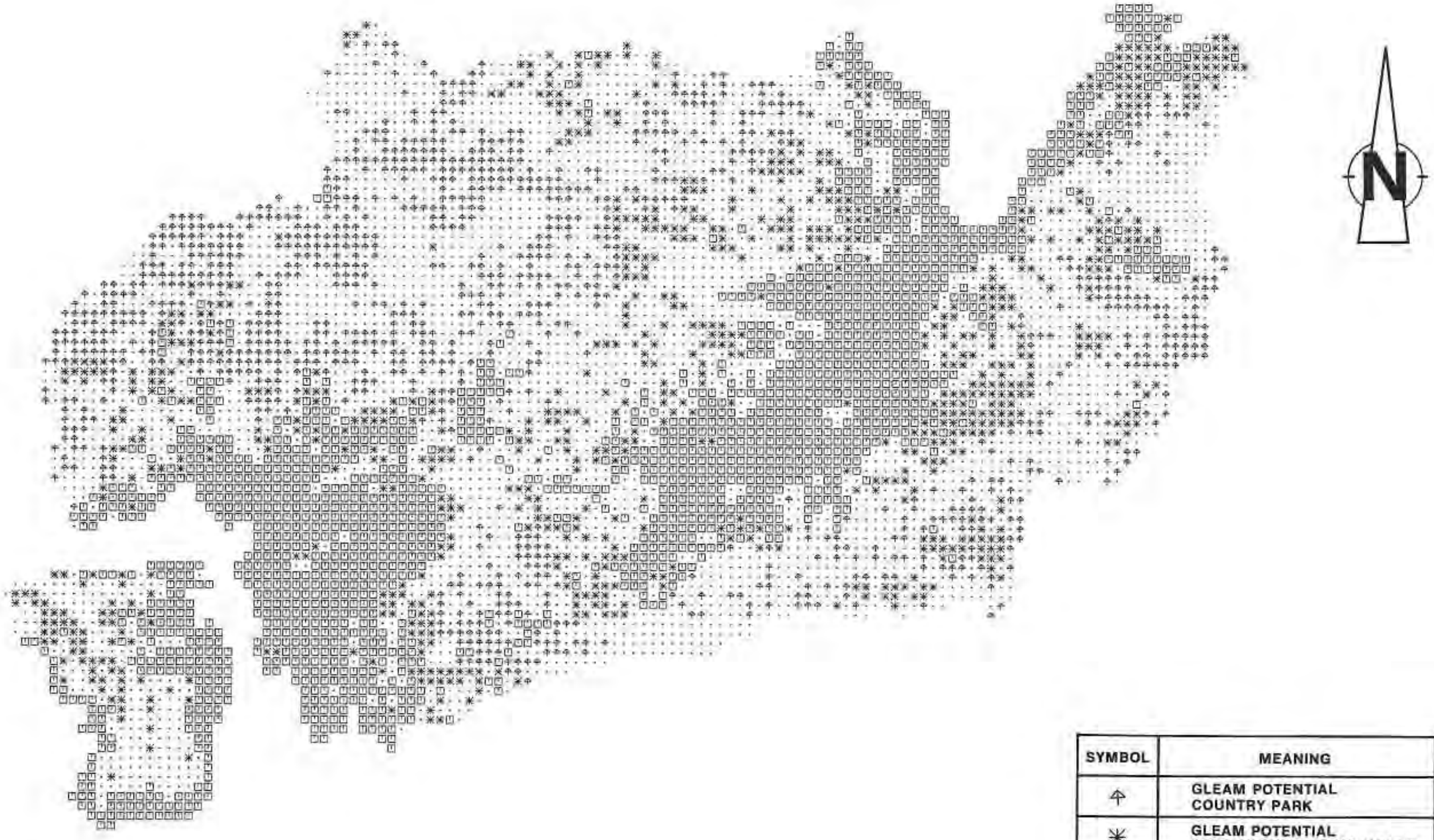


SYMBOL	MEANING	%TOTAL
·	GLUM CLASS I	3.1
+	GLUM CLASS II	36.8
△	GLUM CLASS IIS	0.5
□	GLUM CLASS III	31.6
✳	GLUM CLASS IV	26.0
~	UNCLASSIFIED GLUM CLASS	2.0

Scale
1:100 000

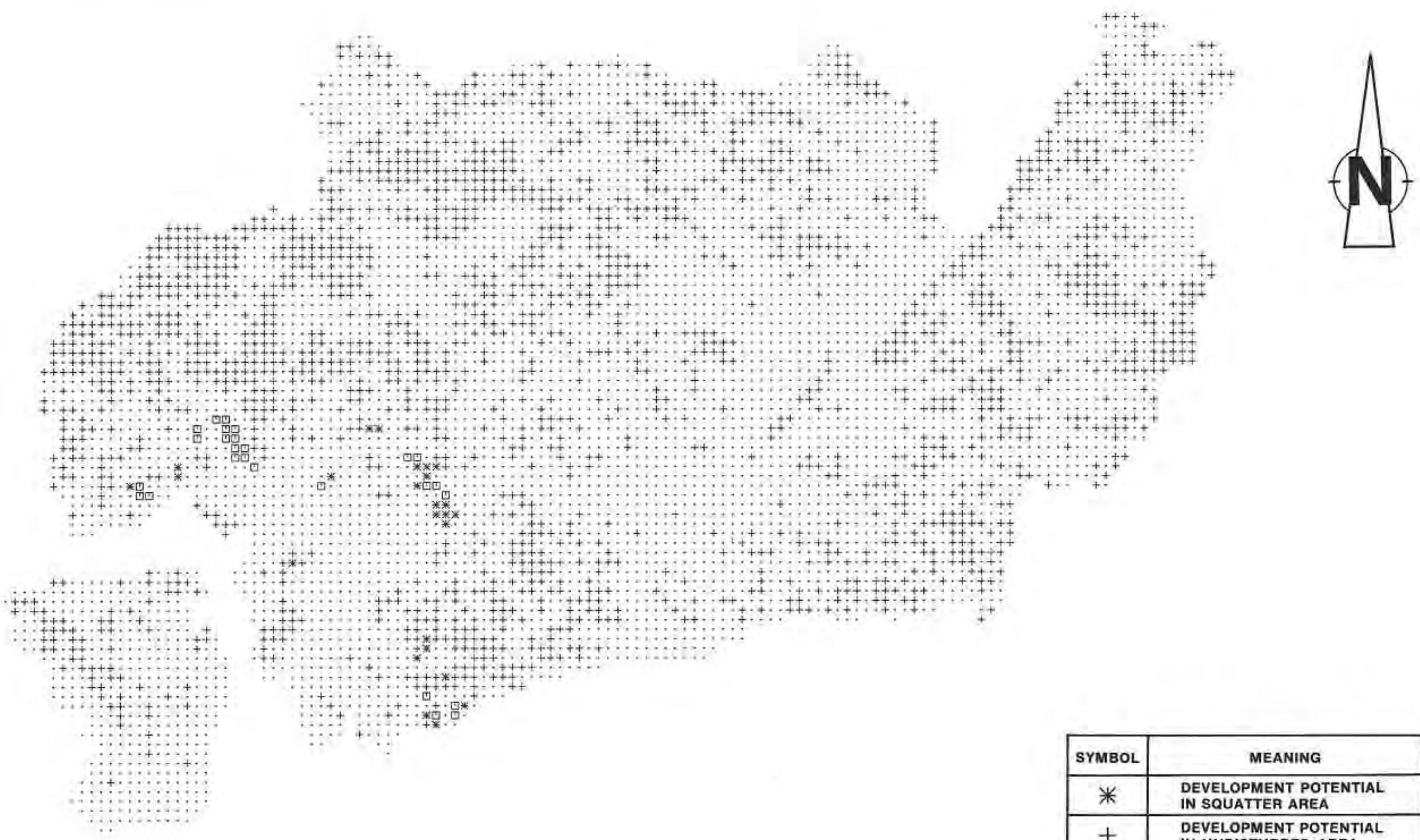
GEOTECS Plot - Geotechnical Land Use Map

Fig. 10



SYMBOL	MEANING	%TOTAL
✢	GLEAM POTENTIAL COUNTRY PARK	16.6
✳	GLEAM POTENTIAL AGRICULTURE OR NO USAGE	13.1
☐	EXISTING DEVELOPMENT OR WATER STORAGE	27.4
·	GLEAM CONSTRAINT	42.9

Scale 1:100 000	GEOTECS Plot - Areas of Development Potential, Summarised from the GLEAM	Fig. 11

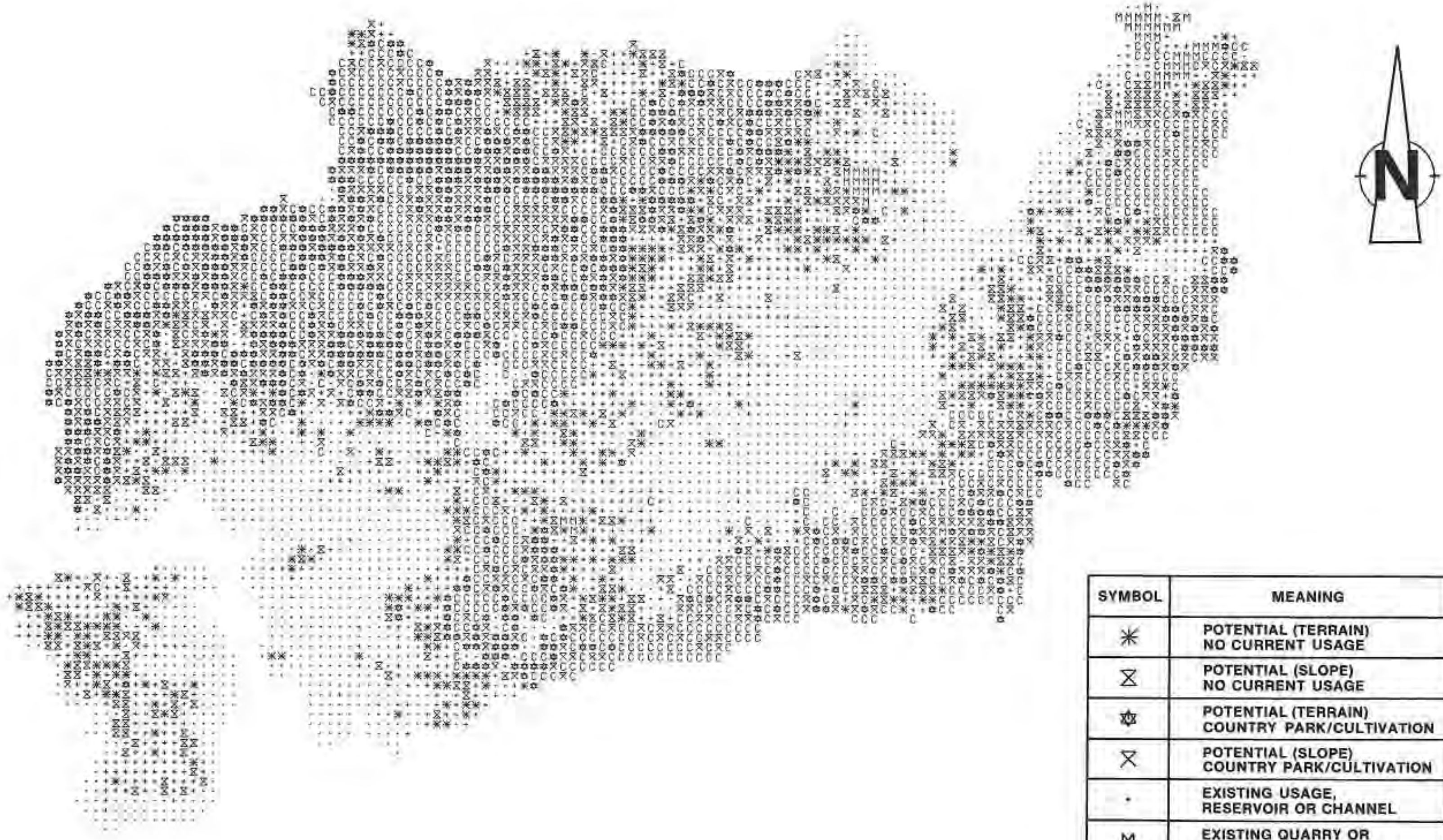


SYMBOL	MEANING	%TOTAL
✳	DEVELOPMENT POTENTIAL IN SQUATTER AREA	0.4
+	DEVELOPMENT POTENTIAL IN UNDISTURBED AREA	28.9
⊡	DEVELOPMENT CONSTRAINT IN SQUATTER AREA	0.4
·	NOT APPLICABLE	70.3

Scale
1:100 000

GEOTECS Plot - Squatters on Land with Potential for Development

Fig. 12

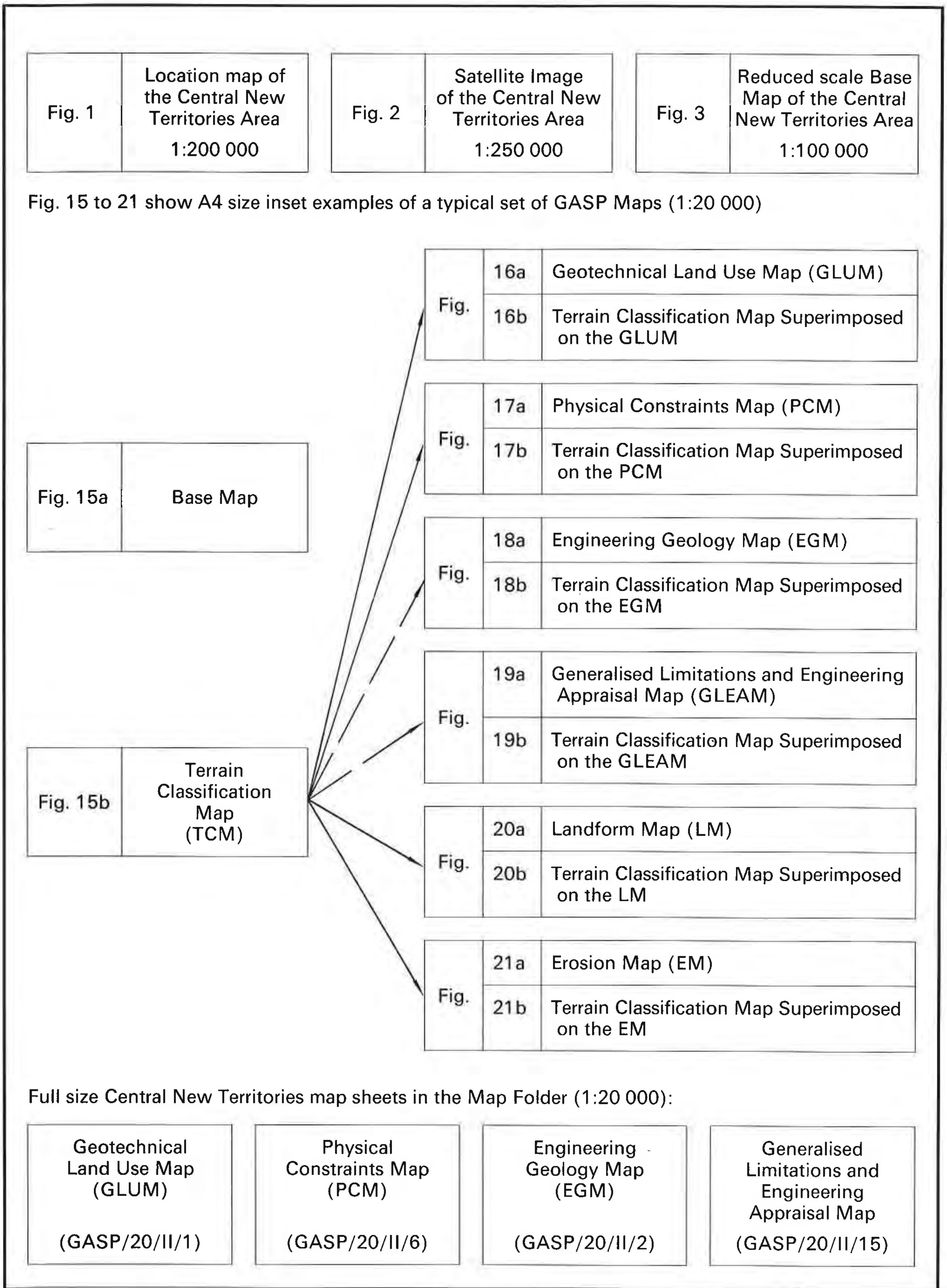


SYMBOL	MEANING	%TOTAL
✳	POTENTIAL (TERRAIN) NO CURRENT USAGE	7.3
⧖	POTENTIAL (SLOPE) NO CURRENT USAGE	6.2
✡	POTENTIAL (TERRAIN) COUNTRY PARK/CULTIVATION	12.7
⧗	POTENTIAL (SLOPE) COUNTRY PARK/CULTIVATION	11.5
·	EXISTING USAGE, RESERVOIR OR CHANNEL	26.2
M	EXISTING QUARRY OR BORROW AREA	0.8
C	OTHER TERRAIN IN COUNTRY PARK, CULTIVATION, POND	19.5
+	UNDESIGNATED - MAY HAVE MINOR POTENTIAL	15.8

Scale
1:100 000

GEOTECS Plot - Distribution of Areas with Potential Use as Quarries

Fig. 13



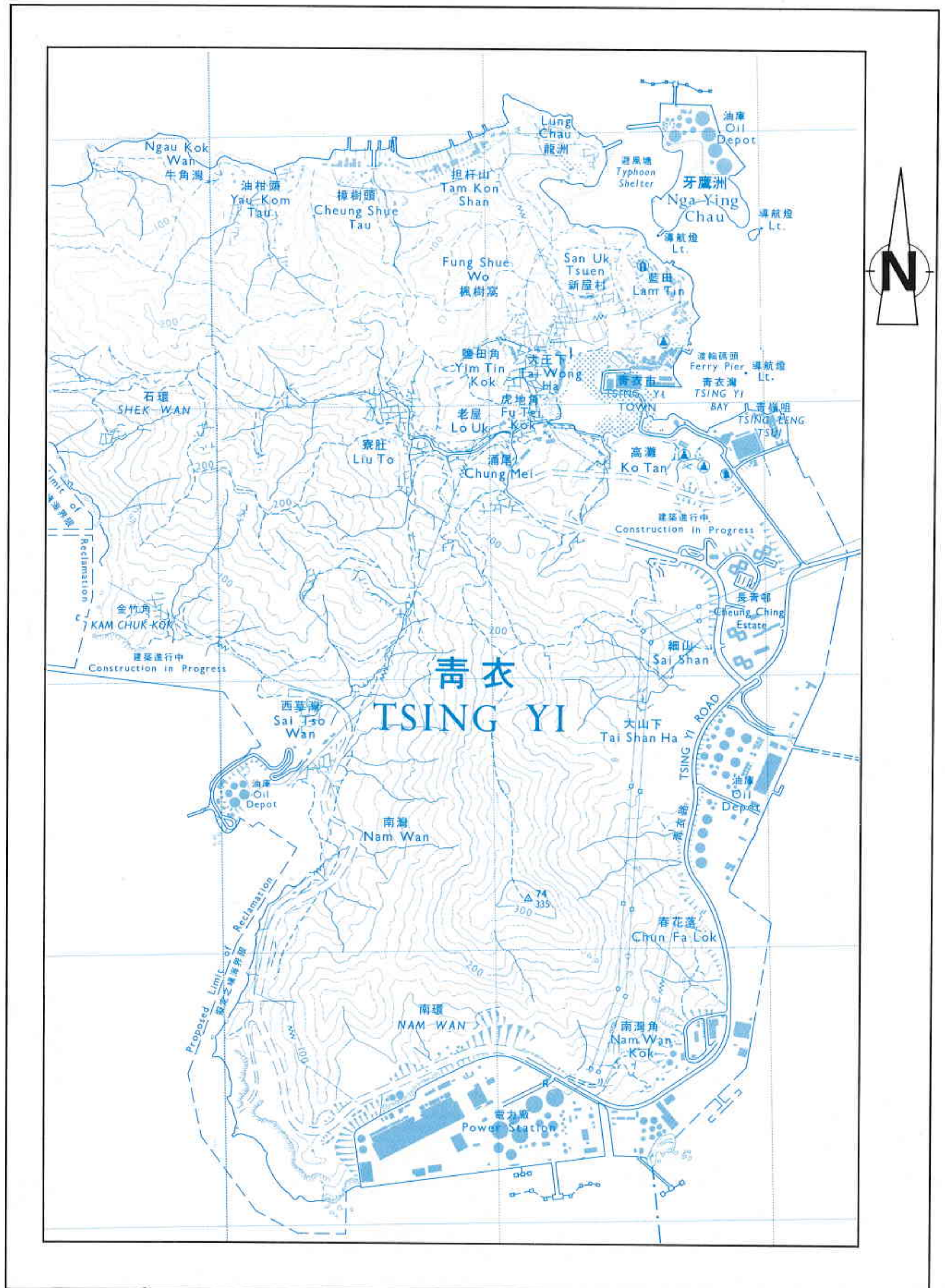
Presentation of Maps — Fig. 14

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 15b)

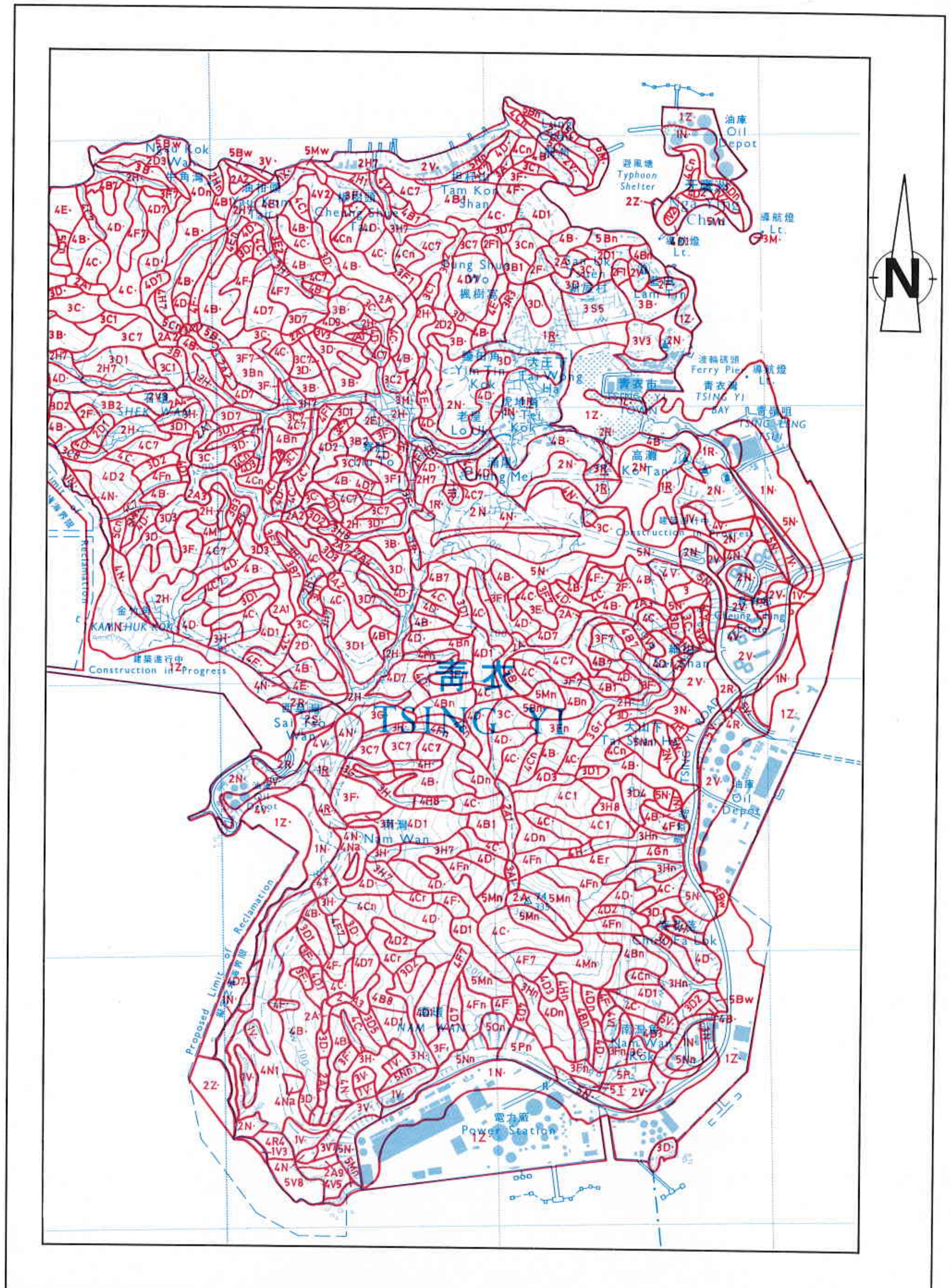
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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. 15a



Scale 1:20 000	Example of the Terrain Classification Map	Fig. 15b

LEGEND FOR GEOTECHNICAL LAND USE MAP (Fig. 16a)

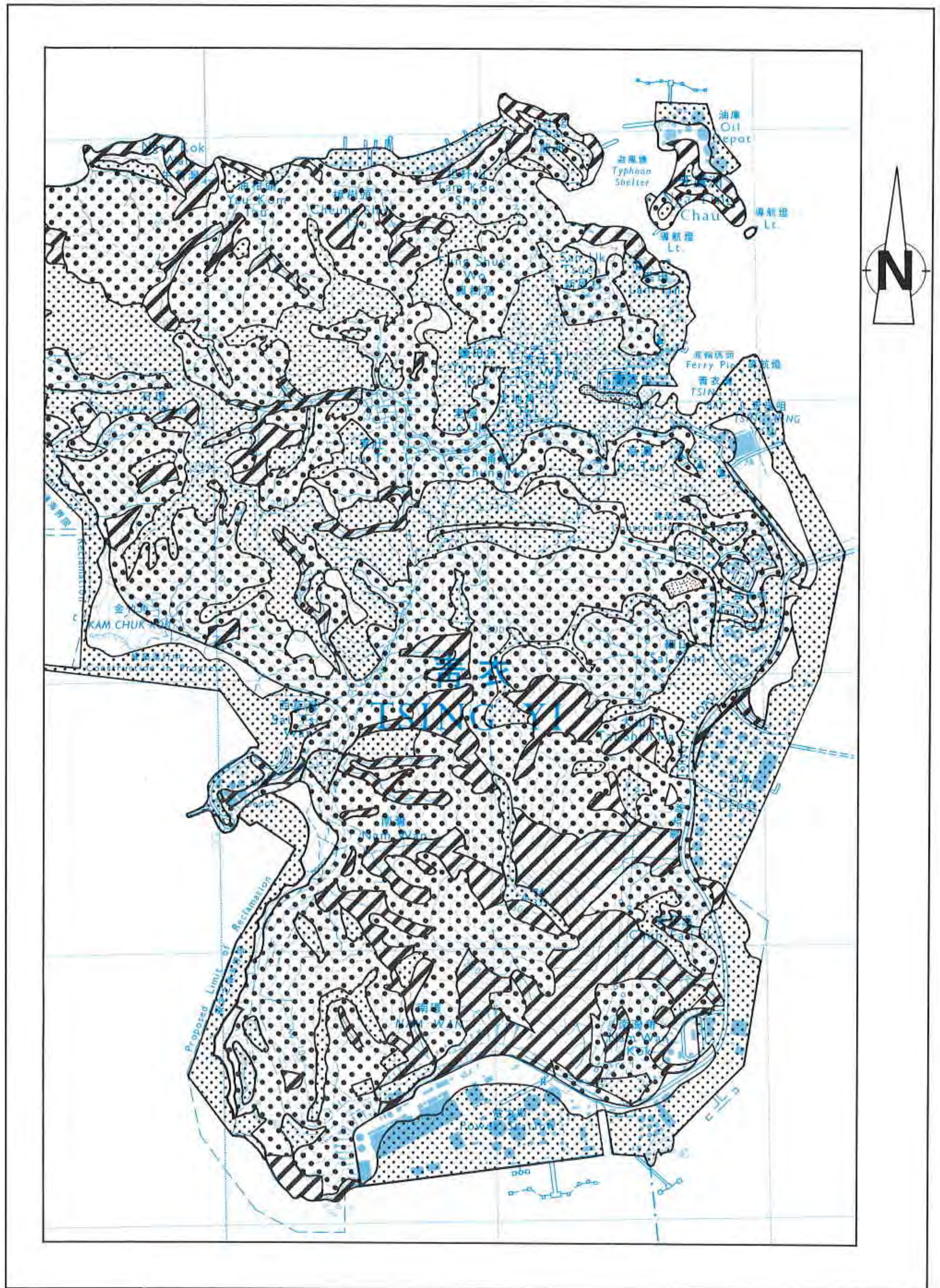
Class I - Low Geotechnical Limitations	
Class II - Moderate Geotechnical Limitations	
Class IIS - Moderate Geotechnical Limitations (including flooding)	
Class III - High Geotechnical Limitations	
Class IV - Extreme Geotechnical Limitations	
Waterbodies (streams, man-made channels, storage dams)	)
Ponds	) Unclassified
Littoral zone (generally subject to tidal action)	)

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 16b)

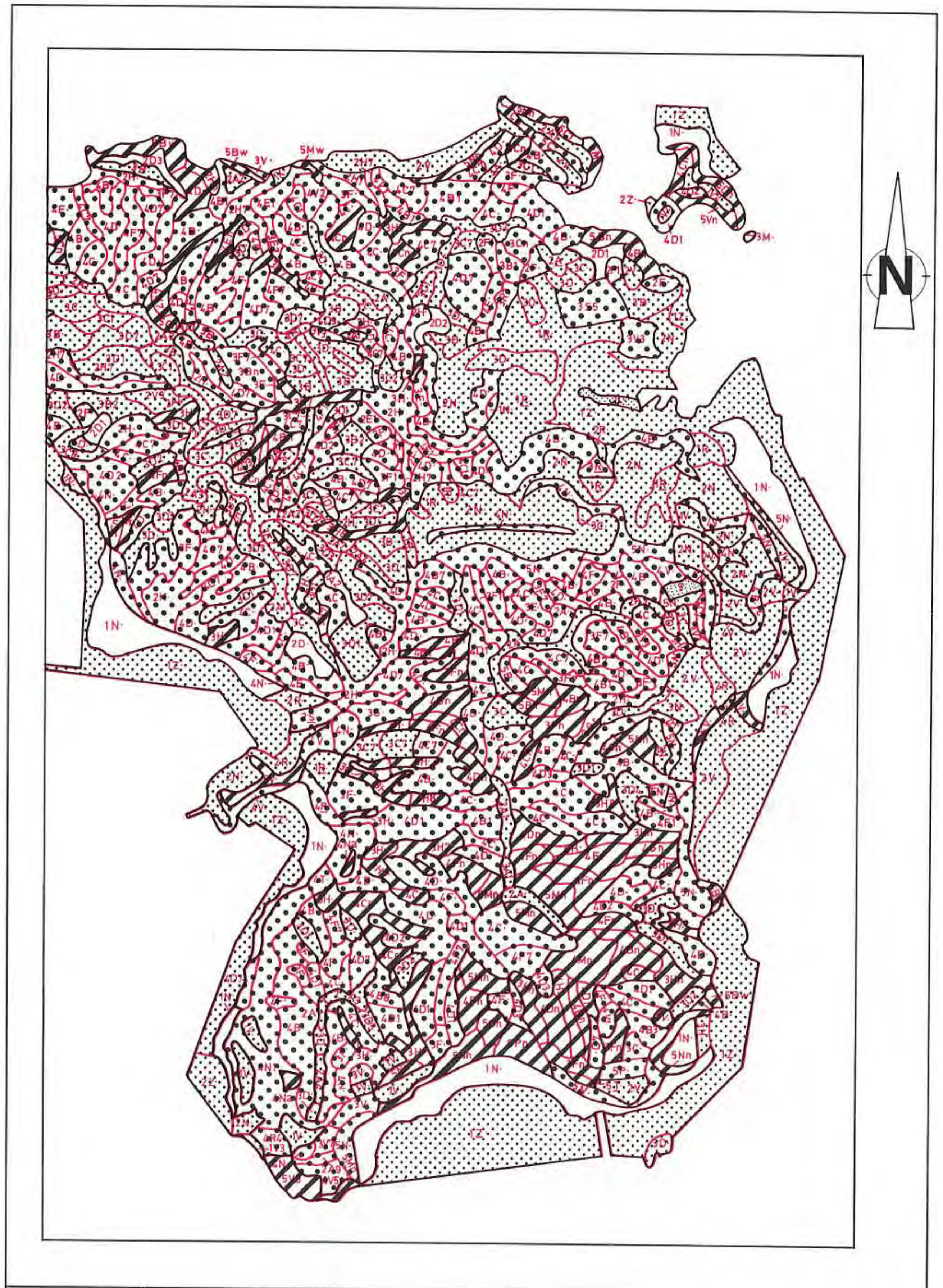
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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. 16a



Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the GLUM	Fig. 16b

LEGEND FOR PHYSICAL CONSTRAINTS MAP (Fig. 17a)

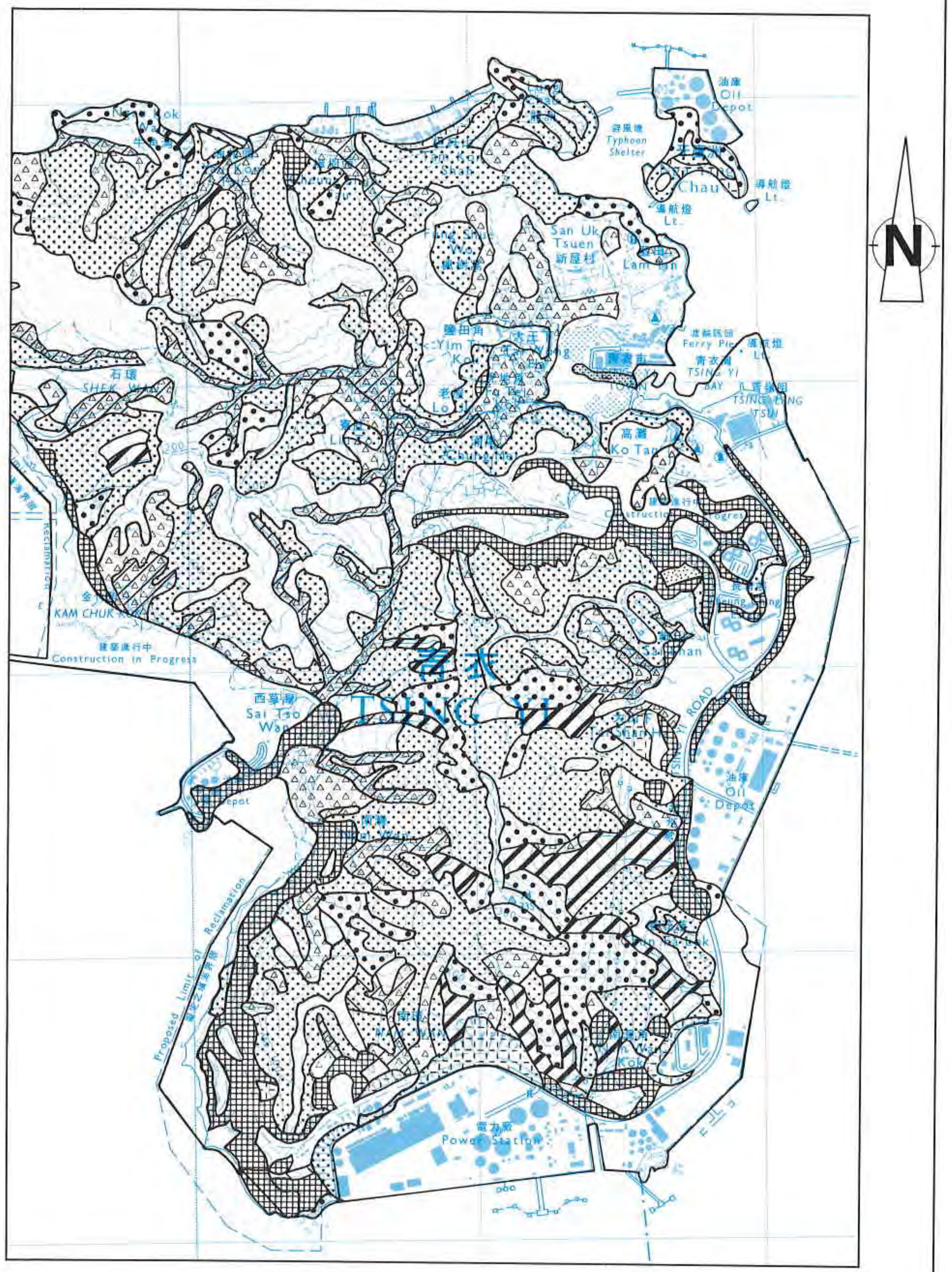
- Colluvium
- Zones of colluvium which are subject to overland flow and periodic inundation. Evidence of unusual groundwater regime (delineated as drainage plain on Landform Map)
- Floodplain - subject to overland flow and regular inundation. Evidence of unusual groundwater regime (delineated as floodplain 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. 17b)

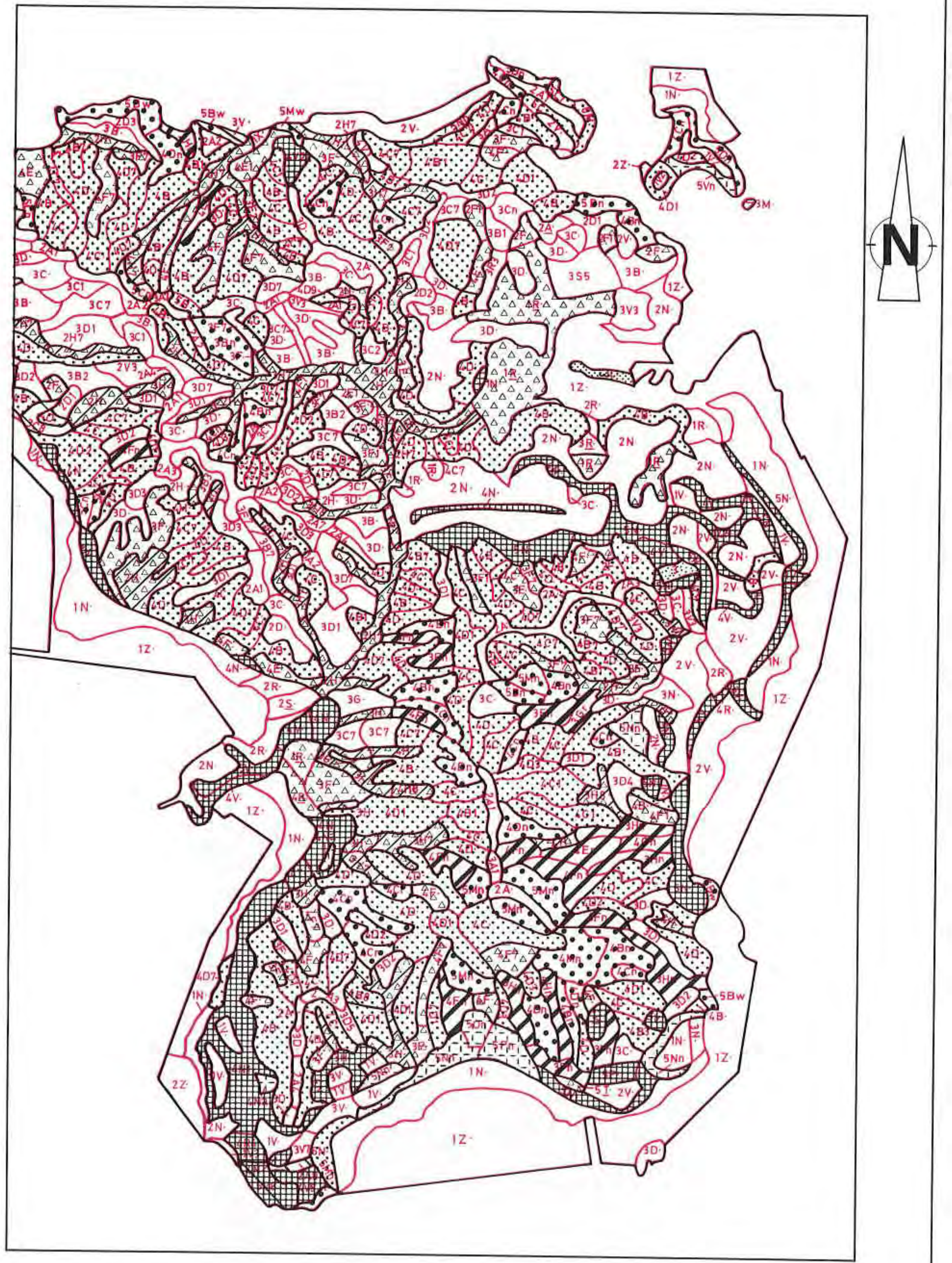
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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 Physical Constraints Map (PCM) | Fig. 17a



Scale 1:20 000 | Example of the Terrain Classification Map Superimposed on the PCM | Fig. 17b

LEGEND FOR ENGINEERING GEOLOGY MAP (Fig. 18a)

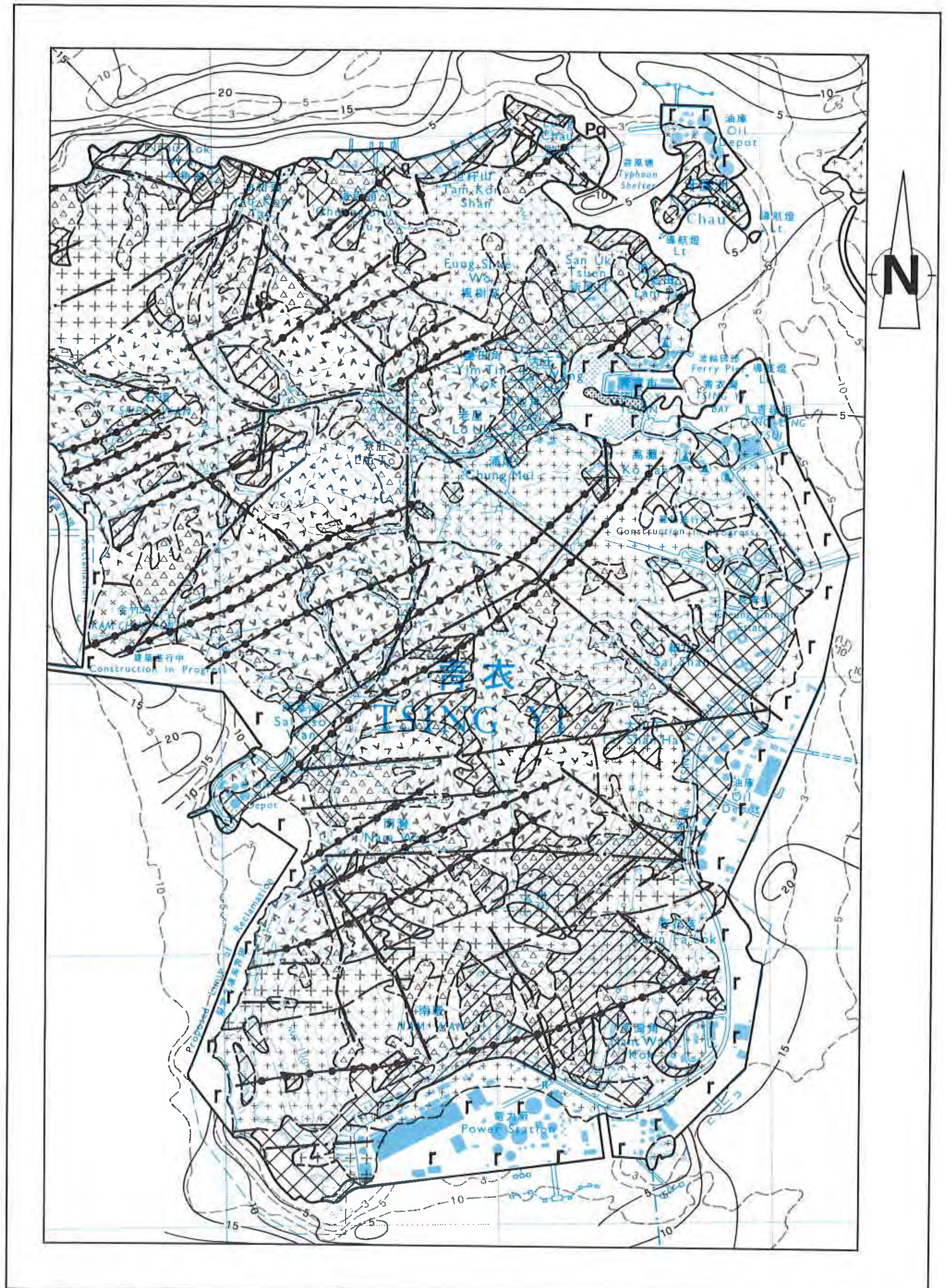
- Fill
- Reclamation
- Littoral deposits
- Alluvium (undifferentiated)
- Colluvium (undifferentiated)
- Undifferentiated volcanic rocks)
- Sedimentary rocks and water-laid volcaniclastic rocks)
- Acid lavas)
- Mainly banded acid lavas and some welded tuffs) Repulse Bay Formation
- Coarse tuff)
- Agglomerate)
- Dominantly pyroclastic rocks with some lavas)
- Tolo Harbour Formation
- Needle Hill Granite : fine-grained porphyritic phase
- Quartz monzonite and porphyritic adamellite
- Ma On Shan Granite
- Cheung Chau Granite
- Sung Kong Granite
- Tai Po Granodiorite
- Feldspar porphyry dyke
- pq Quartz porphyry dyke
- D Dolerite dyke
- Mo Quartz monzonite and porphyritic adamellite
- q Quartz veins
- Geological boundary (solid)
- Geological boundary (superficial)
- f Fault
- Geological photolineament
- General instability
- A A' Geological cross-section line
- Catchment boundary (order indicated by number of dots)
- Isopach of submarine superfical deposit (in metres)
- Depth in fathoms

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 18b)

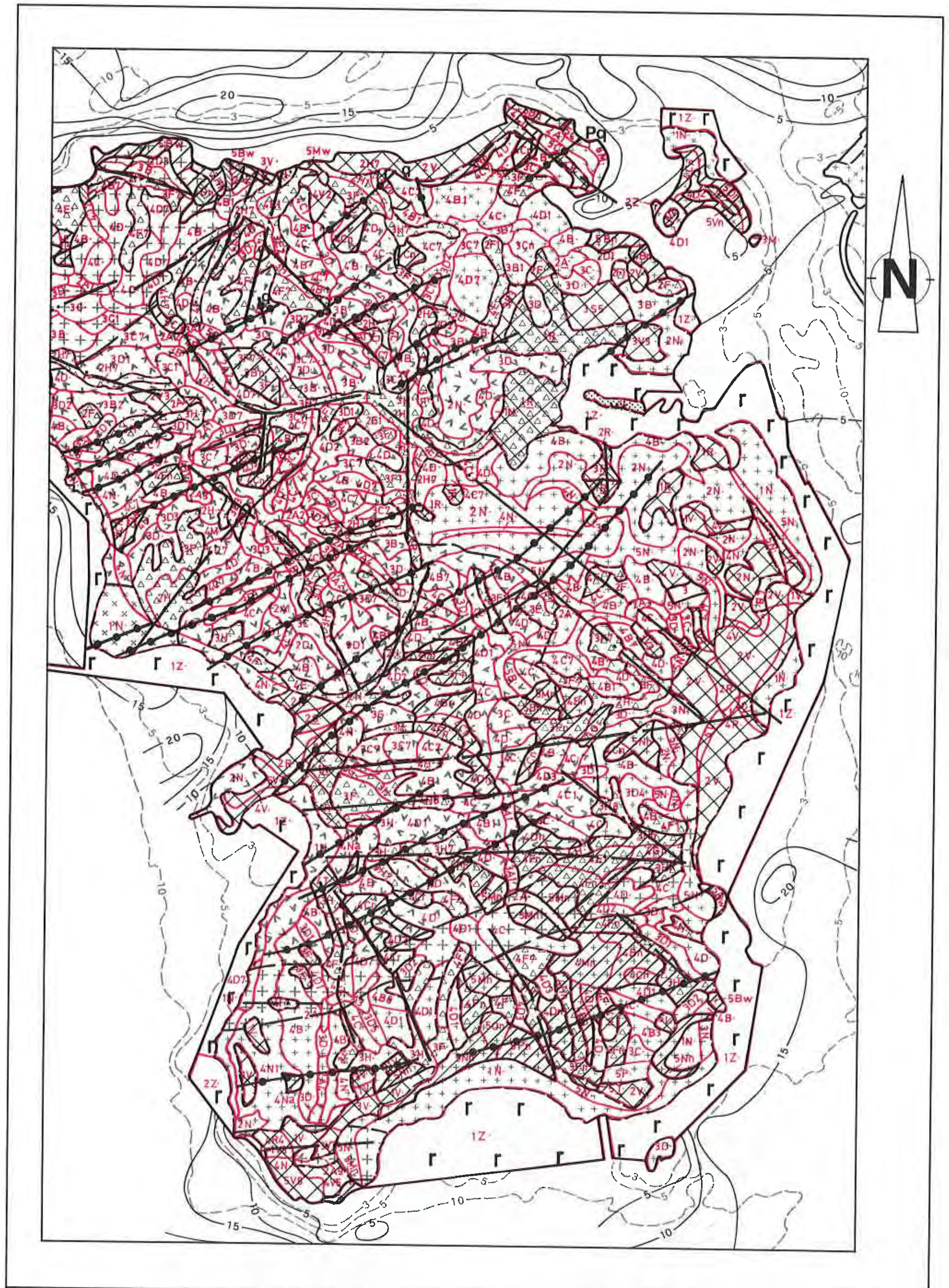
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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 Engineering Geology Map (EGM) | Fig. 18a



Scale 1:20 000 | Example of the Terrain Classification Map Superimposed on the EGM | Fig. 18b

LEGEND FOR GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP (Fig. 19a)

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

High voltage power lines

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

ABBREVIATIONS :

cont.	control
devt.	development
gran.	granite
instab.	instability
mod.	moderate
pot.	potential
sed.	sedimentary
sh.	shallow
st.	steep
volc.	volcanic

FEATURES OF ENGINEERING SIGNIFICANCE :

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

NOTES

i) Features are generally indicated only where of significance to identified potential development areas.

ii) For explanation of significance of identified features, see Report Appendix A, Table A6, and Section 4.2.

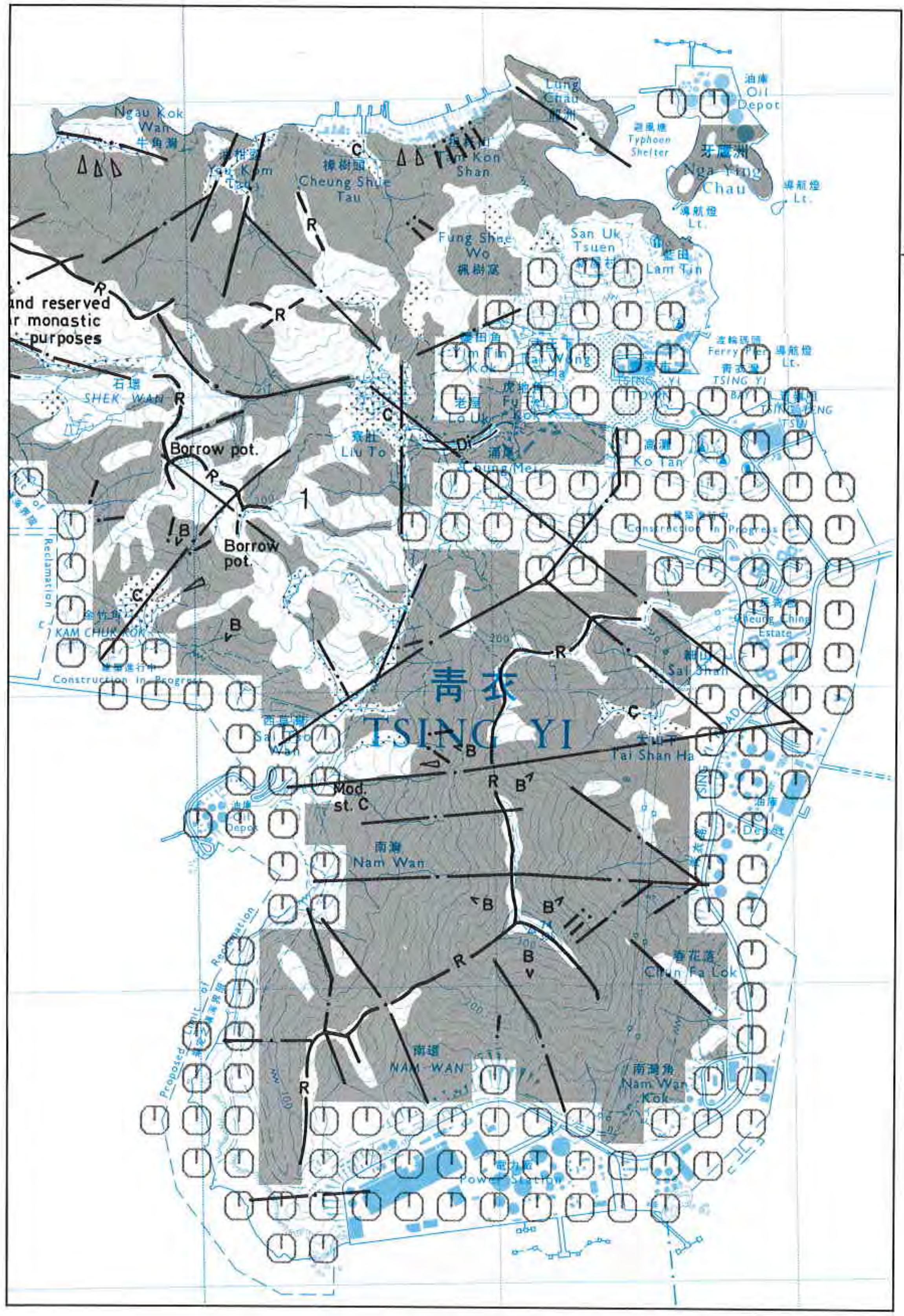
iii) Geological boundaries and photolineament are shown in full on the EGM. Those lineaments indicated represent the surface epxression of obvious structural discontinuities which affect the PDA's.

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 19b)

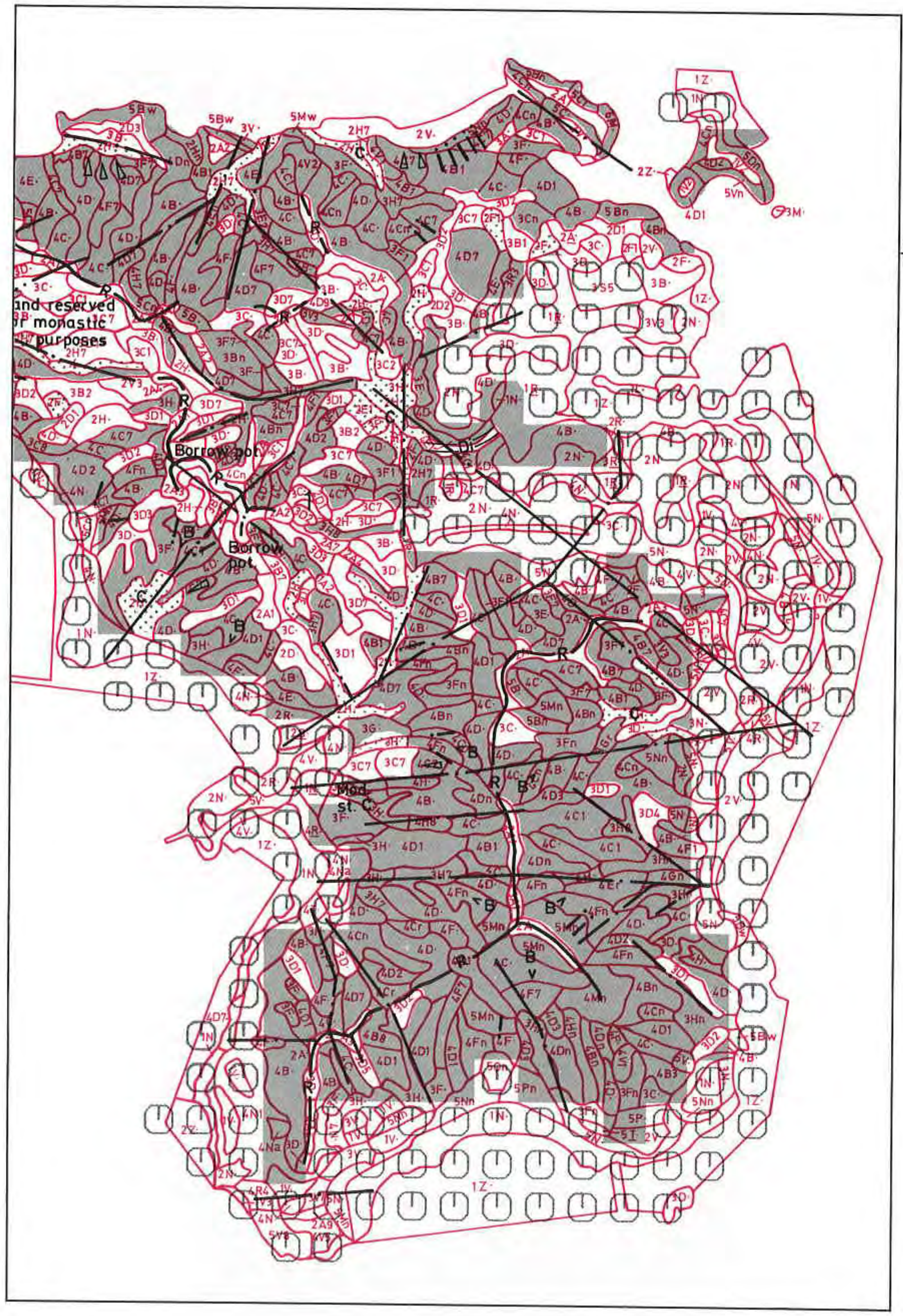
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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 Generalised Limitations and Engineering Appraisal Map (GLEAM)	Fig. 19a



Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the GLEAM	Fig. 19b

LEGEND FOR LANDFORM MAP (Fig. 20a)

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

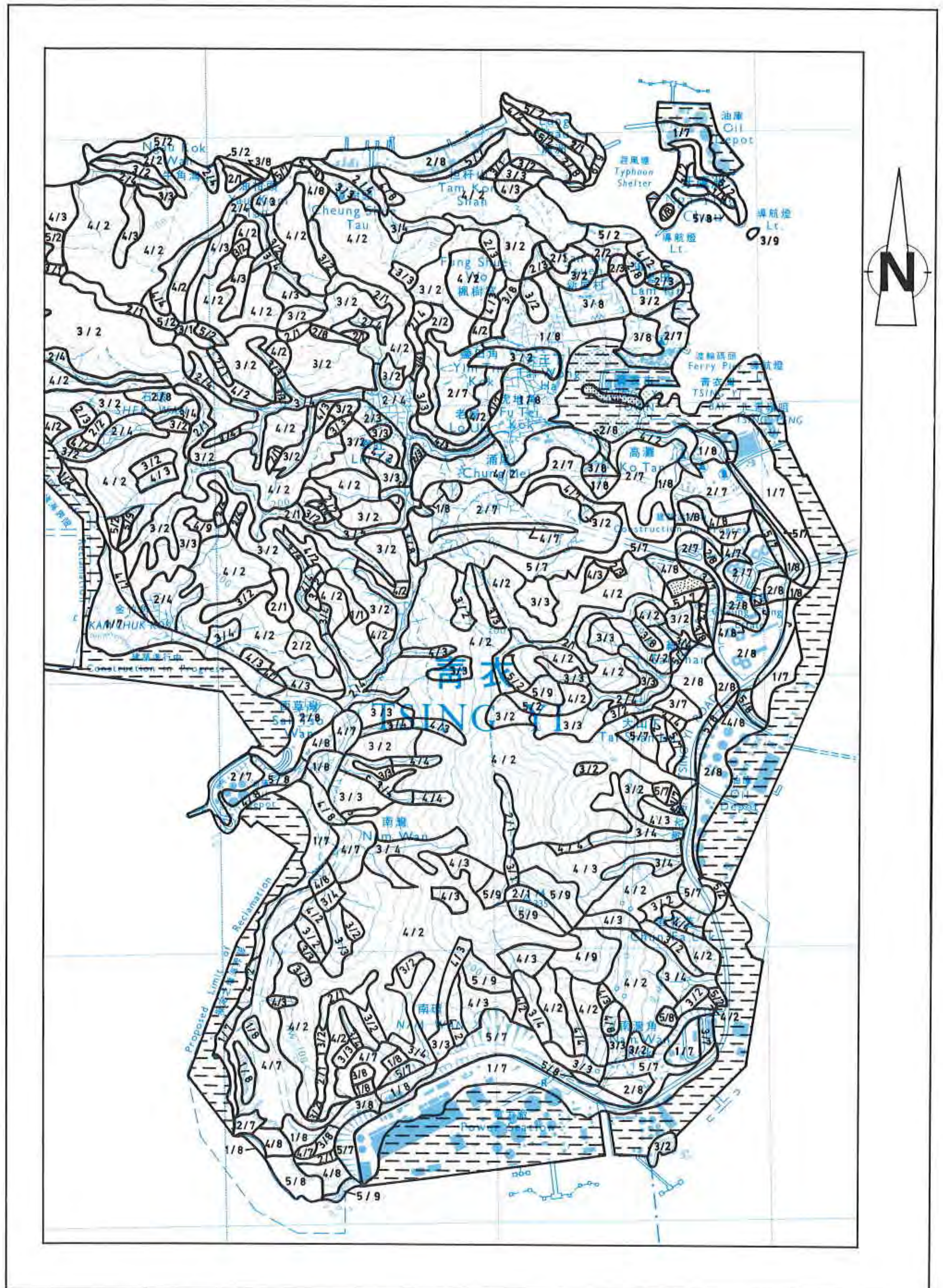
DESCRIPTION	CODE
Crest or ridge	1
Sideslope - insitu	2
Footslope - colluvium	3
Drainage plain - colluvium subject to overland flow and regular inundation. Unusual groundwater regime.	4
Alluvial plain - includes raised terraces.	5
Flood plain - portion of alluvial plain subject to overland flow and regular 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)	ω

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 20b)

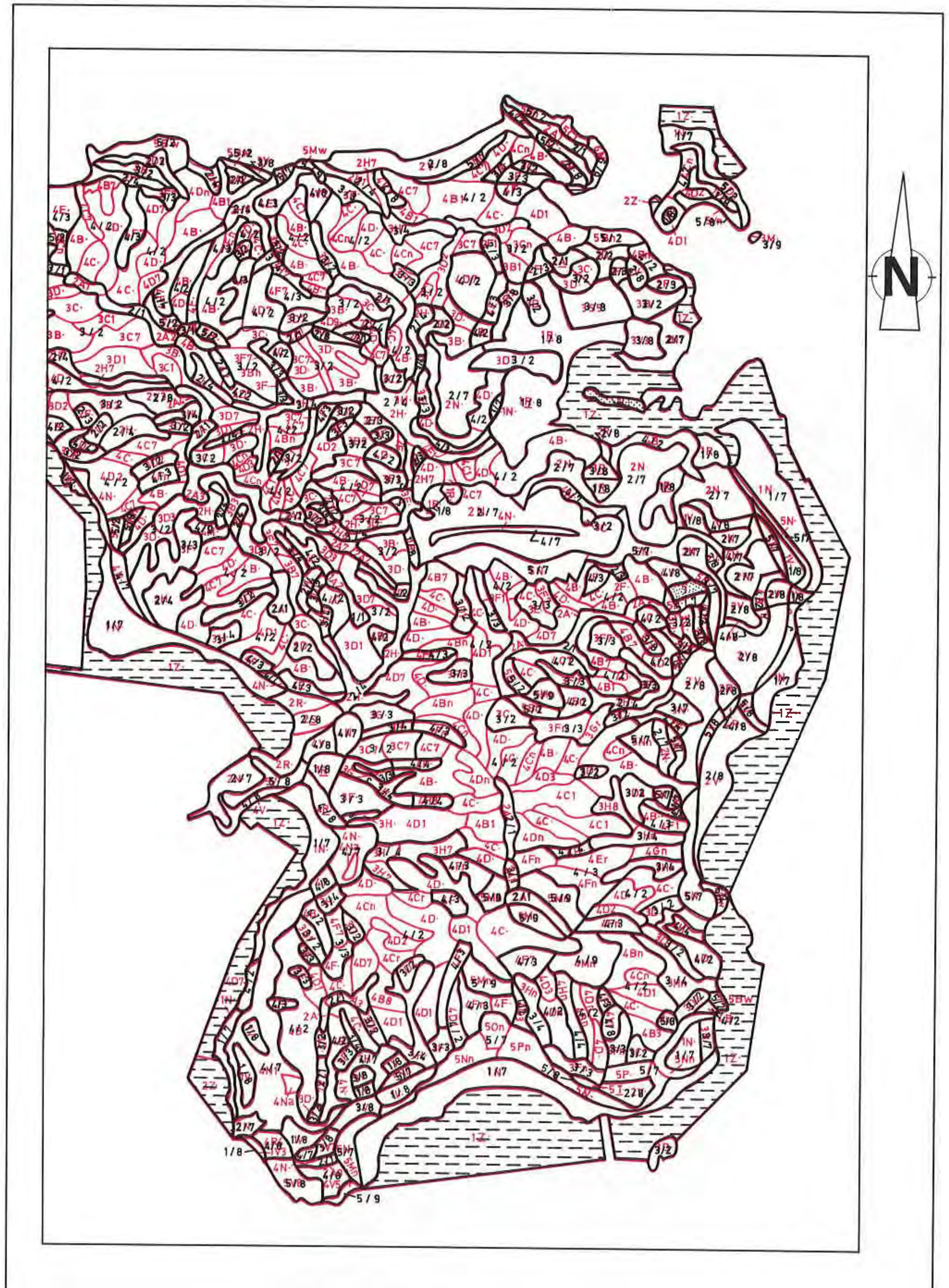
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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 Landform Map (LM)	Fig. 20a



Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the LM	Fig. 20b

LEGEND FOR EROSION MAP (Fig. 21a)

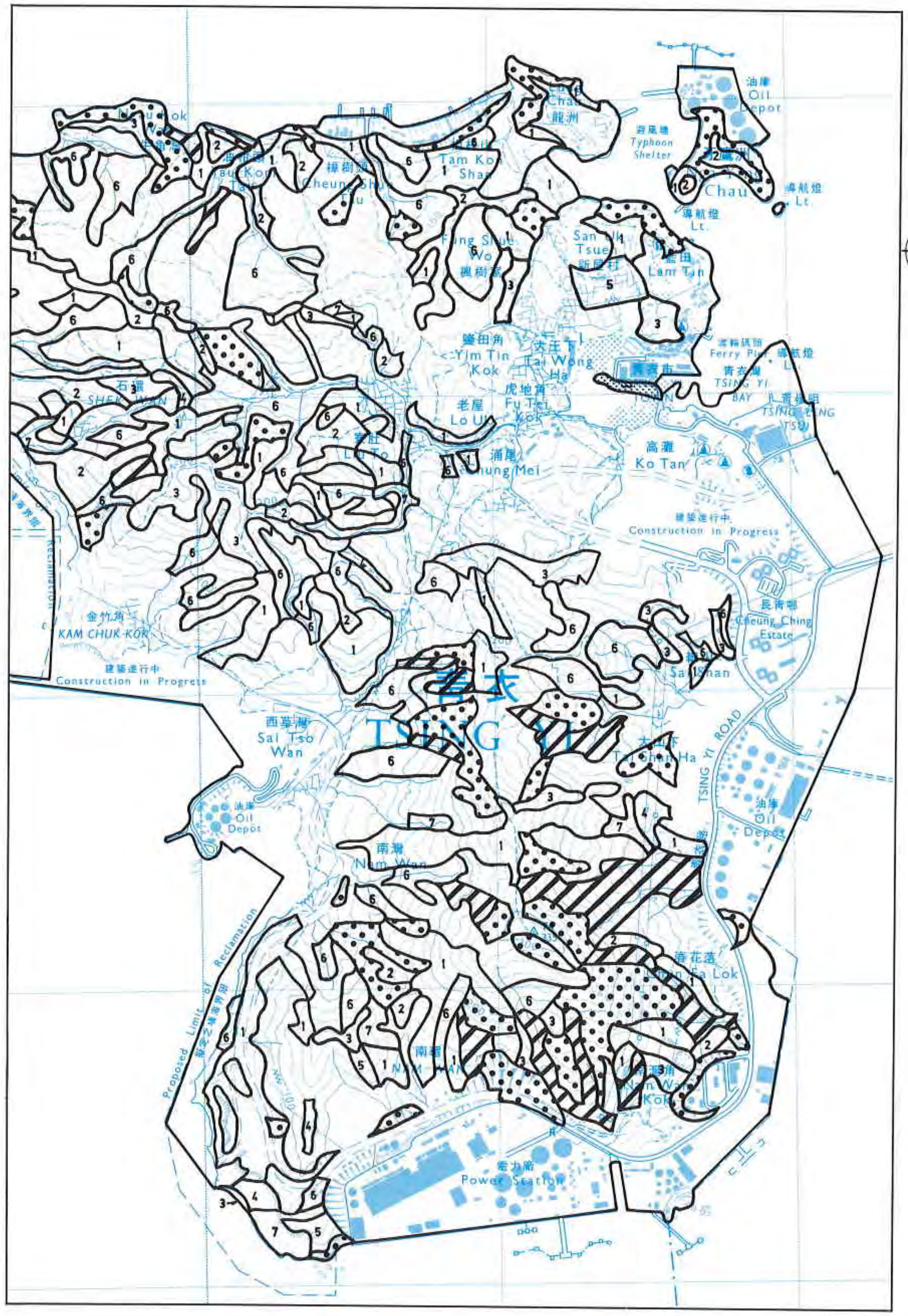
	No appreciable erosion
1	Minor sheet erosion
2	Moderate sheet erosion
3	Severe sheet erosion
4	Minor rill erosion
5	Moderate to severe rill erosion
6	Minor gully erosion
7	Moderate to severe gully erosion
	Zones of general instability associated with predominantly insitu terrain
	Zones of general instability 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. 21b)

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. 21a

Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the EM	Fig. 21b

Plate 1. Oblique Aerial Photograph Looking Northwest across the Study Area. (1983/48681)

Plate 2. Oblique Aerial Photograph Looking Southwest towards Tsuen Wan and Tsing Yi Island. (1983/48739)

Plate 3. Oblique Aerial Photograph Looking Southwest across the Sha Tin Valley towards Hong Kong Island. (1983/48628)

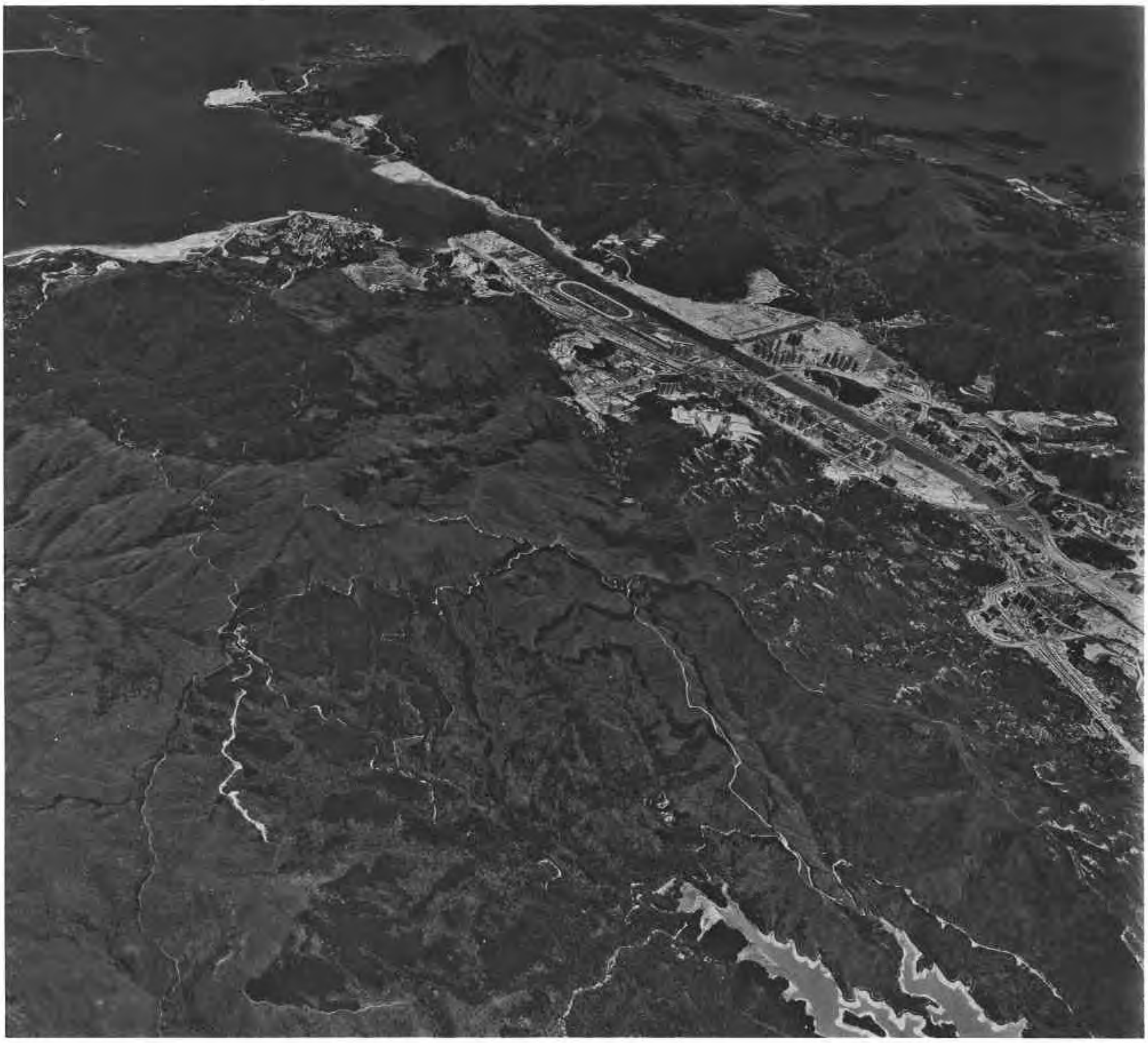
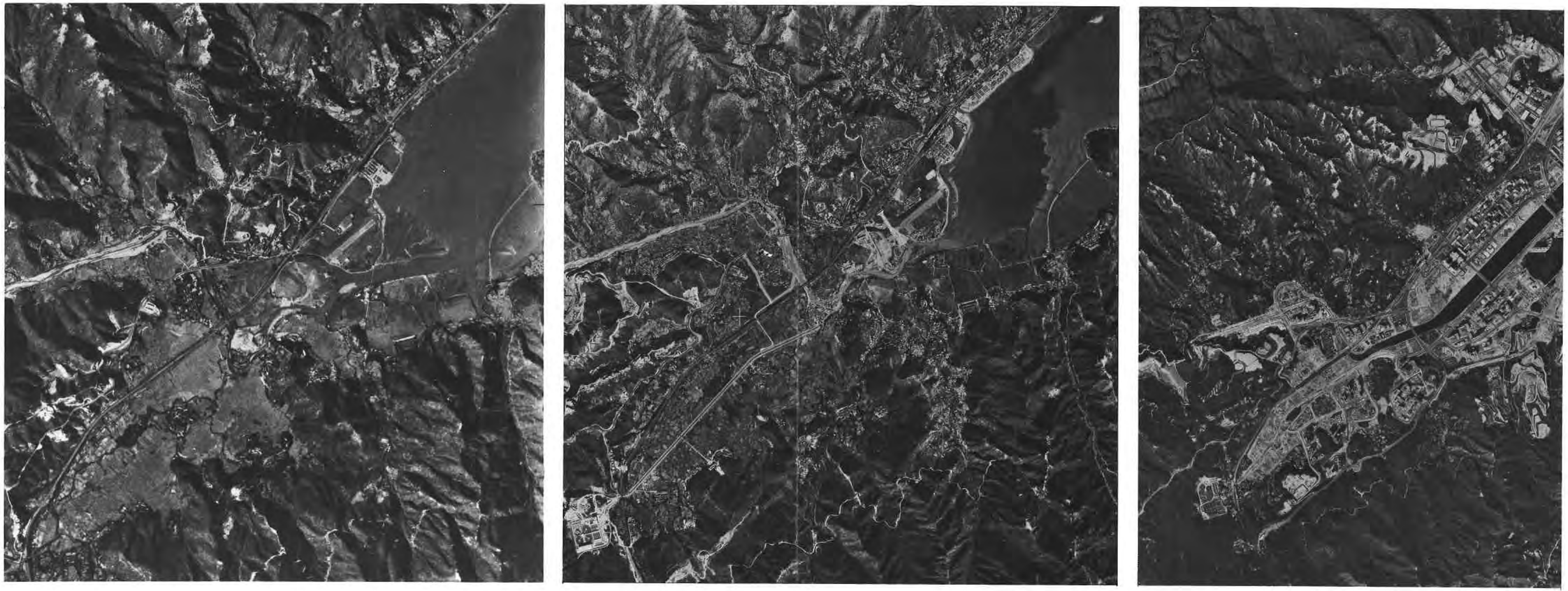


Plate 4. Oblique Aerial Photograph Looking East across the Sha Tin Valley towards Sai Kung. (1983/48753)



a. The Terrain in 1954

b. The Terrain in 1964

c. The Terrain in 1983

Plate 5. Aerial Photographs of the Southwestern Portion of the Sha Tin Valley in 1954, 1964 and 1983.
(1954/81A/RAF552-0078; 1964/2579; 1983/47114)

Plate 6. Oblique Aerial Photograph of Wu Kwai Sha Tsui and Ma On Shan. (1981/39398)

Plate 7. Oblique Aerial Photograph Looking West across Lei Uk Tsuen towards the Lower Shing Mun Reservoir. (1978/21057)

Plate 8. Oblique Aerial Photograph of Mining Operations near Ma On Shan. This photograph was taken in 1963 whilst the Ma On Shan Mine was in production. The mine tailing dumps have now been covered by reclamation. (1963/5309)

Plate 9. Aerial Photograph of the Sha Tin Valley. (1981/39179)

Plate 10. Low Level Oblique Aerial Photograph Looking North across the Sha Tin Valley. (1983/47567)

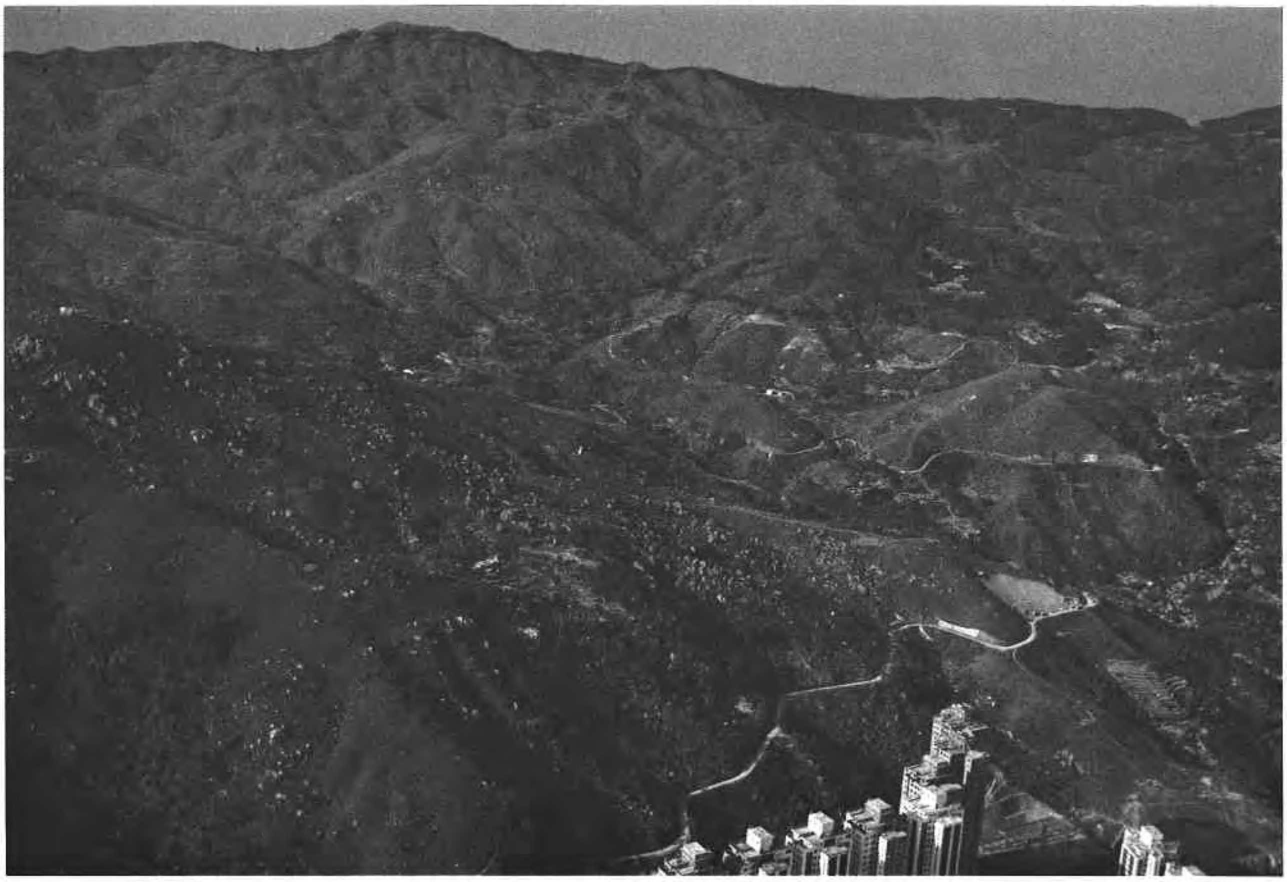


Plate 11. Dissected Upland Terrain and Boulder Strewn Sideslopes Northwest of Tsuen Wan. Predominantly coarse-grained pyroclastic rocks and coarse tuffs of the Repulse Bay Formation are shown in this Plate. Numerous large residual corestones and tors at bottom-left indicate the presence of the Repulse Bay Formation Agglomerate. These boulders may influence future developments down slope. The extensive valley floors and footslopes are liable to flood during storm periods. Stream entrainment, infilling and platforming may render these lowerlying areas suitable for development. (GCO/OAP 1980/2866).

Plate 12. Ridgecrest Erosion on the Needle Hill Granite. The Needle Hill Granite is less susceptible to erosion than other coarser—grained granites in Hong Kong. The resultant topography is correspondingly less rounded with moderately steep sideslopes. Gully erosion, occasionally severe, is generally confined to ridgecrests and spurlines. (GCO/OAP 1981/4897).

Plate 13. Terraced Colluvium in the Shek Kwu Lung Valley. Colluvial valley and footslope terrain has been extensively terraced for agricultural purposes. The underlying geology consists essentially of granitic rocks with surrounding volcanic sideslope terrain. Slope angles are relatively low and local instability is usually associated with drainage incision and undercutting of valley floor colluvium. Complex groundwater conditions are expected in colluvial terrain of this nature. The Plate shows portion PDA 24—Shek Kwu Lung. (GCO/OAP 1982/7893).

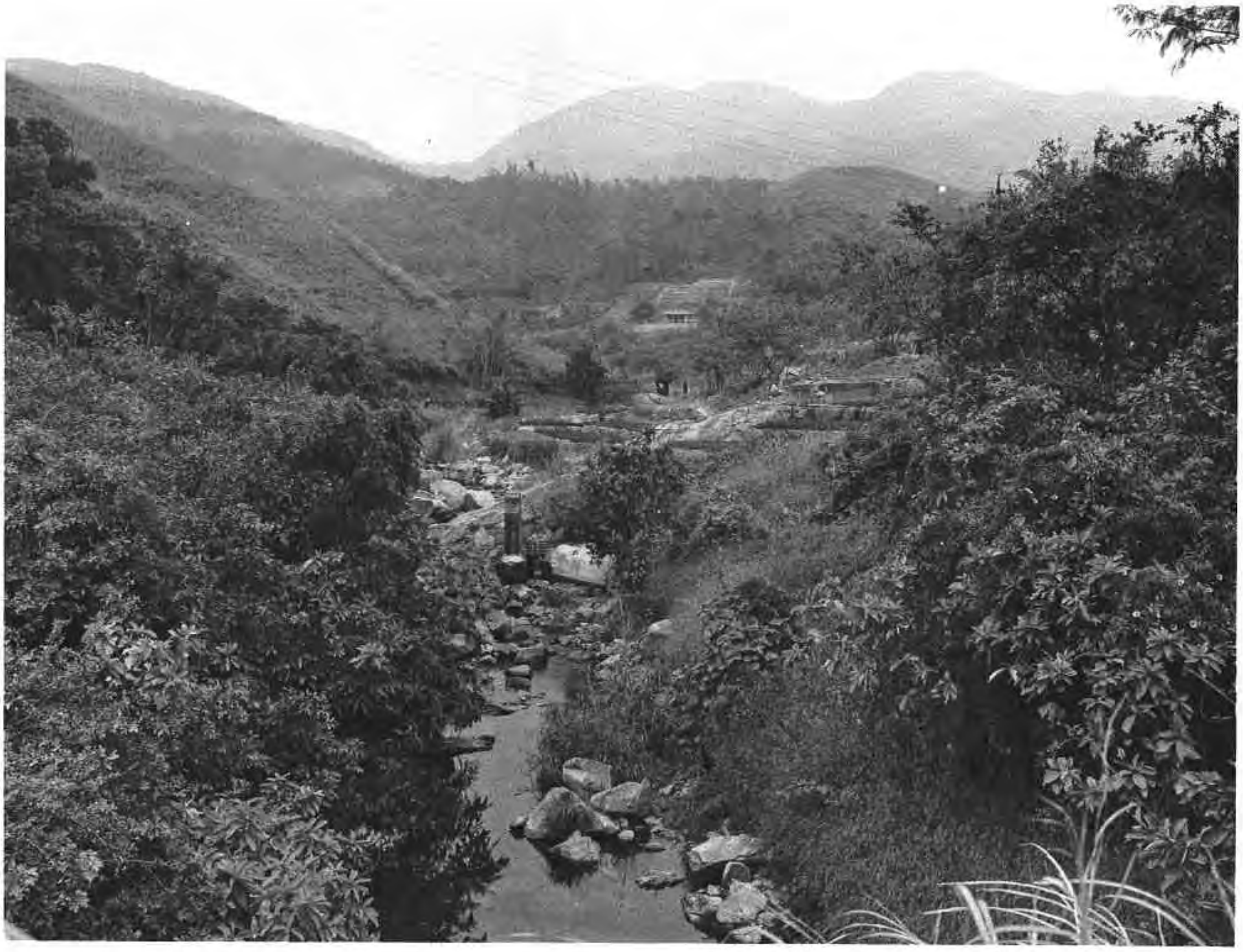


Plate 14. Low Volcanic Hills surround an Extensive Drainage Plain Infilled with Colluvial Detritus. Erosion is restricted to streambed incision. Entrainment of natural drainage and special provision for anomalous subsurface water conditions could render this area suitable for future development (Part of PDA 4—Chuen Lung).

Plate 15. Terraced Lenticular Colluvium to the East of Sha Tin Pass. Extensive valley floor colluvial deposits have been terraced for agricultural purposes. Complex groundwater conditions are probable in these materials. Structural geological discontinuities coincide with the valley floor alignment, and differentially weathered (deep) insitu materials are likely.

Plate 16. Upper Sideslope and Ridgecrest Terrain on Tai Mo Shan. Grass and shrub covered volcanic ridgecrest and upper sideslope terrain at Tai Mo Shan provide opportunities for future development from a geotechnical view point (Part of PDA 6—Tai Mo Shan).

Plate 17. *Alluvial Fan and Deltaic Deposits at Wu Kai Sha.* The area is part of the Ma On Shan New Town Development. Recent alluvial sands and gravels overlying older clays silts and sands predominate in these flat-lying superficial deposits. Some interdigitation of these materials with colluvial fan deposits is expected on footslope and drainage plain terrain in the middle-left of the Plate. (GCO/OAP 1983/9000).

Plate 18. *Unstable Terrain Associated with the Mine near Ma On Shan.* A very large, well-defined landslip is evident in the middle-left of this Plate. The workings at the now abandoned mine probably caused the slope failure. Extensive mine tailings are evident at bottom of the Plate. These superficial deposits (man-made) are probably poorly compacted. Both the above features constitute significant geotechnical constraints for future development. (GCO/OAP 1982/7452).

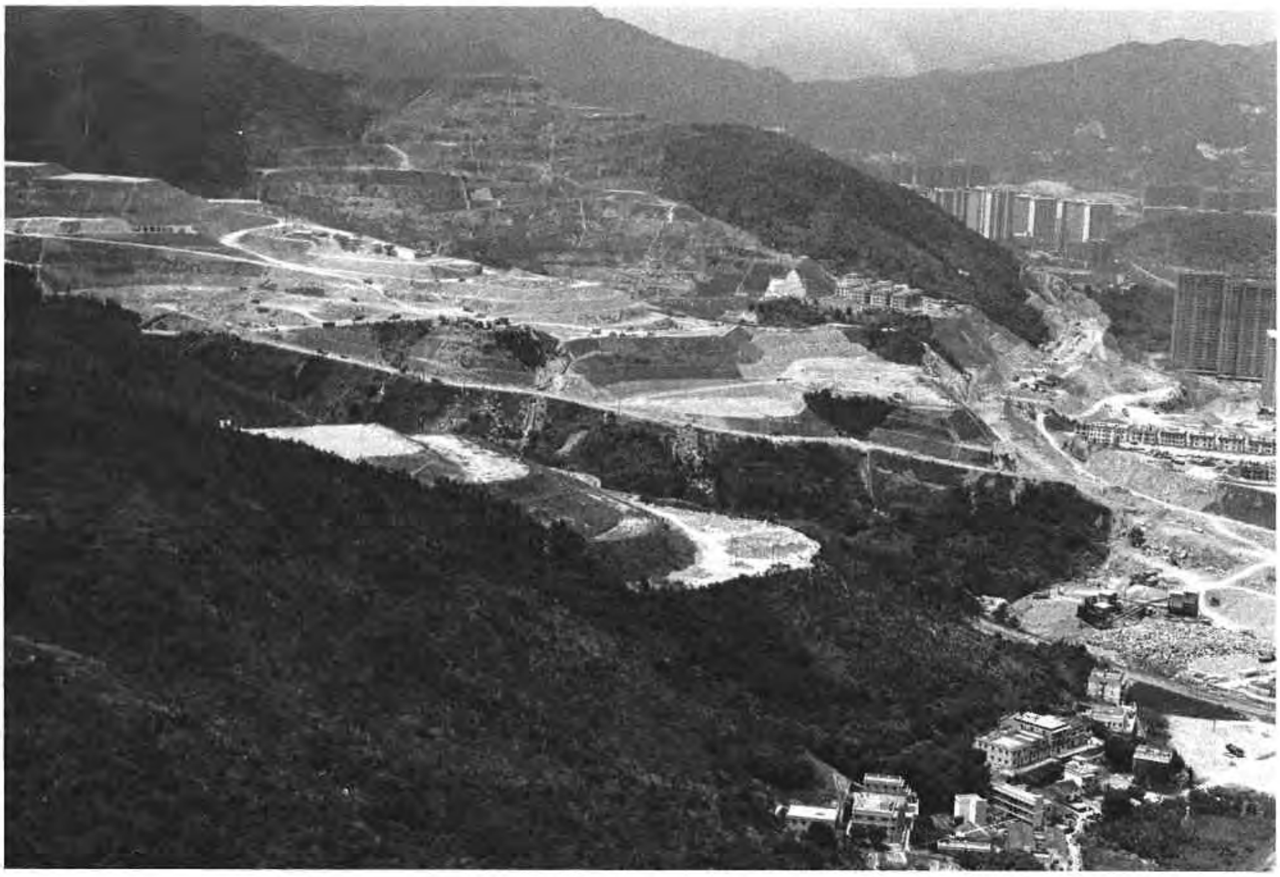


Plate 19. Construction in Progress to the South of the Sha Tin New Town Development. Large platforms have been created in deeply weathered granitic terrain (Sung Kong Granite) to yield fill for reclamation. The formed platforms (Area 57, Area 52b and 52c) are for residential development. (GCO/OAP 1982/7895).

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

Terrain evaluation involves the identification of landform and terrain related features. This technique is used both to identify land use limitations and to assess in broad terms overall land use suitability. It is used as a planning tool and has a major application in the field of geotechnical engineering. In this Geotechnical Area Study, a systematic approach is used to collect, characterise and rationalise the natural variations which occur across the terrain. The structure and presentation of the terrain evaluation system used in this Report is illustrated in Figure 14.

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

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

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

A flow-chart depicting the basic technique of data acquisition and map production is shown in Figure A1. The GAS Programme is discussed by Styles & Burnett (1983, 1985), Styles et al (1982, 1984, 1986), Brand et al (1982 a & b), Burnett & Styles (1982) and Burnett et al (1985).

A.2 Technique of Terrain Classification

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

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

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

In this study, three characteristics (attributes) are delineated on the 1:20 000 scale Terrain Classification Map, of which an example is given in Figure 15b. The three terrain attributes adopted for the analysis are:

(*a*) Slope gradient.

(*b*) Terrain component and morphology.

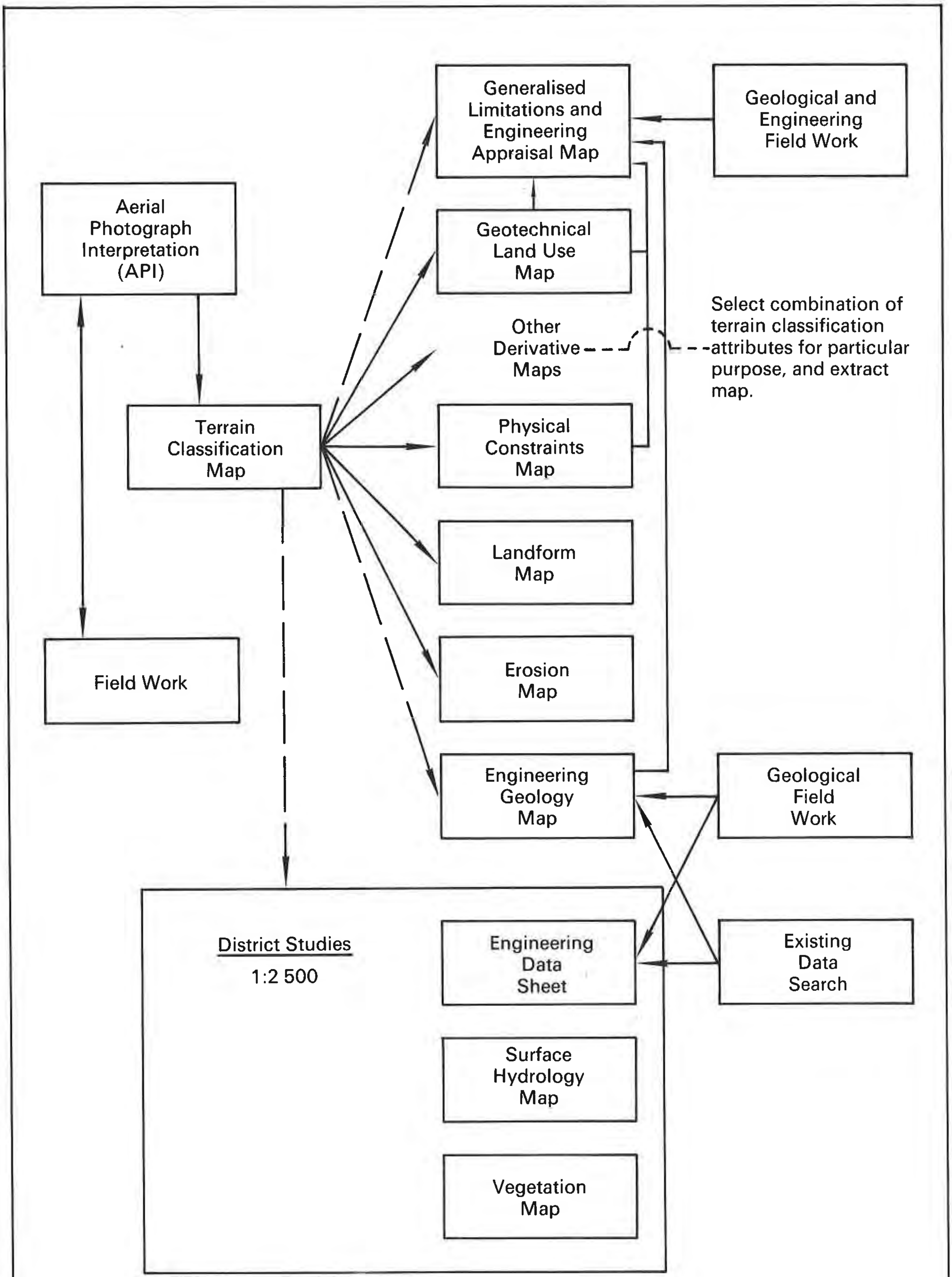
(*c*) Erosion and instability.

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

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

A.3 Terrain Classification Map

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



Technique of Data Acquisition and Derivation of Maps

Fig. A1

Table A1 Terrain Classification Attributes

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

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

A.3.1 *Slope Gradient*

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

A.3.2 *Terrain Component and Morphology*

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

There are the following 13 major terrain component classes:

(*a*) Hillcrest (Code A).

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

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

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

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

(*f*) Floodplain (Code I).

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

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

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

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

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

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

(*m*) Reclamation (Code Z).

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

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

A.3.3 *Erosion and Instability*

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

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

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

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

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

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

A.4 Landform Map

The Landform Map provides a simple model of the broad geomorphological classes and delineates the extent and distribution of the major terrain units within the study area. The Landform Map (example in Figure 20a) extracts from the Terrain Classification Map the significant terrain component and slope gradient classes. This information is presented as a separate map. In this form it is easier to appreciate, understand and interpret the pattern of landform distribution.

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

(*a*) Hillcrest or ridge.

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

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

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

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

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

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

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

(*i*) Cliff and rock outcrop.

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

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

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

A.5 Erosion Map

The Erosion Map is derived from the Terrain Classification Map and delineates the major forms of erosion within the Central New Territories. 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 21.

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

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

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

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

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

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

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

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

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

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

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

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

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

A.6 Physical Constraints Map

The Physical Constraints Map (PCM) presents the major physical constraints which will influence development in the area. It is extracted from the Terrain Classification Map and is designed specifically to supplement the GLUM. An example is presented in Figure 17.

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

The major constraints which are shown on the map are:

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

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

(*c*) Colluvium.

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

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

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

(*g*) Disturbed terrain (extensive cut and fill batters which generally 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

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

The GLUM is derived from the Terrain Classification Map. The slope, terrain component and erosion attributes described in Table A1 are considered in evaluating the general level of geotechnical limitation. A GLUM class is assigned to each combination of attributes to represent the limitation which is likely to be imposed on development. An appropriate GLUM class can therefore be allocated to each landform unit identified during the terrain classification of the study area. These are represented on the GLUM, an example of which is presented in Figure 16. There are four GLUM Classes.

(i) *Class I—Low Geotechnical Limitations*
These areas are characterised by a low level of geotechnical limitation, and consequently have the highest suitability for development. Costs of site formation, foundation works and drainage works are expected to be low. Only normal geotechnical investigations will probably be required and investigation costs are expected to be low.

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

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

(iii) *Class III—High Geotechnical Limitations*
These areas are characterised by high geotechnical limitations, and consequently are of low suitability for development. Costs of site formation, foundation works and drainage works can be expected to be high. Intensive geotechnical investigations will be necessary, and investigation costs will be high.

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

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

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

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

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

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

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

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

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

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

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

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

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

A.8 Engineering Geology Map

A.8.1 *Background*

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

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

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

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

A.8.2 *Production of the Engineering Geology Map*

The Engineering Geology Map was compiled from selected information from the Terrain Classification Map, to which was added various existing data (Appendix C) and information collected during the field reconnaissance. The 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.

The Engineering Geology Map for the Central New Territories GASP is contained in the Map Folder accompanying this Report and an example is located at Figure 18. Note that this map will be superseded during the remapping of the geology of the Territory (See Section 1.1).

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

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

(*b*) Major photolineaments.

(*c*) Major topographic features.

(*d*) Isopachs of submarine superficial deposits.

(*e*) Boundaries of major catchments.

(*f*) Zones of general instability.

(*g*) Zones of reclamation.

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

A.8.3 *Colluvium Classification System*

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

(*a*) Essentially volcanic derived.

(*b*) Essentially granite derived.

(*c*) Essentially metasediment derived.

(*d*) Mixed origin.

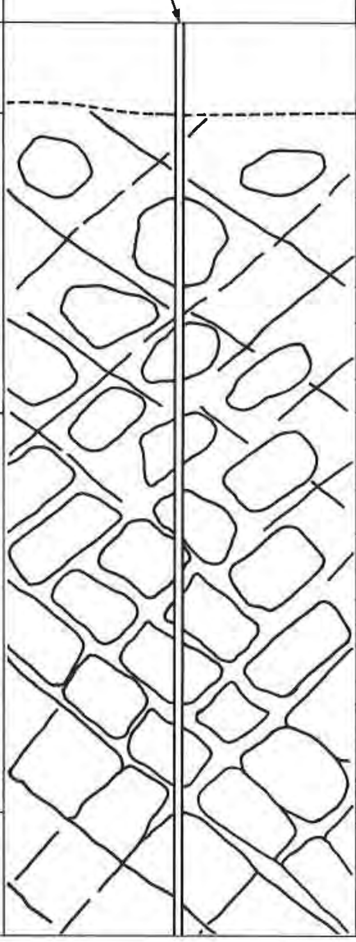
This classification is applied to the colluvial deposits on the basis of the parent geology. The classification is based on API and is not extensively field checked. These classes are not presented on the Engineering Geology Map but are included in the GEOTECS data bank.

A.8.4 *Data Collection*

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

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

Table A3 Rock Weathering System

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

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

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

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

A.9 Generalised Limitations and Engineering Appraisal Map

A.9.1 *Introduction*

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

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

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

A.9.2 *Derivation of the GLEAM*

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

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

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

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

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

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

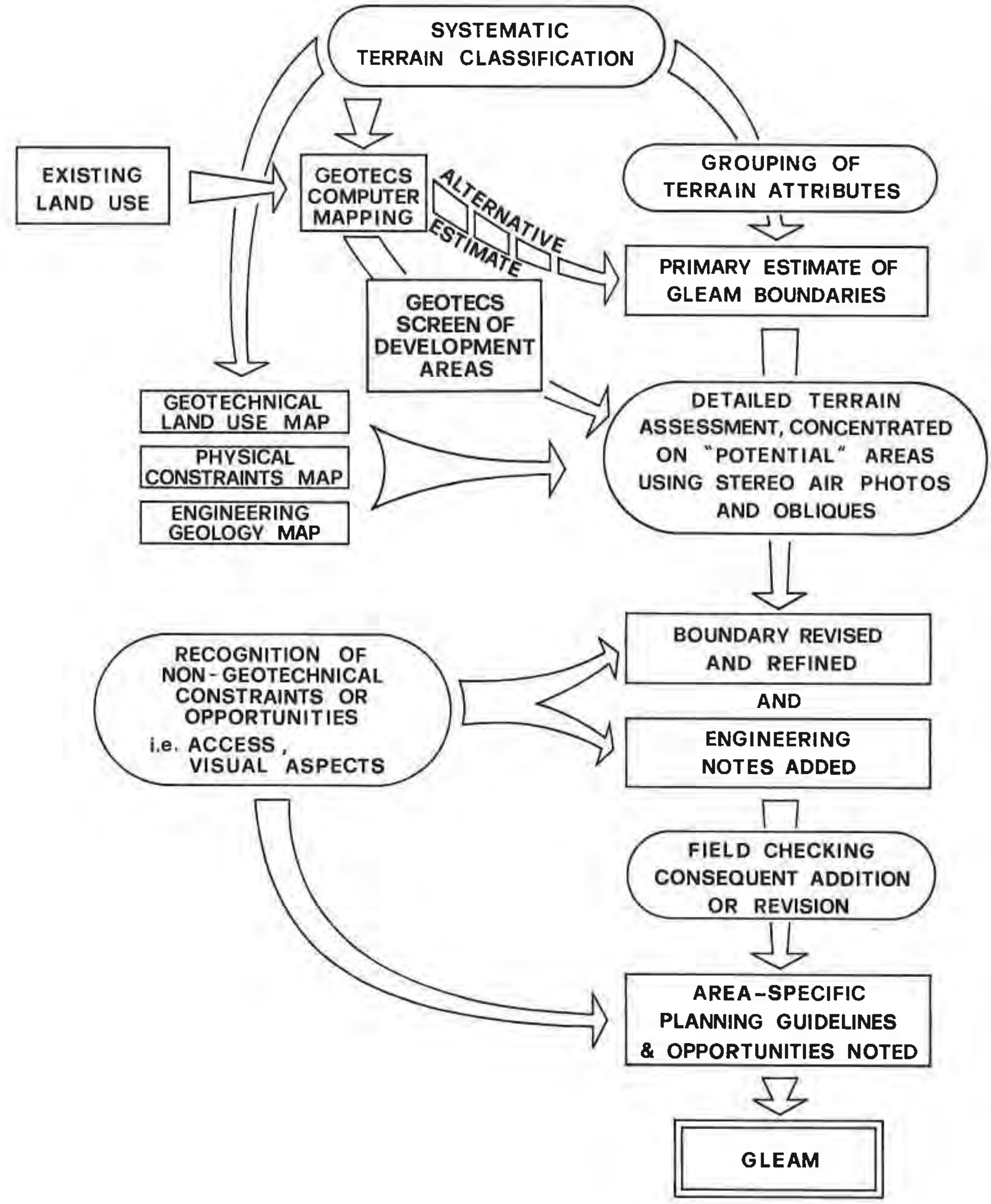
The engineering notes are presented in the form of standard symbols which are described in the legend. They highlight local geotechnical constraints which would influence layout or the design details of a project. General constraints identified on the Physical Constraints Map are shown as a background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

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

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

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

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



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

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

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

$^{\Delta}$ Terrain components I, K and X are only mapped at slope gradients of 1 and 2.

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

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

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

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

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

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

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

Table A5 Notes on Features Indicated on the GLEAM

1. Colluvium
   - indicated where expected to be deep or irregular.
   - extent of colluvium is shown on PCM & EGM.
   - notes on colluvium are given in Sections 3.1.2 and 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 information presented in the GLEAM, because it is interpretative in nature, cannot be conclusive in its application to a particular engineering project; nor from the nature and scale of the study can the comments be exhaustive. The GLEAM does indicate areas of potential for development whilst clearly defining the major geotechnical restrictions which are likely to influence planning and engineering feasibility.

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

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

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

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

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

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

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

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

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

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

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

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

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

The terrain classification for this study is part of the small-scale (1:20 000) systematic terrain classification which has been completed for the entire Territory of Hong Kong. The GASP II data bank consists of 6 553 grid cells, each of which covers approximately 2.04 hectares (49 cells per grid kilometre square) and is referenced to the Hong Kong Metric Grid. This programme, which is known within the Geotechnical Control Office as the Geotechnical Terrain Classification System (GEOTECS), is discussed briefly in Section 1.5.9. Nine natural resource attributes are recorded for each grid cell. The attributes are: slope gradient, terrain component, erosion and instability, aspect, relief, superficial and bedrock geology, existing land use, and vegetation.

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

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

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

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

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

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

APPENDIX B

DATA TABLES FOR THE CENTRAL NEW TERRITORIES GEOTECHNICAL AREA STUDY

Table B1 Slope Gradient

Slope Gradient	% of Total Area	Area (ha)
0– 5°*	16.0	2 136
5–15°	14.8	1 983
15–30°	32.6	4 358
30–40°	32.9	4 394
40–60°	3.6	483
>60°	0.1	14
	100.0	13 368

* Approximately 120 ha of uncovered reservoirs and ponds are included in the 0–5° Class.

Table B2 Erosion and Instability

Erosion		% of Total Area	Area (ha)
Instability			
—well-defined landslips and coastal instability		0.2	27
—general instability		24.9	3 323
Appreciable Erosion	Sheet erosion—minor	4.0	539
	—moderate to severe	3.2	424
	Rill erosion —minor	0.3	39
	—moderate to severe	0.2	24
	Gully erosion—minor	7.5	1 010
	—moderate to severe	0.5	63
No Appreciable Erosion*		59.2	7 919
		100.0	13 368

* Approximately 120 ha of uncovered reservoirs are included within No Appreciable Erosion.

Table B3 Aspect

Aspect	% of Total Area	Area (ha)
North	8.5	1 140
Northeast	10.8	1 444
East	9.2	1 228
Southeast	13.6	1 820
South	9.6	1 289
Southwest	10.8	1 442
West	10.2	1 359
Northwest	11.3	1 510
Flat/Unclassified*	16.0	2 136
	100.0	13 368

* Approximately 120 ha of uncovered reservoirs are included in the Flat/Unclassified category.

Table B4 Aspect and Slope Gradient

Aspect	Slope Gradient					Total Area (ha)
	5–15°	15–30°	30–40°	40–60°	>60°	
North	236	322	545	35	2	1 140
Northeast	194	461	679	108	2	1 444
East	190	537	461	39	2	1 228
Southeast	337	826	612	45	0	1 820
South	284	573	393	37	2	1 289
Southwest	222	657	502	61	0	1 442
West	245	474	563	73	4	1 359
Northwest	275	508	639	86	2	1 510
0–5° (Flat/Unclassified)						2 136
						13 368

Table B5 Landform

Terrain (Landform)	Slope Gradient	% of Total Area	Area (ha)
Hillcrest		4.4	586
Sideslope	0– 5°	<0.1	10
〃	5–15°	1.3	172
〃	15–30°	19.1	2 558
〃	30–40°	29.2	3 909
〃	>40°	1.7	233
Cliff/Rock outcrop	0–30°	0	0
〃	>30°	0.9	116
Footslope (colluvium)	0– 5°	0.5	71
〃	5–15°	3.1	416
〃	15–30°	6.4	852
〃	30–40°	1.7	226
〃	>40°	<0.1	4
Drainage plain (colluvium)	0– 5°	0.7	96
〃	5–15°	4.0	530
〃	15–30°	2.6	351
〃	30–40°	0.3	37
〃	>40°	0	0
Alluvial plain	0– 5°	<0.1	8
Floodplain	0– 5°	0.5	72
〃	>5°	<0.1	2
Littoral zone	0–15°	0.1	14
Cut platforms: insitu	0– 5°	1.5	194
: colluvium	0– 5°	0	0
: alluvium	0– 5°	<0.1	2
Cut slopes : insitu	>5°	4.9	659
: colluvium	>5°	<0.1	8
: alluvium	>5°	<0.1	8
Fill platforms : insitu	0– 5°	0.2	24
: colluvium	0– 5°	0.4	47
: alluvium	0– 5°	2.1	277
Fill slopes : insitu	>5°	0.4	59
: colluvium	>5°	0.3	41
: alluvium	>5°	0.2	31
Reclamation	0–30°	7.5	1 000
General disturbed terrain/platforms: insitu	0– 5°	0.6	82
General distrubed terrain/slope: insitu	>5°	2.5	331
: colluvium	>5°	0.5	65
: alluvium	>5°	0.2	31
Natural stream		<0.1	4
Man-made channel		0.9	122
Water storage		0.9	120
		100.0	13 368

Approximately 22 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	1.6	216
Colluvium: volcanic	10.1	1 353
: granitic	5.5	738
: sedimentary	0.8	106
: mixed	3.0	394
Littoral deposits	0.1	14
Marine deposits	0.6	78
Reclamation	7.6	1 022
Fill	7.6	1 010
Repulse Bay Formation: undifferentiated volcanics	1.2	159
: sedimentary rocks and waterlaid volcanics	2.7	357
: acid lavas	0.8	104
: mainly banded acid lavas, some welded tuffs	0.2	20
: coarse tuff	11.7	1 571
: agglomerate	1.2	155
: dominantly pyroclastics and some lavas	15.3	2 050
Needle Hill Granite (Fine grained phase)	5.3	716
Hong Kong Granite	0	0
Quartz Monzonite	0.1	16
Feldspar Porphyry	0.7	90
Ma On Shan Granite	2.6	351
Cheung Chau Granite	8.1	1 081
Sung Kong Granite	7.2	967
Sung Kong Granite (Medium grained phase)	4.1	547
Tai Po Granodiorite	1.9	253
	100.0	13 368

Approximately 22 ha of reclamation and 22 ha of fill are associated with Man-made channels, and approximately 120 ha of uncovered reservoirs have been categorised as possessing alluvial deposits.

Table B7 Vegetation

Vegetation	% of Total Area	Area (ha)
Grassland	27.6	3 696
Cultivation	3.4	453
Mixed broadleaf woodland	17.8	2 383
Shrubland (<50%)	11.0	1 467
Shrubland (>50%)	10.3	1 377
No vegetation on natural terrain	1.3	171
No vegetation due to disturbance of terrain by man*	25.9	3 458
No vegetation due to rock outcrop	0.9	116
Zoological and botanical gardens	0	0
Waterbodies	1.8	247
	100.0	13 368

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

Table B8 Geology and GLUM Class

Geological Unit	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Alluvium: undifferentiated	0	91	0	0	125
Colluvium: volcanic	0	6	784	563	0
: granitic	0	16	465	257	0
: sedimentary	0	8	75	23	0
: mixed	0	51	292	51	0
Littoral deposits	0	0	0	0	14
Marine deposits	0	0	0	0	78
Reclamation	0	976	24	0	22
Fill	0	566	408	14	22
Repulse Bay Formation: undifferentiated volcanics	2	33	39	85	0
: sedimentary rocks and waterlaid volcanics	2	78	94	183	0
: acid lavas	0	31	42	31	0
: mainly banded acid lavas, some welded tuffs	0	12	0	8	0
: coarse tuffs	73	792	365	341	0
: agglomerate	4	69	61	21	0
: dominantly pyroclastics and some lavas	49	859	302	840	0
Needle Hill Granite (Fine grained phase)	24	283	162	247	0
Hong Kong Granite	0	0	0	0	0
Quartz Monzonite	0	8	6	2	0
Feldspar Porphyry	2	20	37	31	0
Ma On Shan Granite	2	112	139	98	0
Cheung Chau Granite	82	369	306	324	0
Sung Kong Granite	74	330	361	202	0
Sung Kong Granite (Medium grained phase)	67	184	161	135	0
Tai Po Granodiorite	33	102	102	16	0
	414	4 996	4 225	3 472	261

Approximately 22 ha of reclamation and 22 ha of fill are associated with Man-made channels and hence have a GLUM designation of Unclassified.

Table B9 GLUM Class

GLUM Class	% of Total Area	Area (ha)
I	3.1	414
II	36.8	4 923
IIS	0.5	73
III	31.6	4 225
IV	26.0	3 472
Unclassified	2.0	261
	100.0	13 368

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

Slope Gradient	Aspect	Surface Geology*	No Appreciable Erosion (ha)	Appreciable Erosion (ha) Sheet	Rill	Gully	Instability (ha) WDL*	GI*	Area (ha)	Area Instability Index
0–5°	Flat	V	24	2	0	0	0	0	26	0
		G	206	16	0	0	0	0	222	0
		C	129	2	0	37	0	0	168	0
		A	204	0	0	2	0	0	206	0
		L	6	6	0	0	0	0	12	0
		F	1 387	16	10	10	0	0	1 423	0
5–15°	N	V	8	6	0	4	0	0	14	0
		G	55	10	0	0	0	0	65	0
		C	86	4	0	39	0	0	129	0
		L	2	0	0	0	0	0	2	0
		F	22	0	0	0	0	0	22	0
	NE	V	18	4	0	2	0	0	24	0
		G	39	4	0	0	0	0	43	0
		C	78	0	0	31	0	0	109	0
		F	14	4	0	0	0	0	18	0
	E	V	33	4	0	0	0	0	37	0
		G	33	10	4	0	0	0	47	0
		C	57	0	0	20	0	2	79	0.03
		F	27	0	0	0	0	0	27	0
	SE	V	39	5	0	0	0	0	90	0
		G	19	6	0	0	0	0	51	0
		C	46	2	0	37	0	2	137	0.01
		A	4	0	0	0	0	0	8	0
		F	23	2	0	0	0	0	51	0
	S	V	49	12	0	2	0	0	63	0
		G	63	16	0	0	0	0	79	0
		C	69	8	0	24	0	4	105	0.04
		A	0	0	0	0	0	0	0	—
		F	29	6	0	0	0	0	35	0
	SW	V	39	6	0	6	0	0	51	0
		G	22	10	0	0	0	0	32	0
		C	51	4	0	31	0	2	88	0.02
		A	2	0	0	0	0	0	2	0
		F	47	2	0	0	0	0	49	0
	W	V	14	8	2	0	0	0	24	0
		G	33	20	0	0	0	0	53	0
		C	80	4	0	41	0	2	127	0.02
		A	0	0	0	0	0	0	0	—
		F	39	2	0	0	0	0	41	0
	NW	V	10	0	0	0	0	0	10	0
		G	47	8	0	2	0	0	57	0
		C	135	4	0	41	0	0	180	0
		F	27	2	0	0	0	0	29	0
15–30°	N	V	67	2	0	10	0	2	81	0.02
		G	67	18	2	0	0	0	87	0
		C	53	4	0	20	0	49	126	0.39
		F	24	0	2	0	0	0	26	0
	NE	V	116	6	0	35	0	12	169	0.07
		G	65	12	0	2	0	12	91	0.13
		C	61	2	0	14	0	86	163	0.53
		F	33	0	4	0	0	0	37	0
	E	V	149	16	0	45	0	24	234	0.10
		G	80	14	0	4	0	4	102	0.04
		C	98	4	0	16	0	59	177	0.33
		F	20	2	0	0	0	0	22	0
	SE	V	298	39	0	43	0	20	400	0.05
		G	118	39	2	4	0	2	165	0.01
		C	84	4	0	45	0	80	213	0.38
		F	41	8	0	0	0	0	49	0
	S	V	159	47	0	33	0	18	257	0.07
		G	94	55	2	8	0	10	169	0.06
		C	47	6	0	22	0	35	110	0.32
		F	31	0	6	0	0	0	37	0
	SW	V	245	35	0	41	0	12	333	0.04
		G	84	59	2	8	0	0	153	0
		C	51	8	0	29	0	53	141	0.38
		F	27	0	4	0	0	0	31	0
	W	V	110	20	0	29	0	12	171	0.07
		G	104	45	0	8	0	10	167	0.06
		C	55	2	0	18	0	37	112	0.33
		F	18	0	4	0	0	0	22	0
	NW	V	110	4	0	18	0	18	150	0.12
		G	120	24	0	10	0	8	162	0.05
		C	55	6	0	20	0	80	161	0.50
		F	31	0	2	0	0	0	33	0

* For legend see Table B10 (continued) on page 125.

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

Slope Gradient	Aspect	Surface Geology*	No Appreciable Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Area (ha)	Area Instability Index
				Sheet	Rill	Gully	WDL*	GI*		
30–40°	N	V	71	4	0	14	0	131	220	0.60
		G	104	6	2	14	0	133	259	0.51
		C	16	0	0	0	0	39	55	0.71
		F	4	2	0	0	0	2	8	0.25
	NE	V	71	2	0	10	0	247	330	0.75
		G	133	6	0	8	0	135	282	0.48
		C	22	0	0	6	0	35	63	0.56
		F	6	0	0	0	0	0	6	0
	E	V	53	6	0	8	0	169	236	0.72
		G	78	8	0	16	0	102	204	0.50
		C	0	0	0	0	0	12	12	1.00
		F	6	2	0	0	0	0	8	0
	SE	V	84	18	0	12	0	210	324	0.65
		G	102	16	2	16	0	116	252	0.46
		C	2	0	0	0	0	18	20	0.90
		F	10	2	2	0	0	0	14	0
	S	V	57	14	0	12	4	84	171	0.49
		G	73	24	2	14	0	90	203	0.44
		C	4	0	0	2	0	8	14	0.57
		F	2	0	0	0	0	2	4	0.5
	SW	V	80	18	0	16	0	116	230	0.50
		G	92	43	0	18	0	73	226	0.32
		C	10	4	0	2	0	16	32	0.50
		F	8	0	2	0	0	2	12	0.17
	W	V	96	8	0	18	2	116	240	0.48
		G	116	35	0	24	2	102	279	0.37
		C	10	0	0	8	0	12	30	0.40
		F	6	2	2	0	0	0	10	0
	NW	V	57	6	0	6	0	235	304	0.77
		G	110	0	0	14	2	165	291	0.57
		C	10	0	0	6	0	20	36	0.56
		F	2	0	2	0	0	2	6	0.33
>40°	N	V	2	0	0	0	0	16	18	0.89
		G	10	2	0	2	0	4	18	0.22
		C	0	0	0	0	0	0	0	—
	NE	V	4	4	0	0	2	53	63	0.84
		G	16	2	0	0	0	27	45	0.60
		C	0	0	0	0	2	0	2	1.00
	E	V	8	2	0	0	0	6	16	0.38
		G	14	0	0	0	0	10	24	0.42
		C	0	0	0	0	0	0	0	—
	SE	V	2	4	0	0	0	4	10	0.40
		G	22	0	0	2	0	10	34	0.29
		C	0	0	0	0	0	0	0	—
	S	V	0	0	0	0	0	14	14	1.00
		G	8	0	0	2	0	12	22	0.54
		C	0	0	0	0	0	2	2	1.00
	SW	V	2	0	0	0	6	12	20	0.60
		G	24	0	0	0	0	14	38	0.37
		C	0	0	0	0	0	0	0	—
		F	0	0	0	2	0	0	2	0
	W	V	4	0	0	2	2	24	32	0.75
		G	27	0	0	2	0	10	39	0.26
		C	0	0	0	0	0	0	0	—
		F	4	0	2	0	0	0	6	0
	NW	V	2	2	0	0	2	35	41	0.85
		G	29	0	0	0	0	18	47	0.38
		C	0	0	0	0	0	0	0	—
		F	0	0	0	0	0	0	0	—

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

Table B11 Geology, Erosion and Instability

Geological Unit	No Apprecia-able Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Total Area (ha)	Area Instability Index
		Sheet	Rill	Gully	WDL	GI		
Reclamation	956	29	27	10	0	0	1 022	0
Fill	957	27	16	2	0	8	1 010	0.01
Alluvium:								
—undifferentiated	214	0	0	2	0	0	216	0
Littoral Zone	8	6	0	0	0	0	14	0
Colluvium:								
—volcanic	647	52	0	228	2	424	1 353	0.18
—granitic	420	6	0	151	0	161	738	0.22
—sedimentary	57	3	0	25	0	21	106	0.20
—mixed	231	10	0	106	0	47	394	0.12
Repulse Bay Formation:								
—undifferentiated volcanics	69	2	0	6	0	82	159	0.52
—sedimentary rocks and waterlaid volcanics	136	19	0	18	9	175	357	0.52
—acid lavas	57	0	0	16	0	31	104	0.30
—mainly banded acid lavas some welded tuffs	12	0	0	0	0	8	20	0.40
—coarse tuff	800	172	2	212	6	379	1 571	0.25
—agglomerate	104	12	0	10	0	29	155	0.19
—dominantly pyroclastics and some lavas	945	108	0	104	4	889	2 050	0.44
Needle Hill Granite (Fine grained phase)	306	116	4	39	0	251	716	0.35
Hong Kong Granite	0	0	0	0	0	0	0	—
Quartz Monzonite	14	0	0	0	0	2	16	0.13
Feldspar Porphyry	39	16	0	6	0	29	90	0.32
Ma On Shan Granite	141	90	2	22	2	94	351	0.27
Cheung Chau Granite	561	118	12	53	4	333	1 081	0.31
Sung Kong Granite	685	61	0	17	0	204	967	0.21
Sung Kong Granite (Medium grained phase)	288	94	0	29	0	136	547	0.25
Tai Po Granodiorite	194	22	0	17	0	20	253	0.08

Approximately 78 ha of marine deposits in the floor of the Shing Mun River Channel have been excluded from this Table.

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

Existing Land Use	Area (ha)	Existing Land Use	Area (ha)
Government housing estate	261	Quarries – government	0
Private development	61	Quarries – private	33
2 Storey development	216	Quarries – borrow	72
1 Storey development	333	Oil storage	29
Temporary resettlement area	71	Power station	26
Intermixed	0	Cemetery	20
Industrial	218	Prison	0
Commercial	10	Service reservoir	10
Commercial/residential	118	Incinerator	0
Park	45	Horticulture	465
Sports complex	59	Undefined agriculture	0
Golf course	0	Dairy farm	0
Race course	75	Undisturbed areas	3 760
Beach	0	Country park	5 370
Zoological & botanical gardens	0	Water storage	120
School and University	41	Natural stream	4
Hospital	14	Man-made channel	123
Temple	0	Squatters – low intensity	51
Police/fire station	8	Squatters – medium intensity	49
Airport runway	0	Squatters – high intensity	4
Airport facilities	0	Construction	594
Wharves	127	Reclamation	257
Railway	61	Temporary land fill	47
Roads	208	Temporary land use	57
Sewerage works	27	Artificial slopes	318
Military	6		
		Total	13 368

Table B13 Existing Land Use and GLUM Class

Existing Land Use	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Government housing estate	8	198	55	0	0
Private development	4	47	10	0	0
2 Storey development	10	96	106	4	0
1 Storey development	4	133	167	29	0
Temporary resettlement area	2	61	8	0	0
Intermixed	0	0	0	0	0
Industrial	21	163	34	0	0
Commercial	0	10	0	0	0
Commercial/residential	6	89	23	0	0
Park	0	37	8	0	0
Sports complex	2	45	12	0	0
Golf course	0	0	0	0	0
Race course	0	75	0	0	0
Beach	0	0	0	0	0
Zoological and botanical gardens	0	0	0	0	0
School and University	0	23	18	0	0
Hospital	0	14	0	0	0
Temple	0	0	0	0	0
Police/fire station	0	8	0	0	0
Airport runway	0	0	0	0	0
Airport facilities	0	0	0	0	0
Wharves	16	111	0	0	0
Railway	4	35	22	0	0
Roads	23	128	55	2	0
Sewerage works	0	25	2	0	0
Military	0	6	0	0	0
Quarries – government	0	0	0	0	0
Quarries – private	6	27	0	0	0
Quarries – borrow	4	49	19	0	0
Oil storage	8	21	0	0	0
Power station	10	16	0	0	0
Cemetery	0	0	20	0	0
Prison	0	0	0	0	0
Service reservoir	0	0	10	0	0
Incinerator	0	0	0	0	0
Horticulture	6	142	280	37	0
Undefined agriculture	0	0	0	0	0
Dairy farm	0	0	0	0	0
Undisturbed areas	72	946	1 406	1 322	14
Country park	133	1 675	1 559	2 003	0
Water storage	0	0	0	0	120
Natural stream	0	0	0	0	4
Man-made channels	0	0	0	0	123
Squatters – low intensity	0	18	25	8	0
Squatters – medium intensity	0	23	16	10	0
Squatters – high intensity	0	2	2	0	0
Construction	67	457	68	2	0
Reclamation	0	245	12	0	0
Temporary land fill	0	16	25	6	0
Temporary land use	8	37	10	2	0
Artificial slopes	0	18	253	47	0
Total 13 368	414	4 996	4 225	3 472	261

APPENDIX C

SUPPLEMENTARY INFORMATION

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APPENDIX C

SUPPLEMENTARY INFORMATION

C.1 Description of Geological Units

C.1.1 *Metamorphic Units – Tolo Harbour Formation*

Within the study area there is no surface outcrop of the Tolo Harbour Formation. It is suspected, however, of being present beneath marine and old alluvial deposits in the floor of Tide Cove. The evidence for its presence is from site investigations carried out for the reclamation for the Ma On Shan New Town.

From interpretation of borehole information, the approximate boundaries of the subsurface extent of the black metamorphosed shales and quartzites have been determined. This group of rocks appears to be fault bounded to the south by the continuation of the major discontinuity passing through Tai Shui Hang and continuing just to the north shore of the Chinese University. The eastern boundary appears to be formed by the major discontinuity passing through the central axis of Tide Cove. The subsurface northern limit of the Tolo Harbour Formation is unknown, although similar rocks outcrop on Centre Island. The rocks on Centre Island are assigned by Allen & Stephens (1971), to the Tolo Harbour Formation and on this basis the metamorphic rocks encountered beneath the sea floor are tentatively assigned to the same unit.

C.1.2 *Volcanic Units – Repulse Bay Formation*

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

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

The Formation was classified into six lithological units (Allen & Stephens, 1971) together with a category of 'Undifferentiated Volcanic Rocks'. Each of these units is discussed in detail below. The boundaries presented in the Engineering Geology Map (EGM) have been partially amended by the revised geological mapping of the area (Addison 1986, Geotechnical Control Office, 1986). Rapid horizontal and vertical changes in rock type are expected due to the nature of volcanic deposits.

(i) *Undifferentiated Volcanic Rocks (RB)*
The area to the north of Buffalo Hill has been mapped as Undifferentiated Volcanic Rocks. The rock types in this unit consist of banded lavas and fine-grained pyroclastic rocks but other members of the Repulse Bay Formation may be present.

(ii) *Sedimentary Rocks and water-laid Volcaniclastic Rock (RBs)*
Sedimentary rocks principally occur in the north and northeast around Tide Cove, although small outcrops are located at Tsuen Wan and on Tsing Yi Island.

The largest area of sedimentary rocks occurs east of Tide Cove and extends from the Ma On Shan Mine northwards towards Nai Chung. The dominant rock type is a white, structureless orthoquartzite, but below ground dolomitic limestone is the host rock to the skarn deposit of magnetite previously worked in the Ma On Shan Mine. Shale, siltstone and fine sandstone also occur in the area. Along the coast of Three Fathoms Cove there is a thick succession of similar rocks. Further west, near the pier at Nai Chung, there is an outcrop of cleaved grey shale, hornfelsed shale, thinly bedded sandstone and a breccia containing fragments of quartz, quartzite and subordinate siltstone and silty shale. These sediments may form a single sedimentary horizon. The general lack of volcanic detritus suggests that they formed from sediments deposited before the major period of volcanic activity and may belong to the older Bluff Head Formation.

(iii) *Coarse Tuff (RBc)*
Extensive areas of coarse tuff occur around Tai Mo Shan in the northwest of the study area and in a broad belt west of Tsuen Wan. A large proportion of Tsing Yi Island is composed of this rock type and a small outcrop occurs to the northwest of lower Tide Cove.

This rock unit generally forms thick massive beds with no internal stratification. Small and medium sized volcanic bombs frequently occur in this unit along with lapilli. The origins of these rocks may be attributed to explosive volcanic episodes. The rock is generally grey with large, well formed crystals of quartz and white feldspar, which are clearly visible. In some areas, especially around Tai Mo Shan, these rocks have been confused with porphyritic intrusive rocks.

Jointing within this rock type is usually moderately-widely spaced and the joint surfaces are usually smooth. Weathering is similar to other volcanic rocks, with the exception that a coarse sandy soil may result and core boulders are sometimes developed due to a wider than normal joint spacing.

(iv) *Dominantly Pyroclastic Rocks with Some Lavas (RBp)*
This lithological unit occupies a large proportion of the north and west of the study area with lesser occurrences near the eastern boundary.

The unit is a broad grouping of varying rock types including welded tuffs, lapilli tuffs, coarse tuffs, fine tuffs, banded tuffs as well as lavas and sedimentary rocks. It contains rock types found in other mapped units of the Repulse Bay Formation. The principal rock type is a fine-grained grey to dark grey rhyodacitic tuff.

The field exposures are generally closely jointed with extensive planar, smooth joints forming a number of distinct sets. The weathering depths vary with grain size and the topography but they are generally less than those encountered in the intrusive igneous suite of rocks. The weathering process tends to produce a pale clayey, silty soil.

(v) *Acid Lavas (RBv)*
Horizons of dense, columnar jointed, rhyodacitic lava flows occur in the eastern part of the study area around Shek Nga Shan.

The main rock type is a purplish-grey acid extrusive rhyolite. It is exposed around Buffalo Hill and contains prominant euhedral phenocrysts of potassium feldspar and less conspicuous, small phenocrysts of albite and quartz. The rock is sometimes streaky in appearance with some apparent folding of the streaks. This structure is most probably due to flow of material and it is likely that some of the streaks are stretched vesicles. There is considerable deuteric alteration in parts of the flow; and many phenocrysts are fragments of euhedral crystals and exhibit a high degree of resorption.

Weathering depths are moderately shallow with a fine grey, silty clay being produced. Jointing is moderately to closely spaced with tectonic and cooling fractures present.

(vi) *Mainly Banded Acid Lavas, Some Welded Tuffs (RBvb)*
The main rock type of this unit it is an amygdaloidal banded rhyolite exposed on a ridge above Nam Shan and Wong Chuk Yeung southeast of Pyramid Hill. Small spherulites are present throughout the rock but large amygdales, measuring as much as 500 mm in diameter, occur in zones. Thin contorted banding is a common feature. The rock crops out again on the peak of Pyramid Hill and along the ridge top. Locally, it is extremely contorted, folded and brecciated. The rock commonly has closely spaced joints and moderate to shallow weathering. Large, steep cliffs of this unit occur on Pyramid Hill.

(vii) *Agglomerate (RBag)*
Agglomerate, breccia and tuff-breccia are generally uncommon rocks in Hong Kong but a moderately large area of mainly tuff-breccia extends from Pak Shek Kiu eastwards to the head of the large valley north of Tsuen Wan. The unit near Tsuen Wan is mainly tuff-breccia or blocky lapilli tuff but grades imperceptibly into coarse tuff or even fine tuff in places. The rock has a greenish grey, fine-grained matrix containing blocks and lapilli of fine tuff, quartzite, some porphyritic lava and, most abundantly, coarse tuff. The individual blocks are most apparent on weathered surfaces.

Jointing is moderately to widely spaced and the surfaces are smooth. Weathering and its products are generally similar to the other units of the Repulse Bay Formation, in that a fairly shallow light coloured silty clay soil is produced. Large residual corestone boulders frequently occur on the surface.

C.1.3 *Intrusive Igneous Units*

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

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

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

(i) *Tai Po Granodiorite (XT)*

This rock type occurs on Tsing Yi Island, northeast of Tsuen Wan near the Jubilee Reservoir and in a minor outcrop to the northeast of the study area, near Tsiu Hang. Other small occurrences are to the west of Tai Mo Shan and on Route TWISK.

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

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

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

(ii) *Sung Kong Granite (SK)*

This rock tyye occurs in a large area in the southern and central parts of the Sha Tin New Town Development. It is subdivided into a coarse-grained (SK) phase, and a medium-grained (SKm) phase.

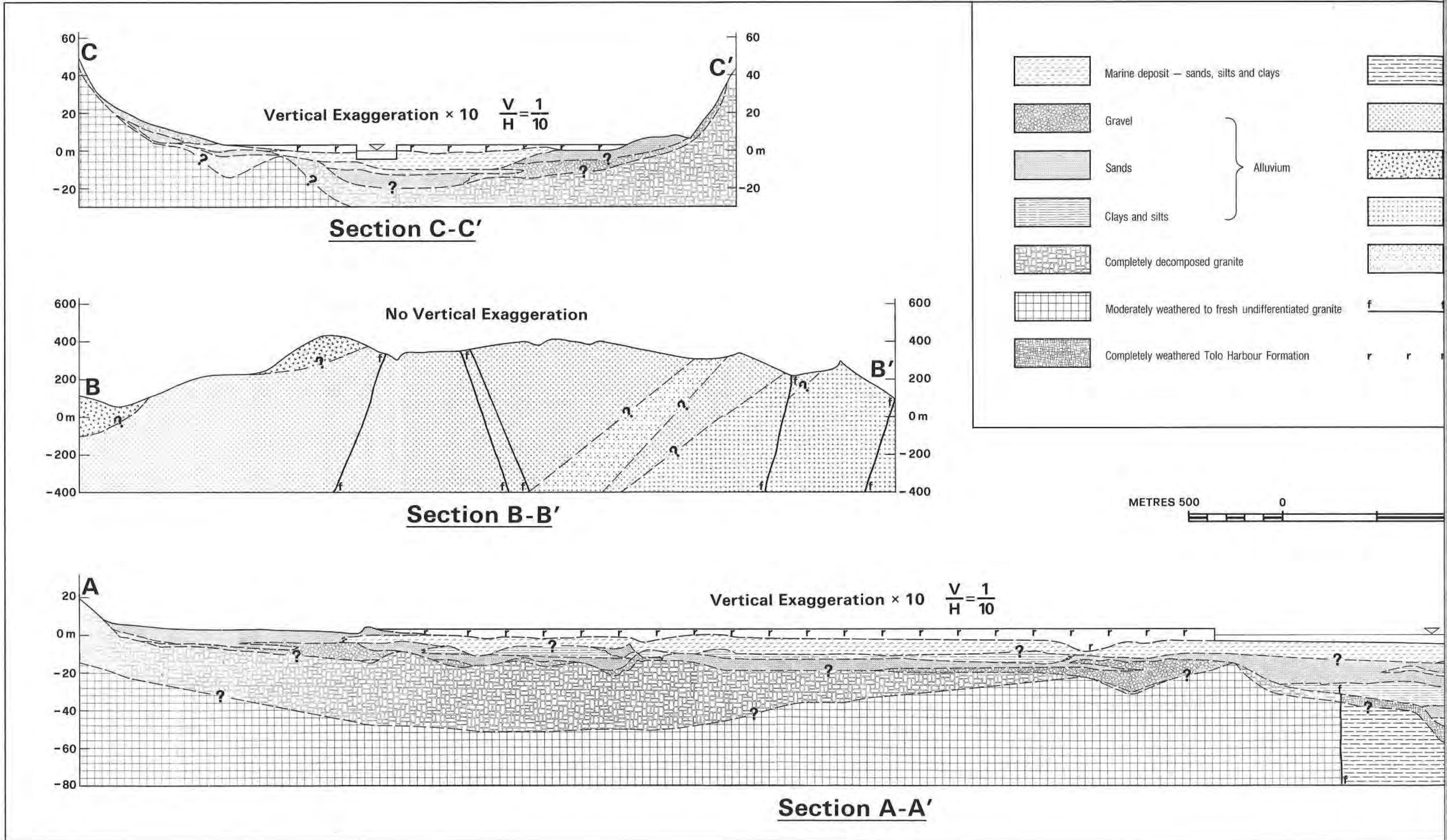
The Sung Kong Granite is typically coarse-grained grey to dark grey and porphyritic, but even in small areas this may grade into varieties with no phenocrysts, or no dark minerals, or a super-abundance of quartz. The medium-grained phase may be porphyritic or non-porphyritic.

The phenocrysts of potassium feldspar are usually squat and may reach 40 mm in length. Biotite is the usual conspicuous dark mineral and it occurs throughout the rock. Pools of quartz may exceed 10 mm in diameter and give the rock the appearance of being very coarse-grained. Xenoliths, usually of dark rocks, may be present.

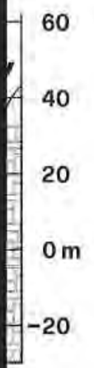
This rock unit is difficult to distinguish from other granites except when weathered, as the coarse quartz particles become prominent. As with most granitic rocks, it has widely spaced irregular tectonic joints and shallow open irregular sheeting joints. The weathering is often deep and the rock tends to produce large corestones and boulders.

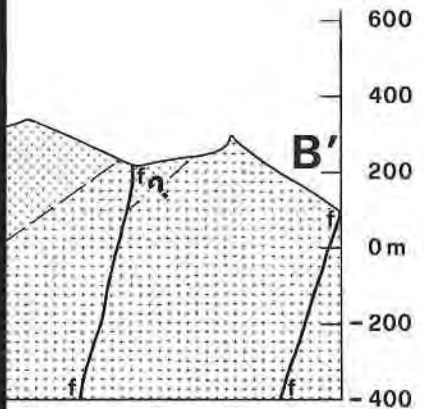
(iii) *Cheung Chau Granite (CC)*

This rock type occupies a large proportion of the north shore of Tide Cove and is also present on Tsing Yi Island and on the headland at Wu Kwai Sha Tsui. Small outcrops occur along the southern boundary of the study area.



Geological Cross-sections – Central New Territories





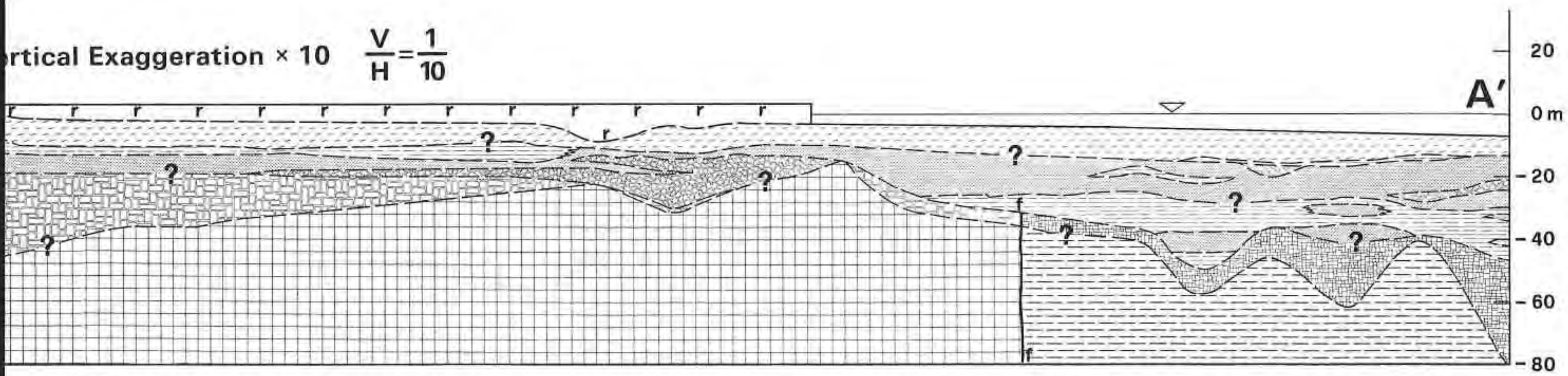
- Marine deposit — sands, silts and clays
- Alluvium:
  - Gravel
  - Sands
  - Clays and silts
- Completely decomposed granite
- Moderately weathered to fresh undifferentiated granite
- Completely weathered Tolo Harbour Formation
- Moderately weathered to fresh Tolo Harbour Formation
- Dominantly pyroclastic rocks with some lavas
- Coarse tuffs
- Cheung Chau Granite
- Tai Po Granodiorite
- f——f Fault
- r r r Reclamation

• These cross sections are scaled schematic diagrams only. The illustrated relationships in sections A–A′ and C–C′ are interpreted from selected site investigation data held in the Geotechnical Information Unit (GIU) of the GCO. The relationships in section B–B′ are consistent with those presented in Allen and Stephens (1971) apart from the postulated outcrop of Tai Po Granodiorite, which has been interpreted from the Tunnel Logs of the Plover Cove Water Scheme (Government of Hong Kong) that are held by the GIU.

• All heights are in metres above Principal Datum which is approximately 1.20m below Mean Sea Level.

Scale 1:20 000

rtical Exaggeration × 10 $\frac{V}{H} = \frac{1}{10}$



Section A-A′

ATTENTION : USERS

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

ns – Central New Territories	Compiled: R. Purser	Drawn: S. B. Ho	Fig. C1
	Scale: 1:20 000	Date: March 1984	

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

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

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

This study area contains the type area for this granite. It is located on the southwest side of Ma On Shan where the granite forms a large body bounded to the south by a discontinuity, which is probably a fault. Smaller outcrops occur along the southern boundary of the study area.

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

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

(v) *Quartz Monzonite (Mo)*

This rock type is not very extensive and principally occurs in elongate dyke-like northeast trending bodies in the southeast sector of the study area. The largest of these bodies extends from the portal of the Lion Rock Tunnel Road to Tsang Tai Uk.

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

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

(vi) *Feldspar Porphyry Dyke Swarm (La)*

This rock type is most extensive on Tsing Yi Island where three east to northeast trending bodies dissect the Island. A small outcrop ocurs north of Tsuen Wan and an elongate body is located at Needle Hill. Numerous individual dykes also occur. The rocks are generally composed of a fine dark groundmass with large euhedral phenocrysts of potassic feldspar. The dykes vary in thickness from a few centimetres to over 25 metres.

Due to the fine matrix, weathering tends to be shallower than the granites but deeper than the volcanics. This results in contrasting topographic expression dependent on the country rock into which the dykes intrude.

Jointing may be complex with cooling, tectonic and sheeting joints present in the one location.

(vii) *Needle Hill Granite (NH)*

This rock unit occurs in the southwest quadrant of the study area, east and northeast of Tsuen Wan. There are two phases of Needle Hill Granite; a fine-grained porphyritic phase and a medium-grained porphyritic phase which appear to grade into each other. The fine-grained variety is the only phase present in this study area.

The main rock type is pink with phenocrysts of quartz and potassium feldspar, but the rock is far from uniform. Varieties with sparse phenocrysts and a fine-grained matrix grade into varieties with numerous phencrysts or into a rock with sparse, small phenocrysts and a matrix with a grain size between 1 and 2 mm. Quartz veins are often plentiful and veins of pegmatitie are frequent near the margins.

The rock type weathers in a similar manner to other granites and jointing consists of smooth, moderately to widely spaced tectonic joints and rough irregular sheeting joints that are orientated subparallel to the topography.

(viii) *Dolerite (D)*

South of Shek Lau Tung a kilometre long dyke of dolerite occurs and, in addition, another small dyke is located on the southern shore of the Jubilee Reservoir. There are numerous other outcrops that were not mapped by Allen & Stephens (1971) due to their small extent.

These dolerite dykes form an igneous phase, mineralogically and chronologically distinct from any of the previously discussed igneous rocks but still conformable with the same structural controls. The rock is undersaturated in silica with no free quartz. It is fine to medium-grained, black in colour and has a chilled margin about 10 mm thick. Dolerite dykes are rarely more than 10 m thick and on weathering decay to dark red clayey soils. Jointing tends to be closely spaced and perpendicular to the dyke walls.

C.1.4 *Superficial Deposits*

Within the study area, the superficial deposits form a complex interrelated sequence. The deposits may be subdivided on the basis of their age, genetic origin, geographic location and material characteristics. From an engineering point of view the latter two are important.

All the superficial deposits are, geologically speaking, very young but represent various events in the recent geological history of this region. The level of the sea has fluctuated with the cyclic advance and retreat of the ice caps. This changing sea level has had a marked effect on the deposition and erosion of superficial materials around Hong Kong. The materials can be classified on a broad generic basis.

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

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

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

Surrounding Tide Cove, steep unstable hillslopes have developed numerous lobes of colluvim. The colluvial deposits extend beneath the sea at Wu Kwai Sha and are overlain by more recent marine deposits of shelly silt and clay. It is apparent in other parts of the Territory that colluvium may be of a variety of ages. The colluvial material that has been covered by marine deposits at Wu Kai Sha was probably deposited at least 10 000 years ago, prior to the last major rise in sea level. The colluvial deposits are younger than the 'old' alluvium which has been dated at around 50 000 years BP. The rock fragments in the deposits are highly weathered. There is a large bed of boulders, cobbles and gravels beneath the Sha Tin Sewage Treatment Works. These materials may be of alluvial origin or represent streambed colluvium. The individual boulders are commonly highly weathered and the deposit consolidated. The debris resulting from recent landslips, which is also classified as colluvium, may be very recent.

This range of ages results in a variety of material properties ascribed to the general class of colluvium.

The older deposits have undergone a change in their particle size distribution as clay is produced in the weathering process. Consolidation also takes place with time and increases the insitu density. The younger deposits may also have a high clay content derived from the weathered mantle but this fraction may be removed if the deposit occurs within a drainage line. Fine material is removed leaving a coarse bouldery deposit similar to those found on Tsing Yi Island and in the streams draining the slopes of Tai Mo Shan.

An additional consideration is the nature of the parent rock type from which the colluvium was derived. Colluvium may be classified on the basis of the lithology of its constituent particles. A broad distinction can be made between colluvium derived from volcanic rocks, intrusive igneous rocks and those from a mixture of both major rock groups. The colluvium derived from volcanic rocks will, in general, have more angular rock fragments in a fine silty matrix whereas granitic material will contain more coarse silty sand, with rounded weathered rock fragments. Colluvium frequently occurs within or adjacent to drainage lines and is commonly eroded and transported to be redeposited as alluvium. The transition from colluvium to alluvium is gradational as illustrated by the interdigitation of colluvial lobes into the small alluvial plains at Hang Hau and Cheung Muk Tau.

(ii) *Alluvium*
These deposits include all material deposited by flowing water and includes colluvial debris that has been reworked by stream flow. Alluvium may be divided on the basis of its age, depending on whether the deposit predates or post-dates the Holocene marine trangression.

The marine sediments in Tide Cove are underlain by 'old' alluvial sediments. These alluvial sediments are typically fluviatile within Tide Cove, although the deeper deposits that extend into Tolo Harbour may be lacustrine in character. The fluviatile deposits generally consist of sands and gravels with minor silt. The deposits are often crudely stratified with a clay horizon (possibly an esturine or mangrove swamp deposit) intermittently developed immediately below the marine deposit. Predominantly sands and gravelly sands occur with a basal gravel layer of variable thickness at around 10 to 20 m below PD.

Within Tide Cove itself, this basal layer is the final horizon which rests either on weathered granite or, as at the Sha Tin Sewage Treatment Works, on relatively fresh rock.

Further out to sea, beneath Tolo Harbour, the alluvial sediments deepen and a succession of well-stratified silts and sands occur, these seem to underlie a gravel horizon. The deposits may be lacustrine in nature deposited when Tolo Harbour was essentially a fresh water lake and may represent the oldest of the alluvial sediments.

The most extensive recent alluvium in the study area is within the Sha Tin Valley and have been deposited by the Shing Mun River. Lesser deposits occur near Lok Wo Sha, on the coast near the Chinese University, northeast of Tsuen Wan and on Tsing Yi Island. In the Sha Tin Valley, the extensive alluvial plain is underlain, in part, by older alluvium and colluvial fans interfinger into it on the valley sides. The younger deposits of alluvium overlay the marine deposits as shown in Figure C1.

The younger deposits of alluvium consist mainly of poorly sorted sandy gravel. The gravel particles consist generally of fresh rock fragments. The deposits can be up to 10 m thick and partially overlie the interdigitated colluvial fans. The colluvium located in stream courses is often transported and redeposited as alluvium and some deposits mapped as colluvium may be intermediate between colluvium and alluvium. If fluvial transport has taken place, even for a short distance, a change in the particle size distribution occurs within the material and this would modify the engineering behaviour. Fine silt and clay sized particles will be removed and the remaining coarse fraction may have a much higher permeability, a lower cohesion and possibly a higher angle of friction.

A further large area of alluvium occurs on the high plateau at Ngong Ping. This type of deposit has formed by the infilling of high valleys with restricted drainage outlets probably associated with change in sea level and possible tectonic uplift.

(iii) *Littoral Deposits*

These materials are formed by wave and tidal action with some aeolian transportation above high tide level. Along the pre-reclamation coastline of the study area, littoral deposits of well-sorted quartz sands and shell fragments have been deposited by wave and wind action. They are usually adjacent to small alluvial plains or colluvial fans in sheltered areas. Most of these deposits are now covered by reclamation but two large beaches remain at Lok Wo Sha. In many areas, such as to the west of Tsing Yi Island, littoral deposits do not occur due to the rocky coastline and high current velocities. Above the high tide level at Lok Wo Sha, sand has been deposited by wind action. These wind blown materials have a different particle size distribution and a lower density than the littoral deposits.

(iv) *Marine Deposits*

These materials have formed within a marine environment and have not been exposed to the atmosphere even at low tides. The marine sediments within this study area have probably been deposited in the last 10 000 years and consist of grey shelly silts, clays and sands. They represent deposits formed during the major rise in sea level at the end of the last ice age. These sediments often have a distinctive odour. The marine deposits are normally consolidated and the silt and clay layers are generally subject to large settlements when surcharged. The sand horizons do not settle markedly, however, but the settlement that does occur is usually rapid due to high permeabilities.

Although the marine deposits are fairly uniform in thickness at about 10 m, they vary considerably in particle size and degree of consolidation. Within Tide Cove, the natural periodic high water velocities resulting from discharge from the Shing Mun River or from storm surges, have resulted in a generally sandy sequence. These sands have been extracted in the past for the construction industry. Marine deposits west of Tsing Yi Island are similar. In the sheltered areas between Tsing Yi Island and the mainland, silty clay deposits seem to predominate. In the main body of Tolo Harbour, where current velocities are low, the marine sediments are generally fine-grained.

(v) *Man-Made Deposits*

There are large areas of man-made deposits. Due to the high level of construction activity in the study area. These deposits include all material placed by man such as reclamation, waste dumps and terrestrial fill.

Reclamation of land from the sea is common within the Territory due to constraints imposed by the natural topography and increasing population. The construction of the Tsuen Wan and Sha Tin New Towns and the industrial developments of Tsing Yi and Kwai Chung have required extensive reclamation works, with fill being derived from a wide variety of sources. In addition to dumped rock and soil, the areas of reclamation may contain refuse and old buried concrete or masonry sea walls.

Northeast of Tsing Chau, a large controlled tip is being formed that may be used later as an urban park. The tip is composed of soft compressible domestic and industrial waste together with weathered granitic material derived from adjacent site formation works. The material characteristics of the waste tip will probably be highly variable and as a result the tip may be subject to large and unpredictable settlements.

Some parts of the study area are now covered by man-made structures. During construction, the natural terrain has been modified by cut and fill activities.

Fill for the preparation of most sites is probably derived from within the vicinity of the site. However, it is possible that some fill may contain imported material that is geologically different to that which is found on or near the site.

The method and degree of compaction of these fill deposits varies, depending primarily on the time at which it was placed. The large deposit of rockfill near Ma On Shan Tsuen dumped during the life of the Ma On Shan Mine was probably placed without compaction, whereas the material currently being placed is compacted to conform to current engineering standards.

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

C.2 Site Investigation Data

The general intensity of the coverage by site investigations of the study area is, illustrated in Figure C2. The listing of site investigations is not comprehensive, as it includes only investigations completed on behalf of the Hong Kong Government. Investigations carried out by private organisations and any investigations completed after December 1983 are not included.

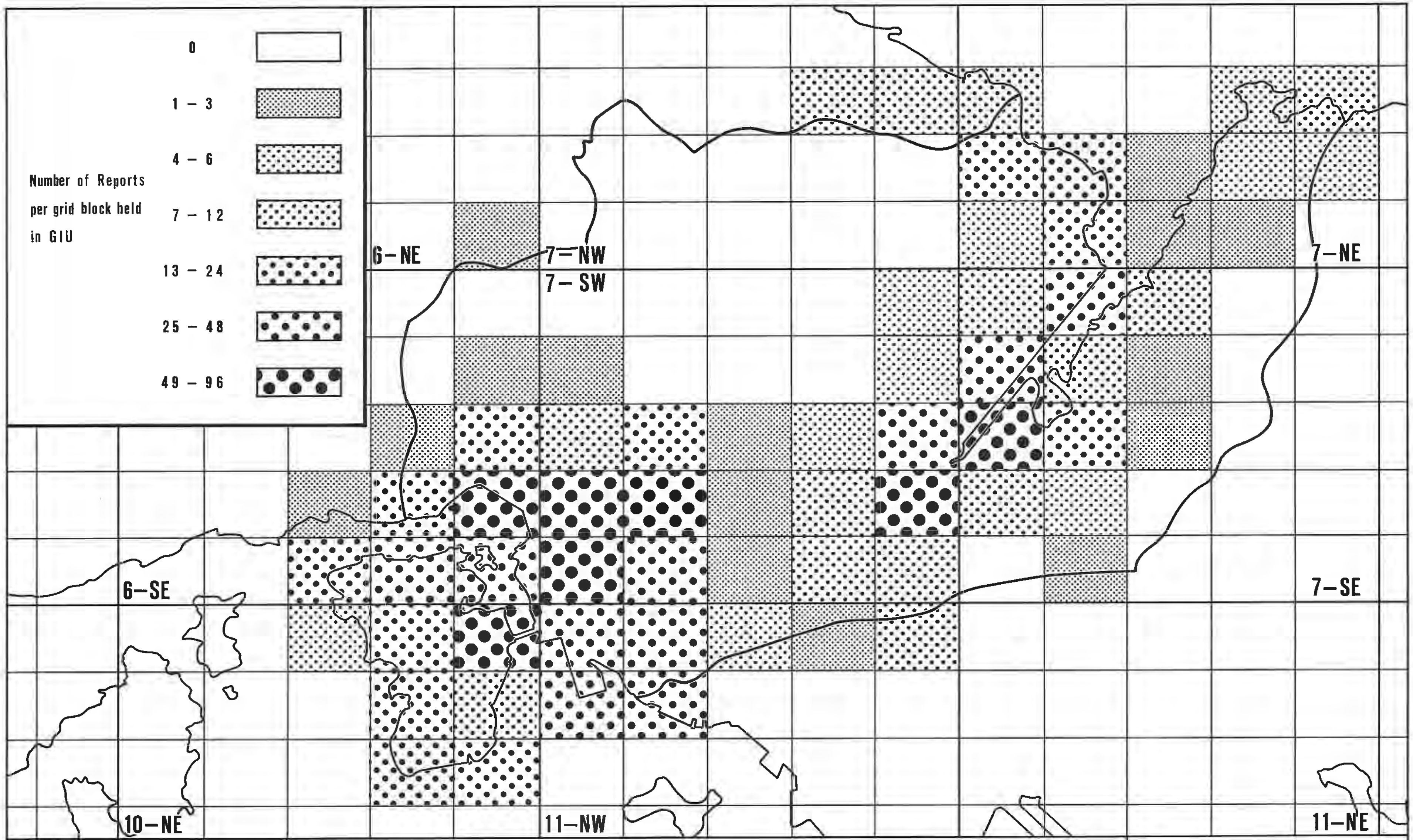
The Geotechnical Control Office GIU Report entry and retrieval system is based on a master grid marked on reference sheets. Each grid block is provided with an index card listing all the reports held within that individual grid block.

C.3 Aerial Photographs

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

C.4 Rainfall Data Relevant to the Central New Territories Study Area

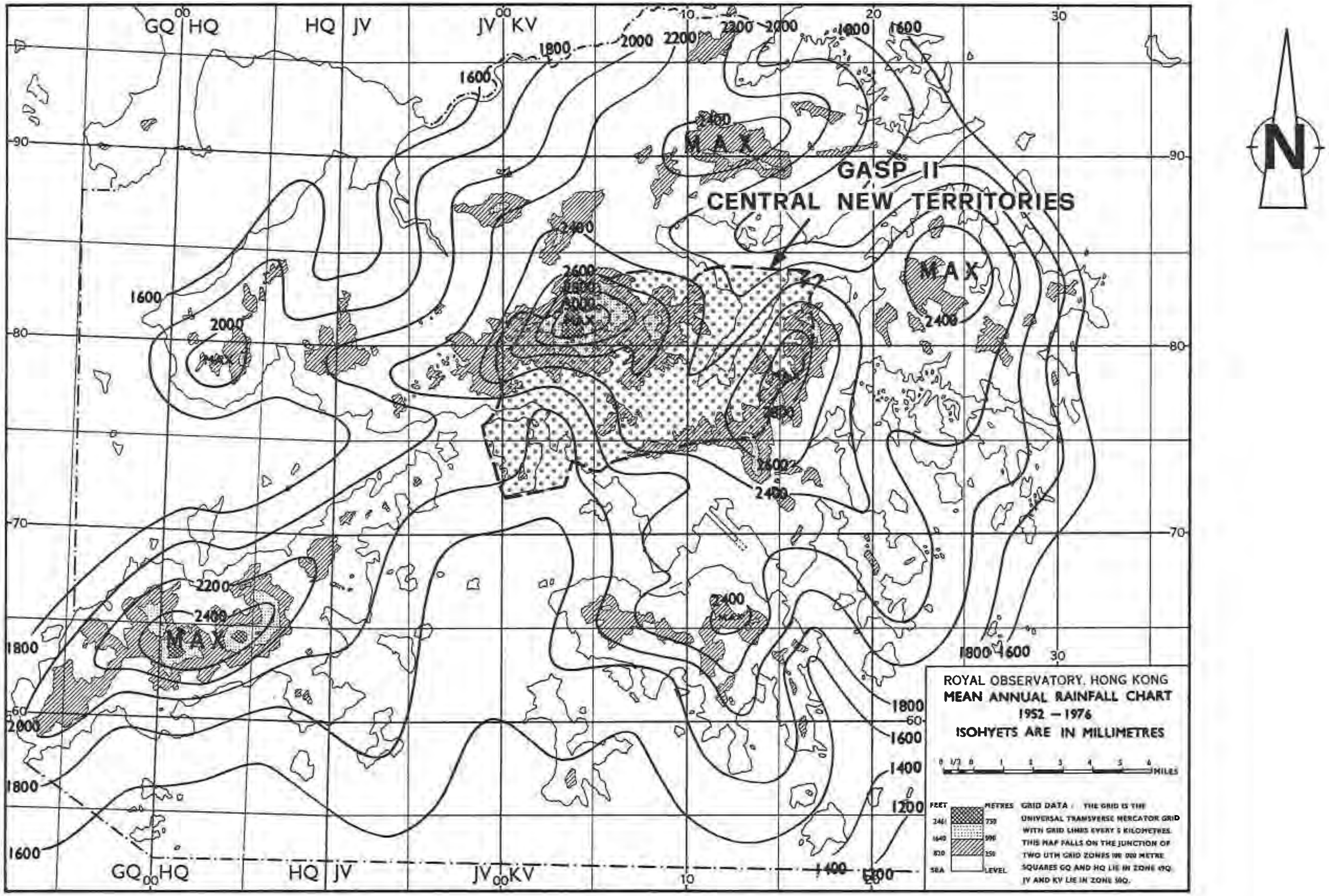
A general appreciation of the annual and monthly rainfall distributions for the Central New Territories can be obtained from Figures C3 and C4. Figure C3 is a reproduction of the mean annual rainfall isohyets for the years 1952 to 1976, published by the Royal Observatory. Figure C4 is a histogram of monthly rainfall for four selected Royal Observatory rainfall stations. There are a total of 18 rainfall stations within the study area the locations of which are indicated on Figure C5. Detailed monthly and annual rainfall information for these stations is available from the Royal Observatory.



Scale
1:100 000

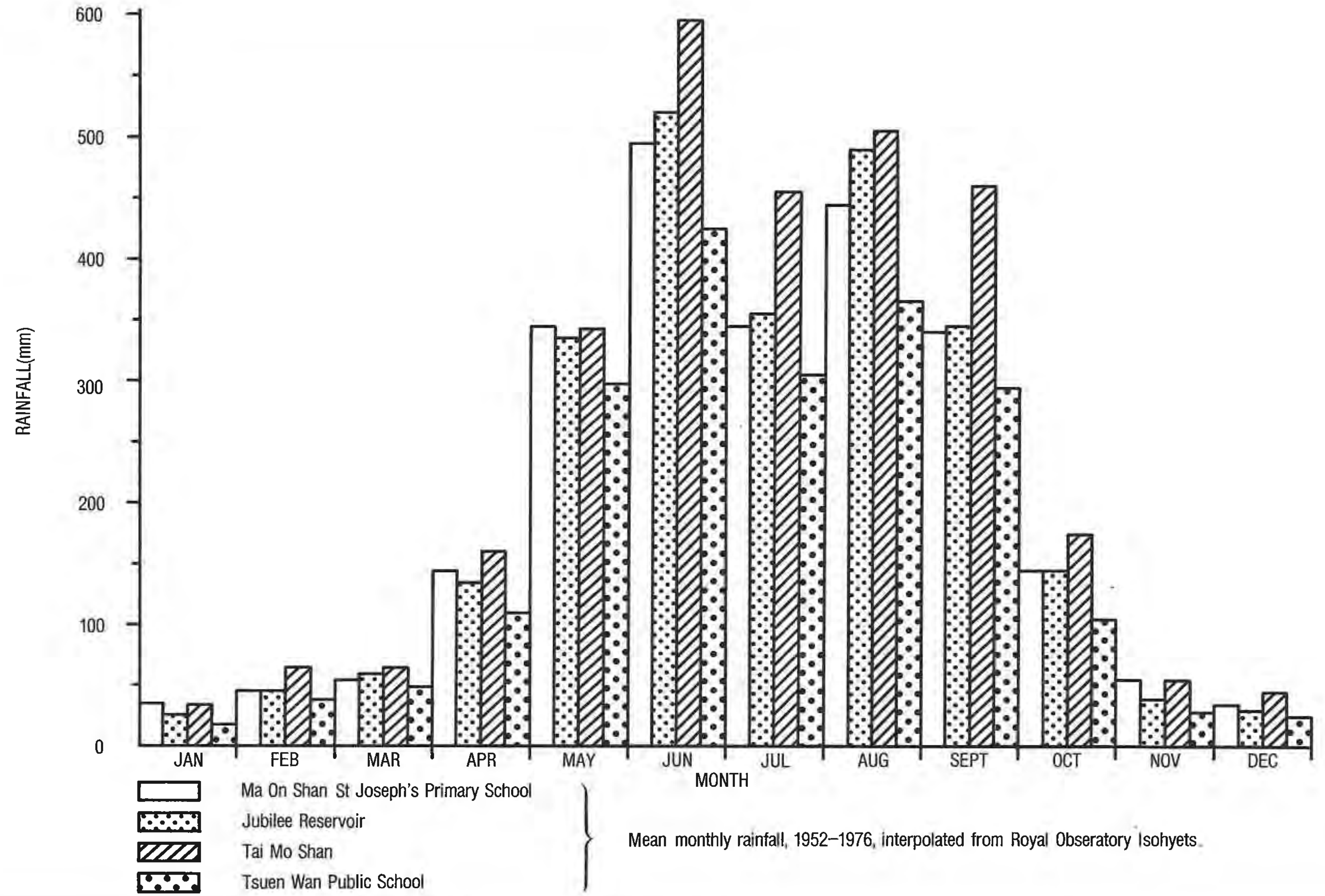
Distribution of Site Investigation Reports
Held in the Geotechnical Information Unit (GIU)

Fig. C2



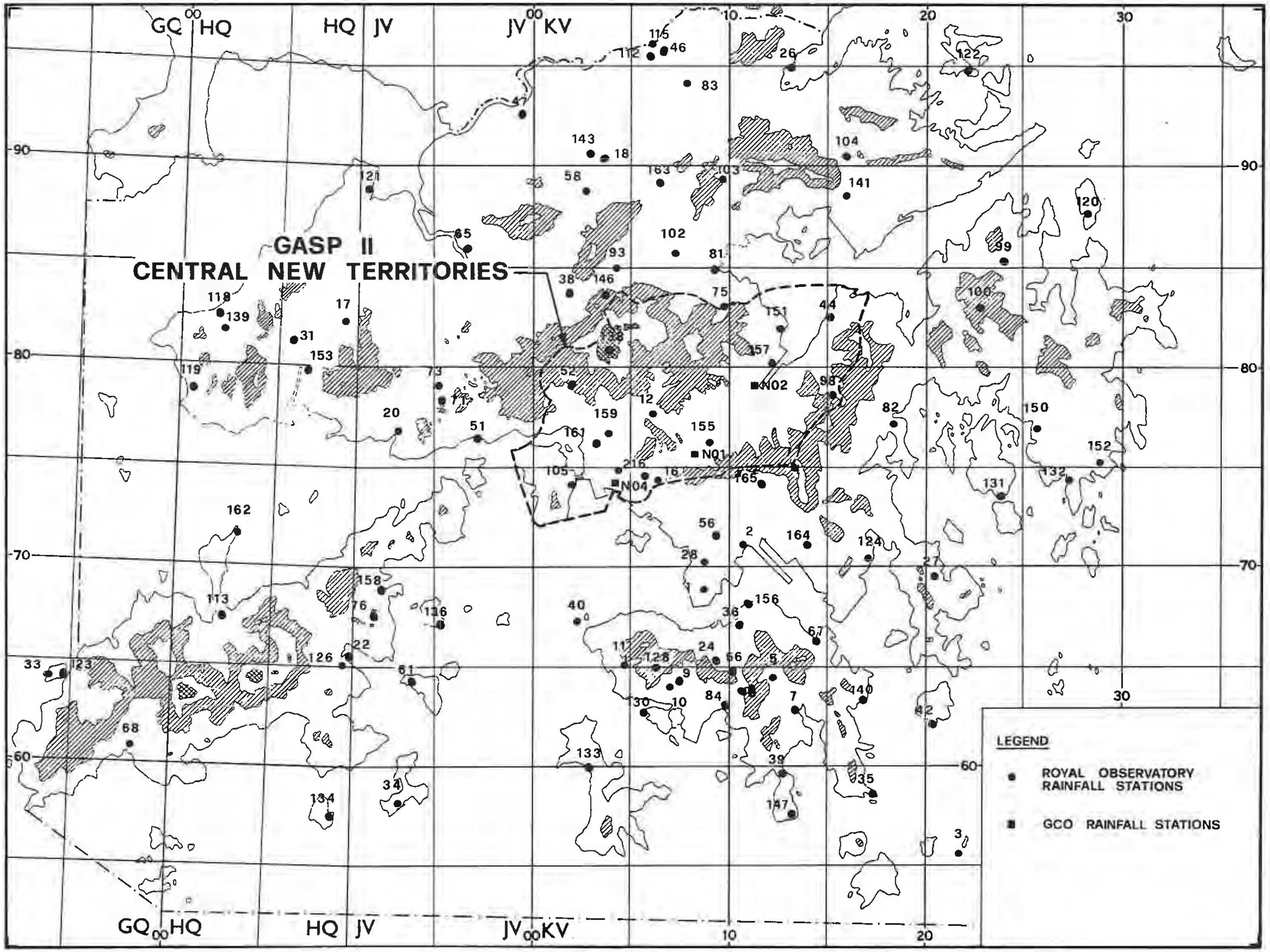
Mean Annual Rainfall Isohyets (1952–1976)

Fig. C3



Summary of Mean Monthly Rainfall Data

Fig. C4



Locations of Rainfall Stations

Fig. C5

Table C2 Selection of Aerial Photographs

Year	Photograph Serial Number	Photograph Scale (Approx.)
1983	47236–47249	1:40 000
	47144–47148	1:40 000
	47108–47120	1:40 000
	47077–47087	1:40 000
1982	44654–44662*	1:20 000
	44621–44631*	1:20 000
	44587–44596*	1:20 000
	44557–44567*	1:20 000
	44532–44539*	1:20 000
1981	39067–39072	1:20 000
	39456–39461	1:20 000
	39241–39249	1:20 000
	39211–39220	1:20 000
	39176–39186	1:20 000
	39164–39165	1:20 000
	39141–39142	1:20 000
	39098–39108	1:20 000
	38130–38138	1:20 000
1980	33465–33471	1:20 000
1979	28621–28629	1:20 000
	28232–28239	1:20 000
	28197–28209	1:20 000
	28159–28170	1:20 000
	28099–28110	1:20 000
	28068–28074	1:20 000
	25839–25847	1:20 000
1978	24378–24379*	1:20 000
	24380–24385*	1:20 000
	24360–24365*	1:20 000
	20744–20748*	1:25 000
	20725–20733*	1:25 000
	20705–20711*	1:25 000
	20658–20663*	1:25 000
1977	19892–19897	1:20 000
1976	16576–16584	1:25 000
	16546–16555	1:25 000
	16518–16526	1:25 000
	16480–16488	1:25 000
	15985–15994	1:25 000
	15958–15964	1:25 000
1975	11992–11997	1:25 000
	11789–11796	1:25 000
	11749–11758	1:25 000
	11721–11728	1:25 000
1974	10081–10085	1:25 000
	10071–10080	1:25 000
	9779–9783	1:25 000
	9838–9845	1:25 000
	9810–9817	1:25 000
	9575–9579	1:25 000
	9580–9583	1:25 000
	8260–8261	1:25 000
	8256–8259	1:25 000
	8246–8253	1:25 000
1973	8012–8014	1:25 000
	7984–7989	1:25 000
	7962–7967	1:25 000
	7959–7961	1:25 000
	7939–7942	1:25 000
	7936–7938	1:25 000
	5496–5499	1:25 000
	5492–5494	1:25 000
	5483–5486	1:25 000
	5479–5482	1:25 000
1972	2312–2314	Variable
1967	5529–5541	1:25 000
	5506–5516	1:25 000
1964	5424–5429	1:8 000
	5350–5363	1:3 600
	5341–5349	1:3 600
	5313–5557	1:3 600
	5285–5294	1:3 600

Table C2 Selection of Aerial Photographs *(Continued)*

Year	Photograph Serial Number	Photograph Scale (Approx.)
1964	5263–5267	1:3 600
	5131–5157	1:3 600
	4976–4984	1:3 600
	4957–4976	1:3 600
	4951–4955	1:3 600
	4892–4911	1:3 600
	4870–4890	1:3 600
	4663–4673	1:3 600
	4602–4623	1:3 600
	4472–4481	1:3 600
	4418–4448	1:3 600
	4332–4335	1:3 600
	4192–4214	1:3 600
	4184–4190	1:3 600
	4165–4172	1:3 600
	4092–4097	1:3 600
	3791–3805	1:3 600
	3756–3766	1:3 600
	3737–3752	1:3 600
	3726–3728	1:3 600
	3712–3724	1:3 600
	3363–3375	1:3 600
	3160–3172	1:3 600
	3111–3129	1:3 600
	3087–3107	1:3 600
	3076–3085	1:8 000
	3050–3061	1:5 400
	3021–3047	1:5 400
	2993–3019	1:5 400
	2951–2955*	1:25 000
	2635–3644*	1:25 000
	2605–2612*	1:25 000
	2575–2582*	1:25 000
	2303–2323	1:5 400
	2255–2277	1:5 400
	2195–2225	1:5 400
	2169–2193	1:5 400
1963	8332–8339	1:8 000
	8291–8320	1:8 000
	8227–8232	1:8 000
	8216–8218	1:8 000
	7751–7757	1:8 000
	7749–7729	1:8 000
	6423–6437	1:8 000
	6417–6421	1:8 000
	6139–6143	1:8 000
	5754–5762	1:5 400
	5700–5729	1:5 400
	5640–5646	1:5 400
	5618–5639	1:8 000
	5467–5483	1:8 000
	5442–5455	1:8 000
	5416–5434	1:8 000
	5385–5409	1:8 000
	5338–5361	1:8 000
	5329–5305	1:8 000
	1266–1276	1:14 000
	1210–1220	1:14 000
	1116–1118	1:8 000
	1108–1114	1:8 000
	0610–0622	1:14 000
	0551–0560	1:14 000
	0498–0512	1:14 000
	0466–0480	1:14 000
	0237–0240	1:14 000
	0230–0235	1:14 000
1949	5156–5161 (81A/125)	1:11 600
	5079–5081 (81A/118)	1:11 600
	5060–5085 (81A/118)	1:11 600
	5001–5020 (81A/118)	1:11 600
1945	4106–4109 (681/5)	1:12 000
	4059–4075 (681/5)	1:12 000
	4017–4030 (681/5)	1:12 000
	3163–3174 (681/4)	1:12 000
1924	26–27 (H24)	1:14 000
	16–20 (H24)	1:14 000
	1–19 (H51)	1:14 000
	4–5 (H24)	1:14 000
	1–7 (H24)	1:14 000
	1–3 (H19)	1:14 000

Note: *indicates aerial photographs used during systematic terrain classification

APPENDIX D

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

List of Figures

APPENDIX D

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

D.1 Introduction

The descriptions of the material characteristics and properties which are contained in this Appendix are intended to give planners and engineers a background understanding of the components of 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 as they are capable of influencing the engineering feasibility of a particular form of project through construction cost, ancillary works and long-term maintenance. Particular problems, if anticipated at the earliest stages, can be avoided or accommodated with the minimum disruption, delay or expense. The main discussion on the planning and engineering significance of geotechnical problems is given in Sections 3 and 4.

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

D.2.1 *Mode of Generation and Texture*

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

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

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

D.2.2 *Joints*

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

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

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

The more randomly oriented, smoother, volcanic joints will influence the stability of cut faces although this may only result in surface 'unravelling'. Granite joints by contrast are less likely to bring about failure in rock unless steeply inclined, due to their high roughness or vertical orientation. Note, however, that weathering on joint planes effectively reduces their roughness, thereby decreasing stability.

D.2.3 *Porosity and Permeability*

Neither the porosity nor the permeability of the rock or soil mass have a significant bearing on large-scale planning decisions. However, the groundwater regime can adversely influence stability if changes of permeability occur, for instance in the construction of piled foundation or basements. Lumb (1964, 1972) discussed building settlements within the Territory.

Porosity relates to the capacity of rock or soil to hold liquid, and is thus an important factor in determining the rate of weathering. Permeability controls the rate of throughflow, which influences weathering and also stability through water pressure. Mass permeability is influenced by jointing in granites, since flow tends to be concentrated in the open joints, whilst in volcanics, water permeation is more uniform. Hence, both porosity and permeability are important factors in weathering decomposition and in the nature of the weathered profile.

D.2.4 *Weathering and the Weathered Profile*

The weathering process and its products exert a significant influence on the performance of the materials and on their response to transport processes. At the planning stage, therefore, consideration of the weathering process and its effects will help to produce feasible layouts for projects, so that they are less influenced by geotechnical threat and, hence, less costly to construct and maintain.

The nature of weathering and its problems may often be inferred from the shape of the terrain, its geology and evidence of existing landforming processes, factors which are all discussed or presented in this Report. The factors shown in Figure D3, some of which are discussed above, all exert varying influences on the weathering process. The rate of weathering breakdown is usually a function of rock porosity and permeability in conjunction with active and fluctuating groundwater flow. The differing chemical stability of various minerals comprising the rock results in non-uniform breakdown of the rock.

The weathered product of granitic rock is a loose, granular quartz soil because feldspars are broken down during weathering. The proportion of clay in the weathered soil depends on the balance between eluviation and deposition, which is related to the terrain. The texture of weathered granite makes it particularly susceptible to erosion on ridgecrests and other situations where natural vegetation is removed. By contrast, the weathered volcanic rocks have a higher proportion of silt size particles and, due to their clay content, to some extent are more resistant to erosion.

Weathering progresses as a function of porosity and permeability. Mass permeability is important in determining the nature of the weathered profile. Table A3 in Appendix A shows schematically the constituents of a complete weathering profile in granitic rock. Water flowing through the joints initiates breakdown of the intact rock away from the joints and leaves core boulders of relatively unweathered material in a matrix of weathered soil. This particular problem is associated with boulders in granite and granitic colluvium. As weathering progresses, the depth of completely weathered material increases (Zone A) until, in an old profile, Zones B and C may be almost completely absent. The depth of Zone D is thought to be related to the lowest depth of active groundwater flow, although weathering by other processes, whilst not likely to be active at present in Hong Kong, may operate below this depth. The depth of the weathered profile in granite may exceed 90 m, which is considerably greater than that established in volcanic rock.

In volcanic rock, where the joint spacing is close and mass permeability is therefore more uniform than in granite, weathering appears to progress more uniformly, so that corestones are not often evident. The reasons for the generally thinner depth of the weathered mantle and for the rapid change from unweathered to completely weathered rock in volcanics are uncertain and are not widely considered in the literature. They may be due to topographic and hydrological factors prevailing during earlier climatic periods as well as to material properties.

Time, climatic change and the landform type combine with the physical characteristics outlined above to influence the processes and the present condition of the terrain. These are important variables, since they may introduce apparent anomalies into the weathered profile. Weathering profiles and landform patterns form over considerable periods of time and are balanced between the processes of weathering and erosion. Hence, rejuvenation or abandonment of an established weathering profile, removal of portions of a weathered mantle, or deposition and subsequent weathering of a colluvial blanket may result in a change in this balance. These changes often result from altered hydrological conditions. Although certain inferences may be made from the shape of the terrain as to trends in depth of the weathered profile (Ruxton & Berry, 1957, Ruxton, 1960), the current terrain may be the result of more recent transport processes, as described in Appendix D.3.

NATURAL AND MAN-MADE INFLUENCES ON LANDFORM EVOLUTION IN HONG KONG ; THE ENGINEERING CHARA - CTERISTICS AND PROCESSES WHICH INFLUENCE LAND USE POTENTIAL , AND THEIR EVALUATION WITHIN THE GAS PROGRAMME.

NATURAL LANDFORMING INFLUENCES :
SUBSURFACE & SURFACE VARIABLES.

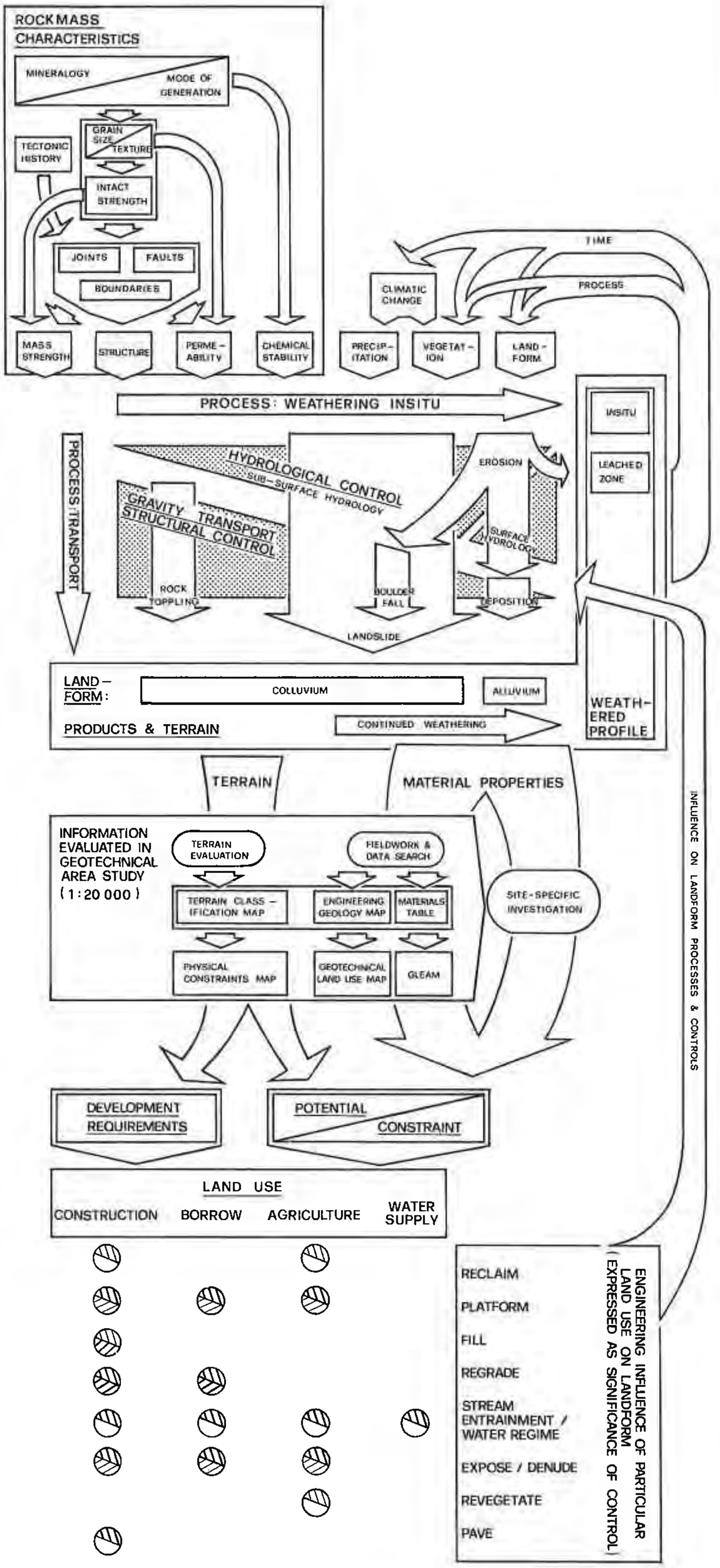
LANDFORMING PROCESSES :
RELATIVE INFLUENCE OF HYDROLOGY, STRUCTURE & WEATHERING ON TYPES OF TRANSPORT PROCESS. (BACKGROUND TRIANGLES SHOW PROPORTION OF INFLUENCE OF CONTROL).

LANDFORM :
INDICATED AS PRODUCTS OF VARIOUS LANDFORMING PROCESSES.

GEOTECHNICAL AREA STUDIES :
CLASSIFICATION OF TERRAIN & ENGINEERING MATERIALS, INTERPRETATION OF LANDFORM IN TERMS OF GEOTECHNICAL POTENTIAL & CONSTRAINT FOR STRATEGIC PLANNING & ENGINEERING FEASABILITY STUDIES. G A S PROVIDES PRELUDE TO SITE SPECIFIC INVESTIGATION.

INFLUENCES ON LAND USE :
POTENTIAL, CONSTRAINT, DEVELOPMENT REQUIREMENTS.

LAND USE CHART :
INTENSITY OF SHADING INDICATES ENGINEERING INFLUENCE OF PARTICULAR LAND USE ON
HYDROLOGICAL CONTROL / STRUCTURAL CONTROL THROUGH MODIFICATION OF LANDFORM :
SLIGHT
MODERATE
SIGNIFICANT



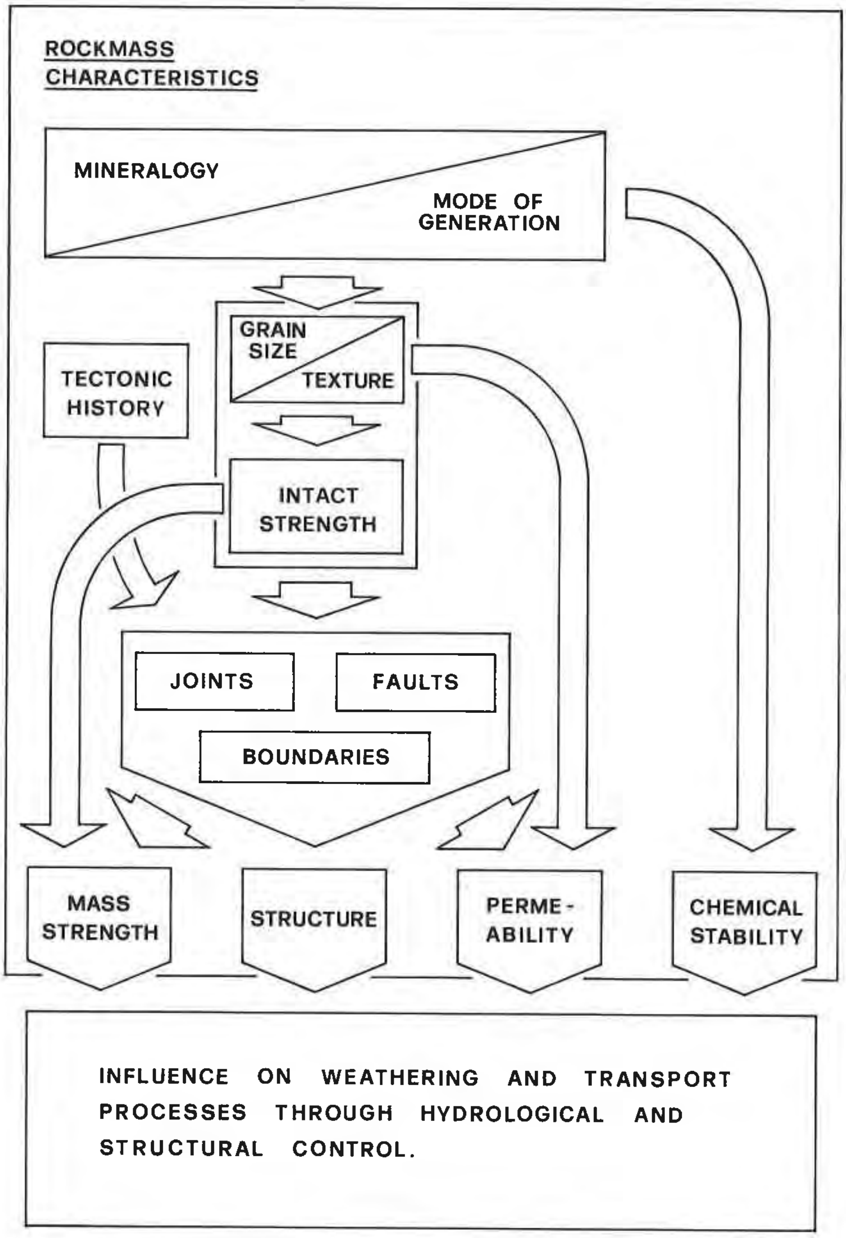
LEGEND :

BOXES INDICATE : CAUSE OR PRODUCT

ARROWS INDICATE : INFLUENCE, PROCESS, OR MECHANISM

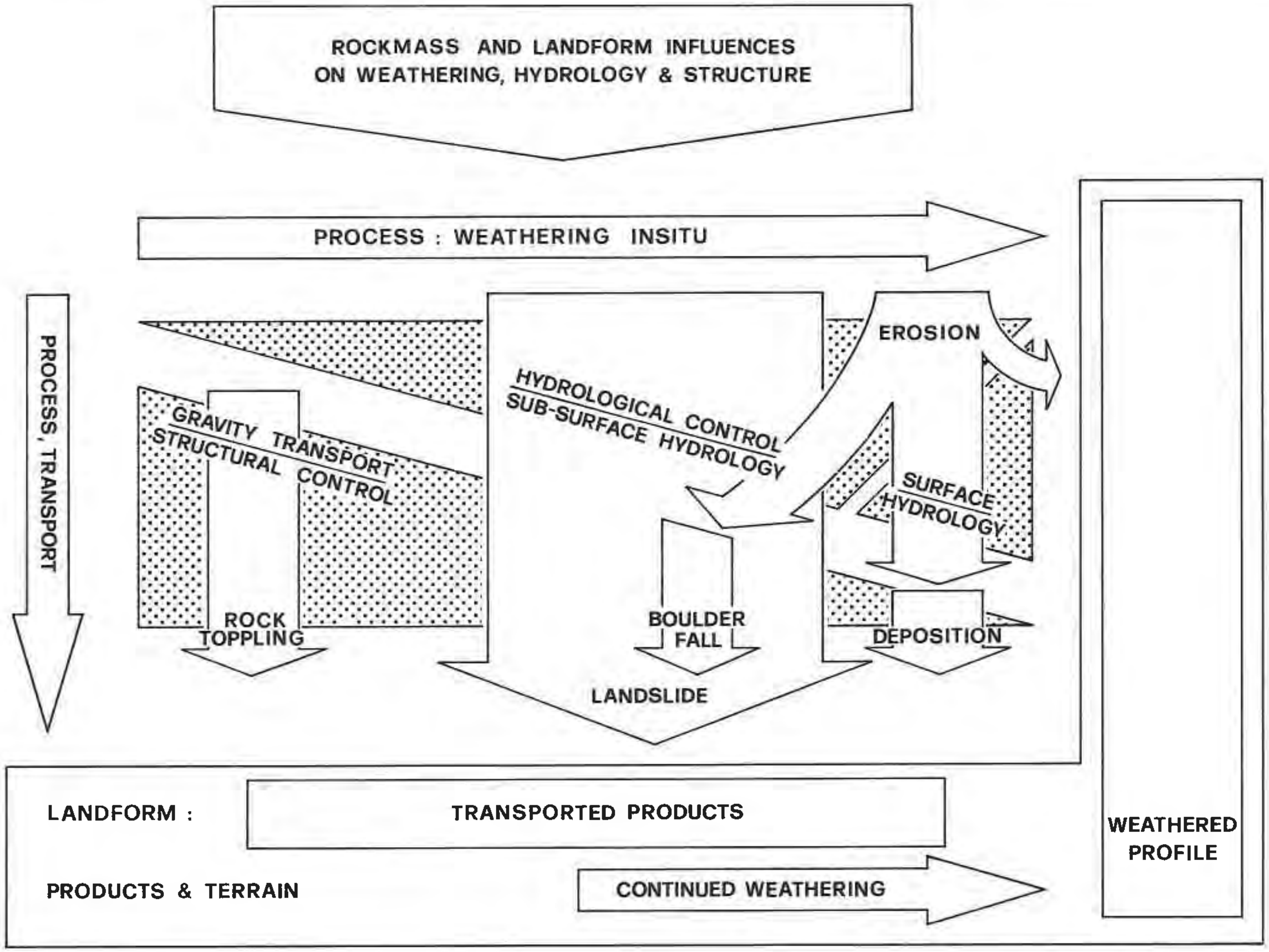
CIRCLES INDICATE : HUMAN INVOLVEMENT

Influence of Landforming Processes — **Fig. D1**



SUMMARY OF ROCKMASS CHARACTERISTICS WHICH ARE SIGNIFICANT IN INFLUENCING NATURAL LANDFORM AND ENGINEERING WORKS IN HONG KONG. (EXTRACT FROM FIG.D1)

Rock Mass Characteristics	Fig. D2



SUMMARY OF LANDFORMING PROCESSES IN TERMS OF THE RELATIVE IMPORTANCE OF WEATHERING HYDROLOGY AND STRUCTURE. (EXTRACT FROM FIG. D1)

(BACKGROUND TRIANGLES SHOW PROPORTION OF INFLUENCE OF HYDROLOGY AND STRUCTURE)

Landforming Processes	Fig. D3

D.2.5 *Faults*

A fault is a fracture in rock along which there is an observable amount of displacement. Faults rarely occur in isolation, and more extensive faults or fault zones often display associated local shattering of the rock. Hence they may cause concentration of groundwater flow which permits deeper weathering to occur. If so, they often become observable in surface reconnaissance and from aerial photograph interpretation as 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 in Hong Kong are also faulted.

D.3 Engineering Considerations for Development Planning

D.3.1 *General*

Geotechnical problems will be minimised if development takes place in a manner which reflects the basic suitability of the terrain for a particular use. The following sections discuss the engineering significance of the major terrain-related factors which influence the suitability of land for development. The discussion relates to those features which are particularly important for planning and engineering feasibility.

In 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 study area will necessitate the utilisation of natural or man-made terrain which has geotechnical limitations. Some of these features continually recur across the landscape and have similar engineering problems. This section seeks to identify the major constraints associated with a number of engineering geological factors.

D.3.2 *Geotechnical Constraints to Development*

Within the study area, slope instability is a major geotechnical constraint to development. Instability may be associated with moderate to steeply sloping insitu or colluvial terrain or with land which has been disturbed by man. Landslips and other forms of slope instability are common occurrences on both natural and man-made terrain in Hong Kong. A number of serious landslip disasters have resulted in considerable loss of life and extensive property damage.

Rock toppling, rock slides and boulder falls are essentially structure controlled, although movement, which is usually sudden and without warning, may be initiated by groundwater pressure. Structural control is also affected by man's influence, because construction exposes release joints along which sliding may occur. Boulder falls usually require the erosion of weathered material or decomposition along planes of weakness through hydrological influence.

Landslips in weathered material pose a considerable hazard, but they are often preceded by signs of distress. Although largely controlled by relict jointing in moderately weathered material, natural failure is often precipitated by the subsurface water regime in conjunction with landslip-prone topography. Leach (1982) and Leach & Herbert (1982) studied the question of groundwater flows on Hong Kong Island.

Whilst erosion alone does not pose as great a hazard as slope instability, it can cause severe problems for engineering work. In addition, changes to the terrain and hydrology through construction or earthworks may cause erosion which may create conditions conducive to mass movement. The loose structure of weathered granites make these more susceptible to erosion than the volcanics when vegetation is removed. Evidence of this occurs in the denuded, eroded and bouldery upper sideslopes of the granitic terrain, where landslips are common at the heads of drainage lines. The debris from such landslips may travel at high velocity for considerable distances, blocking drains and resulting in surface water infiltration.

Deep weathering may be present, particularly where it is accelerated by shattered rock structure or active subsurface groundwater. Although weathering is not a severe constraint, it may pose considerable difficulties during construction, especially if very localised. Localised problems associated with geological photolineaments are discussed in Section D.3.4.

The following sections outline a number of specific problem areas which are important for planning and engineering feasibility.

D.3.3 *Fill and Reclamation*

Fill is soil or rock which has been used to provide site formation above the level of the natural terrain. The nature of the fill depends on the source material, the natural terrain, and the quality and control of construction. These factors, together with the history of filling, influence the engineering characteristics of the material.

The locations of fill and reclamation are shown on the Engineering Geology Map and the Physical Contraints Map. Large areas of fill are associated with the Housing Estates which occur on the Sha Tin Valley footslopes. Areas of Fo Tan and Ma On Shan are located on fill.

The nature and the engineering problems associated with fill can be categorised into the following:

(i) *Cut and Fill Platforms on Steep Terrain*
This technique is used in Hong Kong to provide level building platforms on otherwise steep terrain. A typical example is in the Sha Tin district, where numerous cut slopes, platforms, fill slopes or retaining walls mask the natural slope profile. Plate 19 shows the extensive development in this area, much of it on slopes approaching 30° in gradient.

Since the disastrous fill slope failures at Sau Mau Ping in 1972 and 1976 (Government of Hong Kong, 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'. This results in:

(*a*) Poor compaction – a generally loose structure makes the fills susceptible to liquification resulting from infiltration of rainwater, movement of groundwater, through flow or from fractured water mains. This leads to sudden loss of strength and failure of the slopes. Loose fill is also liable to settlement and possible lateral movement on loading.

(*b*) Stratification parallel to the natural slope – this enables the infiltration of water from the level platform into the fill and also creates inclined planes of potential weakness liable to preferential failure.

Old fill has often been tipped into unprepared natural drainage lines, and the natural groundwater regime may persist beneath the fill, leading to infiltration and instability. The material behaviour is also subject to the variability of the source material. Completely weathered rock would result in a fairly uniform fill, whilst fill of less weathered rock may contain boulders and voids.

Areas of fill platform are used in the Tsuen Wan and Sha Tin areas for industrial and high density housing. Although they are generally located on more gently sloping terrain than those discussed above, they are very extensive in nature and obliterate the natural drainage pattern. Most of these areas are designed for their current land use.

(ii) *Fill on Low Lying Terrain*
Few engineering problems are envisaged in these areas, with the exception of settlement. Large buildings are generally piled. Deep excavations may experience difficulties due to high groundwater tables in underlying alluvium.

(iii) *Land Reclaimed from the Sea*
Almost all of the coastal areas are modified by reclamation and considerable recent and proposed development is based on these areas.

The historial development of reclamation is recorded on the Engineering Geology Map and is illustrated in Plate 5.

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 increase in water levels if drainage paths are blocked.

(*f*) Settlement—unpiled structures are subject to settlement and should be designed to redistribute loads or else to be flexible. Foundation stresses are subject to variation from fluctuating water levels in response to the tide. Piled structures may require design for negative friction in recent or deep reclamation.

(*g*) Underlying materials—the problems of construction on reclamation may be aggravated by considerable depths of marine or alluvial deposits and weathered bedrock. The depth of these will vary depending on the original ground profile. The general depth of underlying materials may be determined from site investigation, whilst local variation may be identifiable in the features of the old coastline and the onshore terrain.

(iv) *Sanitary Landfill*
Sanitary landfills are used for the disposal of domestic refuse. Typical engineering problems associated with the development of sanitary landfills include:

(*a*) Heterogeneous materials which are difficult to remove.

(*b*) Unpredictability of stability of landfill slopes and embankments.

(*c*) Unpredictable, large settlements.

(*d*) Fire hazard from methane gas emission.

(*e*) Erratic water flows within landfill.

(*f*) Noxious leachates, posing pollution problems and chemical attack of concrete and steel.

For these reasons, recently completed sanitary landfills and adjacent platforms are probably unsuitable for development other than as open space or recreation areas.

D.3.4 *Geological Photolineaments*

Major geological photolineaments are shown on the Engineering Geology Map for the study area. These features and some more minor lineaments are also shown on the GLEAM if they are significant in the engineering feasibility of potential development areas.

Lineaments are the surface expression of subsurface structural features and, hence should be carefully examined during planning and engineering feasibility. Differences in rock type, structure or strength are amplified by the landforming processes to produce contrasts in erosion or vegetation, or linear patterns in relief or drainage. Such contrasts are readily identified using API and are often apparent during site reconnaissance. It should be noted that structural features causing lineaments will probably continue beneath superficial deposits such as alluvium, colluvium or fill and their influence should be anticipated in foundation works through these materials.

In general terms, contrasts in the terrain are a reflection of the resistance or susceptibility of the underlying material to erosion. Surface features are often good indicators of local engineering characteristics.

Lineaments tend to be localised and therefore they may often be avoided during the layout and design stages of an engineering project.

Engineering factors which are often associated with lineaments may be classified into the following:

(i) *Deep Weathering*
Shatter and shear zones in the rock tend to concentrate water flow and result in deep weathering. Localised rock shattering may be due to faulting and is likely to appear as a major lineament. The GLEAM shows the influence of structure on drainage in this area; foundation difficulties may occur due to rapidly changing ground conditions.

Many of the lineaments are major features which are continuous across the study area.

(ii) *Slickensiding*
Slickensiding is evidence of larger scale movements in rock and soil. Smoothing and striation on a fault plane render it more susceptible to failure if a cut slope were to intercept and release a slickensided joint. Whilst this problem may not be obvious prior to excavation, it should be anticipated where fault lineaments are indicated.

(iii) *Changes in Rock Mass Structure and Properties*
Smaller scale lineaments are often identified from preferential drainage caused by a weakness or adjacent strength of the rock mass. This may be due to variation in the rock itself or in its structure. Where the lineament is evidence of a structural weakness, problems may be encountered in the founding of caissons and in the construction of rock cut slopes.

Small scale, as well as major, lineaments may be associated with anomalies in the general pattern of weathering depth which may cause differential settlements of raft foundations.

Regular patterns of lineaments are evidence of the regional pattern of structure present at smaller scale. Engineering works in the area may experience instability problems on cut slopes at particular orientations.

In areas of active coastal erosion, the local rock structure is often apparent from the pattern of erosion and instability. This is shown on the GLEAM and often confirms the pattern of lineaments and the local structure.

Boundaries between rock types may or may not form lineaments, partly depending on whether they are faulted or not. Identified rock boundaries are shown on the Engineering Geology Map and the GLEAM. Changes in structure are likely at granite/volcanic boundaries due to cooling stresses, and in strength and weathering due to contact metamorphism.

(iv) *Preferential Groundwater Flow*
The preceding engineering features of lineaments are usually associated with preferential ground-water flow, both at and below the surface. This should be a consideration in the construction of fills in valleys where the subsurface hydrology may be largely unaffected inspite of surface water entrainment.

(v) *Seismic Influence*
Some lineaments are identified on the Engineering Geology Map (after Allen & Stephens, 1971) as faults, and other major lineaments may also have been caused by ground movements.

D.3.5 *Colluvial Deposits*

Colluvium is a transported material, whose nature and engineering characteristics depend on the origin of the material, the conditions of its deposition and its subsequent history. Various types of colluvium exist within the study area, and their location, nature and material properties are discussed in Sections 2.3, 2.4 and 3.1.4. The extent of colluvium as identified by terrain classification is shown on the Engineering Geology Map.

Colluvium need not necessarily be regarded as a constraint for engineering. Relict colluvium in a completely weathered state 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.

Engineering factors which are often associated with colluvium may be classified into the following:

(i) *Physical Properties*
Colluvium is subject to local variations of structure, density, strength and water content, both horizontally and vertically. In particular, concentrations of subsurface water flow may result in voids and pipes caused by the removal of fines, and in local piezometric variation. Stratification of these deposits may cause perched water tables and variations in the strength profile. Settlements under load may be unpredictable. Hence, heavily loaded structures should be founded on caissons through to bedrock. In situations were loading of the colluvium could cause instability, measures should be taken to ensure that loads are not transferred to the colluvium. The variable nature of colluvium will usually require the use of hand dug caissons. As discussed for boulder colluvium in Section 3.1.4, 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 the Sha Tin footslopes show zones of water seepage. Local instability in natural oversteepened colluvial slopes results from emerging groundwater. In cuts in colluvium such conditions may lead to progressive collapse of a loose soil structure upslope with considerable debris flow.

(iv) *Site Investigation*
In heterogeneous deposits such as extensive recent colluvium and boulders, site investigation alone cannot reveal a comprehensive model of the ground, nor can appropriate strength values be accurately assessed. Carefully monitored trial caissons are often justified in colluvial deposits. Attention should be paid to variations in bedrock and its level in boreholes to ensure that foundations do not rest on boulders.

D.3.6 *Boulders and Rockfalls*

Boulder and rockfalls are a feature of the wet season in Hong Kong and have on occasion resulted in loss of life and considerable property damage.

Boulders are large blocks of rock which often result from wide joint spacing. They occur often in granitic rocks as the unweathered remnant corestones between completely weathered joints. If exposed on steep hillsides or in drainage lines, they may be liable to movement.

Adverse jointing and exposed location may result in potential rockfalls in both granitic and volcanic terrain. In this case, weathering, except as a local weakening of the joints, is not a major contributing factor. In granitic rock, the presence of extensive sheeting joints also contributes to the rockfall potential.

Boulders, joint blocks and wedges may also be present in, or as exposed remnants of, both granitic and volcanic colluvium. Large colluvial granite boulders rest on the slopes of Beacon Hill.

Boulders may also exist in drainage lines where they are likely to be restrained and interlocked. However, high flows caused by torrential rain is liable to increase the likelihood of movement. Boulders in drainage lines may also trap detritus and torrential flows may cause mud or debris flows.

In areas with potential for development, boulders and rock outcrops are indicated on the GLEAM where they are obvious in aerial photographs. In many situations, boulders are hidden from view by dense vegetation.

Engineering solutions to the boulder and rockfall problem depend largely on the local situation, but may consist of one or a combination of the following:

(*a*) Removal—isolated boulders may be removed from the slope if the situation permits. This could be achieved by blasting or excavation.

(*b*) Restraint—it may be possible to restrain or support isolated boulders and rock wedges by buttressing, anchoring, or cable support.

(*c*) Protection—in areas with long slopes and many potentially unstable boulders or blocks of small to moderate size, identification and removal of critical boulders may not be warranted or may detrimentally affect stability. In such cases, general protection measures may be more appropriate, such as sterile zones, trap ditches or bunds, catch fences, protection nets or deflection barriers.

D.3.7 *Boulders below Ground*

In the granites and colluvium of the study area, boulders are often present within the weathered matrix. Site investigation and construction of load bearing foundations should examine these features. For deep foundations, hand excavation may be required. Blasting of boulders in caissons or cuttings may cause loosening or collapse of the surrounding matrix. Variations in the bedrock level and in the bedrock material may also indicate the presence of boulders.

In bouldery colluvium, voids are likely beneath boulders as a result of the nature of deposition or due to washing out of the matrix in underground drainage lines. This poses particular problems for the construction of deep foundations through these materials.

D.3.8 *Marine Deposits*

Marine deposits are not considered in detail from an engineering point of view in this Report, except in relation to reclamation. Their geological characteristics are discussed in Appendix C.

D.3.9 *Cut Slopes*

Cut slopes and/or slope support structures are an aspect of most large-scale developments in Hong Kong. Different considerations govern the use and design of slopes depending on the geological material, its state and structure. Hence, the overall form of a development should also relate to the engineering opportunities of the terrain.

The height and angle of a cut slope is a matter for design based on a model of the rock or soil strength and structure as determined by site investigation. Preliminary assessment of the size and form of slopes and retaining structures may be made on the basis of the engineering properties of the local rock type, as indicated on the Engineering Geology Map and in the Materials Table (Table 3.1). At the planning stage, flexibility of layout should be retained, especially where large cuts are involved, so that local variations in strength and structure can be accommodated in design. Lineaments and structural control are indicated on the GLEAM. Structural control may indicate shallow bedrock, and the structure will influence the stability of cuts in rock. Lineaments indicate a local structural feature which may influence the final slope design, probably requiring a shallower angle cut on the weaker rock zone.

In large developments on steep terrain, a more geotechnically economical use of the site can be made by providing a stepped site formation which follows the terrain, rather than a large level formation with very large cuts. The benefits of this approach occur in different ways, for each of the major geological materials occurring on steep terrain:

(i) *Volcanic Terrain*
Weathering depths of less than 15 m are generally noted for steep volcanic terrain in the study area, with rapid transition from weathered to fresh rock. In such terrain, structures can economically be founded at shallow depths and large fresh rock cuts avoided. Where fresh rock cuts are formed, the jointing of the rock may cause some surface unravelling, and net protection or a safety zone may be required to maximize slope angles. Locally persistent or unstable joints may require shallower angled cuts or support measures.

(ii) *Granite Terrain*
Considerable depths of various grades of weathering are encountered in the granitic areas. Large structures founded in this terrain will generally require caisson foundations to bedrock. If large flat site formations are to be created in steep granitic terrain, major cuttings and retaining structures should be provided through a range of weathered rock. The only advantage of this is that shallower caissons can be used, and that extensive flat areas can be created.

The design of cut slopes in less weathered granite (less than Grade III) may require empirical approximations to model the strengthening influence of boulders. In cuts in fresh rock, sheeting joints are likely to be encountered which require additional support or the draining of water. These local measures enable steep cuts to be made in fresh granite, but the particular form of additional support cannot be determined in advance.

(iii) *Colluvial Terrain*
The creation of extensive cuts in colluvium should be avoided. Aspects of the material affecting stability are noted in Section 3.1.4. Colluvium overlies the insitu rocks in almost all the potential development areas outlined in this Report. Colluvium has been associated with a number of serious slope failures in the Territory, and there are many instances where local failure has occurred on cuts formed for development platforms on steeper terrain.

D.3.10 *Maintenance of Natural Drainage*

In colluvial areas and in the vicinity of man-made fills, where stability of excavations and slopes is particularly sensitive to water pressure and localised erosion, the pattern of natural drainage should be maintained as far as is practicable.

Diversion of natural drainage, if poorly maintained or of inadequate capacity, may cause overtopping of channels with consequent erosion and infiltration on slopes during heavy rains when stability is most vulnerable. Many streams in the study area carry large amounts of silt from surface wash, which is often deposited on bends or flatter sections of entrainment schemes.

The pattern of subsurface flow beneath any superficial or partly weathered material is unlikely to be affected by most surface water entrainment schemes. Subsurface flows may enter fill in valleys from beneath, even though surface drainage reduces infiltration. It is possible that the fill slope failures at Sau Mau Ping were the result of such subsurface flows.

Even in situations where the natural drainage pattern is not significantly altered, an impermeable surface cover such as a large paved area can considerably increase the quantity of surface runoff and reduce the time of concentration. Flooding and consequent infiltration of slopes may become a problem even though, in the natural terrain, it is not the case. Old nullahs located in developing areas are often subject to overtopping in intense rain for this reason.

The natural and post-development hydrology requires careful investigation and design due to their influence on slope stability.

D.3.11 *Site Investigation*

A 'desk study' is a necessary preliminary to any site investigation. The GASP report summarises, interprets and presents much of the information which would be reviewed in a desk study and, in addition, is reinforced by field reconnaissance.

The 1:20 000 GASP Report is designed for use at a strategic planning and engineering feasibility study stage. The GLUM indicates the general level of site investigation envisaged for each class of map unit and is summarised in Table A2. Information on the engineering geological characteristics, the local geological and terrain constraints, and the general suitability of an area are shown on the EGM, PCM and GLEAM. Only in determining the engineering feasibility of a large uninvestigated area should a preliminary site investigation be based only on a 1:20 000 GASP Report.

When interpreting the GLUM with regard to site investigation, the following points should be considered:

(*a*) In the study area, extensive site investigation for a range of engineering projects is available. Some of the reports are accessible in the GCO's Geotechnical Information Unit (GIU), and many provide a great deal of the background geotechnical information necessary for a new project. Figure C2 gives an indication of the distribution and intensity of site investigation records held in the GIU.

(*b*) A field reconnaissance of the site and the surrounding area is a necessary preliminary to planning a site investigation. On undisturbed sites, much can be inferred with regard to the strength of underlying materials, the pattern of superficial deposits, and local weaknesses in rock from site observations of the contrasts in landform and the pattern of drainage on and around the site.

(*c*) The site investigation should be designed to highlight the scope of any available information, the anticipated material, its nature and variability, and the type and form of the engineering project.

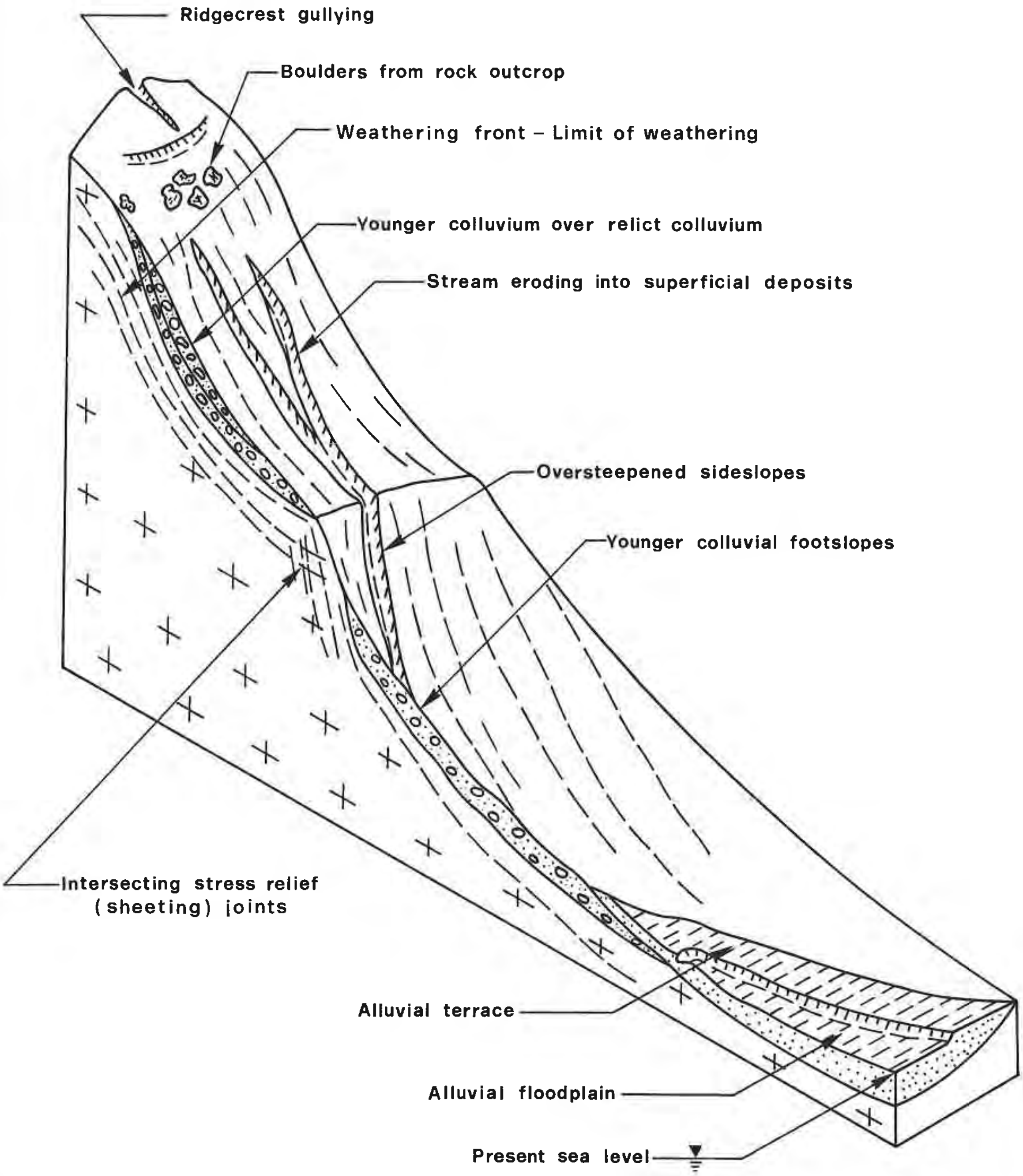
(*d*) Approximately 243 ha of the study area has been evaluated at a scale of 1:2 500 within the GASP District Stage 1 Study Programme. The EGM and Engineering Data Sheet (EDS) produced for this study should be used to aid the design of site investigation.

D.4 Landform Model of the Terrain in Hong Kong

Landforms are the product of the local balance between weathering, erosion and deposition and are continually evolving. The mechanics of the system and its various components are shown in Figure D1 and described in Appendix D.3.1 (Hansen, 1984 a & b). This section discusses the significance of the sequence of landform evolution to the engineering properties of the materials within the study area. This is achieved in terms of their distribution and thickness. Many of the geomorphological processes act at rates that engineers consider insignificant. However an understanding of the evolutionary system will aid an engineering appreciation of the terrain, because the consequences of slope processes affect the materials with which an engineer constantly deals. Figure D4 provides a simplified hillslope model and relates to the following text.

Slopes that are too steep for the weathered material to remain stable are subject to periodic failure. The magnitude of failure may be isolated and small or catastrophic in nature. Therefore, the recognition of slope process is important in order to highlight the landslip hazard. The origin of many of the oversteepened inland slopes in Hong Kong lies in the consequences of the fall in sea level that resulted from the growth of the ice sheets during the Pleistocence. During this period, the sea level fluctuated dramatically; there is evidence in southern China that stream incision occurred and produced oversteepened slopes adjacent to the channels. Gradually, the incision progressed inland, taking advantage of structural weaknesses in the underlying geology, with the result that many valleys are narrow with steep sides. The increased rate of erosion removed much of the weathered mantle adjacent to the streams. This, in part, explains the occurrence of shallow weathering depths and slightly weathered bedrock along the floors of many incised valleys in the Territory.

Drainage courses are the main axes of erosion within a valley. The density of drainage pattern responds to and is influenced by the materials and structural control. Incision and removal of material creates over-steepened sideslopes adjacent to the drainage lines by erosion and slope failure. This process continues to induce oversteepening of the terrain, which causes lateral recession of the hillsides. Oversteepening progresses upslope through erosion by instability, as the depth of weathered mantle increases to a limiting value. The terrain on either side of the oversteepened slope section contains different associations of landforms (as shown in Figure D4) as each part of the slope is reacting to a different set of denudational conditions. Below the oversteepened sideslopes, the landforms are comparatively young. Boulders in the colluvium, deposited as a result of landslips and slopewash from the oversteepened slope, are generally unweathered. The oversteepened sideslopes contain many landslip scars, often as recent and relict features, as well as rock outcrops protruding through the thin soils. Above the level of slope oversteepening, the landforms are generally much older. Thus, the spurlines are more deeply weathered and may possess a relict colluvial cover with boulders that are decomposed insitu. In some situations in the study area, younger colluvium overlies older relict deposits. Stream incision occurs at a faster rate than the upslope migration of the oversteepened slopes. This promotes instability adjacent to the stream channels through undercutting. Erosion may result in the exhumation of corestones or boulders which are either distributed across the terrain or are concentrated within drainage lines.



Hillslope Model	Fig. D4

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 intercalating 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.

ALLUVIUM

Sediment transported and deposited by a river or stream.

ALLUVIAL FAN

Mass of sediments deposited at a point along a river or drainage line where there is a decrease in gradient. The fan is thickest at its point of origin and thins rapidly in a downstream direction.

AQUIFER

Water-transmitting rock or soil. Type aquifers are those which are normally associated with high transmissivity such as sandstone, limestone and chalk 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 rockmass.

BEDROCK (=SOLID GEOLOGY)

Insitu rock exposed at the surface or underlying any superficial material such as topsoil, residual soil, alluvium or colluvium.

BLOCKS

Solid pyroclastic fragments greater than 60 mm ejected from volcanoes by volcanic action.

BOMBS

Partially or wholly molten pyroclastic fragments greater than 60 mm ejected from volcanoes by volcanic action. These fragments often acquire distinctive shapes or surface textures during ejection and subsequent transport.

BRECCIA

Rock consisting of coarse grained (>60 mm) angular fragments implying minimal transport of material. Breccias are poorly sorted and commonly contain rock fragments derived from a restricted source. Also see FAULT BRECCIA.

CATCHMENT AREA

Area from which a river or stream collects surface runoff. Often used synonymously with DRAINAGE BASIN.

CHLORITISATION

Replacement by, conversion into, or introduction of chlorite into the rock substance.

CHUNAM

Cement-lime stabilised soil used as a plaster to protect the surfaces of excavations from erosion and infiltration. The recommended mix for chunam plaster, the proportions being measured by weight, is one part Portland cement, three parts hydrated lime and 20 parts clayey decomposed granite or volcanic soil.

COASTAL PLAIN

Terrain component defined as flat terrain lying between the littoral zone and mountain footslopes.

COLLUVIUM

Heterogeneous deposit of rock fragments and soil material transported downslope through the influence of gravity, including creep and local slopewash.

COUNTRY ROCK (=HOST ROCK)

General term applied to rocks penetrated by and surrounding an igneous intrusion.

CUT SLOPE AND CUT PLATFORM

Surface which remains after volume of soil and/or rock has been excavated. Within the terrain classification system, such units with gradients in excess of 5° are cut slopes, while those with gradients less than 5° are cut platforms.

DETRITAL

Term applied to any particles of minerals or, more commonly, rocks which are derived from pre-existing rocks by processes of weathering and/or erosion.

DIP (or TRUE DIP)

Angle of a plane to the horizontal, measured in a direction perpendicular to the strike of the plane.

DIP DIRECTION

Direction or azimuth of dip.

DISCONTINUITY

Interruption, usually of a planar nature, to the homogeneity of a rockmass (i.e. joints, faults). The description and classification of discontinuities is given in the 'Geotechnical Manual for Slopes' produced by the Geotechnical Control Office. (1984).

DISTURBED TERRAIN

Terrain component, defined as land permanently altered from its original state by man. Cut and fill slopes are usually designated as 'disturbed terrain'.

DRAINAGE PLAIN

Terrain component, defined as an area subject to periodic overland flow of water, and within the GASP it is defined as colluvial in nature. It may be an area of spring activity. In some situations, drainage plains may include deeply incised drainage channels.

DURICRUST (=HARD PAN)

Near surface cemented layer occurring in soils or weathered rocks as a result of groundwater action. The cementing agent may be siliceous, calcareous, ferruginous or aluminous.

DYKE

Wall-like body of igneous rock which is discordant, i.e. cuts across bedding or structural planes of the host rock. Usually near vertical. A set of dykes in a parallel or radial pattern constitutes a DYKE SWARM.

EPHEMERAL STREAM

Stream which only flows for short periods of the year.

EROSION

Natural process which involves the wearing away and/or removal of the land surface by the action of a transporting medium or its entrained debris. The agents of transportation can be water, wind or gravity.

FABRIC

Overall appearance of a rock or soil exposure or hand specimen resulting from the combined features of texture and structure.

FAULT

Fracture in rock along which there has been an observable amount of displacement.

FAULT BRECCIA

Assembly of broken fragments formed by crushing or grinding along a fault plane.

FILL SLOPE AND FILL PLATFORM

Surface which is artificially constructed from soil or rubble transported by man. Within the terrain classification system, such units with gradients in excess of 5° are fill slopes, while those with gradients less than 5° are fill platforms.

FLOODPLAIN

Terrain component, defined as a flat area in alluvial terrain which is subject to periodic inundation.

FOOTSLOPE

Terrain component, which is essentially a zone of deposition and which usually occupies a basal position in the terrain. Within the Regional GASP, footslopes are defined as being colluvial in nature.

GENERAL INSTABILITY

Terrain attribute defined for use in 1:20 000 scale GASP mapping to describe areas where large numbers of small landslips or other instability occur.

GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP (GLEAM)

Map which delineates potential development areas in terms of geotechnical and other constraints.

GEOTECHNICAL AREA STUDY PROGRAMME (GASP)

Geotechnical study of a specific area by the GCO on the basis of systematic terrain classification using aerial photograph interpretation, fieldwork and engineering assessment.

GEOTECHNICAL LAND USE MAP (GLUM)

Map which delineates the general geotechnical limitations of the terrain for planning purposes.

GULLY EROSION

Terrain attribute, characterised by incised drainage channels formed by the removal of soil or decomposed rock by the surface flow of water.

HILLCREST

Terrain component, which is convex in shape. The terrain surrounding this component falls away in all directions.

HYDROGRAPH

Graph showing the volume of stream (or channel) discharge against time. A 'flashy' hydrograph has a steep rising limb and indicates a very rapid increase of discharge following rainfall.

IGNIMBRITES (=WELDED TUFFS)

Chiefly a fine-grained rhyolitic tuff formed mainly of glass particles (shards), in which crystals of quartz, feldspar and sometimes other minerals are embedded. The glass shards are welded or bent around the crystals, having been viscous when deposited. The glass shards are often devitrified.

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 involving shear failure. Term is generally restricted to failures in soils. Rock failures are more commonly termed ROCKSLIDES or ROCKFALLS.

LAPILLI

Pyroclastic fragments measuring between 2 and 60 mm ejected from volcanoes by volcanic action.

LENTICULAR COLLUVIUM

Colluvial deposit which is essentially confined by valley sideslopes or is marginal to a natural drainage line. These deposits are usually ribbon shaped features.

LITHOLOGY

General physical character of a rock, including mineral constituents, texture and structure.

LITHOSTRATIGRAPHY

Stratigraphy based only on the physical and petrographic features of rocks (as opposed to a biological or age basis).

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, i.e. beach.

MANTLE (=REGOLITH)

Weathered rock material overlying fresh rock.

MASS WASTING

General term for the dislodgement and downslope movement of soil and rock material.

MATRIX

Finer grained fraction within a soil or rock containing large particles.

MAXIMUM DRY DENSITY

Density obtained using a specific amount of compaction at the optimum moisture content (British Standard Test: BS 1377).

NATURAL SLOPE

Area of sloping ground substantially unaltered by man.

OUTCROP

Part of a geological formation or rock that appears at the ground surface. The exposure of bedrock or strata projecting through the overlying cover of detritus or soil.

PEGMATITE

Igneous rocks of very coarse texture found usually as dykes or veins associated with a large mass of plutonic rock of finer grain size (e.g. granite).

PERENNIAL STREAM

Stream that flows throughout the year.

PHYSICAL LAND RESOURCES

Physical characteristics of land.

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.

RELICT

Term used to describe remnants of earlier landscapes or surface deposits. Also used to describe traces of lithological features in residual soil.

RESIDUAL SOIL

Soil resulting from the weathering of rock insitu.

RILL EROSION

Terrain attribute characterised by subparallel sets of small narrow channels formed by the concentration of surface runoff.

ROCK EXPOSURE (=ROCK OUTCROP as defined for Terrain Classification)

Discrete area of rock exposed at surface.

ROOF PENDANT

Mass of older country rock forming the roof of a major igneous intrusion (e.g. a granite batholith). On a map, a roof pendant is completely surrounded by the rock of the batholith.

SCREE (=TALUS)

Debris resulting from the mechanical weathering of rock which accumulates at the foot of a cliff or a steep slope.

SESQUIOXIDES

Oxides of iron and aluminium (e.g. Fe_2O_3 & $Al(OH)_3$) which are generally mobilized as ions in solution by groundwater and which, upon precipitation, often act as the cementing agent in the formation of duricrust.

SHEET EROSION

Terrain attribute, characterised by the removal of the surface layers of soil by wind or water.

SHEETING JOINT

Discontinuity produced by pressure release or exfoliation. Sheeting joints may separate large rock masses, e.g. of granite into tabular bodies or lenses, roughly parallel with the rock surface. Often persistent for large distances and generally following the shape of the landform.

SIDESLOPE

Terrain component, used to describe the terrain between footslope and hillcrest. This terrain unit is usually erosional.

STRIKE

Azimuth of a horizontal line drawn on a bedding plane. Strike is at right angles to the direction of true dip.

STRUCTURE

Relationship between different features (and their causes) in a rock mass or soil, e.g. bedding, jointing, cleavage, faulting, contacts between different lithologies and, in a regional context, the geographical distribution of these features.

TECTONIC

Relating to a period of deformation or mountain building e.g. granite emplacement. Post-tectonic refers to events occurring after a particular deformation period. Syntectonic implies an event taking place coextensively with a definite period of deformation, intrusion, etc.

TERRAIN ATTRIBUTE

Characteristic of the terrain as defined within the terrain classification system. (Refer to Table A1).

TERRAIN 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.

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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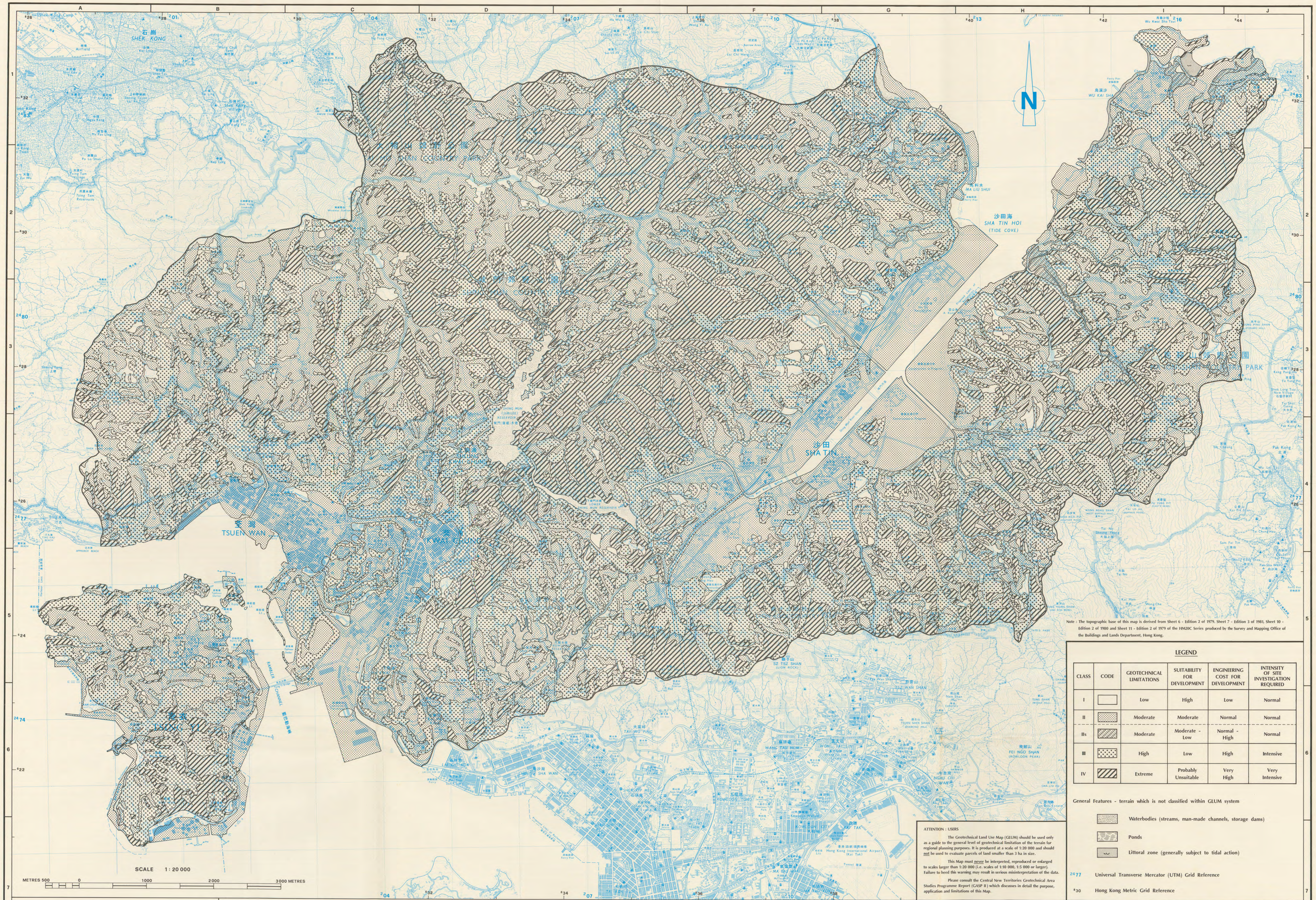

Note : The topographic base of this map is derived from Sheet 6 - Edition 2 of 1979, Sheet 7 - Edition 3 of 1981, Sheet 10 - Edition 2 of 1980 and Sheet 11 - Edition 2 of 1979 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.

LEGEND

CLASS	CODE	GEOTECHNICAL LIMITATIONS	SUITABILITY FOR DEVELOPMENT	ENGINEERING COST FOR DEVELOPMENT	INTENSITY OF SITE INVESTIGATION REQUIRED
I		Low	High	Low	Normal
II		Moderate	Moderate	Normal	Normal
IIs		Moderate	Moderate - Low	Normal - High	Normal
III		High	Low	High	Intensive
IV		Extreme	Probably Unsuitable	Very High	Very Intensive

General Features - terrain which is not classified within GLUM system

Waterbodies (streams, man-made channels, storage dams)

Ponds

Littoral zone (generally subject to tidal action)

24 77 Universal Transverse Mercator (UTM) Grid Reference

8 30 Hong Kong Metric Grid Reference

ATTENTION : USERS

The Geotechnical Land Use Map (GLUM) should be used only as a guide to the general level of geotechnical limitation of the terrain for regional planning purposes. It is produced at a scale of 1:20 000 and should not be used to evaluate parcels of land smaller than 3 ha in size.

This Map must never be interpreted, reproduced or enlarged to scales larger than 1:20 000 (i.e. scales of 1:10 000, 1:5 000 or larger). Failure to heed this warning may result in serious misinterpretation of the data.

Please consult the Central New Territories Geotechnical Area Studies Programme Report (GASP II) which discusses in detail the purpose, application and limitations of this Map.

Geotechnical Control Office
Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECHNICAL LAND USE MAP - CENTRAL NEW TERRITORIES

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Compiled: R.Purser/A.Hansen	Drawn: S.W. Lam
Scale: 1:20 000	Date: Original January, 1984 2nd Edition July, 1987
Map Ref. No: GASP/20/II/1 2nd Edition	Sheet:

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GEOTECHNICAL AREA STUDIES PROGRAMME

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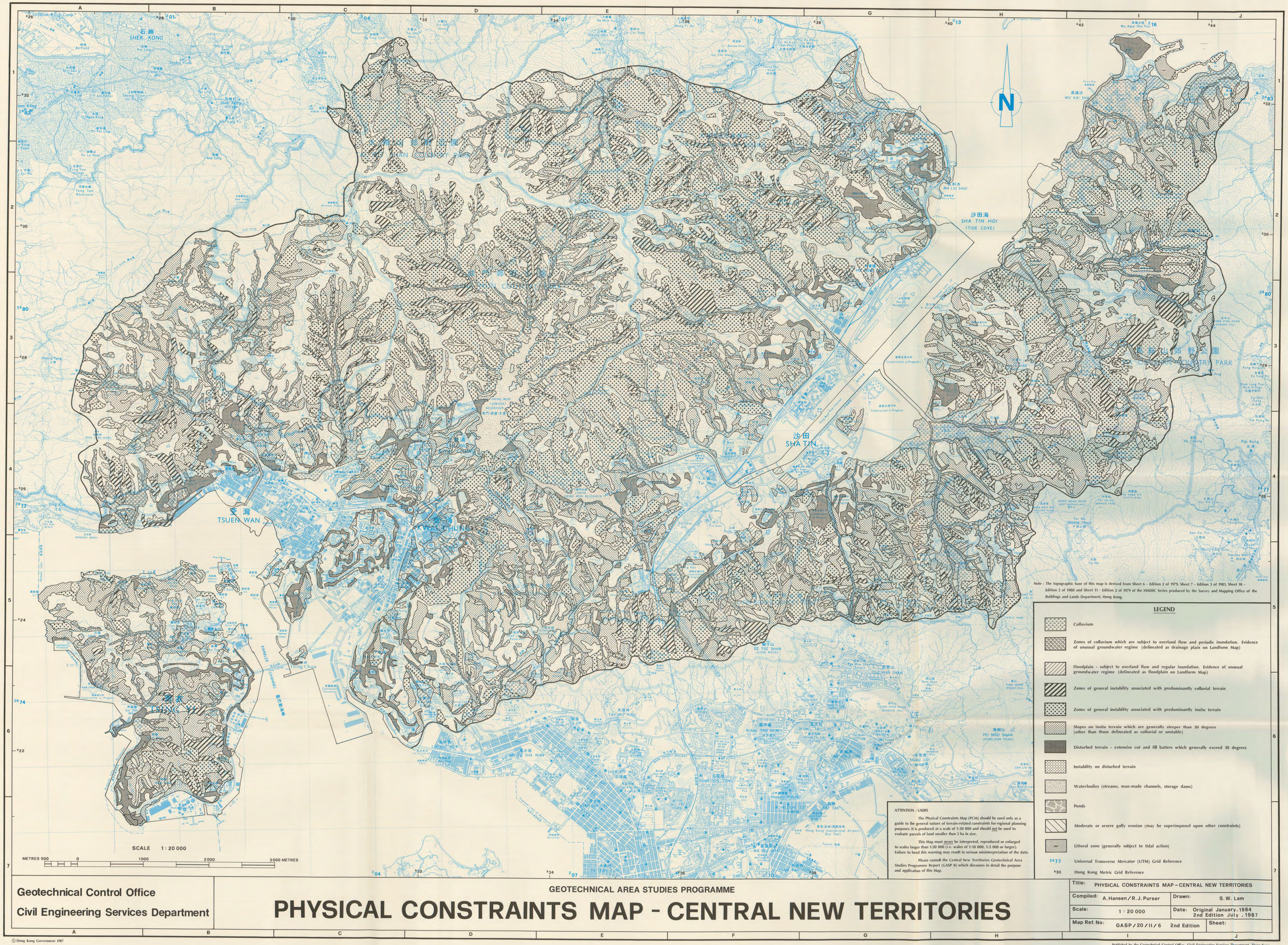

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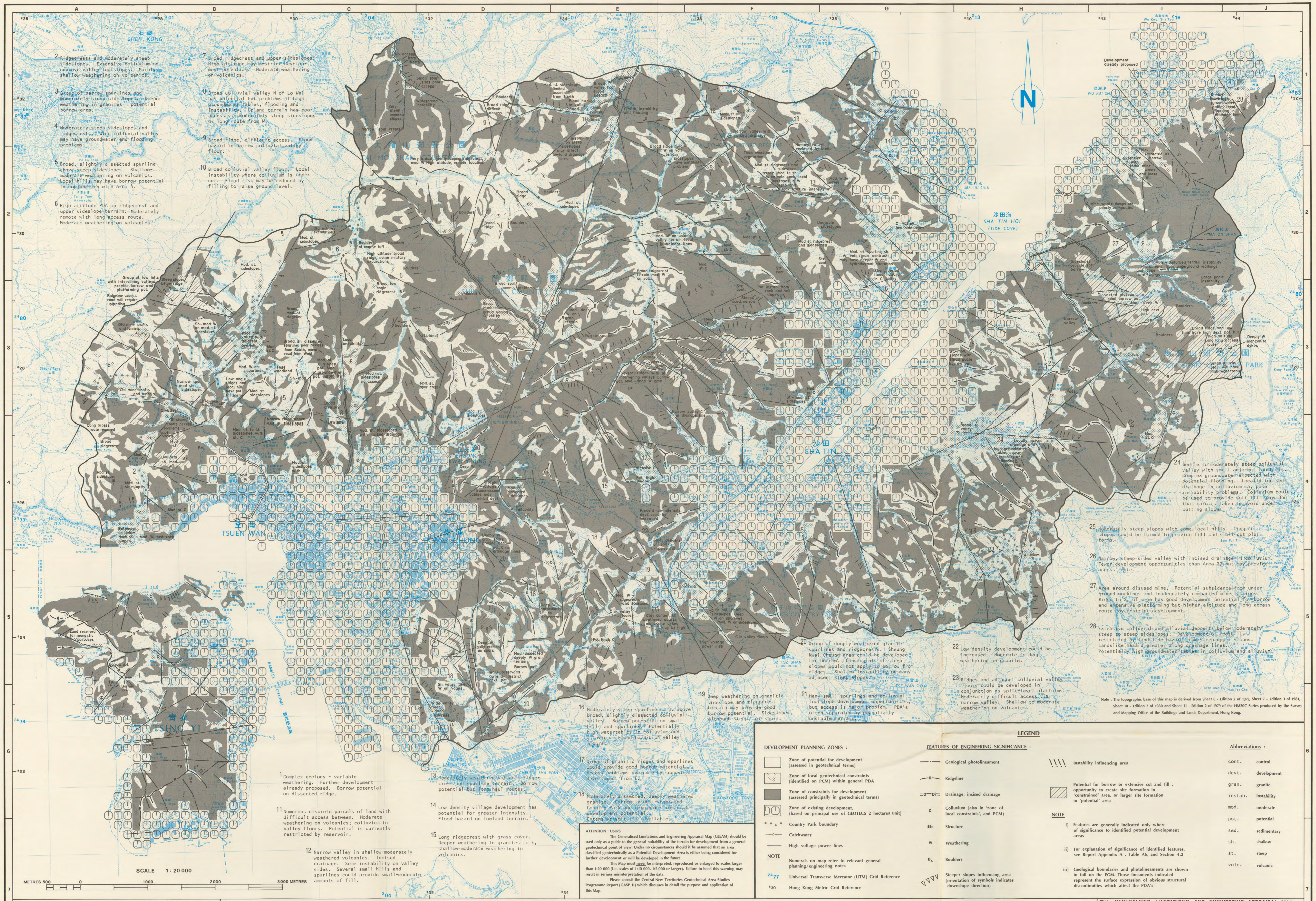

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ATTENTION : USERS

The Generalised Limitations and Engineering Appraisal Map (GLEAM) should be used only as a guide to the general suitability of the terrain for development from a general geotechnical point of view. Under no circumstances should it be assumed that an area classified geotechnically as a Potential Development Area is either being considered for further development or will be developed in the future.

This Map must never be interpreted, reproduced or enlarged to scales larger than 1:20 000 (i.e. scales of 1:10 000, 1:5 000 or larger). Failure to heed this warning may result in serious misinterpretation of the data.

Please consult the Central New Territories Geotechnical Area Studies Programme Report (GASP II) which discusses in detail the purpose and application of this Map.

LEGEND

DEVELOPMENT PLANNING ZONES :

- Zone of potential for development (assessed in geotechnical terms)
- Zone of local geotechnical constraints (identified on PCM) within general PDA
- Zone of constraints for development (assessed principally in geotechnical terms)
- Zone of existing development, (based on principal use of GEOTECS 2 hectares unit)
- Country Park boundary
- Catchwater
- High voltage power lines

NOTE

Numerals on map refer to relevant general planning/engineering notes

24 77 Universal Transverse Mercator (UTM) Grid Reference

8 30 Hong Kong Metric Grid Reference

FEATURES OF ENGINEERING SIGNIFICANCE :

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

NOTE

i) Features are generally indicated only where of significance to identified potential development areas

ii) For explanation of significance of identified features, see Report Appendix A , Table A6, and Section 4.2

iii) Geological boundaries and photolineaments are shown in full on the EGM. Those lineaments indicated represent the surface expression of obvious structural discontinuities which affect the PDA's

Abbreviations :

cont.	control
devt.	development
gran.	granite
instab.	instability
mod.	moderate
pot.	potential
sed.	sedimentary
sh.	shallow
st.	steep
volc.	volcanic

Geotechnical Control Office
Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP CENTRAL NEW TERRITORIES

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Map Ref. No: GASP/20/II/15 2nd Edition	Sheet:

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