GASP Report V

Geotechnical Area Studies Programme

North New Territories

Geotechnical Control Office
Civil Engineering Services Department
Hong Kong

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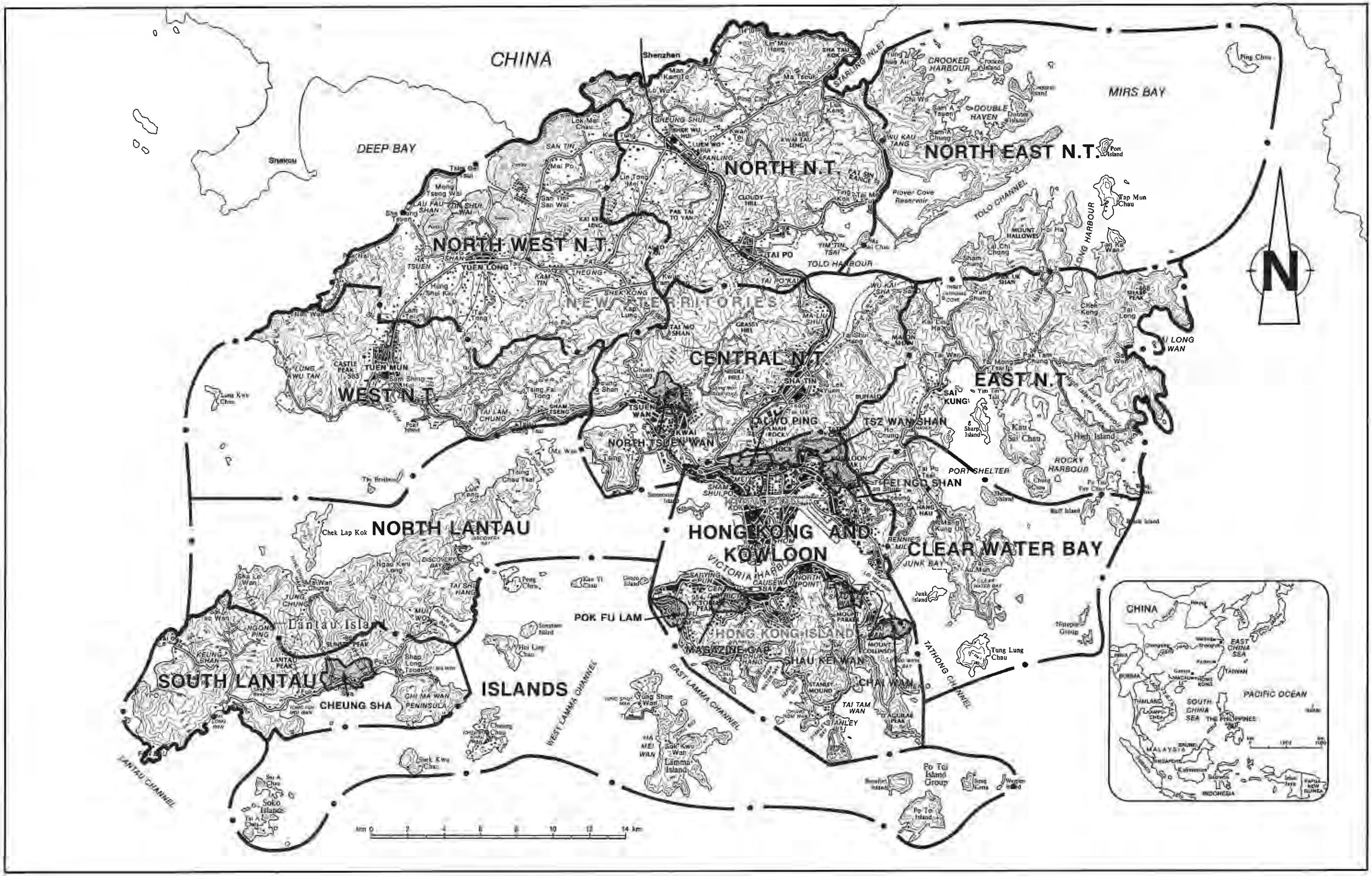

Map of the Territory of Hong Kong Showing the Locations of the Geotechnical Area Studies.
(Boundaries of the Regional Studies are shown by dashed lines and locations of District Studies are indicated by dark screens)

FOREWORD

This Report aims to provide an adequate geotechnical basis for the planning and land use management of the North New Territories, mainly by way of information presented on a series of maps at a scale of 1:20 000. It is the fifth 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 six user-oriented maps. Three of these are supplied with this published Report—the Engineering Geology Map (EGM), Geotechnical Land Use Map (GLUM) and Physical Constraints Map (PCM). The GLUM classifies the terrain into four classes according to the level of geotechnical limitations, and the PCM presents the major physical constraints that are likely to influence development. In addition to the three 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 Tai Po area, together with the accompanying Memoir, has recently been published (Geotechnical Control Office, 1986; Addison, 1986). The new Geological Maps and Memoir for most of the remaining area will be published by 1991. The Map and Memoir for the northwestern portion of the area will be available in 1988.

This Report was originally produced in January 1983, for use within the Hong Kong Government on the basis of information assembled during the period January 1980 to October 1982. 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 Dr A. D. Burnett and Messrs A. Hansen, P. D. Houghton, R. J. Morse 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 Messrs P. D. Houghton and R. J. Morse, specialist Aerial Photograph Interpreters, to participate in the study. Acknowledgements are also due to the Survey and Mapping Office, Buildings & Lands Department of the Hong Kong Government, who provided most of the aerial photographs used in the study, a few of which are reproduced in this Report.

E. W. Brand
Principal Government Geotechnical Engineer
March 1988

CONTENTS

List of Figures

List of Maps

List of Plates

List of Tables

1. INTRODUCTION

1.1 The North New Territories Geotechnical Area Study

This Report presents the results of a 1:20 000 scale Regional Geotechnical Area Study of the Tai Po to Lo Wu area, which was carried out in the Geotechnical Control Office between January 1980 and October 1982. The area covered by the study, which is designated as GASP V, 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 the southern part 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 fifth of the Reports to be published; seven others will follow in due course. A number of District Studies: Stage 1 have been carried out. Whilst these District Study Reports are only for use within Government, some information in map form is available on request (see Section 1.7).

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 Appendix A.

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, instability and land use of the North New Territories area.

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 suitability for development.

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 13 illustrates the system, and Figures 14 to 19 are extracts from the set of maps. The full size originals of these maps are held by the Geotechnical Control Office.

A selection of photographs follow the example figures in the report, and these are presented as Plates 1 to 17. 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 site investigations, aerial photographs and rainfall relevant to the North 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) and the Engineering Geology Map (EGM) 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.

There are six conventional line maps produced at a scale of 1:20 000 for this 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.9.

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 14b.

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 18a.

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 19a.

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 15a, 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 16a 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 (Allen & Stephens, 1971). 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 17a and it is discussed in detail in Appendix A.8. A copy of the map is located in the Map Folder.

1.5.8 *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
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 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 Study: Stage 1 Programme are available for areas within the Territory. No District Stage 1 studies have been completed within the North New Territories.

2. DESCRIPTION OF THE NORTH NEW TERRITORIES STUDY AREA

2.1 Geographical Location

The study area occupies approximately 16 095 ha situated in the central northern New Territories, as shown in Figures 1 to 3. It includes the major new town developments of Tai Po, Fanling and Sheung Shui. The study area has a common western boundary with the North West New Territories Geotechnical Area Study (GASP IV). The northern boundary is marked by the Sham Chun River, while the eastern boundary with the North East New Territories (GASP VIII) lies between Starling Inlet and the Plover Cove Reservoir and follows the Bride's Pool to Luk Keng road. The islands of Ma Shi Chau and Yim Tin Tsai are in the study area, the southern limit of which lies along a topographically controlled east to west line from Tai Po Kau to Kwun Yam Keng. To the south is the Central New Territories (GASP II). Selected information is included in this Report on the marine deposits of Tolo Harbour.

2.2 Topography

The topography of the study area is difficult to characterise because it does not fall into a readily discernable pattern. Use may, however, be made of the drainage pattern to divide the area into a large, relatively low and undulating northward draining basin, separated by an approximately east-west trending mountain range, from a smaller southward and eastward draining basin centred on Tai Po and Tolo Harbour.

The large northern portion of the study area consists of a series of broad long valleys separated by ill-defined, generally low, undulating ranges of hills. One of the main valleys follows the course of the Sham Chun River, while several of the others radiate from Sheung Shui. To the west of Sheung Shui, a valley follows the River Beas to Kwu Tung before turning south to Lin Tung Mei. Another valley trends northwest from Sheung Shui to Lo Wu, while the valley southwest of Sheung Shui carries the Ganges River from Cloudy Hill past Fanling. One of the most spectacular of the valleys radiates northwest from Sheung Shui past Kwan Tei to Ma Tseuk Leng at Starling Inlet. This valley carries the Indus River and is crossed at right angles by a northwest trending secondary valley which links Man Kam To to Ping Che.

The east-west trending mountain range starts in the east at Plover Cove as the Pat Sin Range and continues to the north of Tai Po as the Cloudy Hill Range leading to Pak Tai To Yan before striking southwest to Tai To Yan.

The smaller south and eastward draining portion of the study area consists of the terrain bounding Tolo Harbour from Tai Mei Tuk in the northeast to Tai Po in the west and Tai Po Kau in the south, together with the Tai Po drainage basin stretching inland from Tai Po and including the Lam Tsuen Valley.

The topography of the study area ranges in character from flat, in the alluvial valleys, to very steep in the Pat Sin Range. Table 2.1 presents the distribution of the slope gradients within the area.

Tables B1, B3, B4 and B5 in Appendix B give basic physiographic data on slope gradient, aspect and landforms. The GEOTECS plot at Figure 5 shows the general distribution of slope gradient within the area.

Table 2.1 Distribution of Slope Gradient

Slope Gradient	% of Total Area	Area (hectares)
0– 5°	35.0	5 630
5–15°	14.9	2 397
15–30°	32.1	5 168
30–40°	16.6	2 664
40–60°	1.3	214
>60°	0.1	22
	100.0	16 095

2.3 Geology

2.3.1 *General*

As described by Allen & Stephens (1971), the geology is dominated by the presence of an extensive outcrop of volcanic rocks. Granite is not present in the study area. Some granodiorite does, however, outcrop in the area.

In the northwest, a northeast trending belt of metasediments of the Lok Ma Chau Formation is centred on Lo Wu. In the southern part of the area, a similar trending belt of intrusive granodiorite occupies the Tai Po drainage basin and the northern portion of Tolo Harbour.

The terrain to the north of the Pat Sin Range between Tolo Harbour and Starling Inlet is underlain by gently dipping Cretaceous sediments of the Port Island Formation. These bedrock materials, which are often heavily weathered insitu to form deep residual deposits, are overlain in places by thin deposits of younger superficial materials which are generally colluvial or alluvial in character.

The oldest rocks of the area are the dark grey marine shales, siltstones and quartzites of the Tolo Harbour Formation which occur on the southern shores of Ma Shi Chau. These rocks are conformably overlain by the lithologically similar Bluff Head Formation which occupies the remaining portion of Ma Shi Chau Island. These latter deltaic rocks pass upwards without significant unconformity into the volcanics of the Repulse Bay Formation which are generally of subaerial deposition.

Of similar age to the Bluff Head Formation are the sediments of the Lok Ma Chau Formation, which are thought to represent the major overturned limb of a fold in the study area.

During the Upper Jurassic, while this entire sequence of warped and folded sediments was buried at considerable depth, it was intruded by the first phase of igneous activity in the region. This produced the granodioritic suite of rocks.

The batholith was of such regional extent across south China that, within the Territory of Hong Kong, the older strata merely exist as roof pendants suspended in the plutonic rocks. At a late stage of this intrusion, numerous dykes were injected into both the early sediments and the newly emplaced granodiorites. The latter contain the majority of the dyke rocks. A long period of quiescence probably followed this sequence of tectonic activity. During this hiatus, prolonged weathering and erosion formed an uncomformity upon which the overlying sediments of the Port Island Formation were deposited by fluviatile processes.

Following a further period of earth movement and late dolerite dyke intrusion during the Upper Cretaceous, another major uncomformity developed. Subsequent to this, extensive deposits of colluvium were formed during the Quaternary which probably blanketed the landscape as a result of numerous individual colluvial episodes. These episodes coincided with fluctuations in the palaeoclimatic regime.

More recently, the alluvium and raised terraces were deposited under the combined influence of higher sea levels and fluctuating climatic conditions. The final episode in the geological history of the area has been the deposition of the littoral sediments and the continued, but much subdued, formation of colluvium on mountain slopes and footslope terrain.

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. The southern 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 (1988). 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 distribution is presented in tabulated form in Table B6 in Appendix B.

In general, the bedrock materials have been subjected to severe weathering. The depth of decomposition is determined by the relative resistance of the individual lithological units and groundwater regimes in association with the local geological structure.

The nature of the individual rock types is summarised below, and their general engineering behaviour and planning significance are discussed in Section 3.1 and summarised in Table 3.1.

2.3.2 *Metasedimentary Units*

(i) *Tolo Harbour Formation (TH)*
Rocks of this Formation are believed to be the oldest in the Territory and are found along a narrow coastal strip on the southern shores of Ma Shi Chau Island. Fossil evidence indicates they are of Permian age. They consist of steeply dipping black, pyritous, marine shales which have undergone low grade thermal metamorphism and have also been intensely folded. This rock unit occupies only 4 ha of the area.

(ii) *Bluff Head Formation (BH)*

Within the study area, the Lower Jurassic age Bluff Head Formation (Allen & Stephens, 1971) rocks outcrop over the majority of Ma Shi Chau Island. These rocks, which are an essentially deltaic sequence, lie with apparent conformity upon the marine Tolo Harbour sediments and typically consist of shallow water-laid, white, current-bedded sandstones and alternating pink and grey weathered mudstones and siltstones. The rocks are variably indurated by very low grade metamorphism and have been subject to complex folding. These rocks pass upwards, apparently with only minor disconformity, into the lowest members of the Repulse Bay Formation, but this transition is not well exposed at Ma Shi Chau and Yim Tin Tsai. This rock unit occupies approximately 47 ha or 0.3% of the area.

(iii) *Lok Ma Chau Formation (LMC)*

At about the same time as the Bluff Head Formation was being deposited in the south of the study area, a lithologically similar suite of deltaic/fluviatile sediments was accumulating further north in the North Downs, Sandy Ridge and Vimy Ridge district. As mapped by Allen & Stephens (1971), the Lok Ma Chau Formation appears to be an interbedded sequence of brightly coloured quartzites, sandstones, phyllites, schists which pass conformably upwards into the volcanic rocks of the Repulse Bay Formation to the north of Sheung Shui. In addition, recent mapping work within the Revised Geological Survey of the Territory confirms the occurrence of marble within the Lok Ma Chau Formation. Outcropping at the surface over 384 ha (2.4%) of the area, the Lok Ma Chau sediments are all affected by low grade regional metamorphism which has altered and indurated some of the rock types and imposed an obvious schistosity on the argillaceous members, and created a coarse-grained marble from the original limestone. The strike of this schistosity is generally northeast and the dip between 30° and 40° northwest. Structural geological evidence indicates that the entire sequence of sediments has been overturned to form the underlimb of a major recumbent fold. The softness of these often deeply weathered rocks results in a generally subdued, rounded topography.

2.3.3 *Volcanic Units—Repulse Bay Formation*

The Repulse Bay Formation is a thick and very widely distributed, mainly subaerially deposited, series of volcanic rocks. The Formation is at least two thousand metres thick and extends in province, along with the intrusive granite batholith, well into southern China. It is probably Middle Jurassic in age, and six main lithological units have been mapped by Allen & Stephens (1971) and are defined on a Territory-wide basis. These units, which are not regionally continuous, are:

(i) Sedimentary rocks and water-laid volcaniclastic rocks

(ii) Acid lavas

(iii) Mainly banded acid lavas with some welded tuffs

(iv) Coarse tuff

(v) Agglomerate

(vi) Dominantly pyroclastic rocks with some lavas

Where it is not possible to classify the volcanic rocks, a seventh unit of 'undifferentiated volcanic rocks' is used.

Within the North New Territories, only the sedimentary and water-laid volcaniclastics, the coarse tuff, the pyroclastics rocks with some lavas and a small area of undifferentiated volcanic rocks were mapped by Allen & Stephens (1971).

(i) *Sedimentary Rocks and Water-laid Volcaniclastic Rocks (RBs)*

Rocks of this unit occupy only a small proportion, 155 ha or 1.0%, of the study area, outcropping in the vicinity of Lin Ma Hang and Starling Inlet in the north, and to the south of Tai Po. In each case, the units are inter-bedded with predominantly pyroclastic rock types and measure up to a few hundred metres in outcrop thickness by up to 2 km in length. South of Tai Po, the rocks are mainly thinly-bedded fine-grained tuffs and banded siltstone. At Starling Inlet, the sediments are purple and red silty shale and sandy siltstone. Thinly-bedded dark grey siltstone interbedded with dark green fine sandstone and black fossiliferous shale with cherts are a common component of smaller outcrops of this lacustrine or fluvially deposited rock unit.

(ii) *Coarse Tuff (RBc)*

This unit of the Repulse Bay Formation occurs in three locations in the study area, namely, Yim Tin Tsai, south of Tai Po and as thin elongate horizons along the western, study boundary. In outcrop, it accounts for 455 ha or 2.8% of the area. The rock is generally a dark grey or greenish/bluish grey medium-grained (1 to 4 mm) strong crystal tuff with occasional lithic lapilli. In composition, the rock is rhyodacitic to dacitic. It generally forms thick, massive beds and shows no internal stratification.

The lack of stratification results from the subaerial explosive eruption of a partly crystallised parent magma. At Yim Tin Tsai, the coarse tuff directly overlies the sediments of the Bluff Head Formation. Elsewhere, contacts are poor; therefore the Bluff Head Formation's relationship with other units is not generally understood.

(iii) *Dominantly Pyroclastic Rocks with Some Lavas. (RBp)*
This unit underlies a major portion of the area (some 6201 ha or 38.5%) and consists of a great thickness of apparently uniform, structureless, explosively erupted fine crystal tuff with occasional lapilli and horizons of incandescent ash flows or ignimbrites. The rock is usually creamy grey or pale green, very fine-grained and contains quartz crystals of about 1 mm size. Pyrite is a common accessory mineral, and some small cherty lapilli also occur. Structural geological analysis is difficult within this uniform rock type, but two possible fold directions, northeast and northwest, are postulated for these rocks. A 2 to 3 km wide zone of rocks of this unit is noted to possess a weak cleavage and to have undergone low grade metamorphism of a character similar to that which affects the Lok Ma Chau Formation. The cleavage strikes between 300° and 70° and dips between 25° and 65° in a northerly direction.

(iv) *Undifferentiated Volcanic Rocks (RB)*
Small areas of this unit are exposed in the study area, and these occur as faulted inliers within the Port Island Formation outcrop area, occupying only some 16 ha (0.1%) of the area.

2.3.4 *Intrusive Igneous Units*

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

(i) *Tai Po Granodiorite (XT)*
As mapped by Allen & Stephens (1971), the type exposure of this rock type occurs within the study area in the region of Tai Po Market. In outcrop, this rock underlies some 2.8% of the study area, and it extends from the head of the Lam Tsuen Valley, northeast through Tai Po to Shuen Wan. Marine borings have also shown granodiorite to underlie much of the northern portion of Tolo Harbour. This rock was the earliest of the plutonic intrusive phases of igneous rocks and appears to have preferentially used a northeast trend in intruding the overlying volcanic rocks of the Repulse Bay Formation. It is also likely that subsequent acid igneous intrusions occasionally used the same zones of weakness since, in places, the granodiorite is now completely surrounded by younger intrusives. The granodiorite is usually coarse or medium-grained (3 to 8 mm), mid to dark grey and somewhat porphyritic. Biotite is the main dark mineral, while euhedral phenocrysts of white plagioclase are present in small quantities. Quartz is present in all these rocks. The most distinctive feature of this rock is the presence of dark, often rounded xenoliths. Granodiorite, which is strong when fresh, weathers readily and deeply to a rust red silty sand with the development of corestones.

(ii) *Quartz Porphyry Dykes (Pq)*
Dyke rocks of many varieties intrude both the volcanic and plutonic igneous rocks of the study area. Although of only very limited extent, these rock types are of importance from a geochronological viewpoint and are sometimes of engineering significance. They occur as a series of quartz porphyry dykes with characteristic marginal banding. At Yim Tin Tsai, they display a northeast trend and cut both coarse tuff and Tai Po Granodiorite. The rock is greenish grey when fresh and weathers to pale pink. Phenocrysts of quartz, plagioclase, biotite and microperthite have been recognised.

2.3.5 *Sedimentary Units—Port Island Formation (PI)*

The Port Island Formation is the youngest bedrock in the area and outcrops over 906 ha of the northern flank of the Pat Sin Range. The outcrop mapped by Allen & Stephens (1971) extends as a broad continuous belt from the eastern study boundary at Bride's Pool to Hok Tau Reservoir, a distance of nearly 5 km. These rocks are of Lower Cretaceous age and are distinctly fluviatile in character. They unconformably overlie the Repulse Bay Formation, and their structure is relatively uncomplicated, displaying a uniform and constant northward dip of between 20° and 30°. The north-facing slopes of the Pat Sin Range tend to follow this dip and form a cuesta, heavily dissected by streams. Lithologically, the Formation consists of a thick basal and other subsidiary conglomerates, together with pebbly sandstones, sandstones and shales. The pebbles and boulders of the conglomerates are almost entirely derived from the Repulse Bay Formation rocks with occasional vein quartz. The lack of granite pebbles indicates that the Port Island beds were deposited before the granitic rocks of the region were exposed at the ground surface.

In the area of Bride's Pool, the argillaceous rocks are red in colour, while the arenaceous and rudaceous beds are unpigmented. In the Pat Sin Range, the argillaceous rocks are pale purple, while at the western end of the outcrop they are only pale pink or more usually grey, in a succession of white conglomerates and sandstones.

The rocks of the Port Island Formation are generally shear cleaved, the planes of which are probably parallel to the axial planes of folds caused by stresses originating from the north, and which also gave rise to zones of intense shearing within the rocks. This shearing takes the form of thrust faulting which usually occurs subparallel to the bedding. The most obvious thrust fault marks the northern edge of the unit where Repulse Bay Formation rocks have been thrust over Port Island Formation rocks from a northwesterly direction.

2.3.6 *Superficial Units*

In addition to the solid geology, both natural and man-made superficial deposits constitute some 45.6% (7 470 ha) of the land surface. These superficial deposits are classified as follows:

(i) *Colluvium*

Colluvium occurs over approximately 18.9% (3 044 ha) of the study area. It is distributed primarily on footslopes associated with steep mountainous terrain and consists of weathered soil and rock material transported downslope by the action of gravity and water. The majority of the colluvium is derived from volcanic detritus (Table B6 in Appendix B). These latter deposits tend to be relatively thicker and more continuous than deposits derived from the granodiorites or from the sediments of the Lok Ma Chau Formation.

The colluvial deposits consist of a wide range of materials from silty and sandy fine slope wash, typical of the granodiorites, through sandy cobble and boulder beds, to boulder fields. The size and thickness of these materials is extremely variable, and detailed mapping is required to accurately define and classify each deposit.

The colluvium derived from the volcanics 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 these larger detrital fragments, which can range from being only slightly weathered in the younger deposits to being completely weathered in some of the older deposits.

Within the study area, the main concentrations of colluvium occur as extensive, relatively continous deposits of detrital material mantling the footslopes of most of the northeast trending hills. In some areas, colluvium partially covers the floors of many of the major valleys, such as the Lam Tsuen Valley, the valley which extends from Fanling to Sha Tau Kok, and the River Ganges Valley.

The colluvial deposits are most clearly developed on the volcanics, and they very often underlie and intercalate with the alluvial deposits occurring on the valley floors. In many cases, the alluvium has been formed from the transportation and reworking of colluvium.

(ii) *Alluvium*

Superficial deposits of alluvial origin are found over extensive tracts of the North New Territories study area. These total some 3 988 ha (24.8%) in area, being located primarily on the floors of the main valleys of the Shum Chun River, the Ganges River, the Indus River, the Sheung Yue Ho (Beas) River and in the Lam Tsuen Valley.

The depth of alluvium in these generally flat-lying valley plains can be quite significant, reaching several tens of metres in places. The deposits are probably of recent geological age and almost certainly result from the fluvial infilling of a network of older, deep valleys which had dissected the Pleistocene topography of the Territory down to a lower elevation than the present sea level.

These deposits occur either as raised terraces, floodplain, or as undifferentiated alluvial deposits. The terraces occur in the major valleys and are recognised by their slightly raised elevation and small escarpments which are generally adjacent to present day rivers. They also occupy the upper part of valley complexes but become much more difficult to distinguish towards the lower, open or seaward end of the valleys where the alluvium is undifferentiated.

The terraces remain as evidence of past sea level oscillation. They result from either emergence (isostatic/tectonic) of the land mass or the fall in sea level associated with palaeoclimatic variation during the late Quaternary Period.

Lithologically, the deposits consist of horizons of pale grey or brown, silty or clayey sand with gravels, interbedded with layers and lenses of sandy gravels or cobbles.

(iii) *Littoral Deposits*

These intertidal deposits are of limited extent and occur primarily as beach sand and mud flats, many of which fringe the seaward edge of alluvial plains.

(iv) *Reclamation and Fill Deposits*

These deposits are mainly located around the Tai Po urban areas, where local imported colluvium or decomposed bedrock borrow has been formed into large platforms in areas of former shallow sea or littoral marshland at the mouth of the Lam Tsuen River. The material is generally less than 10 m in thickness and is a mixture of silt, sand and occasional gravel and cobbles.

2.4 Geomorphology

The geomorphology of the study 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 in Figure 5. Relatively large areas of sideslopes with moderate to steep gradients occur within the study area.

Granodioritic terrain exhibits the most rounded topography, with a maximum relief of approximately 360 m. The majority of ridge crests are eroded and are weathered to a greater depth than on volcanic terrain slopes, which are generally concavo-convex. Many of the upland depressions contain colluvial and alluvial deposits.

Unlike the insitu volcanics and granodiorites, a large proportion (32% or 973 ha) of the colluvium occurs on slope gradients of less than 5° (Table B5 Appendix B). A further 1 249 ha lie between 5° and 15°, and 822 ha occur on slopes steeper than 15°. Much of the steep colluvium occurs within drainage lines and steep stream courses. These drainage lines discharge across the flatter footslope terrain, where thick deposits of colluvium are common. Footslope terrain which is subject to periodic inundation is important because the likelihood of slope failure is higher than on adjacent relatively well-drained areas of colluvium. Within the Territory, there is considerable evidence of instability associated with low angle (less than 15°) colluvial slopes in this type of hydrological setting. Approximately 52% of the colluvial terrain with slope gradients up to 15° are areas of concentration of surface runoff. These areas will require careful planning and land use management to minimise the likelihood of slope failures.

2.5 Surface Hydrology

2.5.1 *General*

The surface hydrology of the North New Territories area is broadly divided into an essentially northward draining basin and a southward draining basin.

The northward draining basin is approximately 10 000 ha in area, and is considerably larger than the southern basin. It is of major influence as it effectively carries all the surface runoff from the central north New Territories toward the Sham Chun River by a network of drainage lines which reach eighth order (Strahler, 1952) in magnitude. The size and importance of a drainage and subcatchment network is described using the system of stream orders proposed by Strahler (1952). This system is discussed in greater detail in Appendix A.8.

The northern basin is bounded to the east by the Starling Inlet coastline, to the north by the Sham Chun River, to the west by the Kai Keung Leng range of hills, and to the south by the Tai Po Yan–Cloudy Hill–Pat Sin Range. The southern basin includes all catchments draining from the north, west and south into Tolo Harbour. These boundaries together with those of lesser order catchments are shown on the Engineering Geology Map.

Information on the size and characteristics of the drainage basins are presented in Table 2.2.

2.5.2 *Southward Draining Catchments*

There are five catchments within the southern basin and, of these, four are substantially self-contained. The fifth, Tai Po Kau, represents only a small portion of a larger catchment, the majority of which occurs outside of the study area.

(i) *Lam Tsuen*
This is the main sixth order catchment in this southward draining category. It is slightly truncated by the study boundary and does not totally occur in the study area. It is broadly circular in shape, is situated west and inland of Tai Po and is some 1 800 ha in size. The catchment has a very high average relief ratio of 14.7% and this, coupled with its strongly circular shape, probably results in relatively rapid times of concentration and severe hydrographs. The dendritic stream network, which has a density of 5.3 km/km^2, concentrates flows through two main tributaries into the Lam Tsuen River which enters Tolo Harbour at Tai Po Market.

(ii) *Tai Po Kau*
The portion of this catchment which occurs within the study boundary represents only a small part of a larger catchment.

Table 2.2 Survey of Major Catchments

Description \ Location		Lo Wu	Hung Lung Hang	Lin Ma Hang	Sha Tau Kok	Hang Tau/ Tai Po	Sheung Shui	Fanling	Hok Tau	Nam Chung	Ham Hang Mei	Lam Tsuen	Fung Yuen	Ting Kok	Wang Shan Keuk	Tai Po Kau
		Catchments														
		Northward Draining Regime										Southward Draining Regime				
Number of Streams per Order Nu	2	172	103	101	85	257	39	220	383	154	64	191	77	153	107	Only Minor Portion of Catchment lies within Study Area
	3	41	29	25	22	59	11	57	84	31	15	55	22	46	25	
	4	9	8	7	5	16	4	15	21	10	3	15	6	12	8	
	5	2	2	3	1	4	2	4	5	2	1	2	2	2	2	
	6	—	1	1	—	1	1	1	1	1	—	1	1	—	—	
	7	3	—	—	—	—	—	—	—	—	—	—	—	—	—	
	8	1	—	—	—	—	—	—	—	—	—	—	—	—	—	
	Nu	228	143	137	113	337	57	297	494	198	83	264	108	213	142	
Total Length of Streams per Order Lu (m)	2	26 600	17 000	22 800	24 000	55 000	9 800	43 000	65 600	35 400	14 000	44 000	12 300	37 000	24 400	
	3	12 600	7 200	11 400	10 500	25 200	3 200	20 800	23 400	8 800	5 200	27 600	5 400	22 400	10 000	
	4	4 800	10 800	6 600	7 300	9 400	1 200	10 700	17 000	7 800	4 200	15 400	2 100	7 300	4 900	
	5	4 000	6 400	4 000	1 400	6 200	3 900	4 800	9 600	5 000	300	3 800	1 000	3 400	4 300	
	6	—	900	7 400	—	7 900	2 800	5 000	8 900	1 000	—	5 800	1 100	—	—	
	7	11 600	—	—	—	—	—	—	—	—	—	—	—	—	—	
	8	8 800	—	—	—	—	—	—	—	—	—	—	—	—	—	
	Lu	68 400	42 300	52 200	43 200	103 700	20 900	84 300	124 500	58 000	23 700	90 600	21 900	70 100	43 600	
Mean Length of Stream per Order Tu (ie) Lu/Nu (m/stream)	2	155	165	226	282	214	251	195	171	230	219	230	160	242	228	
	3	307	248	456	477	427	291	365	279	284	347	502	245	487	400	
	4	533	1 350	943	1 460	588	300	713	810	780	1 400	1 027	350	608	613	
	5	2 000	3 200	1 333	1 400	1 550	1 950	1 200	1 920	2 500	300	1 900	500	1 700	2 150	
	6	—	900	7 400	—	7 900	2 800	5 000	8 900	1 000	—	5 800	1 100	—	—	
	7	3 867	—	—	—	—	—	—	—	—	—	—	—	—	—	
	8	8 800	—	—	—	—	—	—	—	—	—	—	—	—	—	
Area of Subcatchment (km²)	Au	14.12	11.08	9.49	8.15	18.49	7.03	15.38	21.38	7.34	3.86	18.23	4.17	13.20	6.2	
Length of Subcatchment (km)	Lb	6.3	3.74	6.30	2.06	7.12	4.34	5.42	6.78	3.86	2.54	5.44	2.04	2.84	3.04	
Bearing of Axis	θ	98°	131.5°	75.5°	317.5°	181.5°	168.5°	171.5°	108°	183°	183°	228°	334.5°	328°	251°	
Width of Subcatchment (km)	Br	6.00	5.08	3.28	5.60	4.10	2.82	4.96	7.64	2.56	2.50	4.70	3.34	7.12	2.98	
Bearing of Axis	θ	188°	221.5°	165.5°	47.5°	271.5°	258.5°	261.5°	198.5°	273°	273°	318°	64.5°	58°	341°	
Subcatchment Perimeter (km)	P	27.20	16.20	17.40	16.40	21.70	11.62	18.00	27.20	11.80	10.20	18.60	10.00	20.60	11.00	
Subcatchment Circularity = Au/Area of Circle with same P	Rc	0.240	0.531	0.394	0.381	0.493	0.654	0.597	0.363	0.662	0.466	0.662	0.524	0.391	0.625	
Subcatchment Elongation = Diameter of Circle with same P/Lb	Re	1.374	1.379	0.879	2.534	0.970	0.852	1.057	1.277	0.973	1.278	1.088	1.56	2.309	1.081	
Drainage Density Lu/Au	Du	4.844	3.818	5.500	5.301	5.608	2.973	5.481	5.823	7.902	6.140	5.299	5.252	5.311	7.243	
Stream Frequency (ie) Nu/Au No of Streams per Order/km	2	12.18	9.30	10.64	10.43	13.90	5.56	14.30	17.92	20.98	16.58	10.48	18.46	11.59	17.78	
	3	2.90	2.62	2.63	2.70	3.19	1.56	3.72	3.93	4.22	3.89	3.02	5.28	3.48	4.15	
	4	0.64	0.72	0.74	0.62	0.87	0.57	0.98	0.98	1.36	0.78	0.82	1.44	0.92	1.93	
	5	0.14	0.18	0.32	0.12	0.22	0.28	0.26	0.23	0.28	0.26	0.11	0.48	0.15	0.33	
	6	—	0.09	0.11	—	0.05	0.14	0.07	0.05	0.14	—	0.05	0.24	—	—	
	7	0.22	—	—	—	—	—	—	—	—	—	—	—	—	—	
	8	8	0.07	—	—	—	—	—	—	—	—	—	—	—	—	
	Fu	16.15	12.91	14.44	13.87	18.23	8.11	14.31	23.11	26.48	21.67	14.48	25.90	16.14	23.59	
Elevation of Highest Point on Watershed (mPD)	Z	185	340	492	480	565	255	470	630	630	340	800	440	630	600	
Elevation of Subcatchment Mouth (mPD)	z	0	10	10	0	10	10	10	10	0	0	0	0	0	0	
Basin Relief Z–z (m)	H	185	330	482	480	555	245	460	620	630	340	800	440	630	600	
Relief Ratio H/Lb	Rh	2.9	8.8	7.7	23.3	7.8	5.6	8.5	9.1	16.3	13.4	14.7	21.6	22.2	18.5	
Geology		Alluvium/ meta-sediments	Alluvium/ Pyroclastic	mainly Pyroclastic	mainly Pyroclastic	Alluvium/ Colluvium Pyroclastic	Alluvium/ Colluvium Pyroclastic	Mainly Pyroclastic	Mainly Pyroclastic	Sediments	Sediments	Superficial Pyroclastic Granodiorite	Pyroclastic	Pyroclastic	Pyroclastic	
Vegetation/ Landuse		Grassland/ Cultivated	Grassland/ Cultivated	Grassland	Grassland/ Cultivated	Cultivated/ Grassland/ Shrubland	Cultivation/ Development	Grassland/ Shrubland/ Development	Grassland/ Shrubland	Grassland/ Shrubland	Cultivation	Cultivation Shrubland	Shrubland	Shrubland	Shrubland/ Grassland	

(iii) *Tung Yuen*
This sixth order catchment lies to the northwest of the Lam Tsuen catchment and drains the southward facing slopes of Cloudy Hill into the western end of Tolo Harbour. It is one of the smallest sixth order catchments in the study area and consists of a series of subparallel southeast trending streams, some of which are independent and do not join a major network. The relief ratio is very high (21.6%), the catchment area is small and stream frequency is also high (25.9 streams per km^2). Low volume, short time of concentration discharges may result.

(iv) *Ting Kok*
This catchment lies on the northern shore of Tolo Harbour between Ha Hong, Chung Pui and the Pat Sin Range. It consists of six major stream networks and about nine minor networks, all of which have relatively low frequency and drain with extremely steep gradients (relief ratio of 22.2%) in a southeast direction, discharging independently into Plover Cove.

(v) *Wang Shan Keuk*
This catchment is only fifth order in magnitude and occurs near Bride's Pool, where three main tributary systems drain eastwards. These join in the Chung Mei Inlet of the Plover Cove Reservoir. The stream pattern is dendritic, the drainage density very high (7.2 km/km^2) and gradients extremely steep (18.5%).

2.5.3 *Northward Draining Catchments*

The northern basin is subdivided into ten major sixth order catchments which, with the exception of two, are complete hydrological entities. The Lo Wu and Lin Ma Hang catchments, however, are hydrologically incomplete and do not represent full regimes, because approximately half of their drainage basins lie in the People's Republic of China.

(i) *Hang Tau Tai Po*
This major sixth order catchment is 18.49 km^2 in size (1 849 ha) and lies along the western boundary of the study area. It is bounded to the west by a major north-south trending ridge which effectively separates the northeast and northwest New Territories. The catchment is approximately 7 km long and 4 km wide, resulting in a circularity ratio of 0.49. It is drained by the relatively dense tributary network of the River Beas and has a low average relief ratio of 7.8%. This catchment is likely to have considerable discharge but probably displays a flat hydrograph and sluggish rates of flow.

(ii) *Fanling*
This major catchment lies to the north of the main east-west drainage divide and is centred upon Fanling. The catchment shape is approximately triangular with the apex to the north. Three main tributary networks drain the Cloudy Hill and Pak Tai To Yan Ranges northward through Wo Hop Shek and the flat floodplain area to finally form a major tributary of the Indus River. The large area (15.38 km^2), relatively low relief ratio of 8.5%, stream length and dendritic pattern, probably results in a slow flowing, long time to concentration, moderate to high discharge hydrograph for this drainage network.

(iii) *Sheung Shui*
This sixth order catchment is relatively small in size, being only some 7 km^2 in area. Only the southernmost border of the catchment displays a dendritic network, while the rest of the catchment has a low stream frequency and is covered by only three tributaries flowing over flat, low-gradient (5.6%), floodplain which is subject to intensive development.

(iv) *Hok Tau*
The Hok Tau catchment is the largest in the study area and, in addition, it has a shorter length than breadth. The widely-spaced dendritic pattern has a number of major tributaries which follow photo-lineaments and are relatively straight. The drainage network consists essentially of five major tributaries which drain westwards to form the Indus River. The Indus is the major river in the study area. The relief ratio is a relatively low 9.1%, and the number and frequency of streams is great (23 streams per km^2). It is likely that discharge volumes are high but times to concentration relatively long.

(v) *Nam Chung*
This small catchment (7.34 km^2) contains a very dense drainage network (7.9 streams per km^2) which is often subparallel in form and consists of four main tributaries, each draining northwards to enter Starling Inlet near Tai Wan. The high relief ratio of 16.3% and relatively direct drainage pattern result in short times of concentration and a peaked hydrograph.

(vi) *Ham Hang Mei*
To the east of Nam Chung lies the small square-shaped catchment of Ham Hang Mei. It consists of three relatively subparallel tributaries which drain northwest from the main, low and ill-defined east-west drainage divide into Starling Inlet.

(vii) *Sha Tau Kok*
To the north of Starling Inlet, a series of southeastward draining subparallel streams forms the Sha Tau Kok catchment, which has a length to breadth ratio of 0.4. Several streams with very high average relief ratios of some 23% occur and, therefore, no single stream has a large discharge, although times to concentration are short.

(viii) *Lin Ma Hang*
This catchment, together with those of Hung Lung Hang and Lo Wu, has the Sham Chun River as its northern boundary. This means that these catchments are incomplete because the streams draining into the Sham Chun River from the northern side of the border are not included. This catchment feeds the headwaters of the Sham Chun River, which dissects the Territory from east to west and forms the Border with the People's Republic of China. The discharge point of the catchment at Ta Kwu Ling, while still in the headwaters region of the river, is already at a low elevation and meanders within its own floodplain with an average relief ratio of 7.7%.

(ix) *Hung Lung Hang*
This relatively large catchment (11.08 km^2) drains the terrain of low relief centred upon Ping Che north of the Sha Tau Kok road and the flat-bottomed valley which drains northwards. Three main tributaries discharge into the higher reaches of the Sham Chum River near Muk Wu. The drainage network is low density (3.8 streams per km^2) and open in character and traverses very low gradient (8.8%) terrain across floodplain and intensively cultivated ground.

(x) *Lo Wu*
This large catchment is formed from the confluence of four major rivers, namely, the Sham Chun, the Beas, the Ganges and the Indus. The area is primarily low-lying floodplain with a 2.9% average gradient. It is the only catchment within the study area which contains drainage lines of seventh and eighth order. At the discharge point from the catchment, the river is already the largest in the Territory with consistent and major perennial flows.

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 12.4% (1 993 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 2 134 ha (13.2%) of the study area and occurs on many of the hill slopes of the Pat Sin Range, Cloudy Hill and Robin's Nest. However, scattered areas of grassland occur throughout the undeveloped areas of the district.

(ii) *Cultivation*
This class occupies 2 833 ha (17.6%) of the study area. Most of the agricultural activity has now ceased in the more remote areas, but some horticulture remains in the Lam Tsuen valley and around Fanling and Sheung Shui.

(iii) *Mixed Broadleaf Woodland*
This class may contain a wide variety of native and exotic species. Extensive areas of woodland occur northwest of Fanling on the Tsung Shan and Ma Tai Leng hills, on the Kei Lak Tsai hills, and in the Tai Po Kau Nature Reserve. A total of 3 552 ha (22.1%) 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 2 087 ha (13.0%) and is scattered throughout the undeveloped terrain.

(v) *Shrubland (Greater than 50% Ground Cover)*
This class is similar to the above but is characterised by denser growth. It covers 3 052 ha (19.0%) and is scattered throughout the undeveloped land.

(vi) *No Vegetation on Natural Terrain*
Predominantly bare soil which is at 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 75 ha (0.5%) of the study area.

(vii) *No Vegetation due to Man's Disturbance*
Approximately 1 993 ha (12.4%) 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 outcrops are rare in this area and are restricted to steep mountainous slopes such as the Pat Sin Range. Only 6 ha of rock outcrops have been recorded within the GEOTECS data base.

(ix) *Waterbodies*
Natural streams, man-made channels and reservoirs occupy some 357 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 chart in Figure 4, tabulated in Table B2 at Appendix B, and illustrated in the GEOTECS Plot in Figure 8.

Erosion and instability affect 48.5% (7 809 ha) of the study area. However, approximately 4.5% (720 ha) of the study area is currently developed, within which erosion is restricted to unprotected platforms and slopes. In addition to this, approximately 75 ha of natural terrain is subject to severe 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, minor sheet erosion occurs on most of the rock types. A total of 4 241 ha (26.4%) of the study area is affected by some form of sheet erosion.

(ii) *Rill Erosion*
This form of erosion is usually associated with cut and fill batters but may also occur on natural terrain. It is characterised by numerous subparallel drainage rivulets, which produce a striated appearance and result in significant soil loss. Within the study area, it is a minor class affecting only 22 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 4.5% (728 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 (Hansen & Nash, 1984).

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 2 818 ha of the terrain displays some form of instability, and this represents 17.5% of the study area.

(i) *Well-defined Landslips*
Within the study area, 'well-defined landslips' occupy only 41 ha (0.3%) of the land surface. Most landslips on natural terrain are too small (< 1 ha in size) to be individually recorded on either the TCM or within the GEOTECS data bank.

(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 2 ha are affected.

(iii) *General Instability—Recent*
This form of instability relates to colluvial and insitu terrain where many failures and other evidence of instability occur, but it is not possible to show them as discrete units on a 1:20 000 scale map due to their small size. This class occupies 2 034 ha (12.6%) of the study area and is common on many of the steep slopes.

(iv) *General Instability—Relict*
This form of instability occupies 4.6% (741 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*, since 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 North New Territories, 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 33 ha (0.2%), and multi-storey private residential development and mixed commercial and residential development occupy 75 ha (0.5%). Low intensity residential development occupies a further 162 ha (1.0%). In total, residential classes form 1.7% of the study area and form the largest group of the 'developed' classes.

Industrial development covers 33 ha (0.2%) and is primarily concentrated around eastern Tai Po, with smaller but rapidly expanding areas in Fanling and Sheung Shui. The exclusively commercial development occurs in the older parts of Tai Po and is associated with approximately 4 ha of land.

Squatters occur on the hills around Tai Po and on many of the lowland agricultural areas. A total of 736 ha is occupied by squatters and this represents 4.6% 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 Fanling Golf Course. Smaller recreational facilities are scattered throughout the developed areas. A total of 187 ha of recreation facilities are mapped in the study area.

Large areas of horticulture exist, and many of these are sites of potential or planned development and may disappear in the future. At the time of data collection (1982), approximately 2 840 ha (17.6%) of the study area was under cultivation, with a further 24 ha used for poultry or pigs and a further 255 ha used for fish or duck ponds.

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 388 ha (2.4%) is subject to site formation or is allocated to temporary use pending construction. Most of these developments and temporary allocations are in the Tai Po or Fanling and Sheung Shui New Towns.

Land used for water storage and treatment covers 28 ha (0.2%), and this principally represents the large sewage treatment works at Tai Po and some small reservoirs.

Outside the developed areas, there are 3 837 ha (23.8%) of Country Park and 6 838 ha (42.5%) 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 15 375 ha (95.5%) of the area is undeveloped, and of this some 30.8% is subject to high geotechnical limitations (GLUM Class III), 12.2% is affected by extreme geotechnical limitations (GLUM Class IV), 48.9% is influenced by moderate geotechnical limitations (GLUM Class II) and 5.3% has low geotechnical limitations (GLUM Class I).

(ii) *Squatters*
Squatters appear to be located on 736 ha, and this represents 4.6% of the study area. Approximately 20.5% of the terrain occupied by squatters is classified as subject to high to extreme geotechnical limitations. 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 61 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; 10.1% GLUM Class 1, 69.4% GLUM Class II and 20.5% GLUM Class III.

(iii) *Residential*
Approximately 1.3% of the area is occupied by residential development; this figure excludes squatters and single storey development. This development is concentrated on the floodplain, raised terrace and lower footslope terrain and on reclamation 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 12.4% in GLUM Class I, 78.0% in GLUM Class II and 9.6% in GLUM Class III. Two-storey village houses around the New Towns and in older villages account for all of the residential land in GLUM Class III.

(iv) *Commercial and Industrial*
Within the area, there are 37 ha used for commercial or industrial purposes (0.2%). The GLUM class distribution is 5.4% in GLUM Class I and 94.6% in GLUM Class II. The location of industrial and commercial activities on reclamation in Tai Po is reflected by the high proportion of GLUM Class II terrain.

(v) *Recreational*
Sporting facilities and urban recreational areas occupy 187 ha, including 163 ha for the Fanling Golf Course. The parks and sports complexes are entirely on GLUM Class II terrain. The GLUM Class distribution for the area of the golf course is 15.3% GLUM Class I, 69.9% GLUM Class II, 12.3% GLUM Class III and 2.5% GLUM Class IV.

(vi) *Community and Institutional*
Community institutions, such as schools and hospitals, occupy only 28 ha (0.2%), entirely on GLUM Classes I & II terrain.

(vii) *Cemeteries*
Cemeteries occupy 169 ha (1.0%) of the area. The large Wo Hop Shek Cemetery is located to the south of Fanling; in addition, there are some small local hillside burial areas. The latter occupy sideslope, footslope and drainage plain terrain, resulting in a GLUM Class distribution of 2.4% GLUM Class I, 83.4% GLUM Class II, 9.5% GLUM Class III and 4.7% GLUM Class IV.

(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 55 ha is mapped for transportation services. The GLUM class distribution is 32.7% in GLUM Class I, 63.7% in GLUM Class II and 3.6% in GLUM Class III.

(ix) *Service Facilities*
This group includes service reservoirs and sewerage treatment works. However, the large water supply reservoirs are unclassified within the GLUM system. One large sewage treatment plant is located in Tai Po on reclamation and is therefore classified as GLUM Class II.

(x) *Borrow Areas*
This land use group occupies approximately 114 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 cut platforms are principally classified as GLUM Class II terrain.

(xi) *Incomplete Development*
Construction zones, areas of vacant reclamation and other temporary uses, including Temporary Resettlement Areas, occupy approximately 385 ha (2.4%) of the area. The intensive construction activity within the New Town areas is reflected by this figure. The GLUM Class distribution is 8.1% in GLUM Class I, 88.8% in GLUM Class II and 3.1% in GLUM Class III.

(xii) *Military*
Military uses occupy 134 ha of the area.

2.8.3 *Future Development*

Development principles for the Territory are presented within the 'Hong Kong Planning Standards and Guidelines' (HKPSG). The future development of natural terrain and the upgrading of existing development are expected to achieve these standards, in as far 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 three large nucleii of development. These are the Tai Po, Fanling and Sheung Shui New Towns.

Large reclamations are located near Tai Po. Once ground settlement is complete, these areas should have few physical restrictions for future development. To the north and northeast of the reclamation at Tai Po, extensive developments are proposed on terrain formed by borrow activities.

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. On gently undulating terrain for example, volcanic rocks normally weather to depths in excess of 10 m, but rock outcrops on steep slopes such as on the south-facing slopes of the Pat Sin Range are devoid of deeply weathered material, and possess only a thin zone of moderately or slightly weathered rock.

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 Figure 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 North 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 geological materials, found in such great variety 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. A method of identifying potential quarry sites is given in the GEOTECS Plot in Figure 12 and discussed in Section 4.2.6 of this Report.

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*) Sedimentary and metasedimentary rocks.

3.1.2 *Characteristics of Fill and Reclamation*

The materials in this group have been placed by man and are therefore the youngest of all the materials in the 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 or by stripping of the soft materials from local hills, 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, and 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 some areas of reclamation consist of sanitary landfill. This material, mixed with layers of natural borrow may be subject to large and unpredictable settlements.

Fill is a natural material 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 a poorly developed or no weathering profile. They form complex coastal and submarine stratigraphies due to the fluctuations in sea level during the last 10 000 years. In geological terms they are immature.

There is a wide range in the particle size distribution in this group. The alluvial material is predominantly a cobbly sand with poor stratification and is usually in a loose condition. The littoral deposits consist of well-sorted coarse sands that are usually well-compacted due to wave action, but are subject to marine erosion. Marine deposits in the 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 because 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 pile type most appropriate for 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 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 Fanling and Sheung Shui New Towns, on areas of alluvium generally restricts 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.

As well as being derived from a range of rock types, colluvium is generally deposited intermittently over a period of time. This intermittent deposition results in considerable variation in the degree of weathering of 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. Colluvial materials occur offshore and beneath areas of reclamation; this indicates a response of the depositional environment to past changes in sea level.

From an examination of Tables B10 and B12, it appears that colluvium has a lower incidence of erosion compared with insitu materials. Instability in colluvium may reflect the mode of origin of these materials and the fact that colluvial deposits often occur in drainage lines, where they are subject to erosion by streams and are generally subject to a high water table. In the North New Territories, the extensive colluvial footslopes appear to be less prone to instability than in other parts of the Territory, probably because the colluvium is less subject to undercutting in this area.

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 the Territory 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.

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	RECENT?	R	RECLAMATION/FILL		Generally local or imported borrow of colluvium, decomposed volcanics or plutonics and crushed quarry rock. Often a mixture of silt, sand, gravel and cobbles. Some building waste, mine waste or sanitary fill may also be included.	Extensive planar deposits adjacent to the coast (reclamation) or as platforms and adjacent slopes (fill) in otherwise undulating terrain.	These materials placed by man have no soil (pedogenic) or weathering profile but may contain weather rocks or be underlain by natural superficial deposits and/or a pre-existing weathered profile.	These materials are highly variable dependent on source of fill. Generally they can be described as low fines, low plasticity granular cobbly soils. Relative density is dependent on method and degree of compactive effort. $\phi \cong 25-35°$. 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 pressure 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.
		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.	Materials are usually saturated and saline. Raised beaches may be leached by rainwater but may remain saline at depth. Groundwater extraction may induce incursion of saline water. Poor grading characteristics—low fines. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or pile foundations.	Main development potential is as beaches for recreational purposes. Excavation of these materials usually prohibited.
		A	ALLUVIAL DEPOSITS	UNDIFFERENTIATED	General 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 increases. Material varies from medium to non-plastic. $c' \cong 0-10$ kPa, $\phi' \cong 20-25°$.	Locally low-lying terrain may be subject to flooding. Materials are usually saturated and of a low density— clay layers are normally consolidated. Buried channels may post local problems of high water flows into tunnels or excavations. Steep excavations require support. Groundwater may be saline if adjacant to coast. Incursion of saline groundwater following abstraction of fresh groundwater may occur. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or piled foundations.	Land deposits easily excavated. Marine deposits often form reasonable hydraulic fill. Excavation by cutter, suction or bucket dredger.
				RAISED TERRACES		Higher alluvial terraces, stepped, level-to-gently sloping with short steep slopes between terrace levels.				
		M	MARINE SEDIMENTS		Usually dark grey silty sand or clay with traces of shell fragments, and some sand horizons, especially near shore. A mixed succession with alluvium and/or colluvium may be present.	Seabed sediments of variable thickness (0-10's of metres) below low tide mark.	Nil	Usually a soft to very soft normally consolidated soil with a high moisture content and high plasticity (LL > 50%), clay content ranges from 20–35%, silt content from 50–70%. Cu < 10 kPa, $c' \cong 0-5$ kPa, $\phi' \cong 25°$. SPT < 10 but increases with depth.	Material is poor to unsatisfactory for hydraulic fill. It is also poor as a foundation because of settlement and bearing capacity problems. Will probably be susceptible to formation of mud waves if fill is end-tipped onto it. Consolidation may be aided by wick drains and/or surcharge loading.	Easily excavated using bucket or possibly suction dredger where necessary. Sandy deposits may be used in construction but silt and clay may pose problems of disposal.
	PLEISTOCENE?	C	COLLUVIUM	VOLCANIC DERIVED GRANITIC/ GRANODIORITIC DERIVED SEDIMENT & METASEDIMENT 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. Coarse boulder colluvium exists in many stream channels.	Mainly occupies the lower sideslope and footslope terrain and may underlie much of the alluvial floodplain. Generally gentle to moderately steep, broad, low, rounded, dissected outwash-fans and interfluves with undulating and hummocky surfaces; elsewhere irregular planar to shallow concave colluvial footslopes, leading upslope to gentle to moderately steep outwash slopes.	Colluvium can occur as independent deposits of a unique age such that one deposit overlies another. The older deposits may be subject to severe weathering and may be completely decomposed to a mottled, coloured sandy silt or clayey silt similar to the insitu residual deposits of their parent materials. The depth of such weathering may be in the order of 10 m or more.	Only very general guidelines can be given for the matrix or finer components of this variable material. MC's average 20–30%, DD varies from 1 300 to 1 700 kg/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 $c' \cong 0-5$ kPa, $\phi' \cong 29-42°$. Standard compaction values: OMC ≅ 17–20%, MDD ≅ 1 630–1 750 kg/m^3. CBR ≅ 3–8%.	This material has moved in its geologic past and is prone to reactivation if not carefully treated by such measures as low batter angles, drainage and surface protection, especially when saturated. Has low to moderate bearing capacity characteristics but should always be carefully drained because it may be susceptible to failure when wet. Voids may cause settlement of roads, services and buildings. Tunnelling probably difficult. 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 bouldery stream deposits will be of limited use. Large boulders may require blasting or splitting.
BEDROCK	LOWER CRETACEOUS	PI	PORT ISLAND FORMATION		Interbedded conglomerate, pebbly sandstone and mudstone. Usually red or pink in colour. Rocks are moderately well cemented, very thickly bedded.	Outcrop essentially forms the gentle northward dipping cuesta ranging from the Pat Sin Range to near Starling Inlet.	Rock generally decomposed to a reddish brown silty sand with pebble traces. Weathering depths are usually small, less than 7 m.	Very few results available. Properties vary dependent on parent material.	Material has seldom been worked hence its characteristics are virtually unknown. The soil profile should be similar to the RBp. The rock profile stability aspects will be controlled by the existing discontinuities. No bearing capacity problems anticipated.	Material could be scraped for borrow when weathered. Fresh rock must be blasted. Not recommended for aggregate until further studied.
	UPPER JURASSIC	XT	INSTRUSIVE IGNEOUS ROCKS (PLUTONIC)	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 granite in that rough sheeting joints and widely spaced tectonic joints are present.	Forms 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.	Not test data available for study area but decomposed grandiorite 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%. $c' \cong 0-14$ kPa, $\phi' \cong 33-42°$. 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 asphaltic concrete.

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

MATERIAL DESCRIPTION								EVALUATION OF MATERIAL		
Type	Age	Symbol		Map Unit	General Lithological Description	Topographic Form	Weathering and Soil Development	Material Properties	Engineering Comment (Stability, Foundation, Hydrogeology)	Material Uses and Excavation Characteristics
BEDROCK	LOWER TO MIDDLE JURASSIC	RBs	REPULSE BAY FORMATION	SEDIMENTARY AND WATER-LAID VOLCANICLASTIC ROCKS	Generally hard, thinly handed black and grey siltstones and black shales, interbedded with volcanic sandstones and tuffs, sometimes cherty. Very closely spaced joints in some units.	Occasionally forms hillcrests, usually ridges, spurs and dissected footslopes with broad, low, irregular, rounded interfluves formed at lower elevations. At higher elevations, ridges and spurs are mainly narrow and sharply rounded.	Shallow to moderately deep, reddish to brown, fine, sandy to silty clay, i.e. residual soil sometimes with ferruginous gravel and weathered rock fragments, overlying completely to highly weathered rock which grades (at bottom 5–20 m depth) into less weathered strongly jointed volcanic rock.	No test data available but likely to be variable, dependent on individual stratigraphic unit.	The sediments are bedded and fissile and weather relatively rapidly to a grey silt when exposed. 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.
		RBc		COARSE TUFF	Grey to dark grey, fine matrix with coarse well formed crystals of feldspar and quartz. Forms massive beds of crystal tuff with no internal stratification. Jointing tends to be moderately closely spaced and smooth.	Massive volcanic peaks with deeply dissected slopes forming a system of subparallel ridges and spurs. Crests are narrow and sharply convex with steep to very steep valley slopes. Rock outcrops are common on the upper slopes.	Rock sometimes produces a poor, thin (< 1 m) 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 18 m has been quoted. Weathering to produce corestones is common.	Fresh rock properties are approximately as follows: Unconfined compressive strength $\cong$ 150–250 MPa. Joint strength parameters are c' $\cong$ 0 kPa, ϕ' $\cong$ 30°, roughness angle 5–10°. DD $\cong$ 2 500–2 700 kg/m^3. Point Load Is(50) $\cong$ 6–12 MPa. Tangent modulus $\cong$ 30 000–60 000 MPa. The near surface completely decomposed material has a DD $\cong$ 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' $\cong$ 0–10 kPa, ϕ' $\cong$ 30–35%.	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.
		RBp		DOMINANTLY PYROCLASTIC ROCKS WITH SOME LAVAS	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.					
		RB		UNDIFFERENTIATED VOLCANIC ROCKS	Rock types not mapped in detail by Allen & Stephens (1971), but probably similar to the above volcanic units.					
		LMC	METAMORPHOSED SEDIMENTARY AND VOLCANIC ROCKS	LOK MA CHAU FORMATION	Metamorphosed sedimentary and volcanic rocks including schist, phyllite, quartzite, metasediments and marble.	Forms hills of moderate to low relief due to its low resistance to erosion. Occurs extensively beneath colluvial and alluvial cover. Local areas of surface boulders and occasional rock outcrops on sideslopes and in gullys.	Metasediments generally weather to produce moderately deep (1–2 m), uniform or gradational, red to red-brown clayey metasediments. Marble(metamorphosed limestone) weathers in two forms: (i) Complete solution, originating along discontinuities; to produce interconnecting cavities which may exceed 1 m in size; (ii) Intergranular solution which produces a weak granular layer at the marble surface.	The near surface completely weathered residual soil acts as a silt with void ratio of $\cong$ 0.25–0.33. Gradings show 5–15% clay, 40–60% silt, 20–30% fine sand. Plasticity varies from PL 25–35%, LL 35–40%. Typical shear strength values are c' $\cong$ 0–15kPa, ϕ' $\cong$ 35°. Completely to highly weathered materials generally have a DD in the range 1 600 to 1 800 kg/m^3. Fresh rock UCS $\cong$ 40–90 MPa. Discontinuity strength parameters are approximately c' $\cong$ 0–5 kPa, ϕ' $\cong$ 25–30°.	Considerable care is required during investigation, design and formation in materials of the Lok Ma Chau Formation. Bearing capacity characteristics are reasonable for low and moderate loads. Stability of this rock in cutting is dependent on the very closely spaced discontinuities, the strengths of which are generally low-considerable care is thus required. Roughness friction values of 0°–5° may be added to ϕ' values. Discontinuity surveys are essential in cutting design. Metasediments may be prone to instability, especially along discontinuities when weathered and saturated. Bearing capacities are reasonable for low to moderate loads on metasediments and marble without large cavities. Interconnecting cavities within the marble provide excellent hydraulic conductivity. Whilst this may be beneficial for water supply wells, rapid fluctuations of the groundwater table can lead to the formation of either collapse sinkholes or gradual settlement in the overlying superficial deposits if hydraulic continuity exists, as soil is washed into the void system.	Material can be used as a source of bulk fill but may break down to silt if overcompacted. Excavation by machine is relatively easy.
		BH	METASEDIMENTARY ROCKS	BLUFF HEAD FORMATION	Variably indurated orthoquartzites, pale coloured fine sandstones, siltstones and mudstones with occasional conglomerate horizons.	Rock type forms the northern portion of Ma Shi Chau and shows rounded form as a short, dissected ridgeline with perpendicular spurlines.	Only a thin (1–2 m) pedogenic horizon develops but the rocks are otherwise (5–25 m) moderately weathered to great depths as shown by the red colouration.	Very little data is available for these steeply dipping, folded strata of alternating mudstones, siltstones and sandstones.	Metasediments may be prone to instability, especially along discontinuities when weathered and saturated. Bearing capacities are reasonable for low to moderate loads on metasediments.	Could be used as very localised source of fill. May break down to silt upon overcompaction. Only the sandstone members will require blasting otherwise machine digging may be possible.
	PERMIAN	TH		TOLO HARBOUR FORMATION	Interbedded black, weak, Pyritous shale and grey and purple moderately strong, laminated, siltstone and mudstone, all very fissile and intensely folded.	Southern coastal cliffs, beach platform and immediate hinterland of Ma Shi Chau.	Palaeosol developed beneath old alluvium. Weathering may be up to 40 m thick extending to –90 mPD.	Little information available. SPT $\cong$ 20–100.	If encountered in foundations the weathered material will be of low strength and contain sulphates. Acid attack on steel piles may occur.	Location precludes borrow activities. Excavation by machine digging with some blasting.

* 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
ϕ' — 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
$\cong$ — about equal to

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, volcanic and metasedimentary colluvium appear to have higher proportions of instability compared with other colluvial materials. This is possibly a result of the steeper slope angles associated with both the parent rock types and this 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, 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. The foothills to the south of the Pat Sin Range have been worked extensively for borrow and reclamation. As stated earlier, these deposits usually occur at the base of steep slopes and are the result of the accumulation of landslip debris, and any excavation for borrow may destabilise the adjacent terrain. Older colluvial deposits may have suitable grading characteristics for use as fill, but the younger streambed deposits, generally lacking in matrix, are probably unsuitable. Excavation by machine methods could be difficult if large boulders are encountered.

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

3.1.5 *Characteristics of the 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).

The main intrusive igneous rock that outcrops within the study area is the Tai Po Granodiorite. Many quartz porphyry dykes also exist, particularly in the south between Tai Po and Yim Tin Tsai.

Granodiorite has a lower quartz content than the granites and is prone to chemical decomposition, resulting in deep, clay-rich soils, often containing corestones. The dyke rocks generally are of limited width, although they may cause localised variations in weathering depths and groundwater conditions.

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 with 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 intrusive igneous granitic rocks. Weathering in these rocks has been the subject of a recent study in Hong Kong (Hencher & Martin, 1982); consequently, only a summary is presented here.

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.

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). This may lead to problems with bored piles and other foundation problems.

The bearing capacity of the highly weathered granodiorite 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.

Site investigations in the granodiorite 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 granodiorite, 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 as the deeply weathered material is easily extracted by machine methods for use as soft borrow.

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 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.

3.1.6 *Characteristics of the Volcanic and Volcaniclastic Rocks*

The location and type of volcanic and volcaniclastic rocks found in the study area are discussed in Section 2.3.3. 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 common on cut slopes. 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. Characteristics of photo-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 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, foundation depths are fairly shallow.

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 Sedimentary and Metasedimentary Rocks*

Within the study area, the following sedimentary and metasedimentary rocks occur:

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

(ii) *Bluff Head Formation*
The distribution of the Bluff Head Formation has been described in Section 2.3. These sediments comprise conglomerates, sandstones, siltstones and shales which were laid down in cyclic sequences. Metamorphism has marginally altered these sediments, mainly by hardening. The extent of induration varies according to rock type, the fine-grained representatives being more thoroughly affected than the coarser-grained rocks. Very little testing data is available from these sediments; however, closely spaced jointing has been observed, and Standard Penetration Tests on conglomerates and sandstones have indicated N values increasing from $N < 30$ in the weathered horizons, to $N > 150$ in the fresher rock, at depth. Laminated siltstones reveal a range of N values between 15 and 98. Hematite and pyrite are present in the finer-grained rock types of the Bluff Head Formation. These materials may produce reactive groundwater charged with sulphides, which could adversely affect reinforced concrete or other foundation materials. Weathering of the Bluff Head Formation can produce deeply weathered profiles (especially in the finer-grained rock types) up to 10 m in thickness. The bearing capacity of these rocks is reasonable for low to moderate loads, but stability depends on joint orientation, and discontinuities would have to be examined to determine stability characteristics.

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

(iii) *Lok Ma Chau Formation*

The Lok Ma Chau Formation includes metamorphosed sedimentary units and a marble-bearing unit which may be up to 300 m thick (Lai & Mui, 1985). The metamorphosed sedimentary units generally exhibit close, smooth jointing, often with some related cleavage. The rock mass is usually significantly weathered to depths in excess of 20 m. Although this facilitates easy excavation, the weathered rock mass is inherently weak, especially along joints and other discontinuities. Discontinuity surveys are essential for the safe design and construction of cut slopes and excavations. Bearing capacities are reasonable for low to moderate loads. Fresh material is usually stronger and is generally more stable. Where accessible, this material is suitable for low grade bulk fill but is not suitable for use as concrete aggregate or roadstone.

Marble has been encountered in boreholes and excavations through the alluvium to the southwest of Lo Wu, where it may occur in isolated patches beneath an approximately 2 km wide strip of land. Ha, Ng & Li (1981) refer to the existence of cavities within the marble, while Siu & Kwan (1982) and Siu & Wong (1984 & 1985) describe problems encountered with the construction of building foundations on marble in Yuen Long. Marble does not occur everywhere under the Lo Wu alluvial plain, and not all of the marble contains cavities. Care is required during site investigation to identify the existence of cavities within the marble if it occurs beneath a site.

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

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

(iv) *Port Island Formation*

The distribution of the Port Island Formation is described in Section 2.3. The formation comprises sequences of conglomerates and pebbly sandstones with shales. The conglomerates and pebbly sandstones form up-standing strike ridges, whilst the finer-grained members form lower relief. All beds in this formation are cleaved and locally sheared. Weathering profiles vary according to rock type, but the coarser beds weather up to 7 m in depth, forming a coarse sandy soil, often with numerous pebbles.

Little data is available on the engineering characteristics of these rocks; however, jointing and shearing characteristics will determine rock slope configurations. The harder beds of the formation, i.e. the conglomerates and sandstones, should support moderate to high loads on bedrock. These rocks could be used as fill, but only the conglomerates should be considered as a potential source of aggregate. Weathered material could be removed by machine methods, and bedrock could be ripped due to close jointing and the large grain size in some of the beds.

4. GEOTECHNICAL ASSESSMENT FOR PLANNING PURPOSES

4.1 Geotechnical Limitations

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, in the GEOTECS plot at Figure 10 and at Table B9 in Appendix B. The relation between GLUM class and existing development is presented in Table 4.1. many small villages and rural settlements exist within the study area, and these occupy significant areas of GLUM I & II terrain. Within the context of this study, these areas are considered as undeveloped. Large areas of development exist in Fanling, Sheung Shui and Tai Po.

Table 4.1 Distribution of GLUM Classes

GLUM Class	Geotechnical Limitations	Area					
		Developed		Undeveloped		Total	
		%	ha	%	ha	%	ha
I	Low	0.4	69	5.1	820	5.5	889
II IIS	Moderate Moderate	3.0 0.5	482 75	32.1 14.6	5 165 2 355	35.1 15.1	5 647 2 430
III	High	0.4	65	29.4	4 739	29.8	4 804
IV	Extreme	0.2	23	11.6	1 870	11.8	1 893
Unclassified (Waterbodies)		<0.1	6	2.7	426	2.7	432
		4.5	720	95.5	15 375	100.0	16 095

4.1.2 *Land with Low to Moderate Geotechnical Limitations*

Within the study area, there exists a significant area (889 ha) with low geotechnical limitations, of which only 69 ha are currently developed. Areas of GLUM Class I terrain, although rather scattered in distribution, range from 20 to 600 ha in size, an average land parcel being about 150 ha. Within GLUM Class I alone, therefore, there exists considerable potential for development.

As illustrated in Table 4.1, GLUM Class II includes a Subclass (Class IIS) consisting of land which will require careful management because it is subject to periodic inundation or flooding. The table also shows that the combined GLUM Class II terrain accounts for 8 077 ha (or 50.2%) of the study area. Considerable potential exists for future development on this land. If Class IIS is excluded for development, there still remains 5 165 ha of Class II land with potential for development.

Although Class IIS is marginally less suitable than the remainder of Class II, it could probably be utilized for development provided that the hydrogeological conditions are considered at the planning stage and in engineering design. A major advantage of the GLUM Class IIS terrain is that it usually occurs as flat, extensive and continuous areas of alluvial flood plain. In the North New Territories, the question of alienation of agricultural land should be considered. Since GLUM Class II areas of alluvium and floodplain are also prime areas for horticultural and agricultural production, an alternative to its selective development is to utilize the floodplain (GLUM IIS) for agricultural purposes. This would maintain the general continuity of the drainage system as well as providing the water supply for agricultural production.

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. Nevertheless the 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.

Should development of GLUM Class IIS prove necessary, the effects of periodic flooding may be avoided by raising the ground level by filling during site formation or, alternatively, adequate surface and subsurface drainage measures may be required. Extensive long term settlement problems may be overcome by means of site preloading, installation of sand drains or similar measures.

4.1.3 *Land with High Geotechnical Limitations*

Approximately 29.8% (4 804 ha) of the study area has a high level of geotechnical limitation (GLUM Class III) and of this, some 65 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.

The GLUM Class III terrain is primarily steep sideslopes or colluvial footslopes subject to overland flow and periodic inundation. In this terrain, access and site layout may be problems. Individual parcels of land are relatively continuous, but they often have GLUM Class IV terrain along parts of their boundaries. The size of these parcels varies considerably, but continuous areas of 400 ha are not uncommon.

4.1.4 *Land with Extreme Geotechnical Limitations*

Approximately 11.8% (1 893 ha) of the area is classified as GLUM Class IV. This terrain should not be developed if alternatives exist. Only 23 ha (0.2%) 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 in most of the mountainous terrain of the Pat Sin Range escarpment and to the north of starling Inlet and on the sideslopes of the larger hills. 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 Pat Sin Range 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 Suitability of Land for Development

4.2.1 *General Planning Considerations*

Land utilisation is governed by development requirements, which are based on demand, potential and constraint. Many of the fundamentals which influence planning decisions are not directly influenced by geotechnical considerations. However, geotechnical considerations are implicit in efficient and secure engineering. Section 4.1 has briefly discussed some of the constraints associated with the terrain 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 North 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 Catchments. 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.

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 *Land of High Suitability for Development*

There exist several relatively extensive areas which occur within GLUM Classes I & II (not IIS) in the study area, and this land is highly suitable for development from a geotechnical point of view. These areas have low geotechnical limitations and probably require only a normal intensity of site investigation.

The most favourable areas for development are in relatively continuous belts which generally occur in the major valleys. These are:

(i) *Lam Tsuen Valley*
This area extends from Pak Ngau Shek at the valley head to the Tai Po–Fanling Road. This major valley is some 8 km long and 2 km wide with an area of approximately 1 600 ha.

(ii) *Ta Kwu Ling Valley*
The approximately circular Ta Kwu Ling valley lies to the north of the Sha Tau Kok Road, and has high potential for development. The area is approximately 200 ha in size.

(iii) *Fanling to Sheung Shui*
An extension of the existing Fanling/Sheung Shui conurbation is particularly suitable for development due to the existence of an established and expanding communications infrastructure.

(iv) *Northern Shores of Plover Cove*
The coastal strip on the northern shores of Plover Cove in the vicinity of Ting Kok has potential for development. This area has the advantage of easy access to Tolo Harbour and forms a developable tract some 80 ha in size.

(v) *Ma Tsuen Leng to Nam Chung*
The entrance to the coastal valley near Ma Tsuen Leng/Nam Chung, although topographically not so favourable, has potential for localised development due to its sheltered waters and access from Starling Inlet and Mirs Bay.

4.2.3 *Land of Moderate to Low Suitability for Development*

Land of this category occurs mainly in the GLUM Class IIS in the North New Territories and, as such, lies essentially on those parts of the flat, low-lying floodplains subject to periodic flooding and inundation. There are two main concentrations:

(i) *Sa Sha Kok*
The low-lying marshy area in the northwest corner of the study area adjacent to the Sham Chung River has potential for development.

(ii) *Ho Sheung Heung*
The area at the confluence of the rivers Beas and Indus northwest of Sheung Shui has potential for development.

4.2.4 *Land of Low Suitability for Development*

A major portion (about 30%) of the North New Territories study area occurs within GLUM Class III. The most problematic areas on this terrain are the colluvial drainage plains which occur on gently sloping footslope terrain. In general, development on Class III terrain requires intensive investigation at the planning and design stages to minimise the likelihood of instability.

Much of the land in Class III is a result of steep natural terrain. Development of these slopes will probably be difficult. The remaining areas of Class III are often covered by extensive deposits of colluvium. This colluvium varies with respect to depth, origin and matrix composition. Stability problems encountered during and after construction of borrow areas on footslope terrain elsewhere in the Territory highlight the fact that development of GLUM Class III land must be approached with caution.

4.2.5 *Land which is Probably Unsuitable for Development*

Undeveloped parcels of land in GLUM Class IV are considered unsuitable for development if alternatives exist. These areas contain one or more of the following geotechnical limitations:

(i) *Very Steep Slopes*
All areas which have slopes with gradients greater than 60°, regardless of their terrain component or erosion characteristics, are allocated to GLUM Class IV. Those areas with average slope gradients in the range of 40 to 60° and which are colluvial footslope, drainage plain, cliff, fill and or disturbed terrain are GLUM Class IV.

(ii) *General Erosion*
The classes within the 'appreciable erosion' category do not necessarily constitute a geotechnical limitation. However, steep slopes associated with the more severe forms of appreciable erosion are classified as GLUM Class IV terrain.

(iii) *Instability*
Areas of instability are considered to have severe geotechnical constraints. They are either GLUM Class III or IV depending on the terrain component and slope angle. All sideslope, footslope, cut and fill terrain with slopes in excess of 15° which display landslip features, as well as colluvial drainage plain terrain, are allocated to GLUM Class IV.

The GEOTECS Plot at Figure 10 shows that GLUM Class IV terrain is extensive and relatively continuous. In parts, it is dissected mainly by disjointed parcels of GLUM Class III terrain and broad diffuse zones of GLUM Class II terrain. The greatest concentration of Class IV occurs towards the south of the study area and is associated with the mountainous east-west drainage divide which extends from Bride's Pool in the east through the Pat Sin Range to Hok Tau and continues from Wo Hop Shek to Tai To Yan.

4.2.6 *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 1.5.8 and described in detail in Appendix A.10.

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) *Undeveloped Terrain with Low to Moderate Geotechnical Limitations*
The GEOTECS Plot in Figure II indicates the areas of land with low to moderate geotechnical limitations to development, (GLUM Classes I and II), subdivided by the intensity of land use.

Approximately 17.6% of the area consists of land with low to moderate geotechnical limitations without current usage. A further 15.6% of this terrain is under agriculture, and 11.3% of this terrain is within Country Parks. Existing development of low intensity occupies 5.9% of the area. High intensity development on terrain with low to moderate geotechnical limitations exists on 5.3% of the area.

(ii) *Potential Quarry Sites*
The GEOTECS Plot in Figure 12 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 that of a convex, straight or rock slope 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 12, 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 26.2% of the area consists of undesignated natural terrain that has potential for quarry usage. A further 19.1% of the area has potential for quarrying but occurs within existing Country Parks or under cultivation. These figures indicate that many options exist, but the number of options would be reduced when rock type is specified.

5. CONCLUSIONS

The findings reached during the North 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) and the Engineering Geology Map (EGM).

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 2 818 ha of the terrain (17.5%) is associated with or affected by instability. Instability is associated with most of the geological materials. Slope failures 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 granodiorite are less common and but tend to be relatively small rotational or joint controlled failures.

(*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 granodioritic areas. There are numerous geological 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. Only a relatively small area of the Lok Ma Chau Formation occurs in the northwest corner of the study area; however, marble has been reported in the Yuen Long District associated with the metasediments of the Lok Ma Chau Formation underlying the alluvium. Subsurface voids and caverns are common problems associated with marble and limestone. Settlement and foundation problems may occur on this terrain. Although the cavities can be large, they do not occur everywhere under the Yuen Long Plain. Investigation, design and construction for heavy structures and structures sensitive to differential settlement should be carefully undertaken if marble is found to exist beneath a site.

(*c*) Approximately 3 044 ha of footslope terrain is covered by extensive colluvial deposits; 13.7% 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 60.9% (1 853 ha) of the generally low angle, colluvial footslope terrain.

(*d*) The granodioritic terrain has a slightly lower proportion of GLUM Classes I & II (38.5%) than either the volcanic terrain (52.3%) or the sedimentary and metasedimentary terrain (61.7%). Of the 3 044 ha of colluvial terrain which occur within the study area, some 86.5% is subject to high to extreme geotechnical constraints (GLUM Classes III & IV).

(*e*) Approximately 48.3% of the study area is characterised by slopes which have gradients between 0 and 15° (excluding reservoirs and ponds). A further 48.7% of the terrain has slope gradients between 15 and 40°, and 1.4% is steeper than 40°.

(*f*) There is approximately 286 ha of reclamation (1.8%) within the study area. The siting of development on extensive reclamation that is underlain by thick compressible marine sediments may give rise to foundation problems and settlement of services. This aspect will require careful design and control during construction.

(*g*) Approximately 4.5% of the study area is currently developed in some form or other. Squatters, and two-storey and single-storey developments occupy 5.6% of the area, and 23.8% is allocated to Country Park. Of the remaining area, 6 838 ha consists of undeveloped natural terrain.

5.2 Land Management Associated with Planning and Engineering Feasibility

(*a*) During the last 20 years a number of large landslips within the Territory have resulted in considerable loss of life and very substantial property damage (So, 1971; Lumb, 1975; Brand, 1984). Landslips have occurred in developed areas, 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 North 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.

(*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 6 838 ha of currently undisturbed natural terrain, which does not include Country Park. Of this figure, GLUM Classes I & II occur on some 40.9% (2 799 ha) of the terrain, and 3 964 ha is associated with high to extreme geotechnical limitations (GLUM Classes III & IV). There is approximately 3 837 ha of land within the Country Parks and, of this figure, 1 815 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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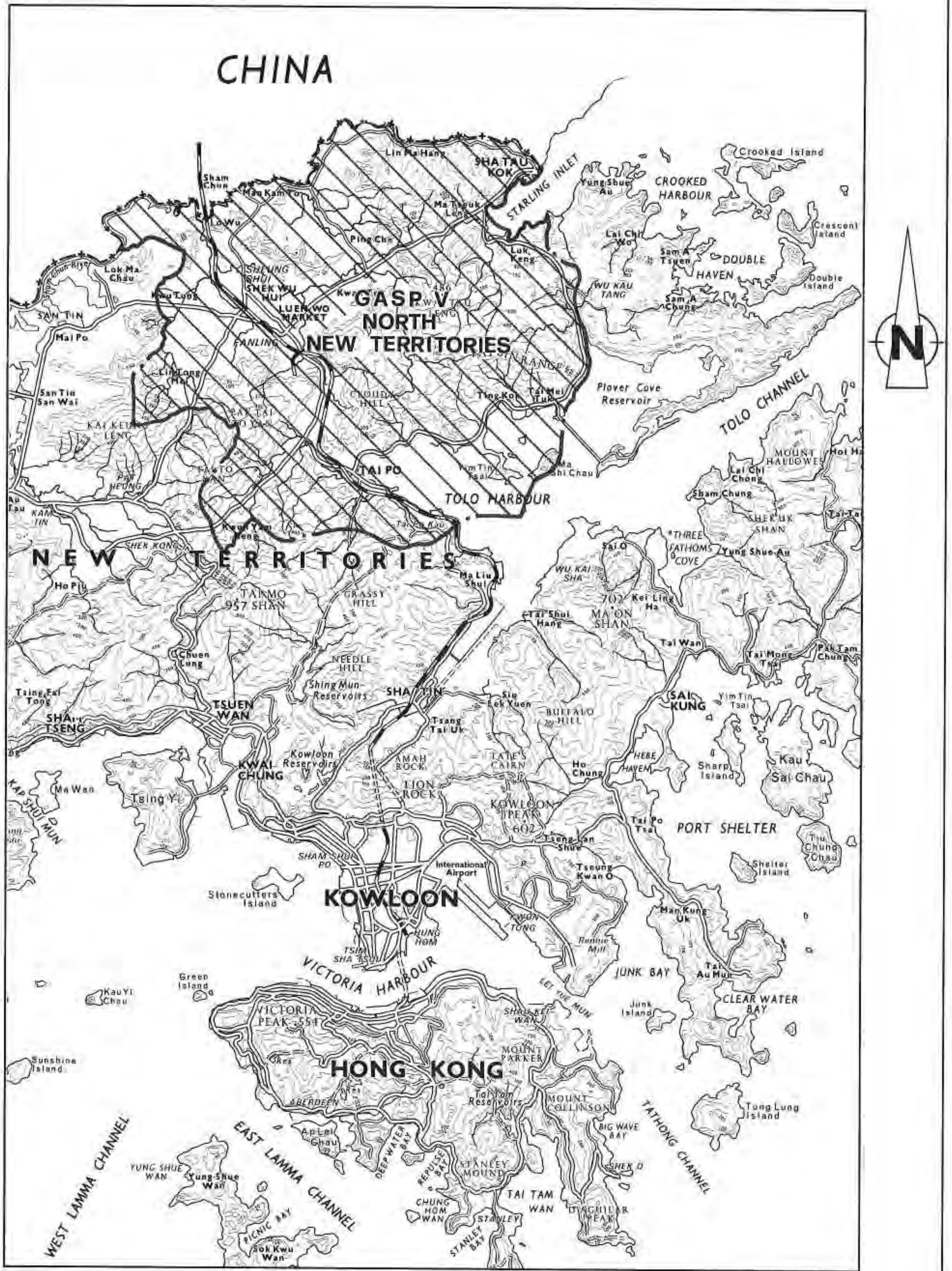
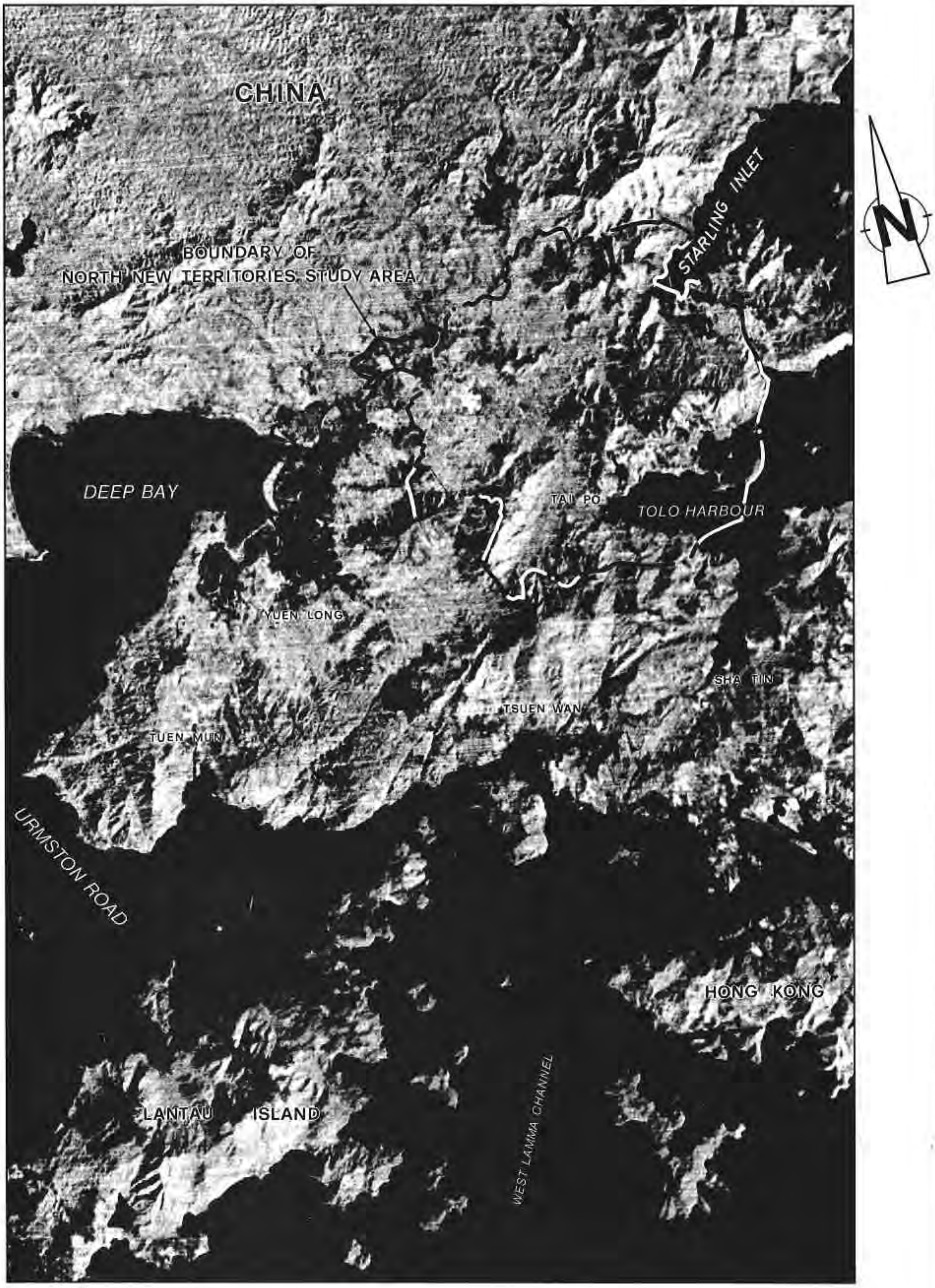
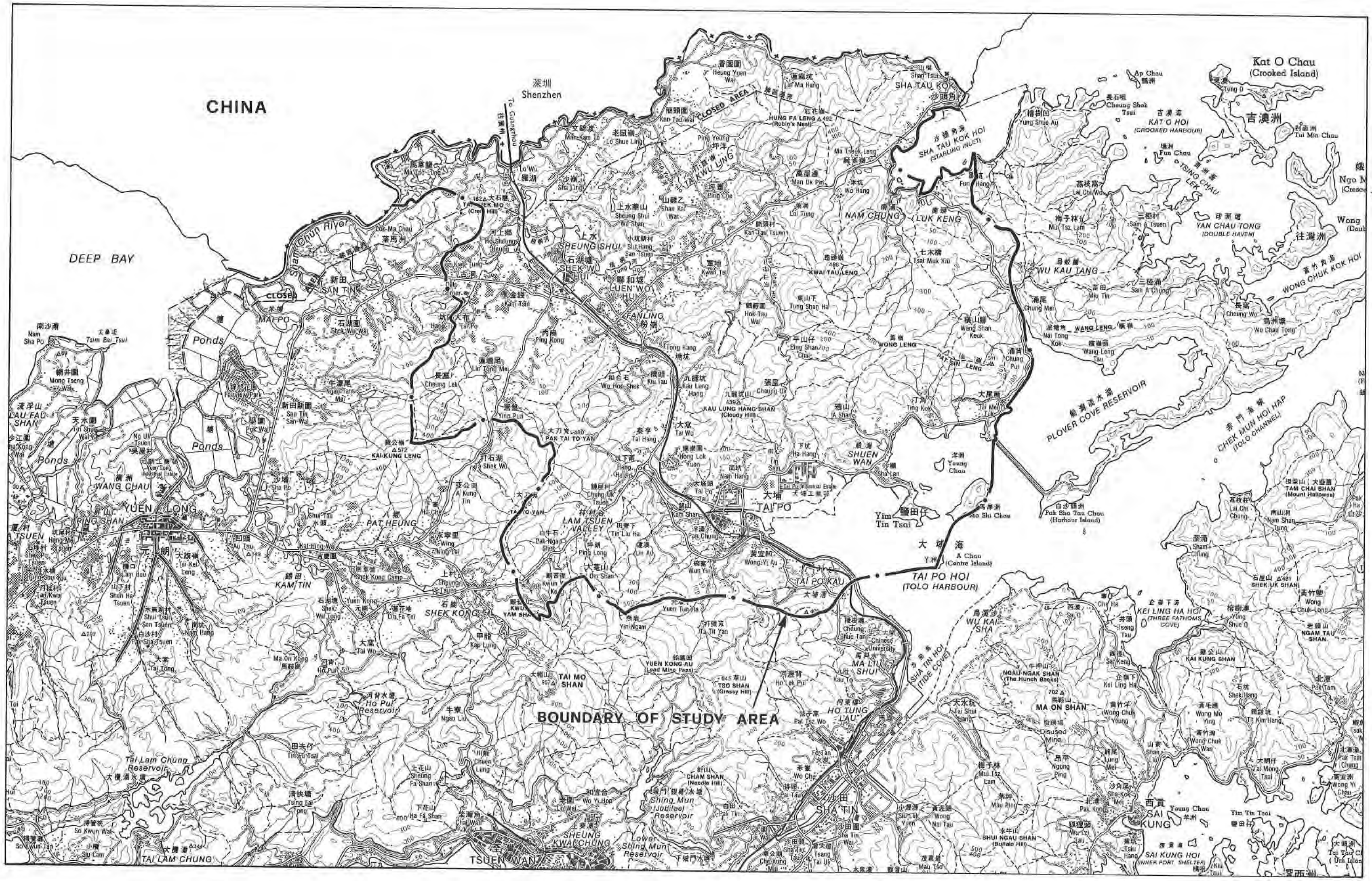


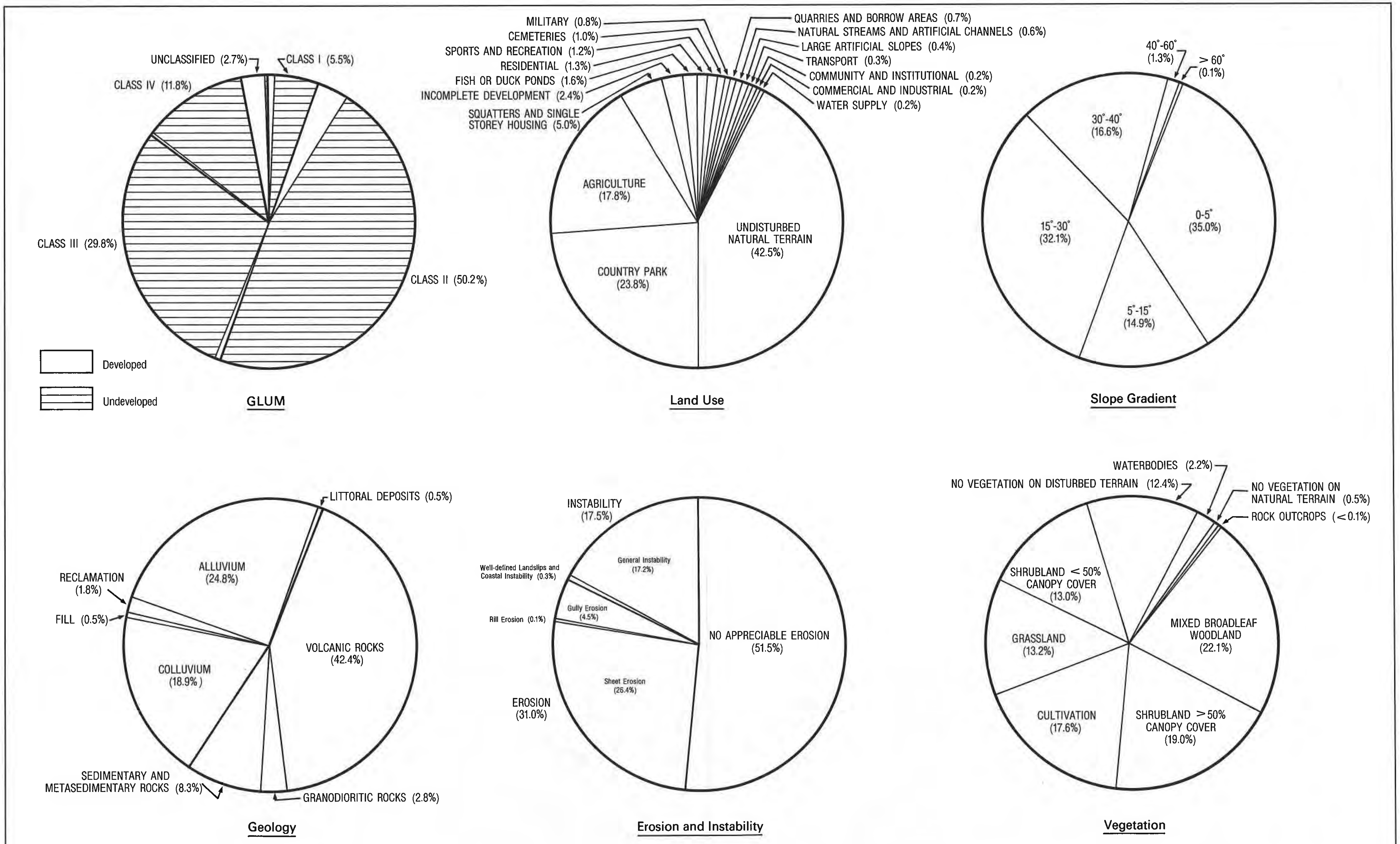
Scale 1:200 000	Location Map of the North New Territories Study Area	Fig. 1



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

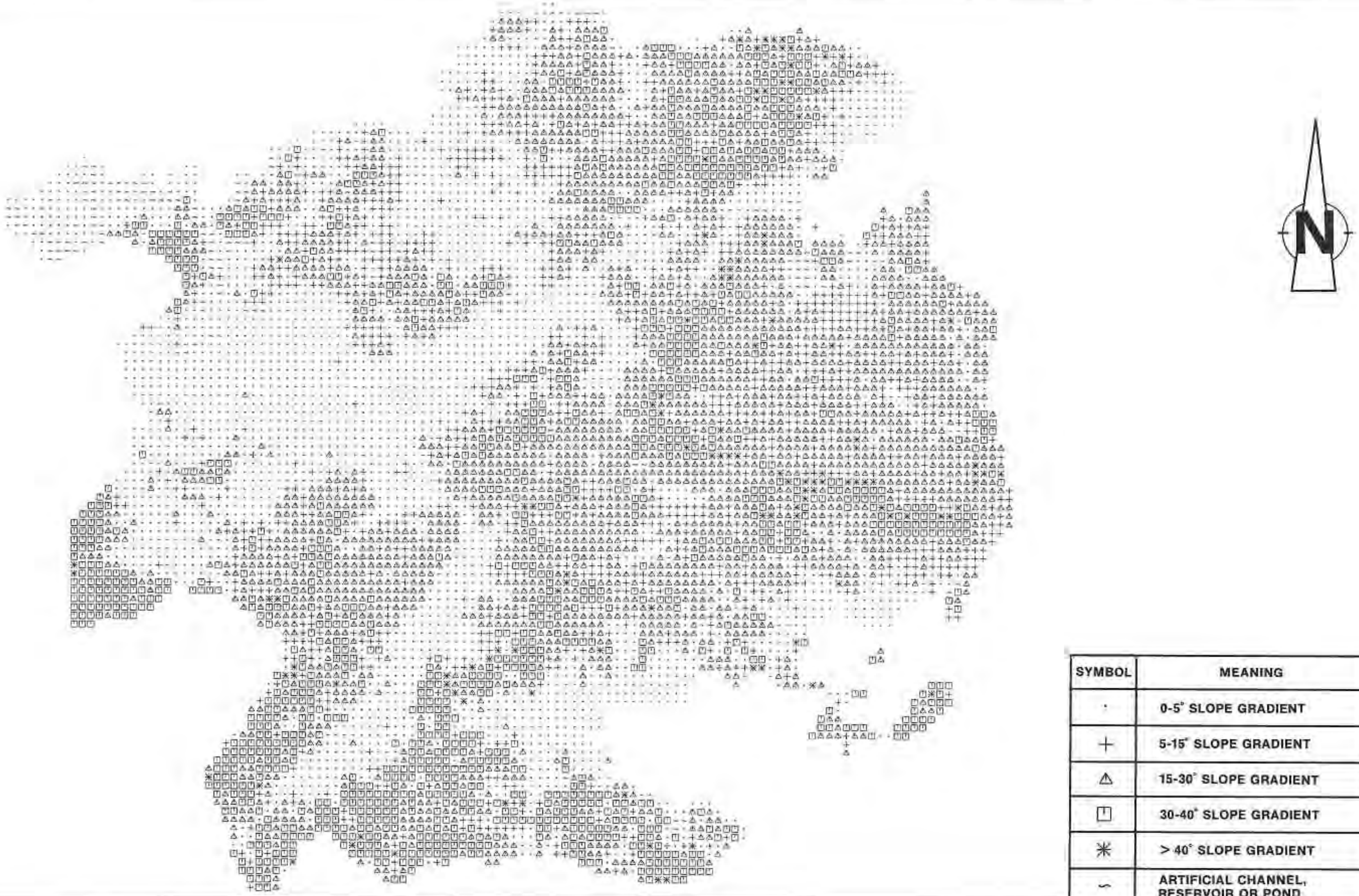


Scale 1:100 000	North New Territories Study Area	Fig. 3



Pie Charts of Selected Attributes of the North New Territories

Fig. 4

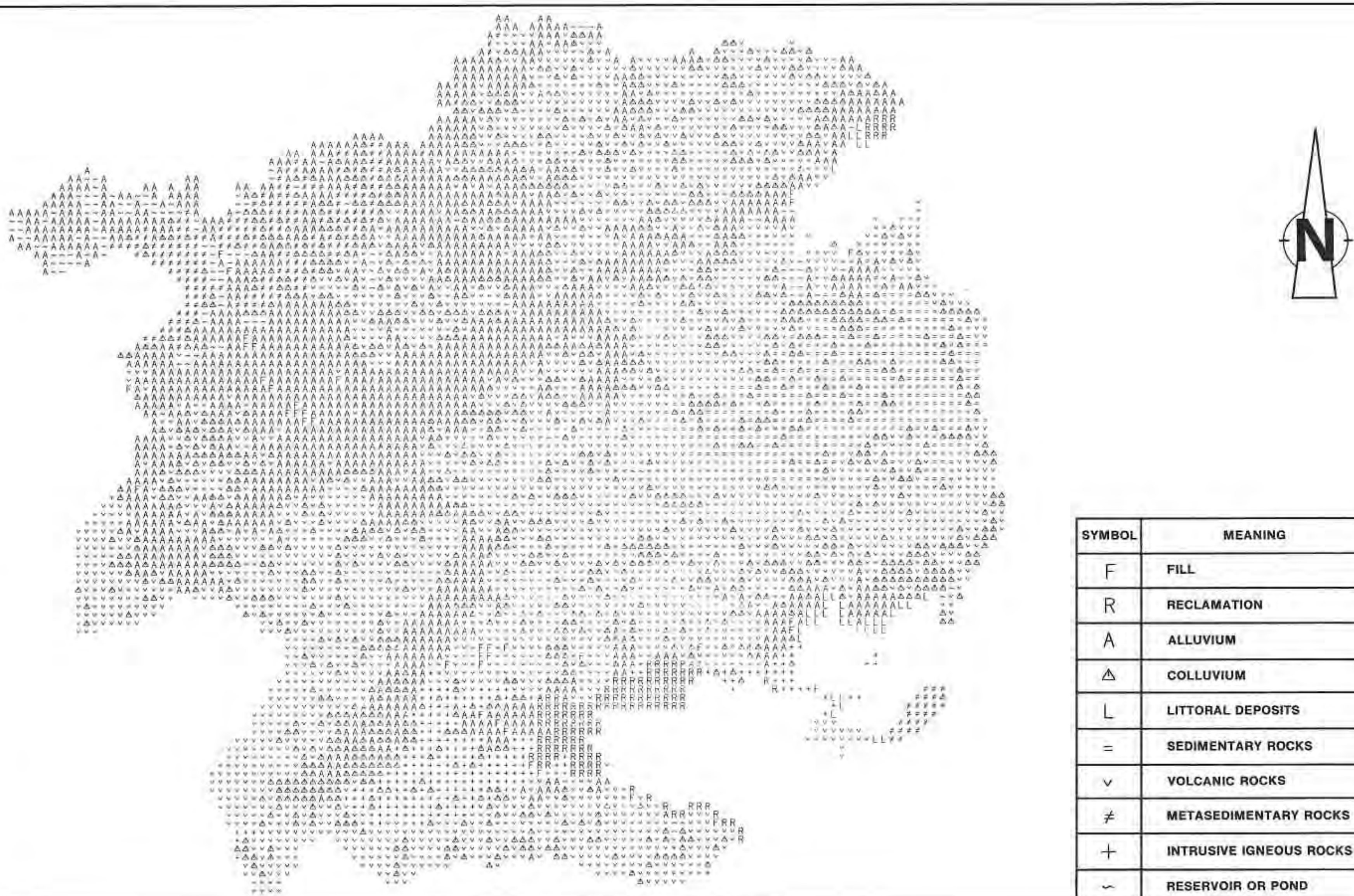


SYMBOL	MEANING	%TOTAL
·	0-5° SLOPE GRADIENT	33.4
+	5-15° SLOPE GRADIENT	14.9
△	15-30° SLOPE GRADIENT	32.1
□	30-40° SLOPE GRADIENT	16.6
✳	> 40° SLOPE GRADIENT	1.4
~	ARTIFICIAL CHANNEL, RESERVOIR OR POND	1.6

Scale
1:100 000

GEOTECS Plot - Slope Gradient

Fig. 5

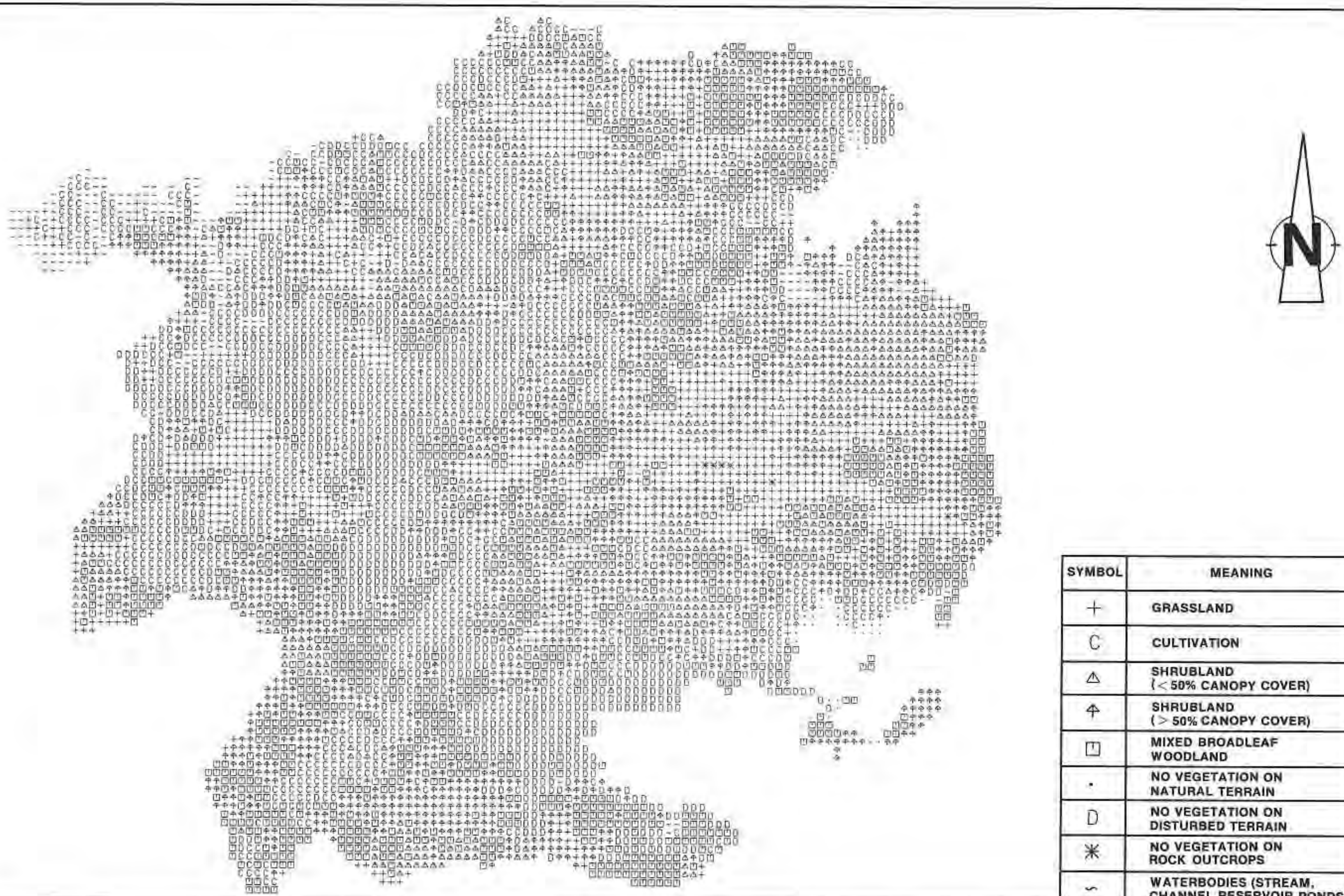


SYMBOL	MEANING	%TOTAL
F	FILL	0.5
R	RECLAMATION	1.8
A	ALLUVIUM	23.2
⩓	COLLUVIUM	18.9
L	LITTORAL DEPOSITS	0.5
=	SEDIMENTARY ROCKS	5.6
v	VOLCANIC ROCKS	42.4
≠	METASEDIMENTARY ROCKS	2.7
+	INTRUSIVE IGNEOUS ROCKS	2.8
~	RESERVOIR OR POND	1.6

Scale 1:100 000

GEOTECS Plot - Geology

Fig. 6

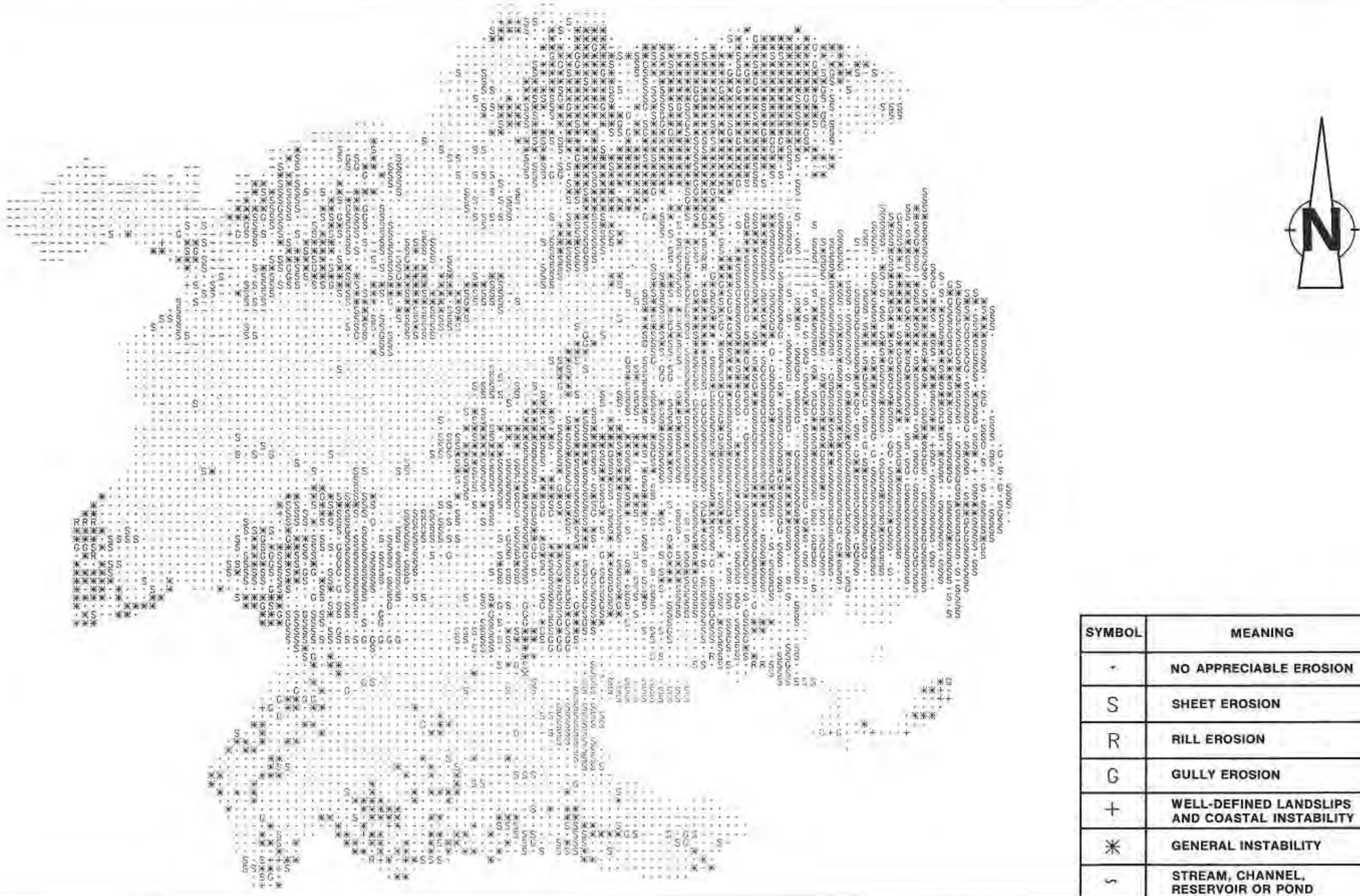


SYMBOL	MEANING	%TOTAL
+	GRASSLAND	13.2
C	CULTIVATION	17.6
△	SHRUBLAND (< 50% CANOPY COVER)	13.0
✦	SHRUBLAND (> 50% CANOPY COVER)	19.0
⊡	MIXED BROADLEAF WOODLAND	22.1
·	NO VEGETATION ON NATURAL TERRAIN	0.5
D	NO VEGETATION ON DISTURBED TERRAIN	12.4
✳	NO VEGETATION ON ROCK OUTCROPS	<0.1
∽	WATERBODIES (STREAM, CHANNEL, RESERVOIR, PONDS)	2.2

Scale 1:100 000

GEOTECS Plot - Vegetation

Fig. 7

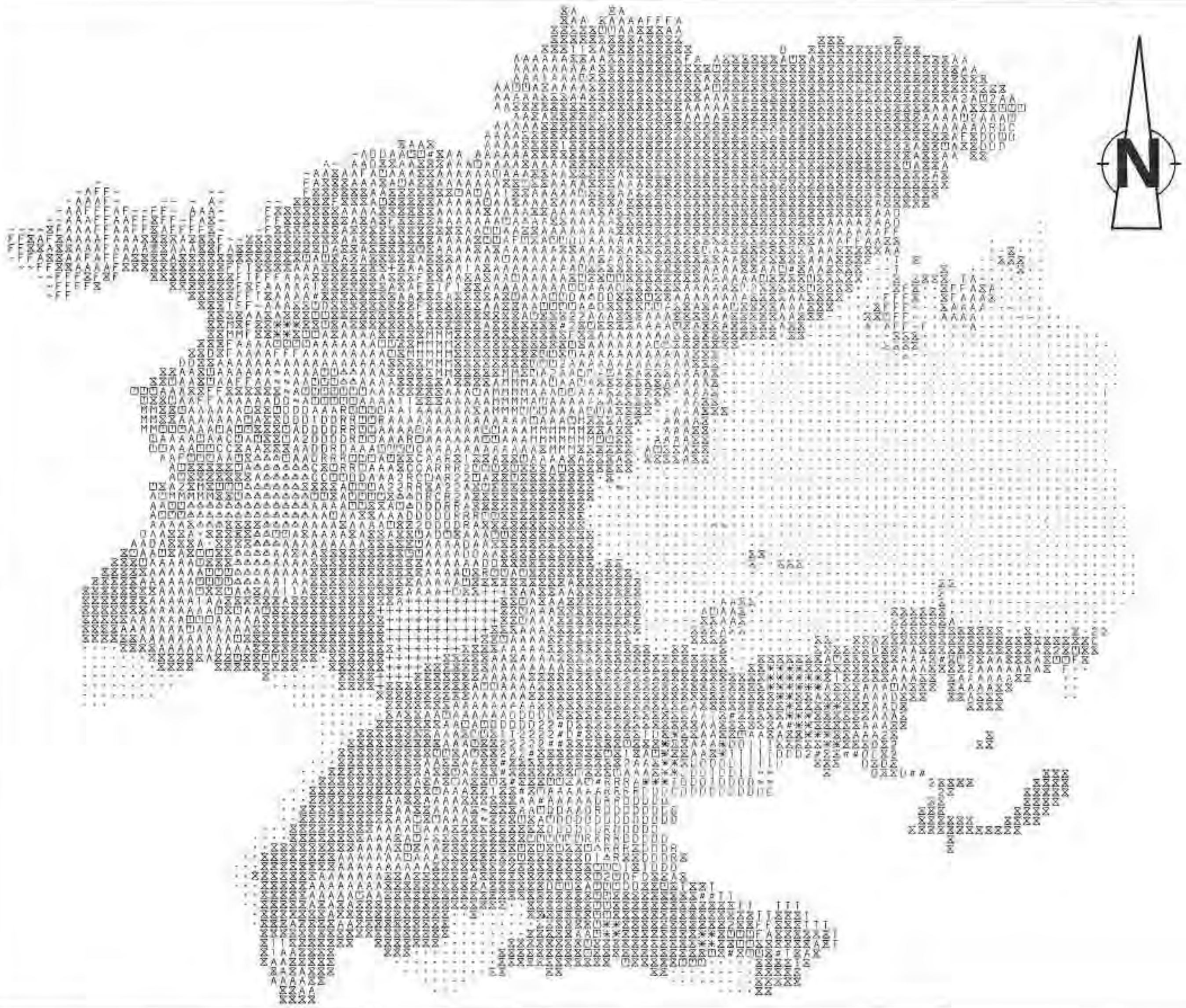


SYMBOL	MEANING	%TOTAL
·	NO APPRECIABLE EROSION	49.3
S	SHEET EROSION	26.4
R	RILL EROSION	0.1
G	GULLY EROSION	4.5
+	WELL-DEFINED LANDSLIPS AND COASTAL INSTABILITY	0.3
✳	GENERAL INSTABILITY	17.2
∽	STREAM, CHANNEL, RESERVOIR OR POND	2.2

Scale 1:100 000

GEOTECS Plot - Erosion and Instability

Fig. 8

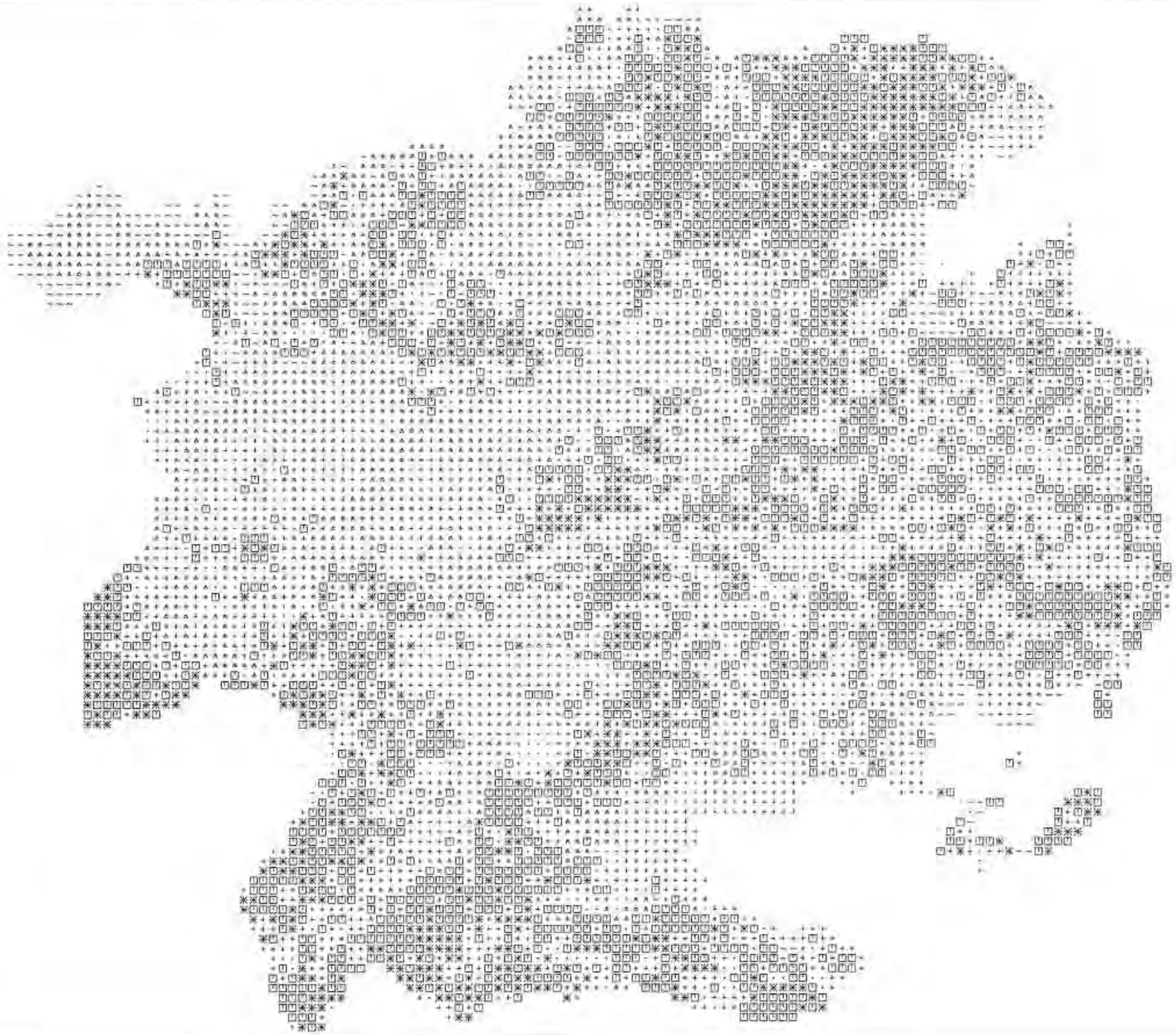


SYMBOL	MEANING	%TOTAL
R	RESIDENTIAL (AND MIXED COMMERCIAL/RESIDENTIAL)	0.7
1	SINGLE STOREY HOUSING	0.4
2	DOUBLE STOREY HOUSING	0.6
I	COMMERCIAL AND INDUSTRIAL	0.2
C	COMMUNITY AND INSTITUTIONAL	0.2
D	INCOMPLETE DEVELOPMENT (INCLUDING TEMPORARY RESETTLEMENT AREA)	2.4
⚠	SPORTS AND RECREATIONAL	1.2
T	TRANSPORT	0.3
≈	WATER SUPPLY (INCLUDING RESERVOIR, SEWAGE & TREATMENT)	0.2
M	MILITARY (UNSPECIFIED)	0.8
✳	QUARRIES AND BORROW AREAS	0.7
+	CEMETERY	1.0
A	AGRICULTURE (UNDEFINED)	17.8
F	FISH OR DUCK FARMING	1.6
⧖	UNDISTURBED NATURAL TERRAIN	42.5
·	COUNTRY PARK	23.8
⍞	SQUATTERS	4.6
~	NATURAL STREAMS AND ARTIFICIAL CHANNELS	0.6
#	LARGE ARTIFICIAL SLOPES	0.4

Scale 1:100 000

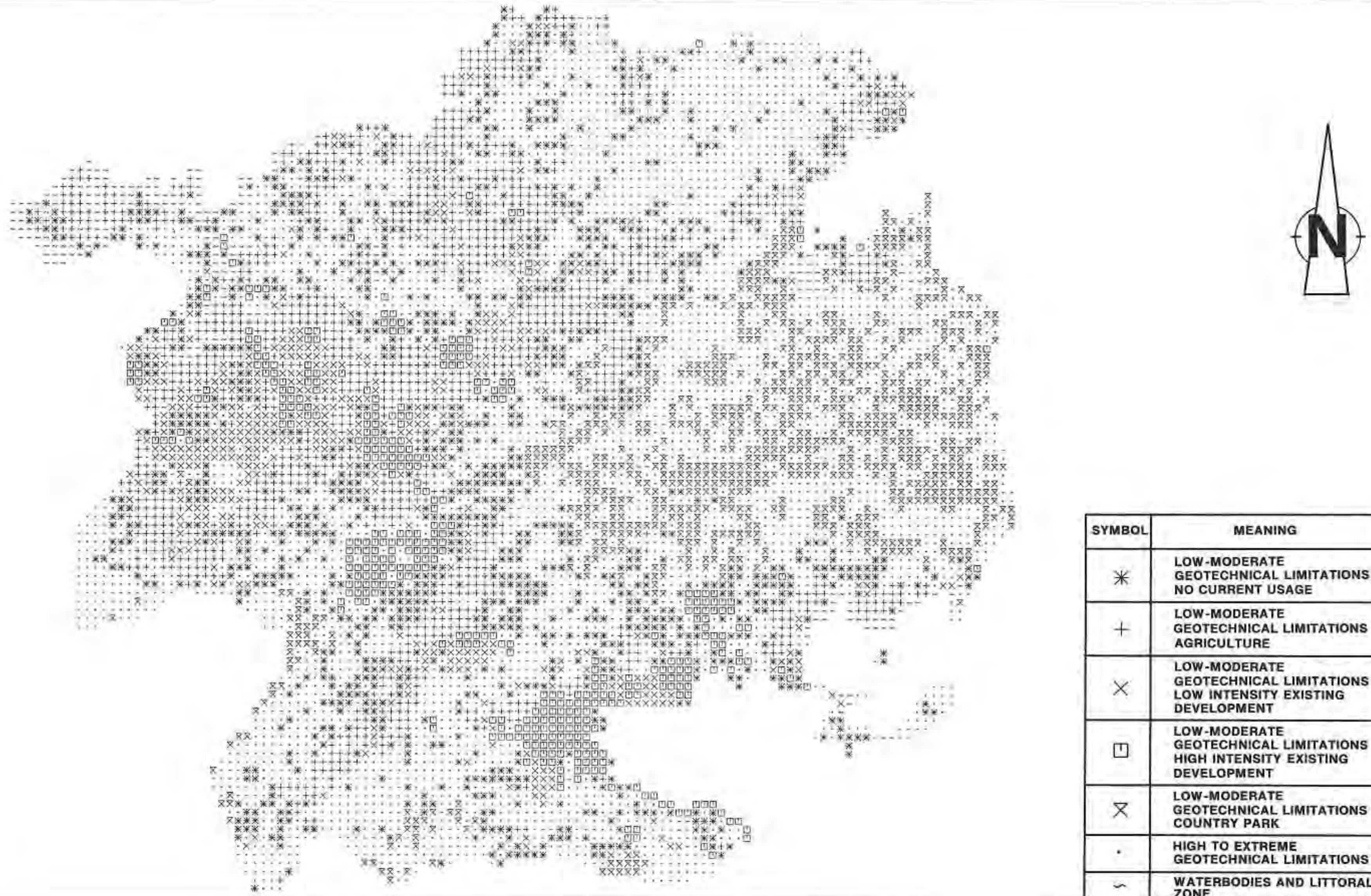
GEOTECS Plot - Land Use

Fig. 9



SYMBOL	MEANING	%TOTAL
·	GLUM CLASS I	5.5
+	GLUM CLASS II	35.1
△	GLUM CLASS IIS	15.1
⊡	GLUM CLASS III	29.8
✳	GLUM CLASS IV	11.8
~	UNCLASSIFIED GLUM CLASS	2.7

Scale 1:100 000	GEOTECS Plot - Geotechnical Land Use Map	Fig. 10

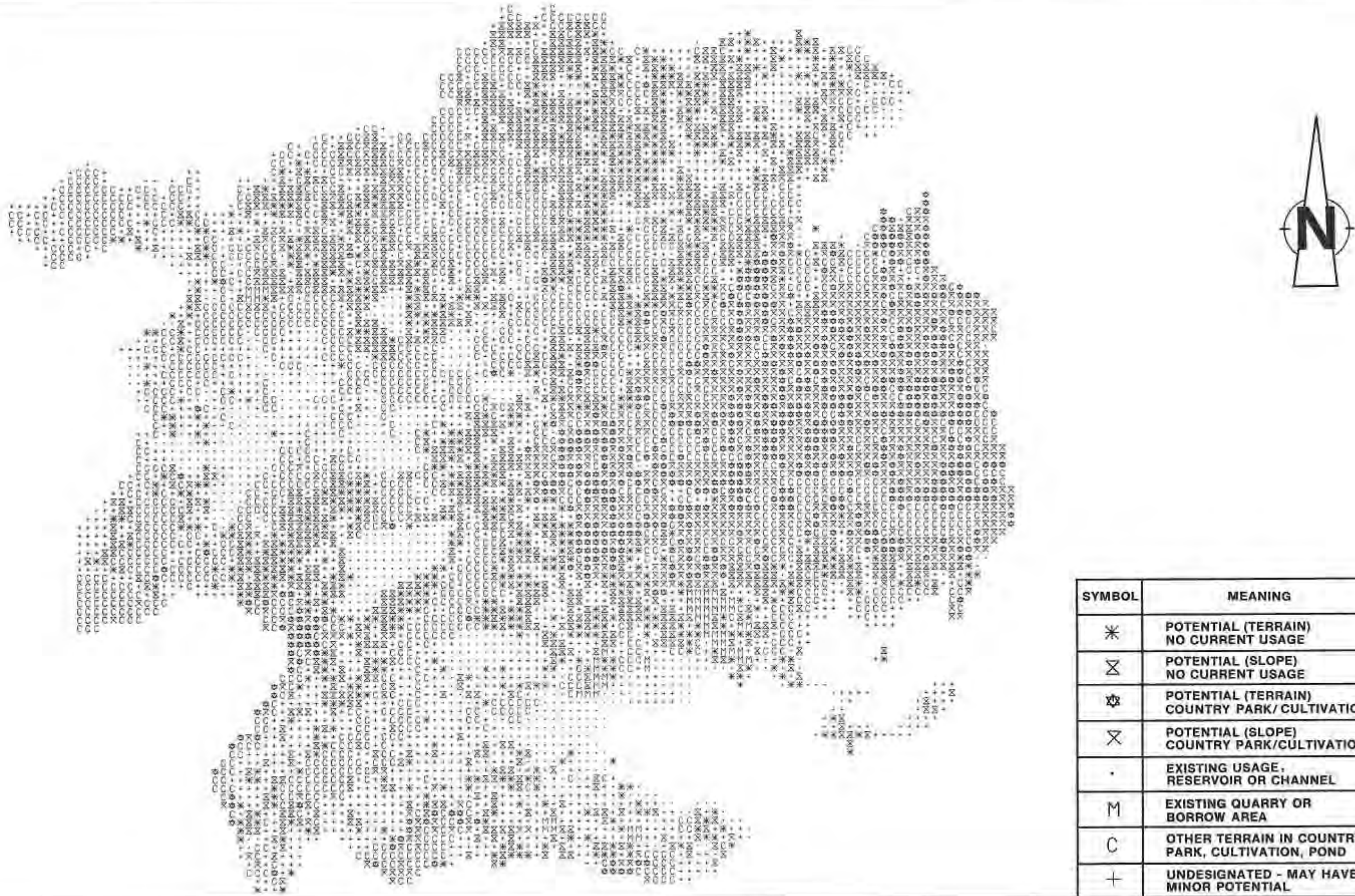


SYMBOL	MEANING	%TOTAL
✳	LOW-MODERATE GEOTECHNICAL LIMITATIONS NO CURRENT USAGE	17.6
+	LOW-MODERATE GEOTECHNICAL LIMITATIONS AGRICULTURE	15.6
×	LOW-MODERATE GEOTECHNICAL LIMITATIONS LOW INTENSITY EXISTING DEVELOPMENT	5.9
◫	LOW-MODERATE GEOTECHNICAL LIMITATIONS HIGH INTENSITY EXISTING DEVELOPMENT	5.3
⧖	LOW-MODERATE GEOTECHNICAL LIMITATIONS COUNTRY PARK	11.3
·	HIGH TO EXTREME GEOTECHNICAL LIMITATIONS	41.6
⌣	WATERBODIES AND LITTORAL ZONE	2.7

Scale 1:100 000

GEOTECS Plot - Undeveloped Terrain with Low to Moderate Geotechnical Limitations

Fig. 11



SYMBOL	MEANING	%TOTAL
✳	POTENTIAL (TERRAIN) NO CURRENT USAGE	9.1
⧖	POTENTIAL (SLOPE) NO CURRENT USAGE	17.1
✡	POTENTIAL (TERRAIN) COUNTRY PARK/ CULTIVATION	8.4
⧗	POTENTIAL (SLOPE) COUNTRY PARK/CULTIVATION	10.7
·	EXISTING USAGE, RESERVOIR OR CHANNEL	7.8
M	EXISTING QUARRY OR BORROW AREA	0.7
C	OTHER TERRAIN IN COUNTRY PARK, CULTIVATION, POND	24.2
+	UNDESIGNATED - MAY HAVE MINOR POTENTIAL	22.0

Scale
1:100 000

GEOTECS Plot - Areas with Potential as Quarries

Fig. 12

Fig. 1	Location Map of the North New Territories Study Area 1:200 000
Fig. 2	Satellite Image of the North New Territories Area 1:250 000
Fig. 3	Reduced Scale Base Map of the North New Territories Area 1:100 000

Fig. 14 to 19 show A4 size inset examples of a typical set of GASP Maps (1:20 000)

Fig. 14a	Base Map
Fig. 14b	Terrain Classification Map (TCM)

Fig.	15a	Geotechnical Land Use Map (GLUM)
	15b	Terrain Classification Map Superimposed on the GLUM
Fig.	16a	Physical Constraints Map (PCM)
	16b	Terrain Classification Map Superimposed on the PCM
Fig.	17a	Engineering Geology Map (EGM)
	17b	Terrain Classification Map Superimposed on the EGM
Fig.	18a	Landform Map (LM)
	18b	Terrain Classification Map Superimposed on the LM
Fig.	19a	Erosion Map (EM)
	19b	Terrain Classification Map Superimposed on the EM

Full size North New Territories map sheets in the Map Folder (1:20 000):

Geotechnical Land Use Map (GLUM) (GASP/20/V/1)	Physical Constraints Map (PCM) (GASP/20/V/6)	Engineering Geology Map (EGM) (GASP/20/V/2)

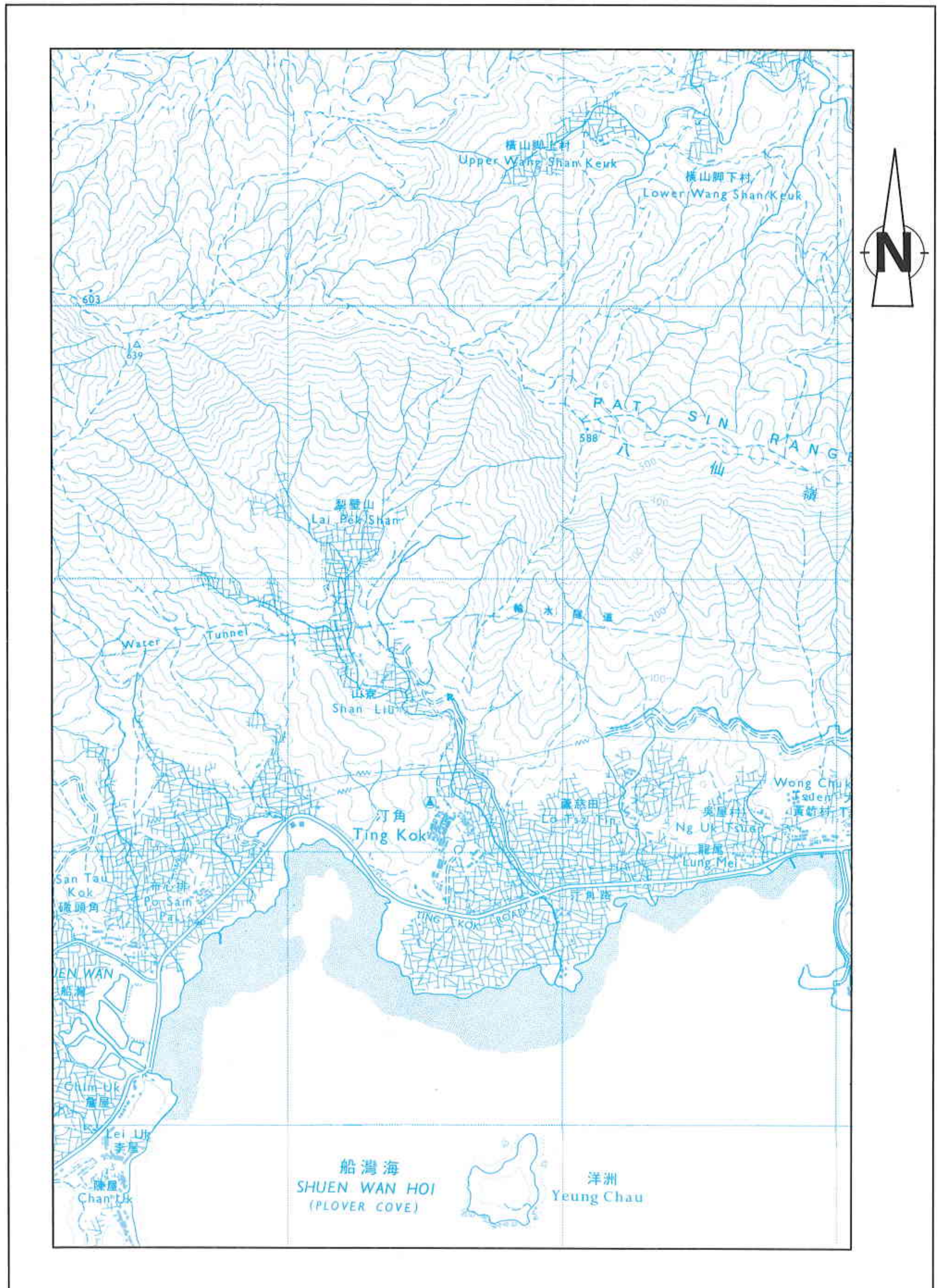
Presentation of Maps — Fig. 13

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig.14b)

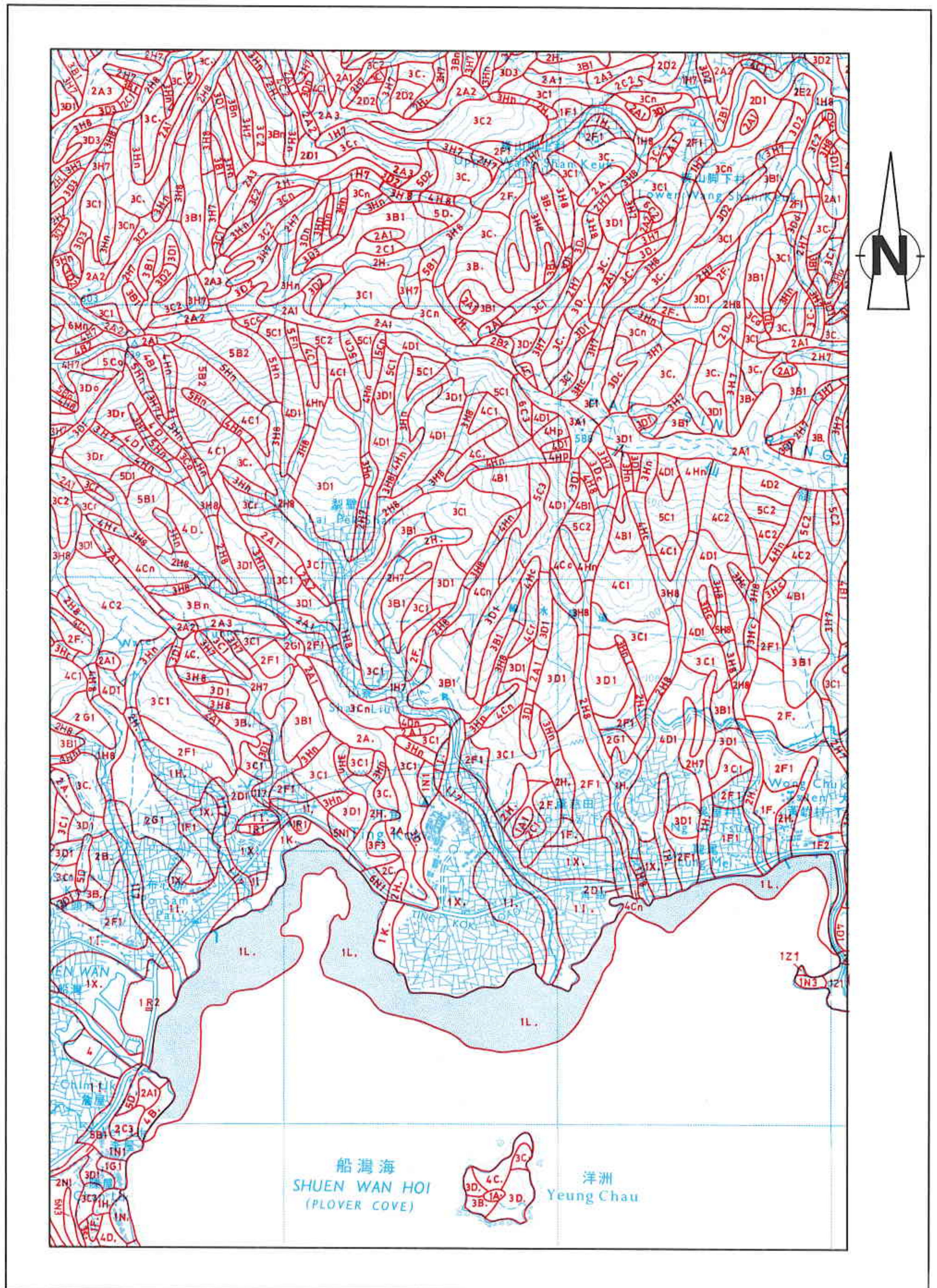
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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
Cliff/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
	- Manmade 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	- integral	- recent	a
		- relict	b
	- scar	- recent	c
		- relict	d
	- debris	- recent	g
		- relict	k
Development of general instability	- integral	- recent	n
		- relict	o
	- scar	- recent	p
		- relict	r
	- debris	- recent	s
		- relict	t
Coastal	- integral		w
	- scar		y
	- debris		z



Scale 1:20 000	Example of the Base Map	Fig. 14a



Scale 1:20 000	Example of the Terrain Classification Map	Fig. 14b

LEGEND FOR GEOTECHNICAL LAND USE MAP (Fig. 15a)

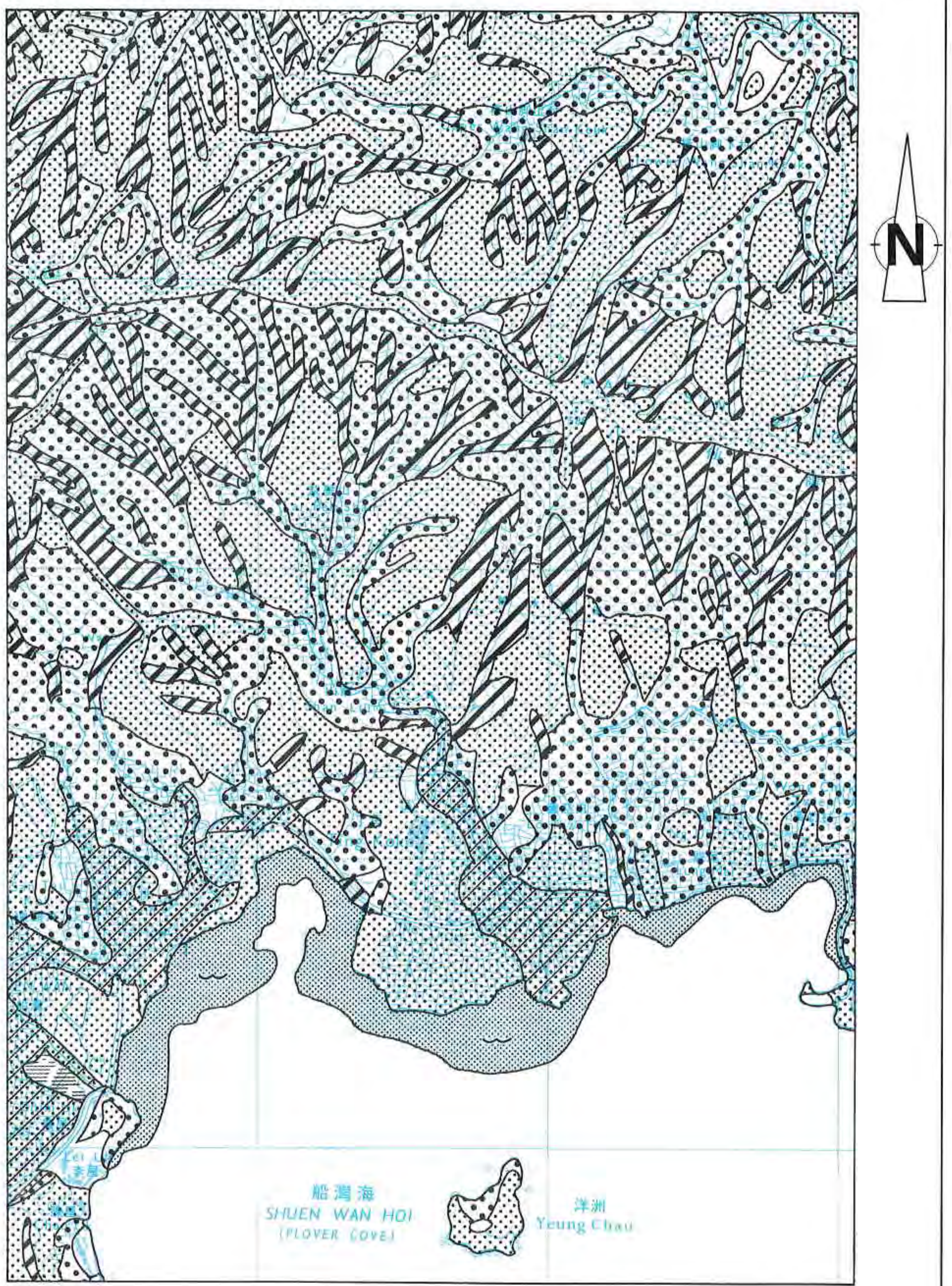
Class I - Low Geotechnical Limitations		
Class II - Moderate Geotechnical Limitations		
Class IIS - Moderate Geotechnical Limitations (including flooding)		
Class III - High Geotechnical Limitations		
Class IV - Extreme Geotechnical Limitations		
Waterbodies (streams, man-made channels, storage dams)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

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 15b)

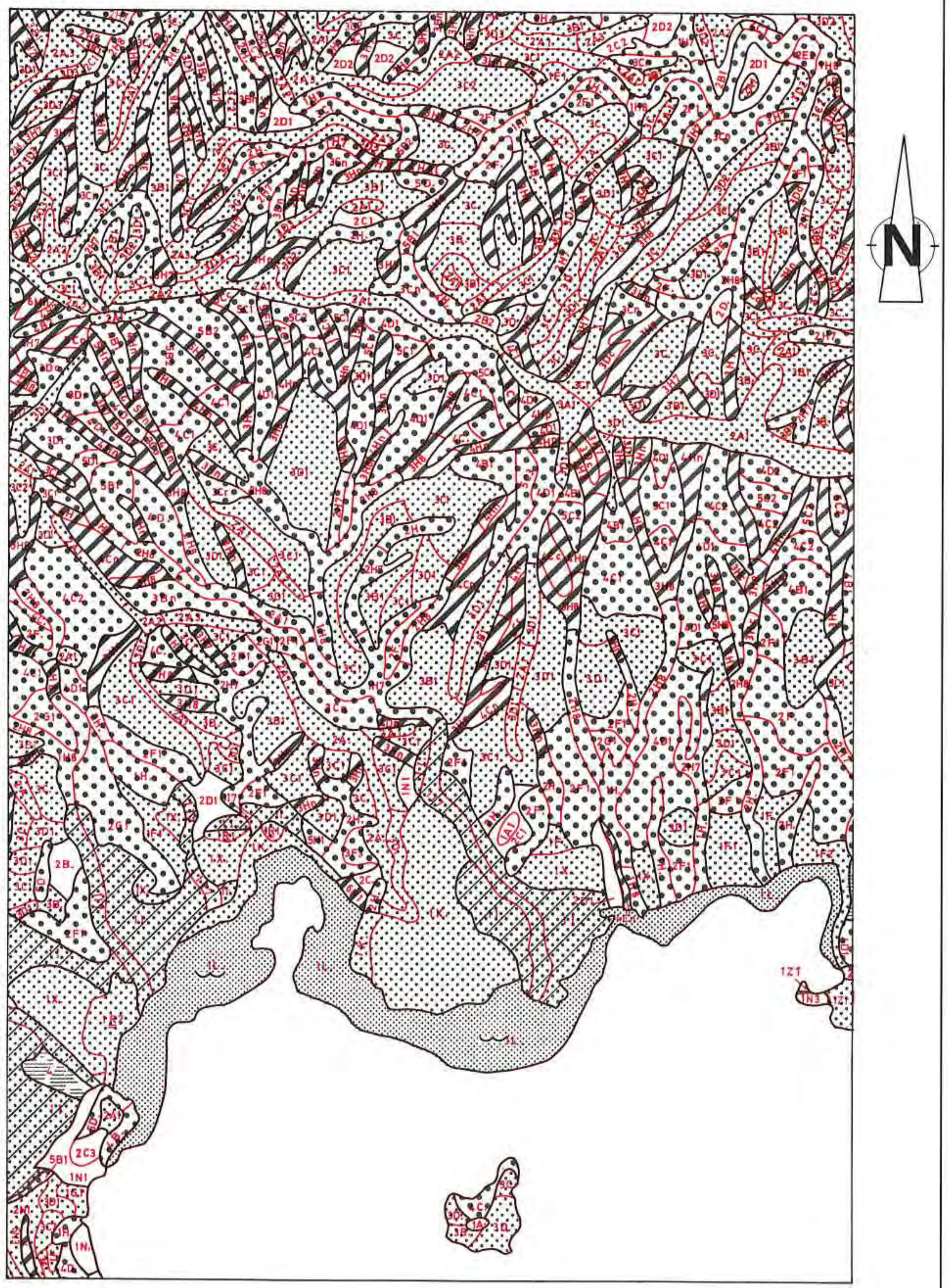
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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
Cliff/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
	- Manmade 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	- integral	- recent	a
		- relict	b
	- scar	- recent	c
		- relict	d
	- debris	- recent	g
		- relict	k
Development of general instability	- integral	- recent	n
		- relict	o
	- scar	- recent	p
		- relict	r
	- debris	- recent	s
		- relict	t
Coastal	- integral		w
	- scar		y
	- debris		z



Scale 1:20 000	Example of the Geotechnical Land Use Map (GLUM)	Fig. 15a



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

LEGEND FOR PHYSICAL CONSTRAINTS MAP (Fig. 16a)

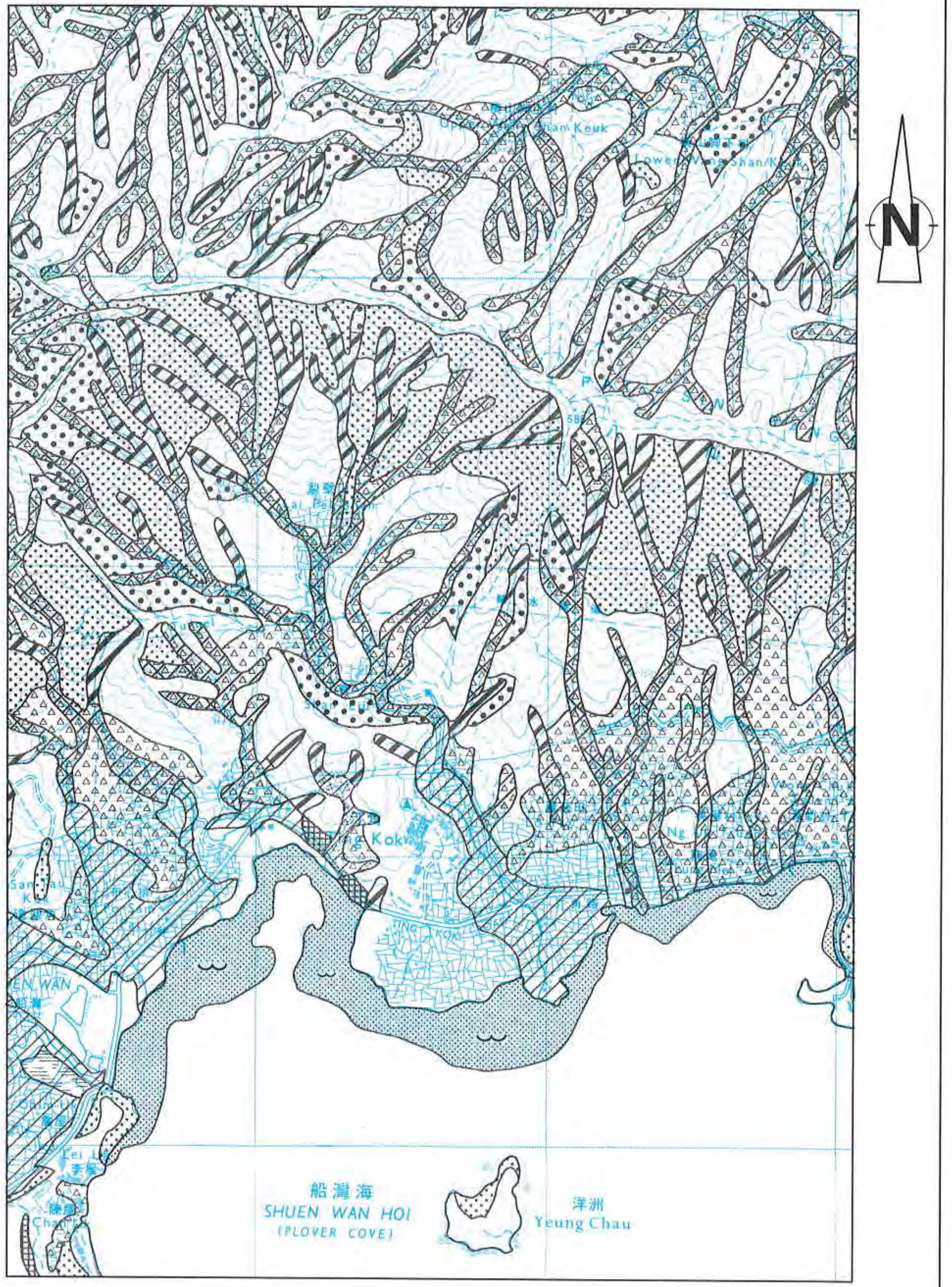
- Colluvium
- Zones of colluvium which are subject to overland flow and periodic inundation. Evidence of unusual groundwater regime (delineated as drainage plain on Landform Map)
- Floodplain - subject to overland flow and regular inundation. Evidence of unusual groundwater regime (delineated as floodplain 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. 16b)

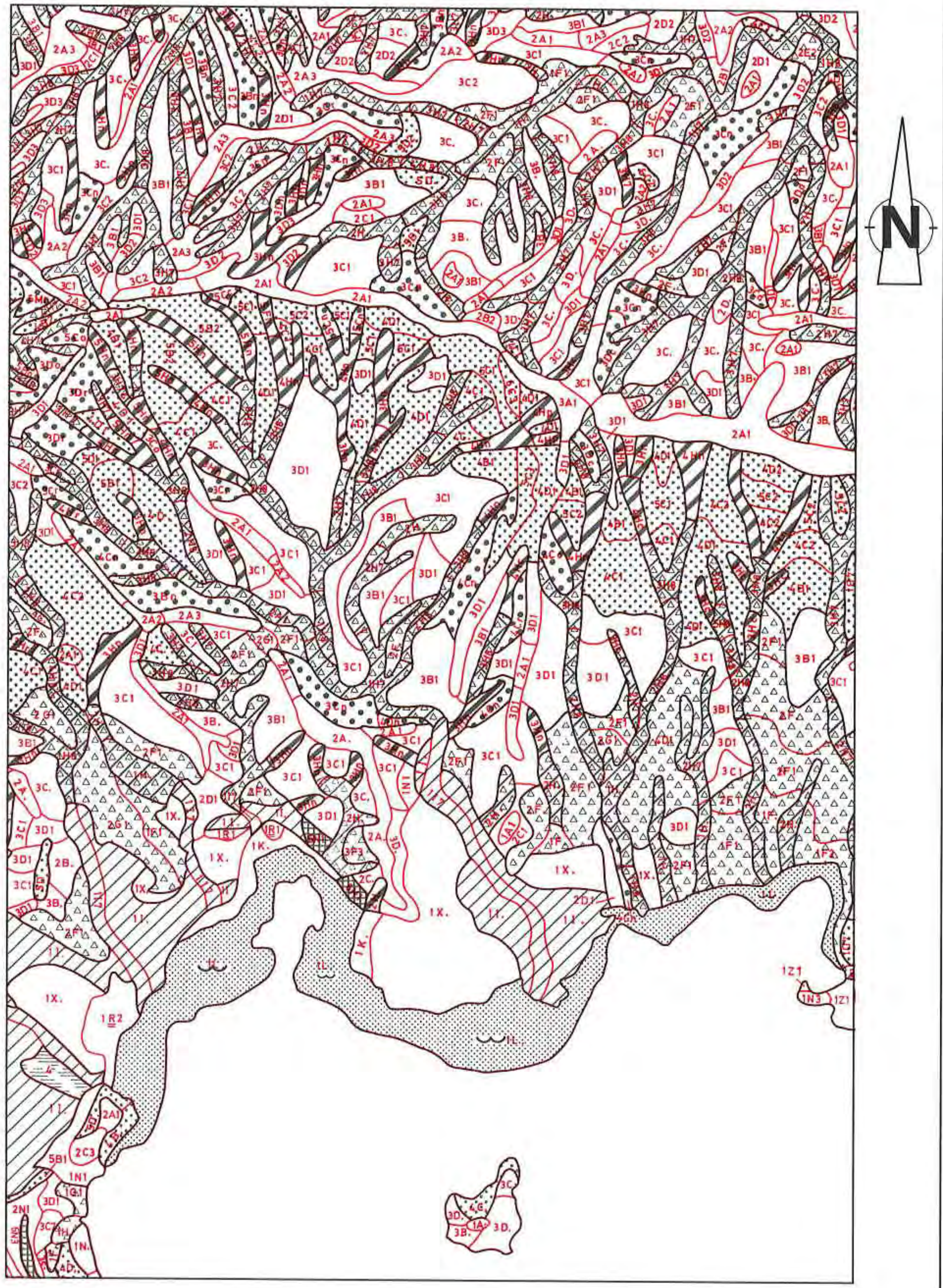
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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
Cliff/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
	- Manmade 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	- integral	- recent	a
		- relict	b
	- scar	- recent	c
		- relict	d
	- debris	- recent	g
		- relict	k
Development of general instability	- integral	- recent	n
		- relict	o
	- scar	- recent	p
		- relict	r
	- debris	- recent	s
		- relict	t
Coastal	- integral		w
	- scar		y
	- debris		z



Scale 1:20 000 | Example of the Physical Constraints Map (PCM) | Fig. 16a



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

LEGEND FOR ENGINEERING GEOLOGY MAP (Fig. 17a)

- Fill
- Reclamation
- Littoral deposits
- Alluvium - exposed at surface
- Alluvium - underlying ponds
- Raised alluvial terrace
- Colluvium (undifferentiated)
- Port Island Formation
- Repulse Bay Formation:
  - Sedimentary rocks and water-laid volcaniclastic rocks
  - Coarse tuff
  - Dominantly pyroclastic rocks with some lavas
- Kat O Formation
- Lok Ma Chau Formation
- Needle Hill Granite : fine-grained porphyritic phase
- Needle Hill Granite : medium-grained porphyritic phase
- Cheung Chau Granite
- Tai Po Granodiorite

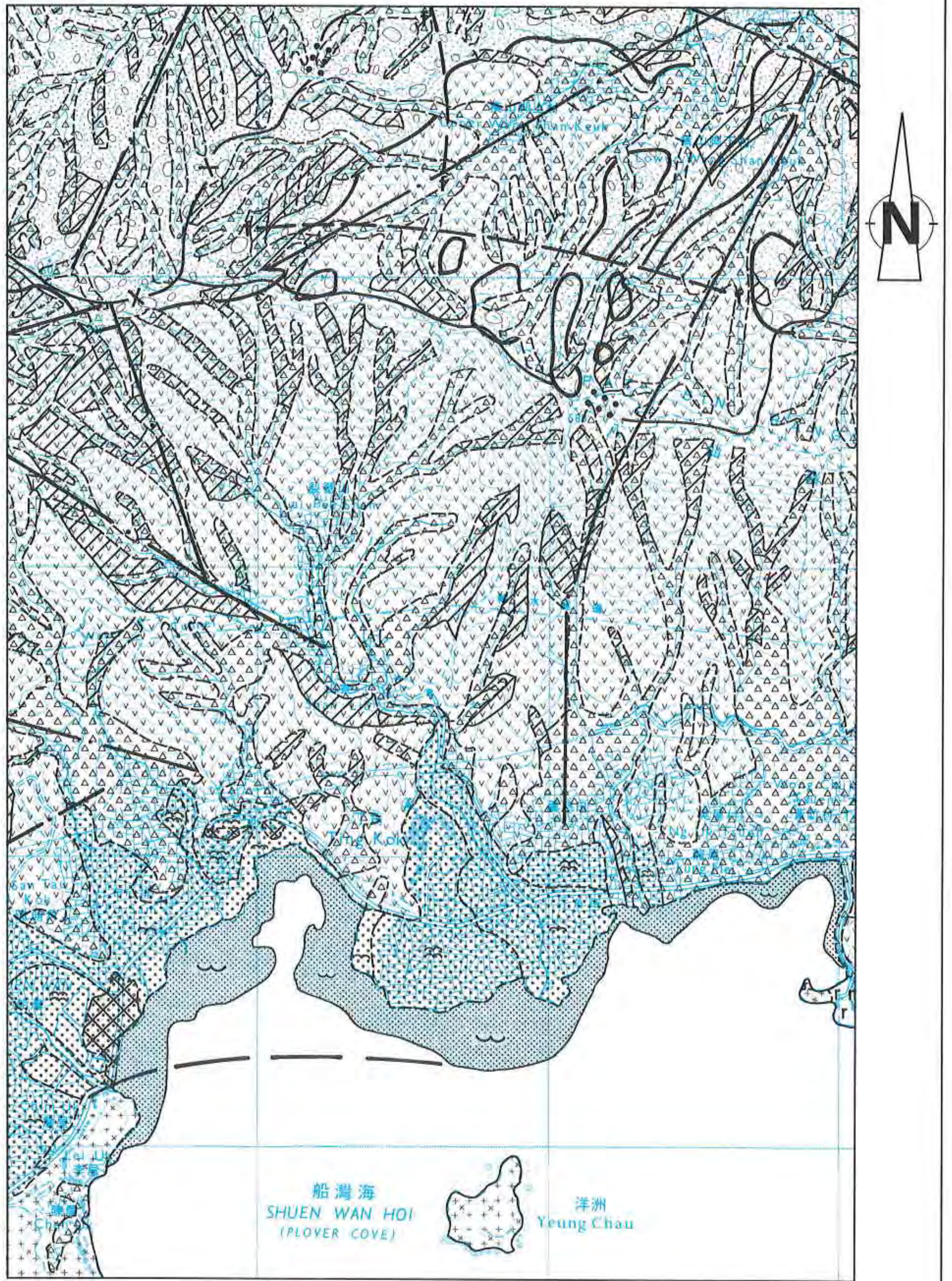
- General instability
- Geological boundary (solid)
- Geological boundary (superficial)
- Geological photolineament
- Fault
- Southern limit of zone of metamorphism
- Thrust (teeth pointing to upper plate)
- Catchment boundary (order indicated by number of dots)
- Major drainage divide

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 17b)

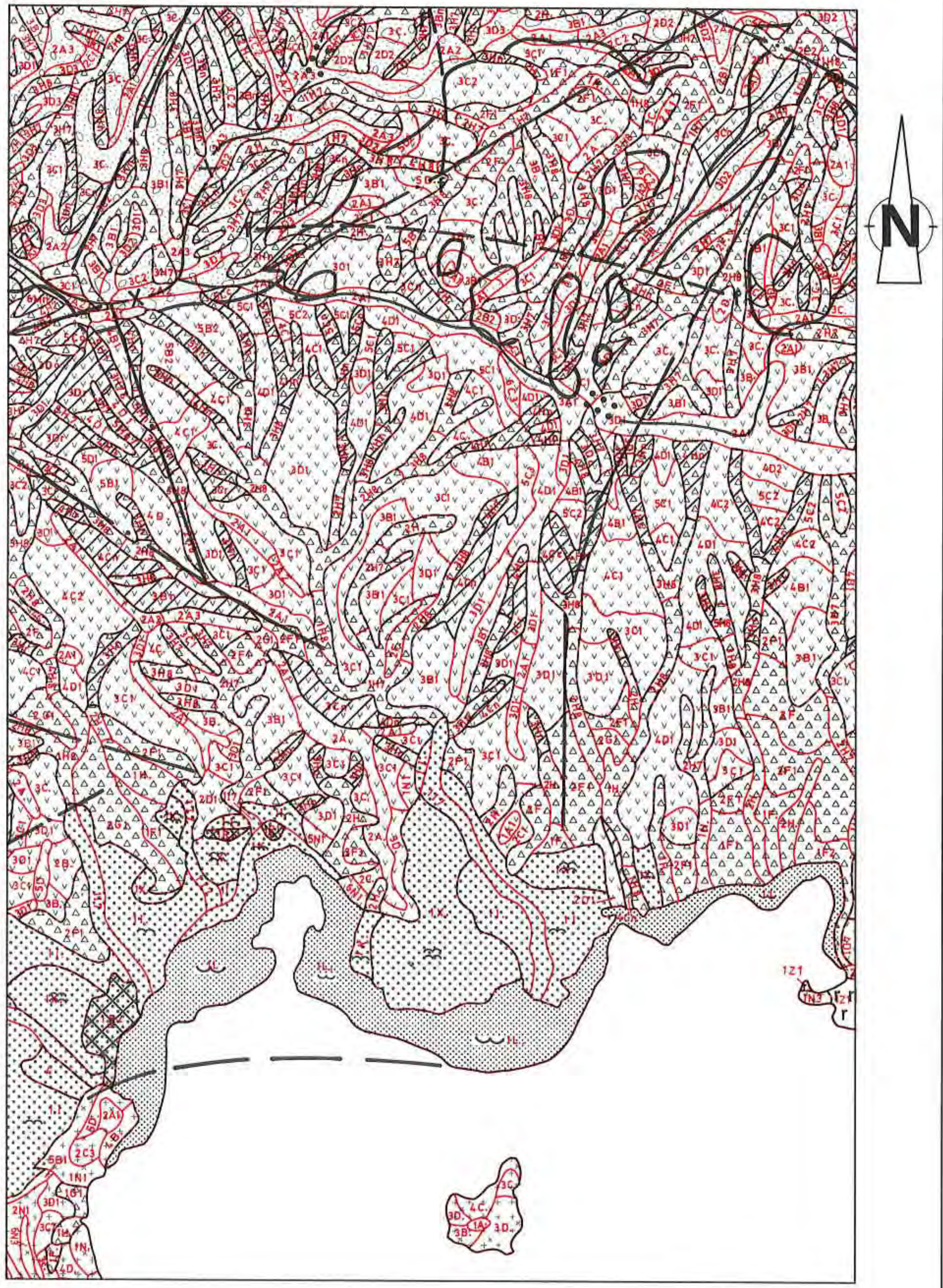
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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
Cliff/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
	- Manmade 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	- integral	- recent	a
		- relict	b
	- scar	- recent	c
		- relict	d
	- debris	- recent	g
		- relict	k
Development of general instability	- integral	- recent	n
		- relict	o
	- scar	- recent	p
		- relict	r
	- debris	- recent	s
		- relict	t
Coastal	- integral		w
	- scar		y
	- debris		z



Scale 1:20 000 | Example of the Engineering Geology Map (EGM) | Fig. 17a



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

LEGEND FOR LANDFORM MAP (Fig. 18a)

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

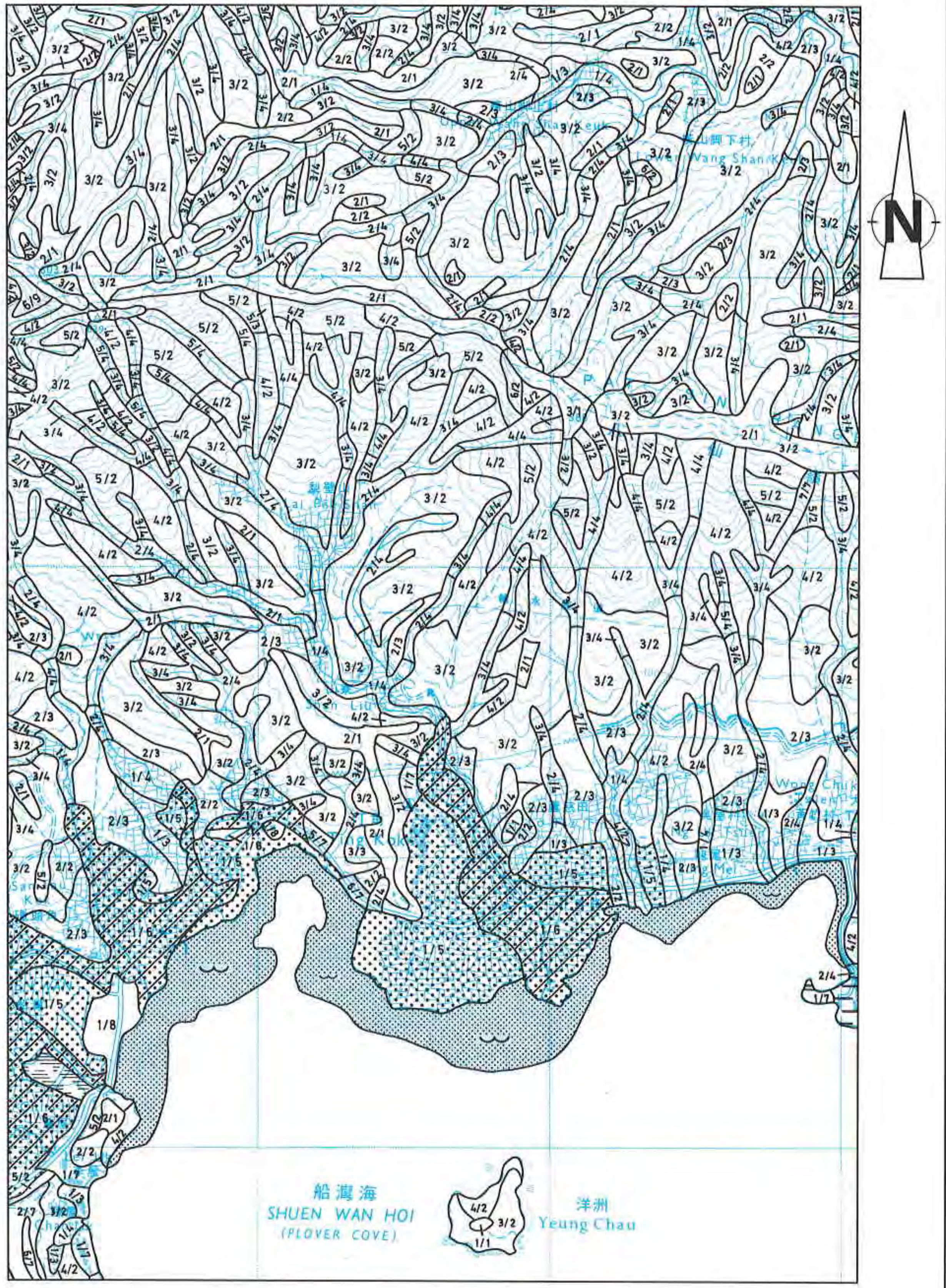
DESCRIPTION	CODE
Crest or ridge	1
Sideslope - insitu	2
Footslope - colluvium	3
Drainage plain - colluvium subject to overland flow and regular inundation. Unusual groundwater regime.	4
Alluvial plain - includes raised terraces.	5
Flood plain - portion of alluvial plain subject to overland flow and regular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

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 18b)

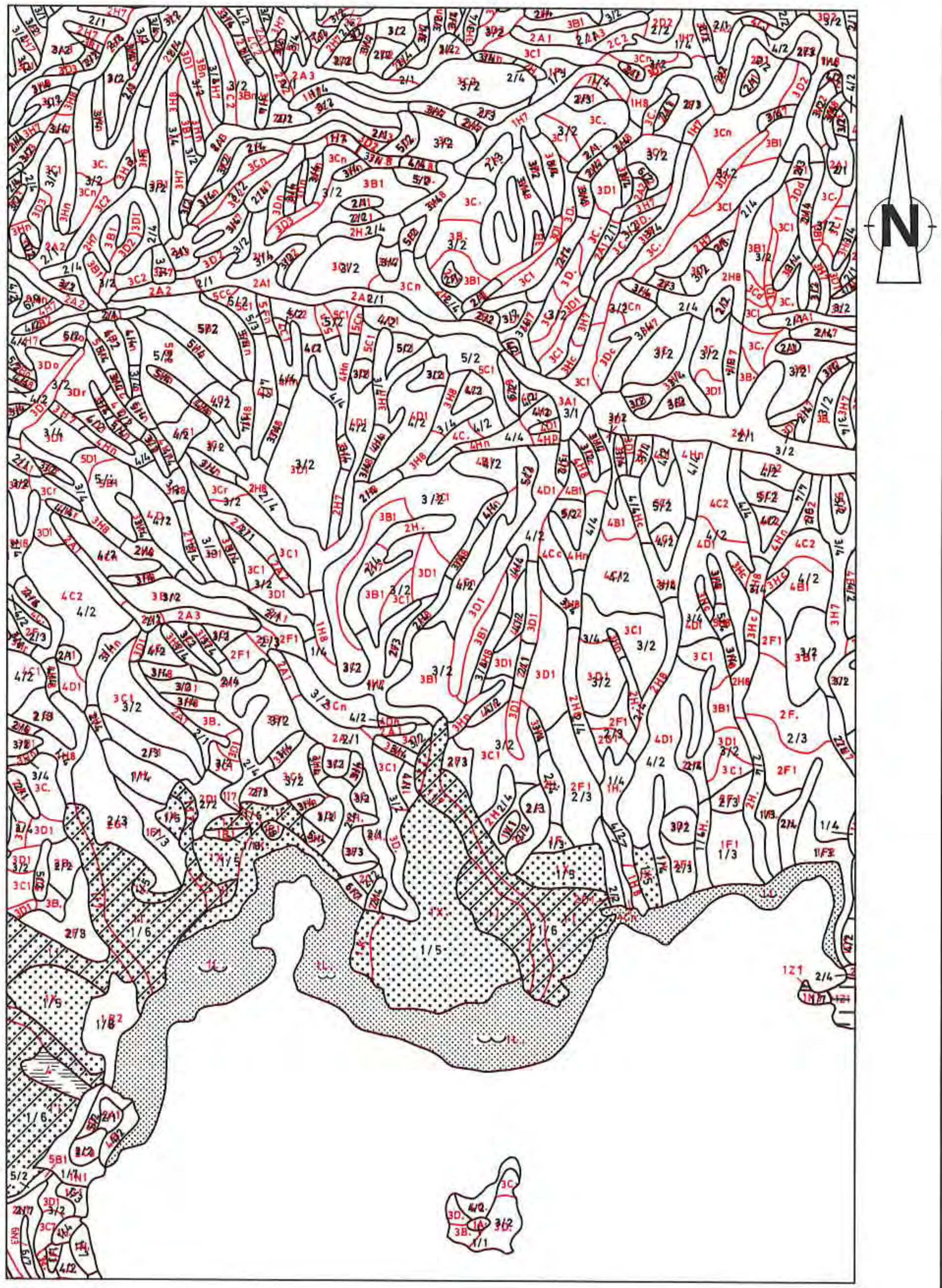
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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
Cliff/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
	- Manmade 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	- integral	- recent	a
		- relict	b
	- scar	- recent	c
		- relict	d
	- debris	- recent	g
		- relict	k
Development of general instability	- integral	- recent	n
		- relict	o
	- scar	- recent	p
		- relict	r
	- debris	- recent	s
		- relict	t
Coastal	- integral		w
	- scar		y
	- debris		z



Scale 1:20 000	Example of the Landform Map (LM)	Fig. 18a



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

LEGEND FOR EROSION MAP (Fig. 19a)

	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)

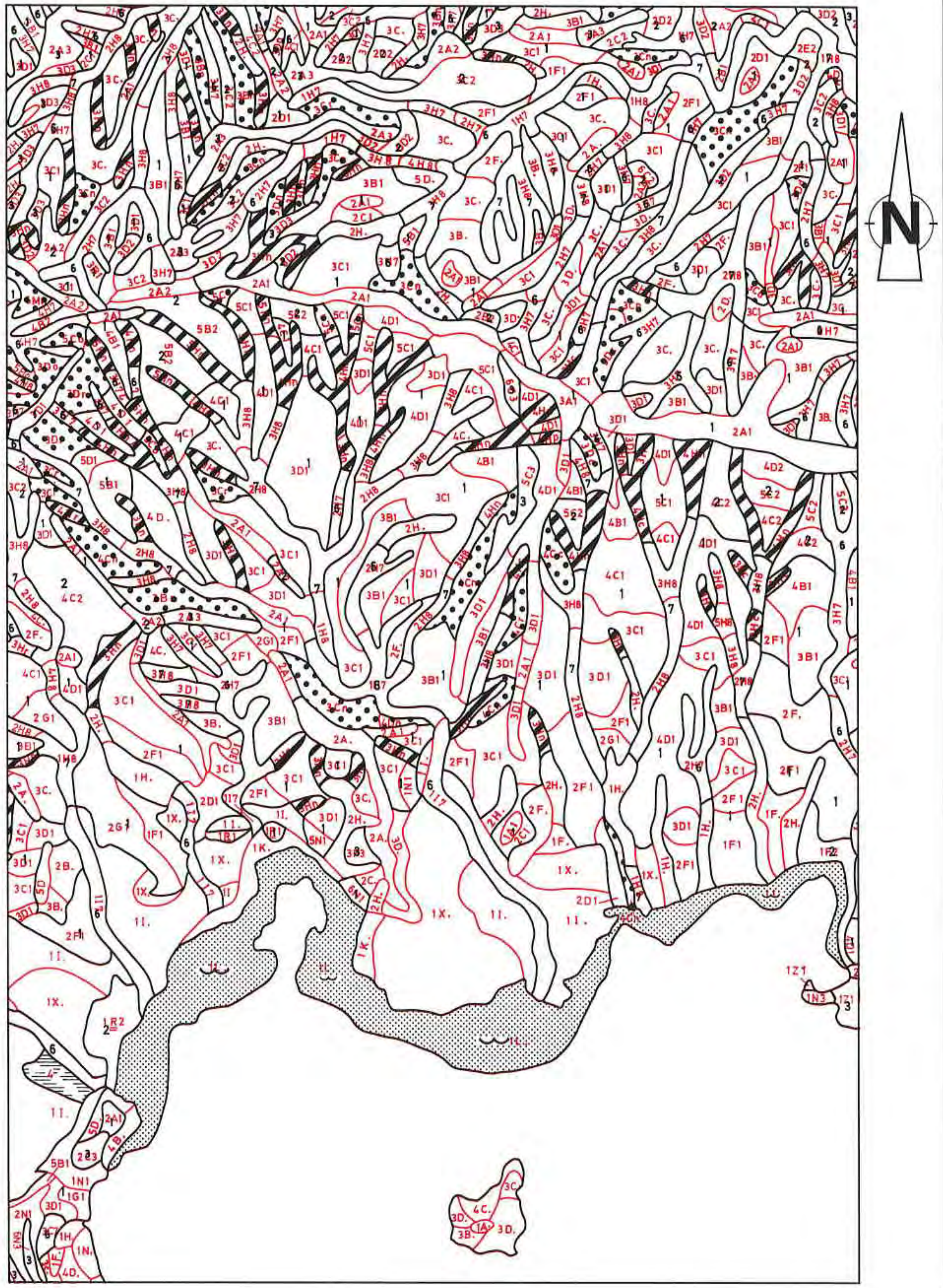
LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 19b)

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
Cliff/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
	- Manmade 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	- integral	- recent	a
		- relict	b
	- scar	- recent	c
		- relict	d
	- debris	- recent	g
		- relict	k
Development of general instability	- integral	- recent	n
		- relict	o
	- scar	- recent	p
		- relict	r
	- debris	- recent	s
		- relict	t
Coastal	- integral		w
	- scar		y
	- debris		z

Scale 1:20 000 | Example of the Erosion Map (EM) | Fig. 19a



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

Plate 1. Low Oblique Aerial Photographs of the Hung Lung Hang Area Looking Northwards from Kwan Tei. In the foreground is part of the alluvial plain of the River Indus and the Tsung Shan range of hills formed of Repulse Bay Formation volcanic rocks. In the central portion of the right hand photograph is part of the River Ganges alluvial plain in the vicinity of Tai Po Tin. (GCO/OAP's 1981/5430 & 5432).

Plate 2. *Low Oblique Aerial Photographs of the Ping Che/Ping Yeung Alluvial Plain.* This plain was formed by the infilling of a previous valley by fluvial deposition of the River Ganges which currently drains northwards through three main tributaries into the Sham Chun River. This area offers considerable potential for development, although it lies in close proximity to the Ta Kwu Ling Border Area, located beyond the low range of hills in the middle background (GCO OAP's 1981/5434 & 5435).

Plate 3. Oblique Aerial Photograph of Sha Tau Kok Looking Northeast from Ma Tsuek Leng. All the hills are formed of Repulse Bay Formation volcanic bedrock. The flat alluvial plains result from the infilling of ancient valleys (GCO/OAP 1981/5439).

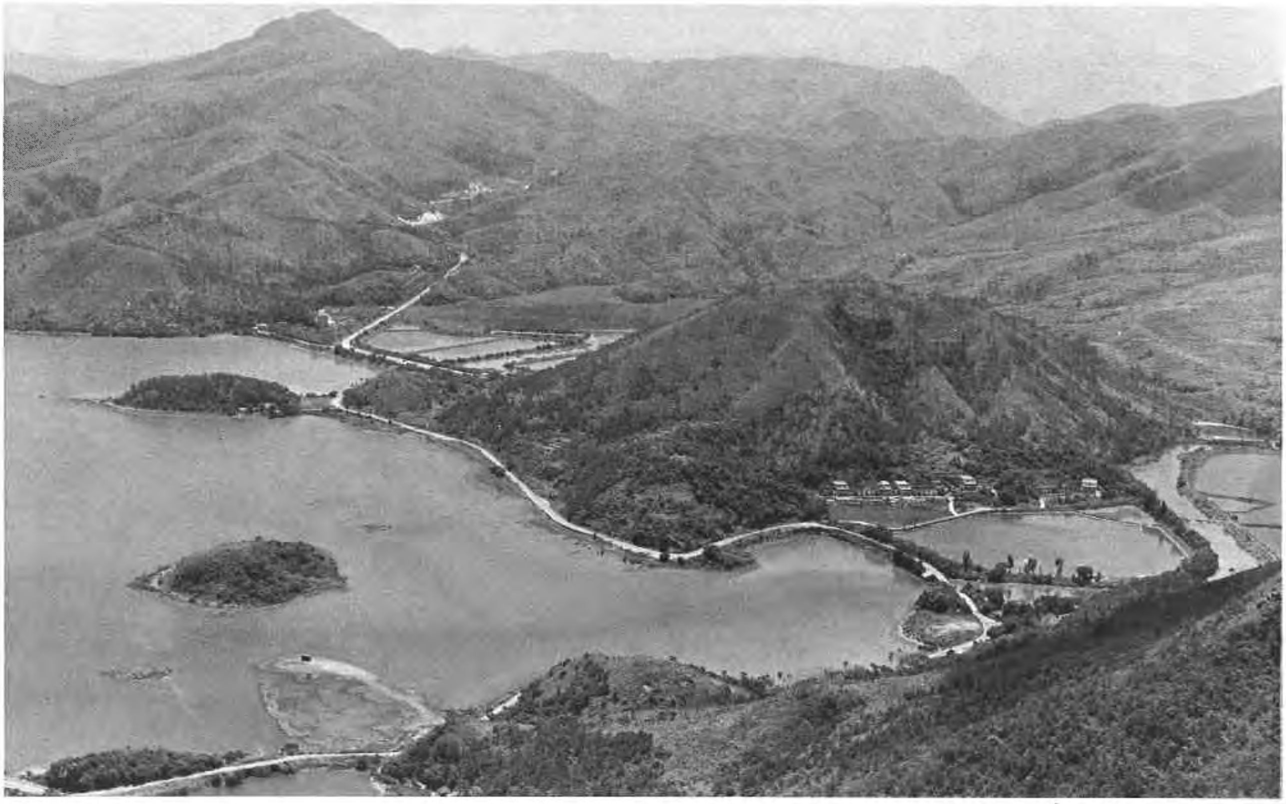


Plate 4. Oblique Aerial Photograph of Nam Chung and Ham Hang Mei Looking East from Wo Hang. The road runs from Nam Chung to Bride's Pool approximately along the line of a thrust fault. The hill in the foreground and the terrain to the left of the road are formed from volcanic rocks. The terrain to the right of the road is composed of sedimentary rocks of the Port Island Formation and is more heavily dissected (GCO/OAP 1981/5417).

Plate 5. Oblique Aerial Photograph from Starling Inlet Looking Southwest along the Valley Containing the Sha Tau Kok Road. In the middle of the photograph are the low hills of the Ma Mei Ha area leading, in the distance, to the broader valley of Kwan Tei, which has considerable potential for development (GCO/OAP 1981/5370).

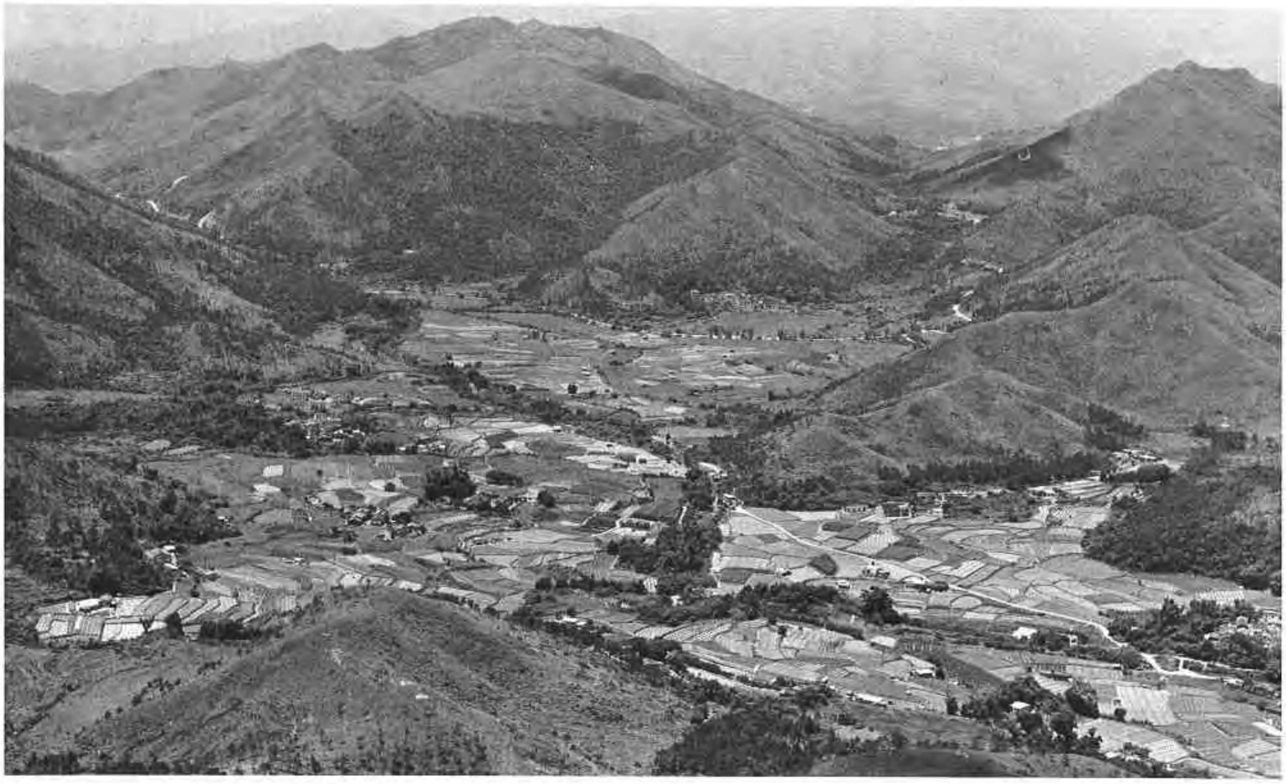


Plate 6. Oblique Aerial Photograph from San Uk Tsai Looking Southwards towards the Hok Tau Reservoir. The small, intensely cultivated, alluvium-filled valley of the River Jhelum is surrounded by hills rising steeply from the valley floor. The sideslopes of the hills are covered with colluvium derived from the tuffs of the Repulse Bay Formation (GCO/OAP 1981/5382).

Plate 7. *View of the Low Dissected Hills and valleys of the Hung Sung Hang Area.* The valley marks the boundary between the sediments of the Lok Ma Chau Formation forming the hills and the Repulse Bay Formation volcanic tuffs in the immediate foreground.

Plate 8. *View of Sandy Ridge Looking Southward between Lo Wu and Man Kam To.* The ridge is formed of argillaceus and arenaceous, regionally metamorphosed sediments of the Lok Ma Chau Formation. These heavily cleaved sediments display a regional northeast dip which, together with severe deep weathering, gives rise to multiple natural hillside landslips,as shown in the photograph.

Plate 9. Well-defined Natural Landslips in Colluvial Materials on the Pat Sin Range. The colluvium is essentially volcanic derived in this locality (GCO/OAP 1981/1324).

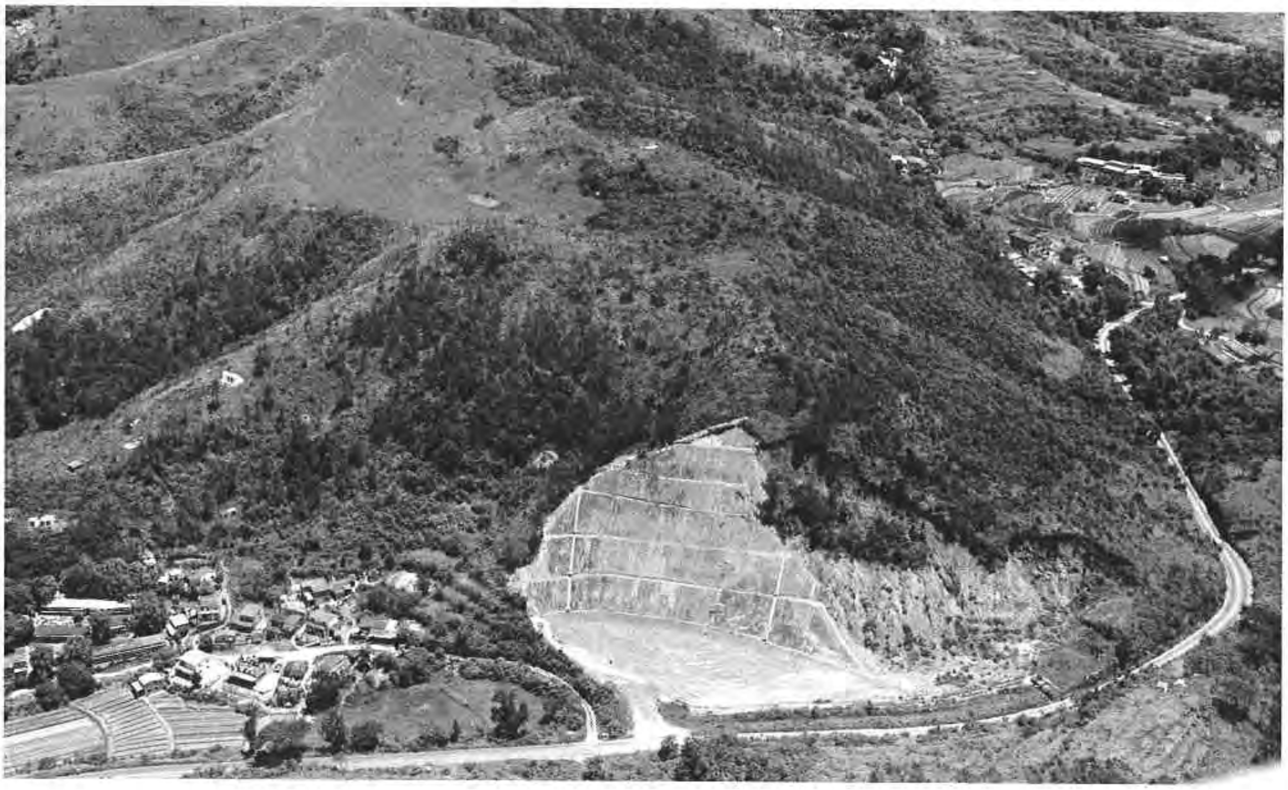


Plate 10. Large-scale Landslip in Weathered Volcanic Tuff of the Repulse Bay Formation. The cut slope lies to the north of the Sha Tau Kok Road at Au Ha at the Four Mile milestone (GCO/OAP 1981/5364).

Plate 11. Phyllites of the Lok Ma Chau Formation Exposed in a Cutting for the Extension of the Lo Wu Railway Station. The phyllites display intense, closely spaced cleavage which dips consistently northeast and results in the highly fractured nature of the rock mass.

Plate 12. Shallow Cleavage and Joint-controlled Wedge and Planar Failures in a Large Cutting on the Lin Ma Hang Road to the North of Muk Wu. The cutting was constructed in steeply inclined phyllites of the Lok Ma Chau Formation.

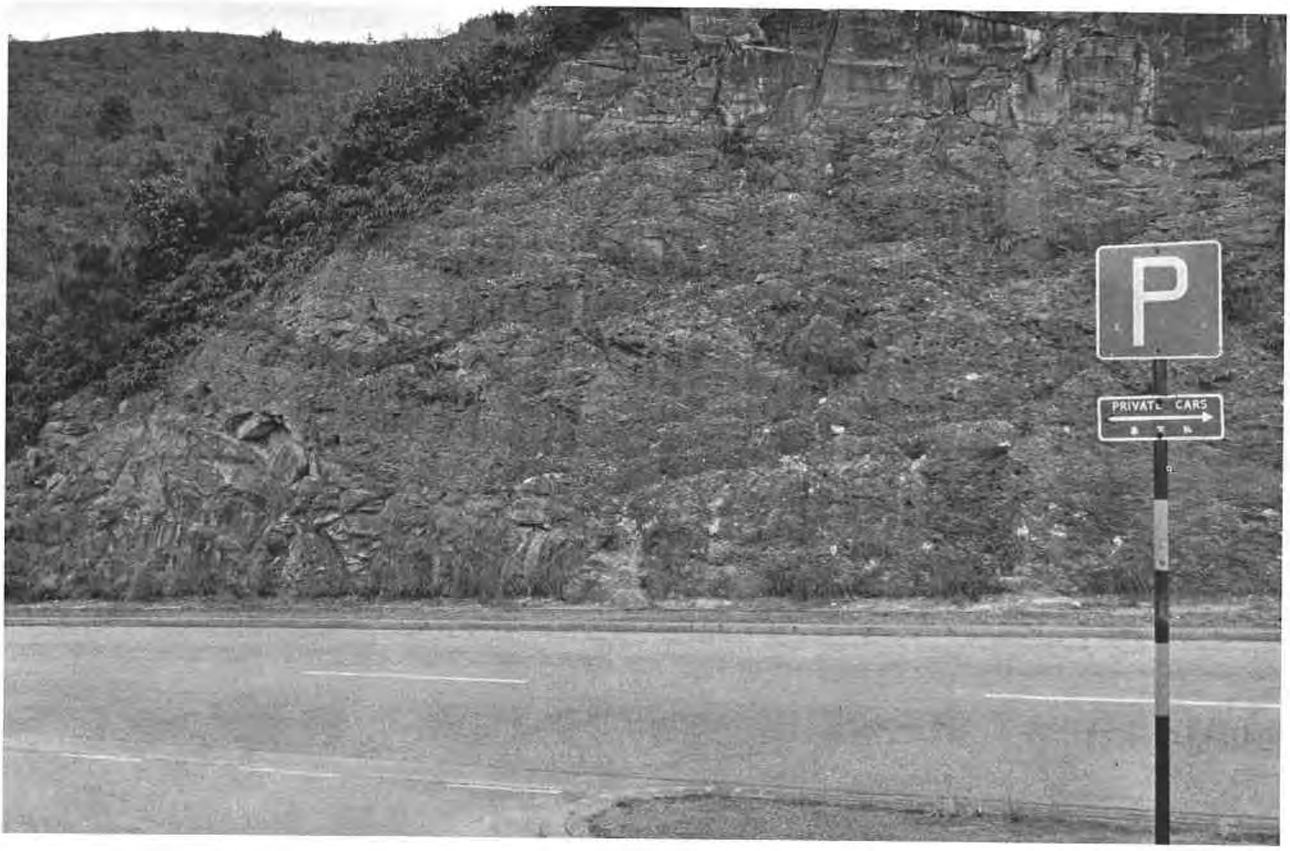


Plate 13. Road Cutting in Rocks of the Port Island Formation at Bride's Pool. Three northward dipping horizons are evident, namely a thick conglomerate lying between two argillaceous sandstone layers.

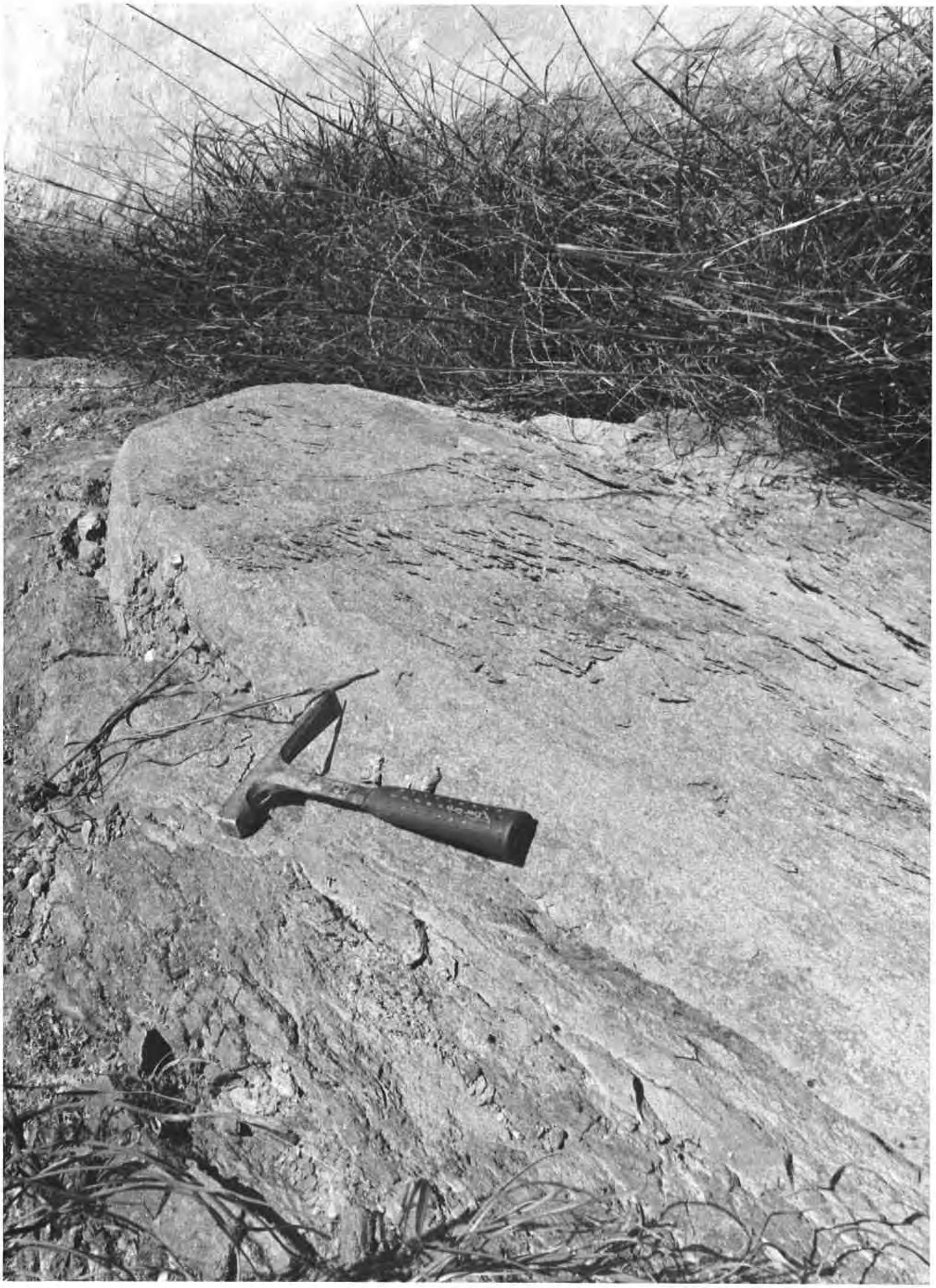


Plate 14. Exposure of Low Grade Metamorphosed Fine Tuff of the Repulse Bay Formation. The rock displays a marked cleavage, which in places imparts a schistosity to these rocks in the northernmost North New Territories.

Plate 15. Vertical Aerial Photographs of Tai Po Showing the Extensive Development between 1967 and 1981. Upper photograph: 1967/4894; lower photograph: 1981/36655 between 1967.

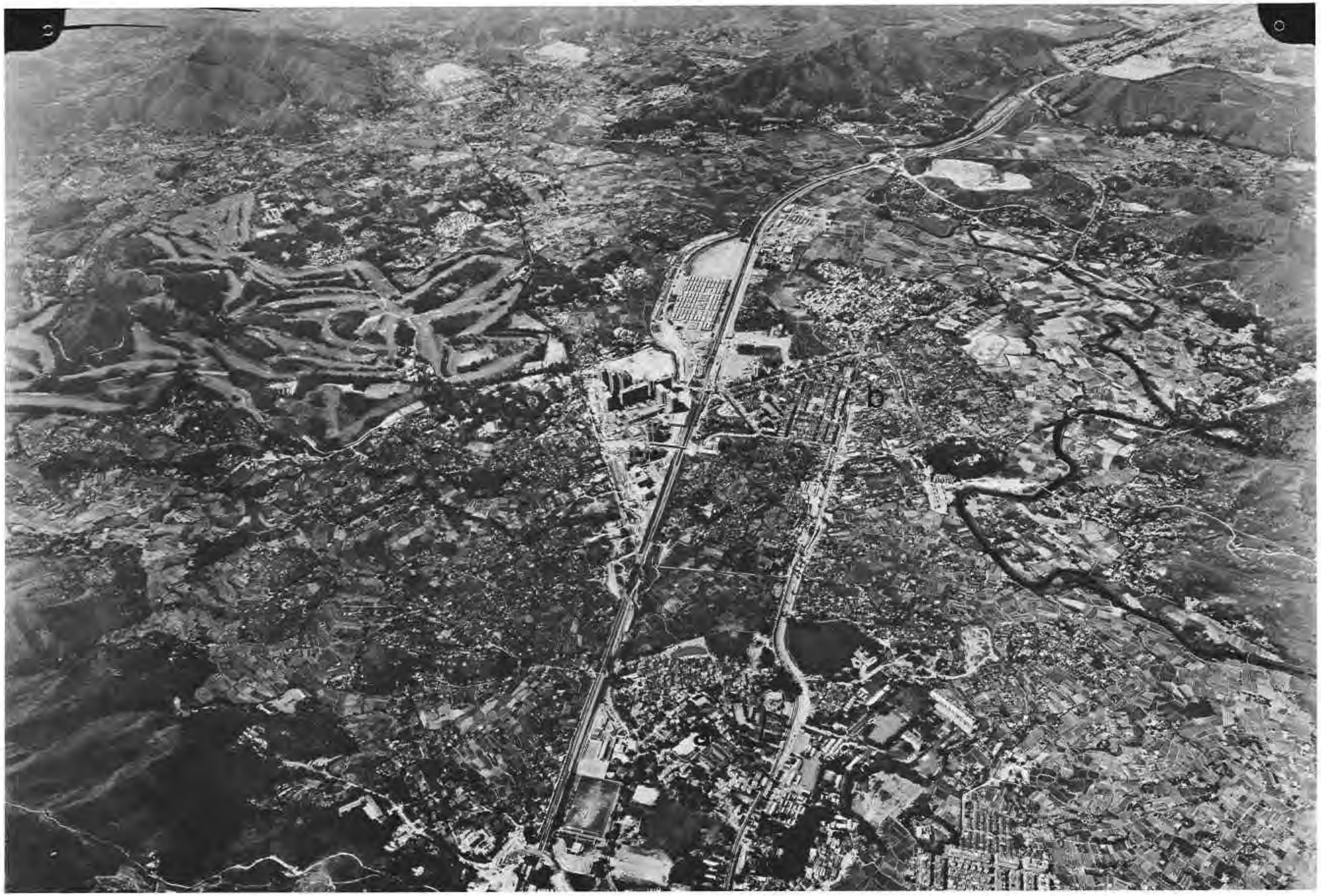


Plate 16. High Oblique Aerial Photograph Looking Northwest from Fanling. The broad alluvial plain contains the Luen Wo Market(a), Sheung Shui(b), the main road and rail communications network and the River Indus (1981/39401).

Plate 17. *High Oblique Aerial Photograph Looking West across Tai Po.* The major areas of recent reclamation and development are shown, as are the communications network, borrow areas D and H(a), the Hong Lok Yuen housing project(b), and the Lam Tsuen Valley(c) (1981/39395).

APPENDIX A

SYSTEM OF TERRAIN EVALUATION AND ASSOCIATED TECHNIQUES

List of Figures

List of Tables

APPENDIX A

SYSTEM OF TERRAIN EVALUATION AND ASSOCIATED TECHNIQUES

A.1 Background

Terrain evaluation involves the identification of landform and terrain related features. This technique is used both to identify land use limitations and to assess in broad terms, overall land use suitability. It is used as a planning tool and has a major application in the field of geotechnical engineering. In this Geotechnical Area Study, a systematic approach is used to collect, characterise and rationalise the natural variations which occur across the terrain. The structure and presentation of the terrain evaluation system used in this Report is illustrated in Figure 13.

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) and the Physical Constraints Map (PCM). 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 14b. The three terrain attributes adopted for the analysis are:

(*a*) Slope gradient.

(*b*) Terrain component and morphology.

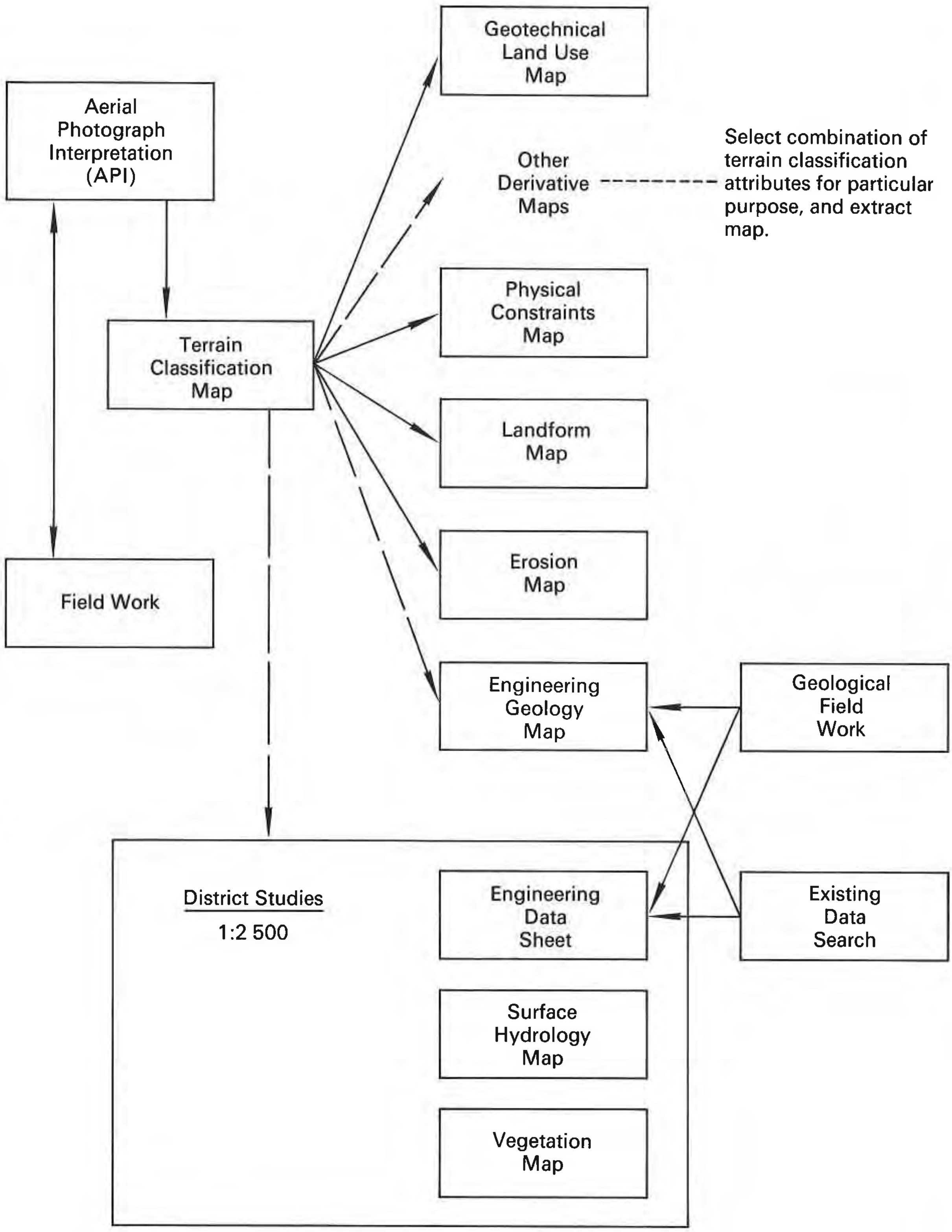
(*c*) Erosion and instability.

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), which is discussed briefly in Sections 1.5.8 and A.10.

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*
0– 5°	1
5–15°	2
15–30°	3
30–40°	4
40–60°	5
>60°	6

Terrain Component		*Code*
Hillcrest 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
Alluvial plain		X
Reclamation		Z
Waterbodies:		
Natural stream		1
Man-made channel		2
Water storage		3
Fish pond		4

Erosion and Instability			*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 recent landslip >1 ha in size	—integral	—recent	a
		—relict	b
	—scar	—recent	c
		—relict	d
	—debris	—recent	g
		—relict	k
Development of general instability	—integral	—recent	n
		—relict	o
	—scar	—recent	p
		—relict	r
	—debris	—recent	s
		—relict	t
Coastal instability	—integral		w
	—scar		y
	—debris		z

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

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 18a) 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 reservoirs), ponds and the littoral zone.

A.5 Erosion Map

The Erosion Map is derived from the Terrain Classification Map and delineates the major forms of erosion within the North 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 19a.

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 to z).

(*j*) General instability associated with colluvial terrain (Codes a to z).

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 16a.

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

The major constraints which are shown on the map are:

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

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

(*c*) Colluvium.

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

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

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

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

(*h*) Major waterbodies.

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 15a. There are four GLUM Classes.

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

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

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

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

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

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

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

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

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

(*c*) The GLUM class system assists in the assessment of the suitability of land for development from a geotechnical point of view. 'Development' is taken to mean high density residential, industrial, institutional and community uses.

(*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.

(*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 0.1 ha, whereas the average area of each map unit at 1:20 000 scale is approximately 2 ha. Therefore, *the GLUM presented in a Regional Study must never be interpreted, reproduced or enlarged to scales larger than 1:20 000.* Failure to heed this warning will result in serious misinterpretation of the GLUM.

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 North 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 (Allen & Stephens, 1971) and information collected during the field reconnaissance. The Engineering Geology Map presents 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 North New Territories GASP is contained in the Map Folder accompanying this Report and an example is located at Figure 17a. 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*) Boundaries of major catchments.

(*d*) Zones of general instability.

(*e*) 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 (including granodiorite) derived.

(*c*) Essentially sedimentary derived.

(*d*) Essentially metasediment derived.

(*e*) Mixed origin.

This classification is applied to the colluvial deposits on the basis of the parent geology as mapped by Allen & Stephens (1971). 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.2 and Table C.1.

A.9 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:

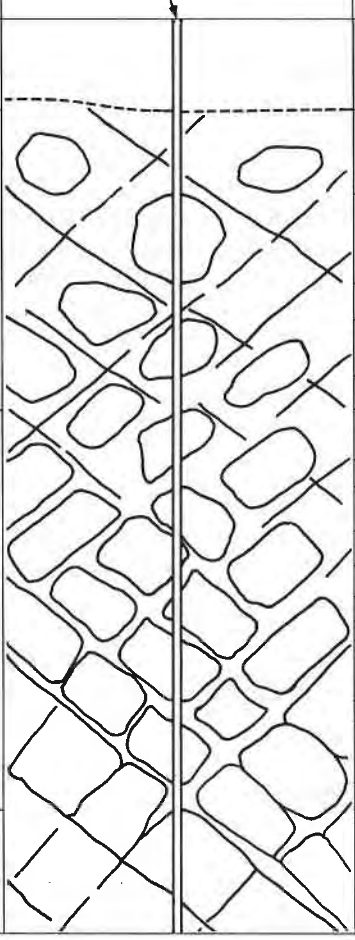
(*a*) The maps are designed for use at a scale of 1:20 000. They should never be enlarged to scales larger than the published scale.

(*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.

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.10 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 V data bank consists of 7 890 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 1.5.8. 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 minimises the errors inherent in this method. Errors are limited to a few percent in total and, in comparison with inaccuracies prevalent in the area measurement of steeply sloping terrain, are considered insignificant.

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

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

(*b*) Single attribute correlations which present the tabulated relationships between one single attribute and another, e.g. slope gradient versus aspect (Tables B4, B8, B11 and B13).

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

APPENDIX B

DATA TABLES FOR THE NORTH NEW TERRITORIES GEOTECHNICAL AREA STUDY

Table B1 Slope Gradient

Slope Gradient	% of Total Area	Area (ha)
0– 5°*	35.0	5 630
5–15°	14.9	2 397
15–30°	32.1	5 168
30–40°	16.6	2 664
40–60°	1.3	214
>60°	0.1	22
	100.0	16 095

* Approximately 261 ha of uncovered reservoirs and ponds are included in the 0–5° Class.

Table B2 Erosion and Instability

	Erosion	% of Total Area	Area (ha)
Instability			
	—well-defined landslips	0.3	41
	—coastal instability	<0.1	2
	—general instability (recent)	12.6	2 034
	—general instability (relict)	4.6	741
Appreciable Erosion	Sheet erosion—minor	19.7	3 168
	—moderate to severe	6.7	1 073
	Rill erosion —minor	<0.1	12
	—moderate to severe	<0.1	10
	Gully erosion—minor	2.6	426
	—moderate to severe	1.9	302
No Appreciable Erosion*		51.5	8 286
		100.0	16 095

* Approximately 357 ha of uncovered reservoirs, ponds and stream channels are included within No Appreciable Erosion.

Table B3 Aspect

Aspect	% of Total Area	Area (ha)
North	7.5	1 212
Northeast	10.5	1 701
East	6.7	1 077
Southeast	11.2	1 801
South	4.5	724
Southwest	8.0	1 287
West	5.0	800
Northwest	11.6	1 863
Flat/Unclassified*	35.0	5 630
	100.0	16 095

* Approximately 261 ha of uncovered reservoirs and ponds are included in the Flat/Unclassified category.

Table B4 Aspect and Slope Gradient

Aspect	Slope Gradient					Total Area (ha)
	5–15°	15–30°	30–40°	40–60°	>60°	
North	218	631	355	8	0	1 212
Northeast	355	856	455	31	4	1 701
East	257	500	298	18	4	1 077
Southeast	410	871	469	49	2	1 801
South	188	351	159	22	4	724
Southwest	318	679	247	41	2	1 287
West	212	378	210	0	0	800
Northwest	439	902	471	45	6	1 863
0–5° (Flat/Unclassified)						5 630
						16 095

Table B5 Landform

Terrain (Landform)	Slope Gradient	% of Total Area	Area (ha)
Hillcrest		3.4	547
Sideslope	0– 5°	0.4	71
"	5–15°	3.8	616
"	15–30°	27.2	4 386
"	30–40°	15.1	2 431
"	>40°	1.2	186
Cliff/Rock outcrop	0–30°	0	0
"	>30°	<0.1	12
Footslope (colluvium)	0– 5°	2.6	412
"	5–15°	4.1	665
"	15–30°	0.4	71
"	30–40°	0.3	43
"	>40°	0	0
Drainage plain (colluvium)	0– 5°	3.5	561
"	5–15°	3.6	584
"	15–30°	3.3	539
"	30–40°	1.1	169
"	>40°	0	0
Alluvial plain	0–15°	7.5	1 202
Floodplain	0– 5°	15.1	2 428
"	>5°	<0.1	2
Littoral zone	0–15°	0.5	75
Cut platforms : insitu	0– 5°	1.0	153
: colluvium	0– 5°	0	0
: alluvium	0– 5°	0	0
Cut slopes : insitu	>5°	1.4	222
: colluvium	>5°	0	0
: alluvium	>5°	0	0
Fill platforms : insitu	0– 5°	0.1	20
: colluvium	0– 5°	0	0
: alluvium	0– 5°	0.2	33
Fill slopes : insitu	>5°	0.1	16
: colluvium	>5°	<0.1	6
: alluvium	>5°	0	0
Reclamation	0–30°	1.8	286
General disturbed terrain/platforms: insitu	0– 5°	0	0
: colluvium	0– 5°	0	0
: alluvium	0– 5°	0	0
General disturbed terrain/slope: insitu	>5°	<0.1	2
: colluvium	>5°	0	0
: alluvium	>5°	0	0
Natural stream		0.6	96
Man-made channel		0	0
Water storage		<0.1	6
Ponds		1.6	255
		100.0	

Table B6 Geology

Geological Unit	% of Total Area	Area (ha)
Reclamation	1.8	286
Fill	0.5	77
Alluvium:		
—undifferentiated	17.4	2 795
—raised terraces	7.4	1 193
Colluvium:		
—volcanic	13.6	2 185
—granitic (including granodioritic)	0.5	88
—sedimentary	1.4	224
—metasedimentary	1.1	184
—mixed	2.3	363
Littoral deposits	0.5	75
Repulse Bay Formation: undifferentiated volcanic rocks	0.1	16
: sedimentary rocks and water-laid volcaniclastic rocks	1.0	155
: coarse tuff	2.8	455
: dominantly pyroclastic rocks with some lavas	38.5	6 201
Port Island Formation	5.6	906
Lok Ma Chau Formation	2.4	384
Bluff Head Formation	0.3	47
Tolo Harbour Formation	<0.1	4
Tai Po Granodiorite	2.8	457
	100.0	16 095

Approximately 6 ha of uncovered reservoirs have been categorised as possessing alluvial deposits.

Table B7 Vegetation

Vegetation	% of Total Area	Area (ha)
Grassland	13.2	2 134
Cultivation	17.6	2 833
Mixed broadleaf woodland	22.1	3 552
Shrubland (<50%)	13.0	2 087
Shrubland (>50%)	19.0	3 052
No vegetation on natural terrain	0.5	75
No vegetation due to disturbance of terrain by man*	12.4	1 993
No vegetation due to rock outcrop	<0.1	12
Waterbodies	2.2	357
	100.0	16 095

Table B8 Geology and GLUM Class

Geological Unit	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Reclamation	0	284	2	0	0
Fill	0	65	12	0	0
Alluvium:					
—undifferentiated	0	2 438	0	0	357
—raised terraces	0	1 193	0	0	0
Colluvium:					
—volcanic	0	287	1 255	643	0
—granitic (including granodioritic)	0	19	63	6	0
—sedimentary	0	4	179	41	0
—metasedimentary	0	14	125	45	0
—mixed	0	88	220	55	0
Littoral deposits	0	0	0	0	75
Repulse Bay Formation: undifferentiated volcanic rocks	4	8	4	0	0
: sedimentary rocks and water-laid volcaniclastic rocks	2	41	61	51	0
: coarse tuffs	67	117	186	85	0
: dominantly pyroclastic rocks with some lavas	612	2 719	2 058	812	0
Port Island Formation	80	532	265	29	0
Lok Ma Chau Formation	75	135	131	43	0
Bluff Head Formation	0	6	23	18	0
Tolo Harbour Formation	0	0	2	2	0
Tai Po Granodiorite	49	127	218	63	0
	889	8 077	4 804	1 893	432

Table B9 GLUM Class

GLUM Class	% of Total Area	Area (ha)
I	5.5	889
II	35.1	5 647
IIS	15.1	2 430
III	29.8	4 804
IV	11.8	1 893
Unclassified	2.7	432
	100.0	16 095

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

Slope Gradient	Aspect	Surface* Geology	No Appreciable Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Area (ha)	Area Instability Index
				Sheet	Rill	Gully	WDL	GI		
0–5°	Flat	V	129	73	2	0	0	0	204	0
		G	24	6	0	0	0	0	30	0
		S	6	29	0	0	0	0	35	0
		C	779	108	4	82	0	0	973	0
		A	3 976	2	0	0	0	0	3 978	0
		L	73	0	0	0	0	0	73	0
		F	159	177	0	0	0	0	336	0
5–15°	N	V	20	41	0	0	0	0	61	0
		G	0	0	0	0	0	0	0	0
		S	0	29	0	0	0	0	29	0
		C	80	22	0	27	0	0	129	0
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	NE	V	49	82	0	2	0	0	133	0
		G	0	2	0	0	0	0	2	0
		S	2	37	0	0	0	0	39	0
		C	82	41	0	55	0	0	178	0
		A	0	2	0	0	0	0	2	0
		F	2	0	0	0	0	0	2	0
	E	V	49	55	0	0	0	0	104	0
		G	0	2	0	0	0	0	2	0
		S	4	18	0	0	0	0	22	0
		C	53	41	0	33	0	0	127	0
		A	2	0	0	0	0	0	2	0
		F	0	0	0	0	0	0	0	0
	SE	V	39	80	0	0	0	0	119	0
		G	6	0	0	0	0	0	6	0
		S	8	33	0	0	0	0	41	0
		C	73	114	0	55	0	0	242	0
		A	2	0	0	0	0	0	2	0
		F	0	0	0	0	0	0	0	0
	S	V	10	49	0	0	0	0	59	0
		G	6	0	0	0	0	0	6	0
		S	6	8	0	0	0	0	14	0
		C	41	43	0	20	0	4	104	0
		A	2	0	0	0	0	0	2	0
		F	2	0	0	0	0	0	2	0
	SW	V	43	88	0	0	0	0	131	0
		G	2	2	0	2	0	0	6	0
		S	4	29	0	0	0	0	33	0
		C	53	61	0	33	0	0	147	0
		A	2	0	0	0	0	0	2	0
		F	0	0	0	0	0	0	0	0
	W	V	33	69	0	0	0	0	102	0
		G	0	2	0	0	0	0	2	0
		S	0	14	0	0	0	0	14	0
		C	43	41	0	10	0	0	94	0
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	NW	V	53	90	0	0	0	0	143	0
		G	0	0	0	0	0	0	0	0
		S	8	49	0	0	0	0	57	0
		C	118	63	0	47	0	0	228	0
		A	0	2	0	0	0	0	2	0
		F	0	8	0	0	0	0	8	0
15–30°	N	V	112	135	0	2	0	120	369	0.36
		G	20	0	0	0	0	0	20	0
		S	18	73	0	0	0	73	164	0.45
		C	6	10	0	27	0	33	76	0.43
		F	0	0	0	0	0	0	0	0
	NE	V	155	169	2	4	2	159	491	0.33
		G	12	6	0	0	0	0	18	0
		S	29	120	0	2	0	78	229	0.34
		C	8	4	0	47	0	53	112	0.47
		F	6	0	0	0	0	0	6	0
	E	V	126	173	0	0	0	69	368	0.19
		G	18	0	0	2	0	0	20	0
		S	12	31	0	2	0	24	69	0.35
		C	6	0	0	16	0	18	40	0.45
		F	0	0	0	0	0	0	0	0
	SE	V	173	294	2	4	2	163	638	0.26
		G	22	6	0	0	0	0	28	0
		S	12	45	0	0	2	29	88	0.35
		C	10	2	0	61	0	43	116	0.37
		F	0	0	0	0	0	0	0	0
	S	V	67	161	0	0	2	71	301	0.24
		G	4	4	0	0	0	0	8	0
		S	2	14	0	0	0	0	16	0
		C	0	2	0	14	0	0	16	0
		F	0	0	0	0	0	0	0	0
	SW	V	88	316	2	2	2	126	536	0.24
		G	8	2	0	0	0	0	10	0
		S	16	24	0	0	0	14	54	0.26
		C	8	2	0	29	0	33	72	0.46
		F	4	2	0	0	0	0	6	0
	W	V	82	167	0	0	0	57	306	0.19
		G	4	0	0	0	0	0	4	0
		S	4	14	0	0	0	8	26	0.31
		C	0	6	0	16	0	16	38	0.42
		F	0	2	0	0	0	0	2	0
	NW	V	118	167	0	2	0	292	579	0.50
		G	10	0	0	0	0	0	10	0
		S	24	100	0	0	0	57	181	0.31
		C	6	2	0	45	0	78	131	0.60
		F	0	0	0	0	0	0	0	0

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	106	18	0	0	4	116	244	0.49
		G	43	2	0	0	0	10	55	0.19
		S	4	4	0	0	0	4	12	0.33
		C	4	0	0	2	0	37	43	0.86
	NE	V	151	22	4	2	6	145	330	0.46
		G	43	2	0	0	0	10	55	0.19
		S	22	4	0	4	0	6	36	0.17
		C	6	0	0	0	0	27	33	0.82
	E	V	100	39	2	6	2	82	231	0.36
		G	20	2	0	0	0	10	32	0.31
		S	4	2	0	0	4	4	14	0.57
		C	2	0	0	6	0	12	20	0.60
	SE	V	116	86	0	16	0	153	371	0.41
		G	20	0	0	0	0	6	26	0.23
		S	10	10	0	0	4	6	30	0.33
		C	2	2	0	18	0	18	40	0.45
	S	V	35	61	0	2	0	33	131	0.25
		G	4	0	0	0	0	0	4	0
		S	6	4	0	0	0	2	12	0.17
		C	2	0	0	4	0	6	12	0.50
	SW	V	20	112	0	4	0	53	189	0.28
		G	12	0	0	0	0	2	14	0.14
		S	8	4	0	0	4	2	18	0.33
		C	2	0	0	4	0	18	24	0.75
	W	V	24	61	0	2	0	67	154	0.44
		G	18	2	0	2	0	10	32	0.31
		S	8	4	0	0	0	4	16	0.25
		C	0	0	0	6	0	0	6	0
	NW	V	133	39	0	0	2	159	333	0.48
		G	31	2	0	0	0	12	45	0.27
		S	22	8	0	0	2	29	61	0.51
		C	8	0	0	8	0	16	32	0.50
>40°	N	V	2	0	0	0	0	6	8	0.75
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
	NE	V	12	4	0	0	0	14	30	0.47
		G	2	2	0	0	0	0	4	0
		S	0	0	0	0	0	0	0	0
	E	V	6	6	0	0	2	4	18	0.33
		G	0	0	0	0	0	0	0	0
		S	0	4	0	0	0	0	4	0
	SE	V	4	24	0	0	0	14	42	0.33
		G	2	2	0	0	0	0	4	0
		S	0	2	0	0	0	2	4	0.50
	S	V	6	14	0	0	0	0	20	0
		G	2	0	2	0	0	0	4	0
		S	0	0	0	0	0	2	2	1.00
	SW	V	6	16	0	0	0	6	28	0.21
		G	2	0	2	0	0	0	4	0
		S	0	4	0	0	0	6	10	0.60
	W	V	0	0	0	0	0	0	0	0
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
	NW	V	12	2	0	0	2	31	47	0.70
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	2	2	1.00

*Note: V=volcanic rocks G=granitic rocks C=colluvium
A=alluvium L=littoral deposits F=fill and reclamation
S=sedimentary and metasedimentary rocks
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	126	159	0	0	0	0	285	0
Fill	47	31	0	0	0	0	78	0
Alluvium:								
—undifferentiated	2 789	6	0	0	0	0	2 795	0
—raised terraces	1 193	0	0	0	0	0	1 193	0
Colluvium:								
—volcanic	946	410	4	496	0	328	2 184	0.15
—granitic (including granodioritic)	82	0	0	0	0	6	88	0.07
—sedimentary	57	37	0	116	0	14	224	0.06
—metasedimentary	65	65	0	20	0	33	183	0.18
—mixed	243	53	0	33	0	35	364	0.10
Littoral deposits	75	0	0	0	0	0	75	0
Repulse Bay Formation:								
—undifferentiated volcanic rocks	4	10	0	0	0	2	16	0.13
—sedimentary rocks and water-laid volcaniclastic rocks	33	37	0	0	0	86	156	0.55
—coarse tuff	328	31	4	8	4	80	455	0.18
—dominantly pyroclastic rocks with some lavas	1 716	2 637	10	41	22	1 775	6 201	0.29
Port Island Formation	78	579	0	2	0	247	906	0.27
Lok Ma Chau Formation	137	139	0	4	8	96	384	0.27
Bluff Head Formation	27	0	0	2	6	12	47	0.38
Tolo Harbour Formation	2	0	0	0	2	0	4	0.5
Tai Po Granodiorite	339	47	4	6	0	61	457	0.13

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	33	Quarries – borrow	114
Private development	61	Cemetery	169
2 Storey development	101	Horticulture	2 345
1 Storey development	61	Fish farming	255
Temporary resettlement area	31	Poultry or pigs	24
Intermixed	6	Undefined agriculture	495
Industrial	33	Undisturbed areas	6 838
Commercial	4	Country park	3 837
Commercial/residential	8	Water storage	6
Park	6	Natural stream	96
Sports complex	18	Squatters – low intensity	228
Golf course	163	Squatters – medium intensity	347
School	6	Squatters – high intensity	161
Police/fire station	22	Construction	219
Railway	12	Reclamation	41
Roads	43	Temporary land use	98
Sewerage works	22	Artificial slopes	58
Military	134		
		Total	16 095

Table B13 Existing Land Use and GLUM Class

Existing Land Use	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Government housing estate	0	33	0	0	0
Private development	4	57	0	0	0
2 Storey development	22	59	20	0	0
1 Storey development	14	35	12	0	0
Temporary resettlement area	0	31	0	0	0
Intermixed	0	6	0	0	0
Industrial	0	33	0	0	0
Commercial	2	2	0	0	0
Commercial/residential	0	8	0	0	0
Park	0	6	0	0	0
Sports complex	0	18	0	0	0
Golf course	25	114	20	4	0
School	4	2	0	0	0
Police/fire station	2	20	0	0	0
Railway	6	4	2	0	0
Roads	12	31	0	0	0
Sewerage works	4	18	0	0	0
Military	21	72	31	10	0
Quarries – borrow	57	39	18	0	0
Oil storage	0	0	0	0	0
Power station	0	0	0	0	0
Cemetery	4	141	16	8	0
Horticulture	37	2 077	229	2	0
Fish Farming	0	0	0	0	255
Poultry or pigs	4	16	4	0	0
Undefined agriculture	10	365	112	8	0
Undisturbed areas	394	2 405	2 683	1 281	75
Country park	165	1 650	1 457	565	0
Water storage	0	0	0	0	6
Natural stream	0	0	0	0	96
Squatters – low intensity	16	149	63	0	0
Squatters – medium intensity	37	251	59	0	0
Squatters – high intensity	14	118	29	0	0
Construction	31	178	10	0	0
Reclamation	0	39	2	0	0
Temporary land use	4	94	0	0	0
Artificial slopes	0	6	37	15	0
Total	889	8 077	4 804	1 893	432

APPENDIX C

SUPPLEMENTARY INFORMATION

List of Figures

List of Tables

APPENDIX C

SUPPLEMENTARY INFORMATION

C.1 Site Investigation Data

Numerous site investigations have been conducted both onshore and offshore, by the public and private sectors. Many reports are held by the Geotechnical Information Unit (GIU) operated by the Geotechnical Control Office. Some of these reports are available to the public in the Civil Engineering Library.

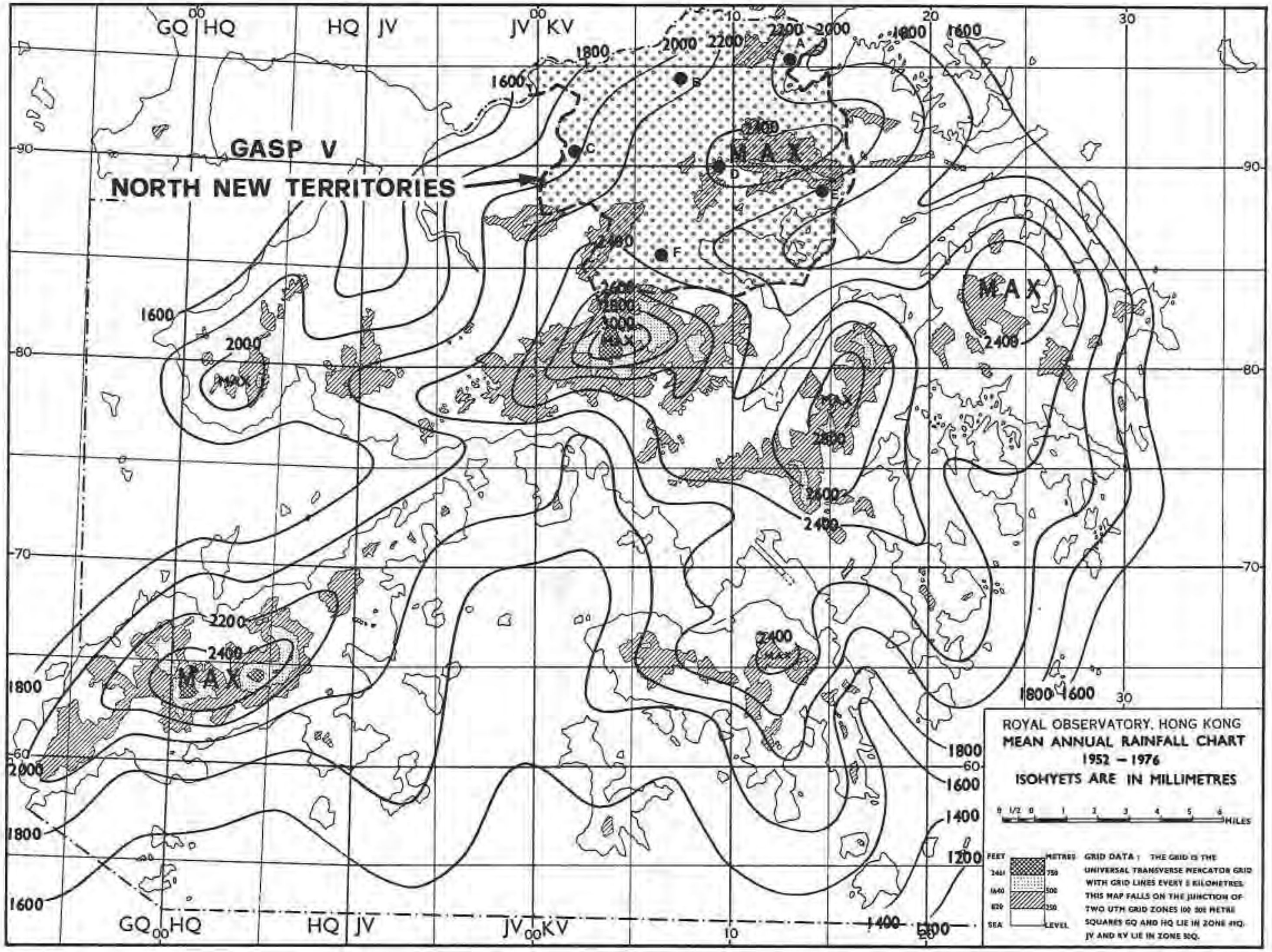
The Geotechnical Control Office GIU Report entry and retrieval system is based on a master grid marked on reference sheets. Each grid block is provided with an index card listing all the reports held within that individual grid block.

C.2 Aerial Photographs

The North 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 Photographic Library of the Survey & Mapping Office, Building & Lands Department. An abbreviated list of photographs is presented in Table C1.

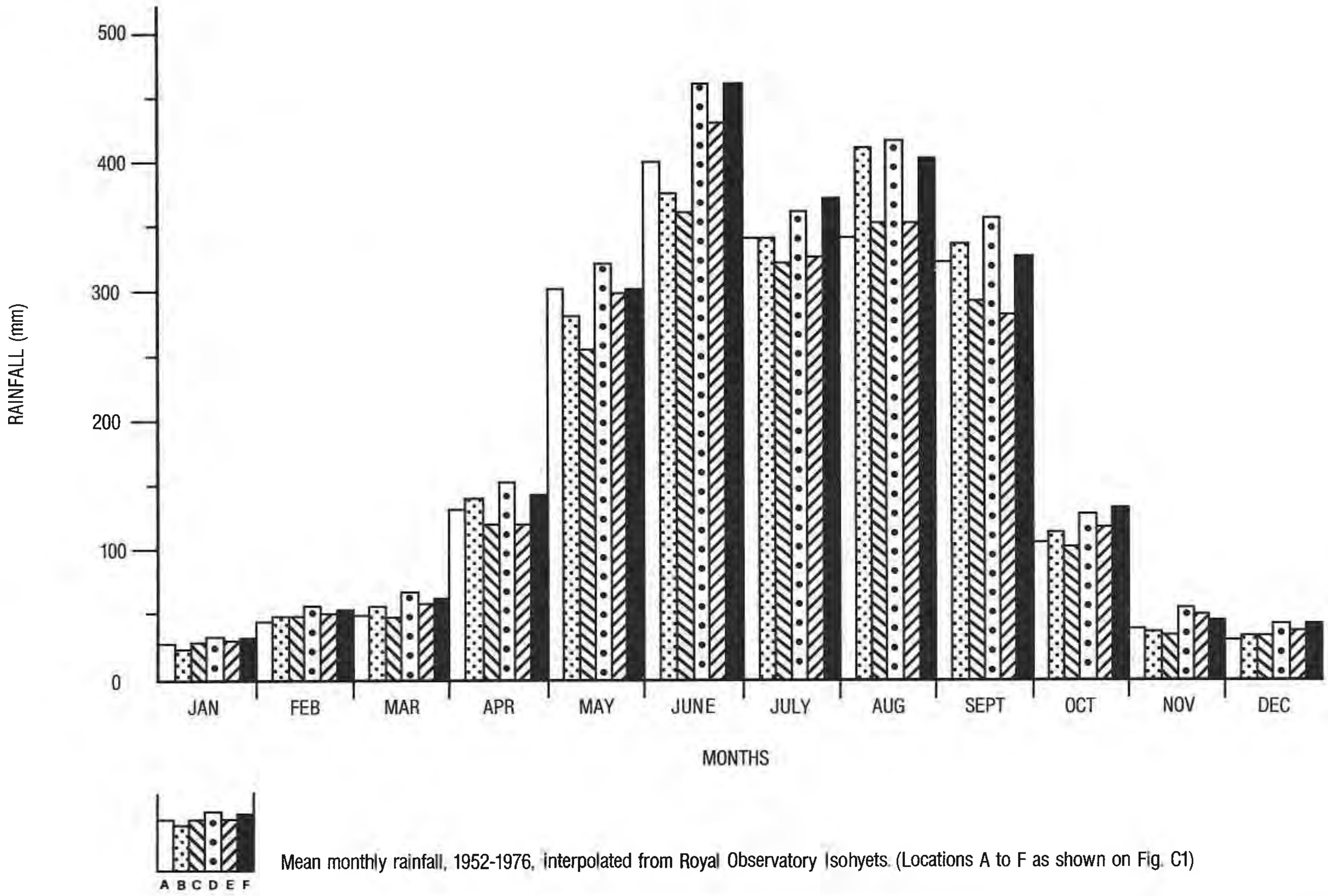
C.3 Rainfall Data Relevant to the North New Territories Study Area

A general appreciation of the annual and monthly rainfall distributions for the North New Territories can be obtained from Figures C1 and C2. Figure C1 is a reproduction of the mean annual rainfall isohyets for the years 1952 to 1976, published by the Royal Observatory. Figure C2 is a histogram of monthly rainfall for four selected Royal Observatory rainfall stations. There a total of 17 rainfall stations within the study area the locations of which are indicated on Figure C3. Detailed monthly and annual rainfall information for these stations is available from the Royal Observatory.



Mean Annual Rainfall Isohyets (1952–1976)

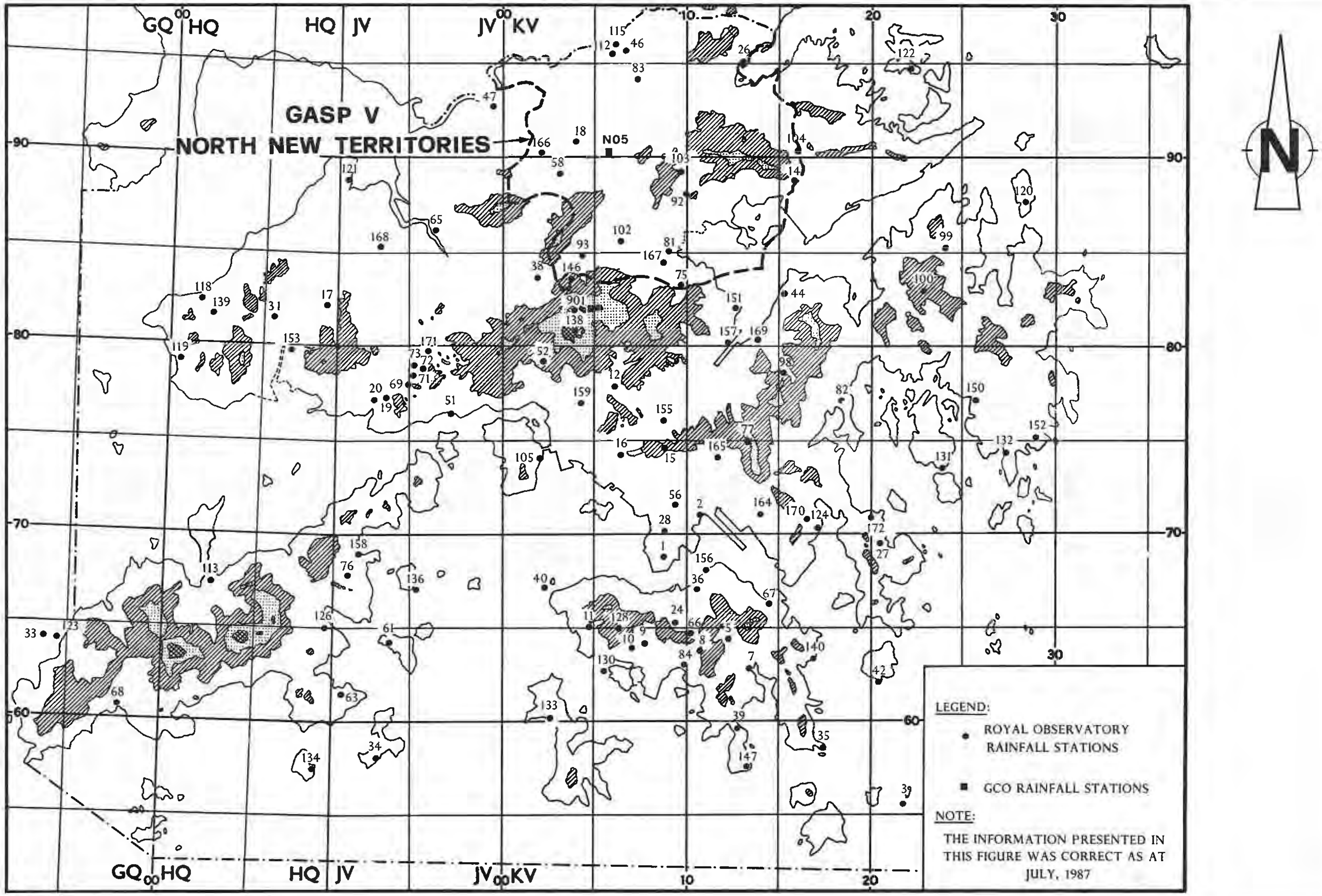
Fig C1



Mean monthly rainfall, 1952-1976, interpolated from Royal Observatory Isohyets. (Locations A to F as shown on Fig. C1)

Summary of Mean Monthly Rainfall Data

Fig. C2



Locations of Rainfall Stations

Fig. C3

Table C1 Selection of Aerial Photographs

Year	Photograph Serial Number	Photograph Scale (Approx.)
1981	38133–38140	1:20 000
	38089–38094*	1:20 000
	38053–38074	1:20 000
	38035	1:20 000
	38009–38021*	1:20 000
	37984–37994	1:20 000
1980	37201–37324	1:8 000
1979	37182–37188	1:8 000
	36336–36347	1:8 000
1980	30374–30364	1:8 000
	32309–32345	1:8 000
	32289–32279	1:8 000
	31904–31911	1:8 000
	33031–33014	1:8 000
	29097–29086	1:6 000
	32092–32101	1:6 000
	29603–29585	1:4 000
	30162–30149	1:8 000
	29128–29112	1:6 000
	33048–33073	1:8 000
	30175–30164	1:8 000
	32992–32977	1:8 000
1979	28437–28450	1:20 000
	28467–28462	1:20 000
	28365–28355	1:20 000
	28343–28330	1:20 000
	28277–28266	1:20 000
	28241–28234	1:20 000
	27028–27049	1:8 000
	25409–25398	1:6 000
	25591–25602	1:6 000
	25410–25425	1:6 000
	25890–25580	1:6 000
	25898–25959	1:8 000
1978	20602–20598	1:25 000
	20596–20593	1:25 000
	20620–20614	1:25 000
	20631–20625	1:25 000
	20642–20646	1:25 000
	20663–20659	1:25 000
	23402–23425	1:8 000
	23061–23058	1:8 000
	22858–22834	1:9 000
	23426–23435	1:8 000
	22871–22859	1:8 000
	22898–22887	1:8 000
	22967–22956	1:8 000
	23177–23169	1:6 000
	22903–22899	1:8 000
	23168–23158	1:6 000
	22980–22968	1:8 000
	22929–22923	1:8 000
	23057–23036	1:8 000
1977	20176–20195	1:8 000
1976	15293–15285	1:6 000
	16335–16350	1:25 000
	16302–16297	1:25 000
	16412–16403	1:25 000
	16431–16422	1:25 000
	16447–16459	1:25 000
	16488–16482	1:25 000
	16679–16692	1:6 000
	16694–16791	1:5 000
	12477–12470	1:8 000
	14528–14512	1:3 800
	12280–12308	1:6 000
1975	11880–11856	1:25 000
	11847–11844	1:25 000
	11905–11898	1:25 000
	11922–11913	1:25 000
	11936–11945	1:25 000
	11730–11723	1:25 000

Note: 1. *indicates aerial photographs used during systematic terrain classification.
2. Vertical and oblique aerial photographs are available from the Photographic Library, Survey & Mapping Office, Building & Lands Department, 5th Floor, Murray Building.

Table C1 Selection of Aerial Photographs *(Continued)*

Year	Photograph Serial Number	Photograph Scale (Approx.)
1973	7881–7890	1:25 000
	3625–3618	1:12 000
	7717–7699	1:4 000
	7742–7727	1:4 000
	7751–7797	1:4 000
	7431–7418	1:4 000
	5749–5738	1:3 400
	7913–7910	1:25 000
	3076–3065	1:10 000
	3104–3117	1:10 000
1964	2724–2718	1:25 000
	2806–2816	1:25 000
	2790–2776	1:25 000
	2702–2692	1:25 000
	2638–2642	1:25 000
1963	8371–8388	1:7 800
	8466–8495	1:7 800
	8653–8699	1:7 800
	8573–8561	1:7 800
	9519–9477	1:7 800
	0133–0165	1:7 800
	9849–9881	1:7 800
	0077–0119	1:7 800
	9996–9968	1:7 800
	9898–9918	1:7 800
1954	0008–0020	1:10 000
	0072–0078	1:10 000
	0042–0050	1:10 000
1949	6110–6142 (81A/130)	1:10 000
	5030–5010 (81A/125)	1:10 000
	5160–6145 (81A/125)	1:10 000
	6199–6198 (81A/122)	1:10 000
	6090–6097 (81A/122)	1:10 000
1945	4018–4032 (681/4)	1:10 000
	4098–4085 (681/4)	1:10 000
	3073–3058 (681/4)	1:10 000
	3116–3130 (681/4)	1:10 000
	4140–4156 (681/4)	1:10 000
	4220–4210 (681/4)	1:10 000
1924	2–5 (H18)	1:10 000
	7–11 (H21)	1:10 000
	22–25 (H21)	1:10 000
	5–8 (H8)	1:10 000
	1–30 (H65)	1:10 000
	18–24 (H28)	1:10 000
	4–5 (H54)	1:10 000

Note: 1. *indicates aerial photographs used during systematic terrain classification.
2. Vertical and oblique aerial photographs are available from the Photographic Library, Survey & Mapping Office, Buildings & Lands Department, 14th Floor, Murray Building.

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. Geological descriptions of the particular rock types are given in Section 2.3. 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 granodiorites, volcanics, sedimentaries and metasedimentaries, 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 granodiorite. Differences between volcanic and granodiorite 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 granodioritic 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 granodiorite sheeting joints are rough and thus usually have a high apparent angle of friction.

The more randomly oriented, smoother, volcanic joints will influence the stability of cut faces although this may only result in surface 'ravelling'. Granodiorite 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 granodiorites, 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 and to the proportions of sand, silt and clay-sized products of weathering.Because of the lower proportion of quartz in the granodioritic rock as compared with granitic rock, the weathered granodioritic soil has a lower sand content. 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 granodiorite 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 may operate below this depth. The depth of the weathered profile in granodiorite 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 granodiorite, 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.

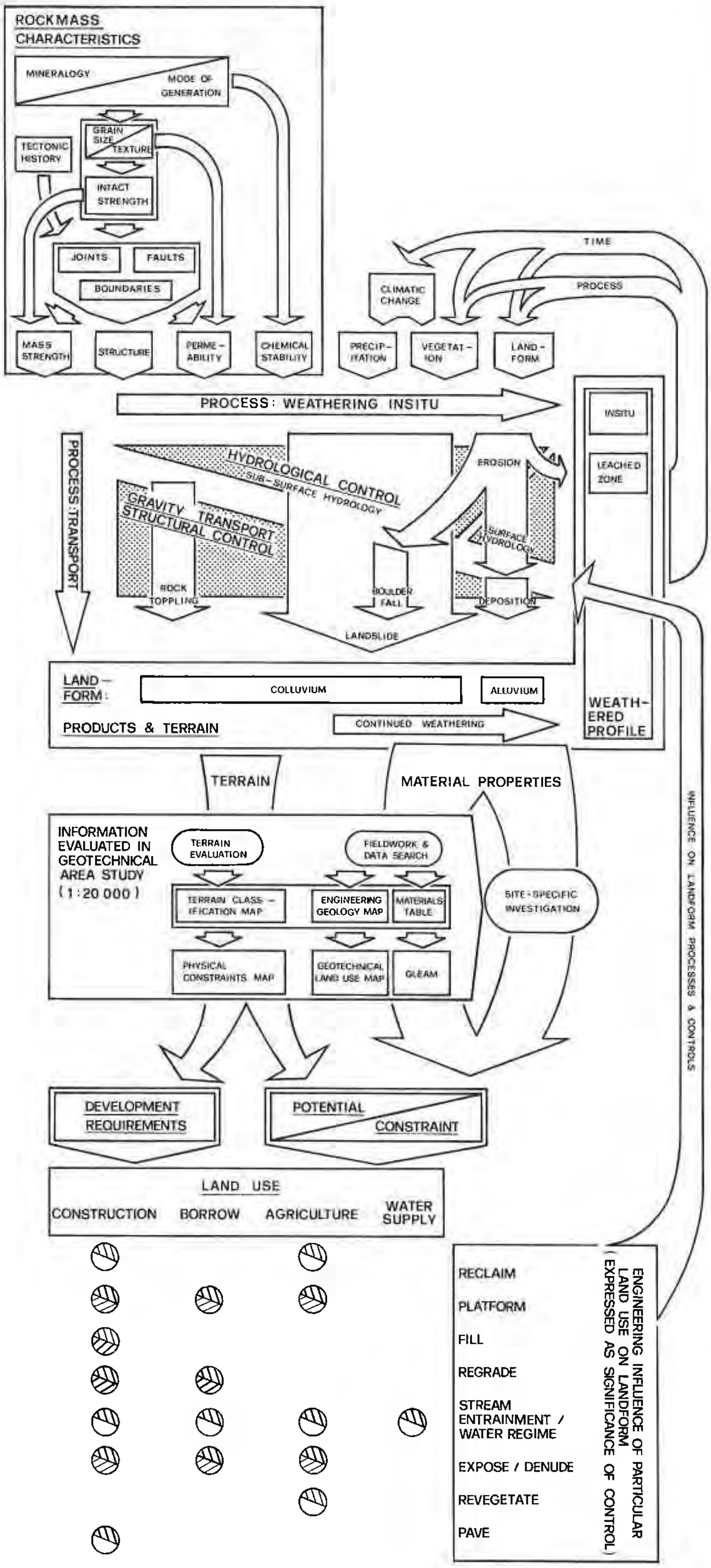
LANDFORMING PROCESSES :
RELATIVE INFLUENCE OF HYDROLOGY, STRUCTURE & WEATHERING ON TYPES OF TRANSPORT PROCESS. (BACKGROUND TRIANGLES SHOW PROPORTION OF INFLUENCE OF CONTROL).

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 FEASAIBILITY STUDIES. G A S PROVIDES PRELUDE TO SITE SPECIFIC INVESTIGATION.

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

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



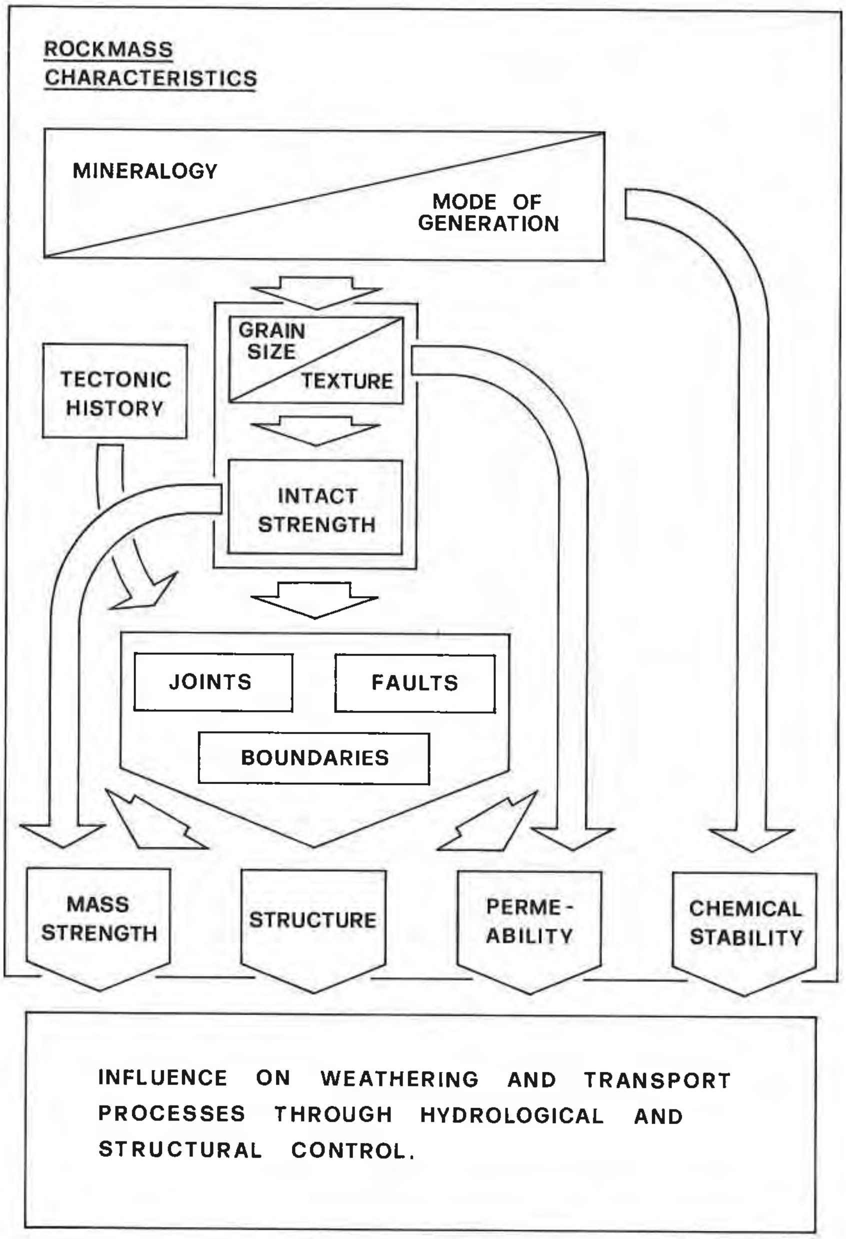
LEGEND :

BOXES INDICATE : CAUSE OR PRODUCT

ARROWS INDICATE : INFLUENCE, PROCESS, OR MECHANISM

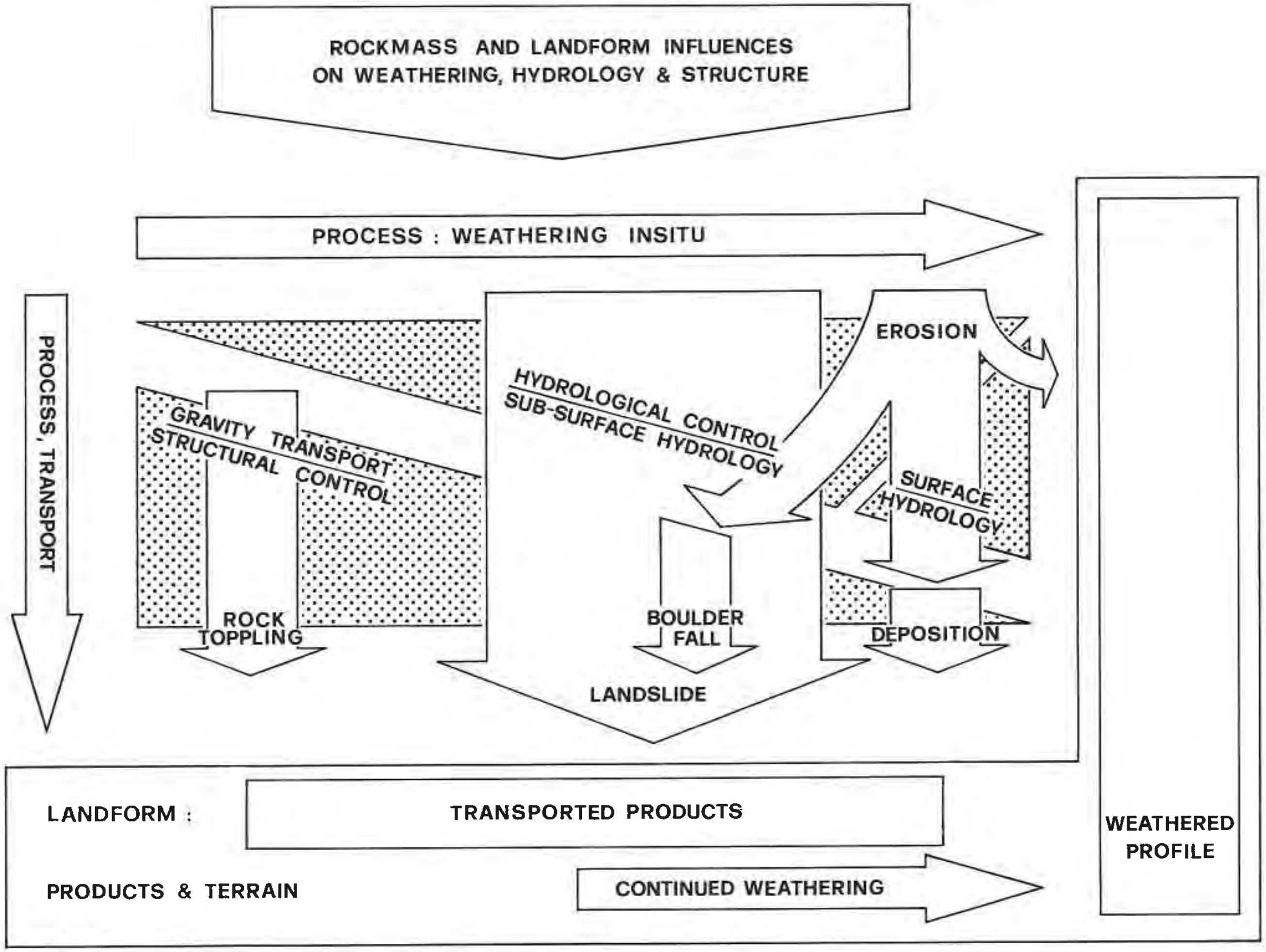
CIRCLES INDICATE : HUMAN INVOLVEMENT

Influence of Landforming Processes — Fig. D1



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

Rock Mass Characteristics	Fig. D2



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

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

Landforming Processes	Fig. D3

D.2.5 *Faults*

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

D.2.6 *Boundaries*

Geological boundaries are often reflected geomorphologically and are sometimes enhanced by changes in vegetation. They commonly control the local hydrological regime and this, together with the local variations in structure and rock properties, is of significance in engineering work. Many geological boundaries are also faulted.

D.3 Engineering Considerations for Development Planning

D.3.1 *General*

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

In the Territory, the relief of the terrain is dramatic, and the pressures for development are very high. A considerable portion of the currently developed terrain and natural terrain with potential for development is subject to high to extreme geotechnical limitations. These limitations are often associated with, or are related to, either natural or man-made features. For example, Vail & Beattie (1985) discuss the failure and stabilization of earthworks in the Territory. Further development within the 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 this 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 the Territory. A number of serious landslip disasters have resulted in considerable loss of life and extensive property damage.

Rock toppling, rock slides and boulder falls are essentially 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 granodiorites 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 granodioritic 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 developments which occur in the New Towns.

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

(i) *Cut and Fill Platforms on Steep Terrain*
This technique is used in the Territory to provide level building platforms on otherwise steep terrain. A typical example is associated with development on the slopes below Kadoorie Farm. Where numerous cut slopes, platforms, and or fill slopes mask the natural slope profile.

Since the disastrous fill slope failures at Sau Mau Ping in 1972 and 1976 (Government of Hong Kong, 1972 a & b, 1977), fill has been recognised as a potentially hazardous engineering material. Consequently, recent fill platforms and slopes are designed and constructed to stringent requirements. Common problems in older fills on steep terrain are due to the fact that many were 'end tipped'. This results in:

(*a*) Poor compaction – a generally loose structure makes the fills susceptible to liquification resulting from infiltration of rainwater, movement of groundwater, throughflow or from fractured water mains. This leads to sudden loss of strength and failure of the slopes. Loose fill is also liable to settlement and possible lateral movement on loading.

(*b*) Stratification parallel to the natural slope – this enables the infiltration of water from the level platform into the fill and also creates inclined planes of potential weakness liable to preferential failure.

Old fill has often been tipped into unprepared natural drainage lines, and the natural groundwater regime may persist beneath the fill, leading to saturation and instability. The material behaviour is also subject to the variability of the source material. Completely weathered rock would result in a fairly uniform fill, whilst fill of less weathered rock may contain boulders and voids.

(ii) *Fill on Low-lying Terrain*
Few engineering problems are envisaged in these areas, with the exception of settlement. Large buildings are generally piled. Deep excavations may experience difficulties due to high groundwater tables in underlying alluvium.

(iii) *Land Reclaimed from the Sea*
Some of the coastal areas are modified by reclamation and considerable recent and proposed development is based on these areas.

The historial development of reclamation is recorded on the Engineering Geology Map and is illustrated in Plates 15 and 17.

Although most areas of reclamation are subject to current or proposed development, it is relevant to note that older reclamation materials may be very variable in quality. The following engineering problems should be anticipated during development in areas of reclamation:

(*a*) Lateral variability of materials—the extension of reclamation areas over a long time may result in material of differing sources and quality being present. Borehole samples should be examined and interpreted with this in mind.

(*b*) Variability of materials with depth—reclamation materials may vary with depth and cause local artificial aquifers and dense or loose zones. These should be anticipated in the choice of construction method and evaluated during site investigation. Boulders, timbers and other extraneous materials may be present in older areas. These may require localised measures during construction, such as hand-dug excavations. Better quality, more uniform material may allow driven piles for low structures such as warehouses, or larger diameter mechanically excavated sleeved caissons for heavier structures.

(*c*) Presence of old structures—within areas of reclamation, features such as old foundations and sea walls may occur. Consultation of archive sources may help avoid local difficulties or anticipate setbacks during the critical foundation construction period.

(*d*) Dewatering problems—the reclamation material, in its loose, permeable, saturated stage, is likely to have water problems which may cause heaving in deep excavations. Grouting or dewatering may therefore be necessary. Dewatering may cause settlement problems in adjacent slabs and unpiled structures. Permanent or temporary impermeable barriers to water flow, such as continuous walling, may also cause problems to adjacent buildings by interrupting groundwater flow and raising water levels.

(*e*) Basements—these require tanking or water resistant design. External drainage may be necessary to prevent an increase in water levels if drainage paths are blocked.

(*f*) Settlement—unpiled structures are subject to settlement and should be designed to redistribute loads or else to be flexible. Foundation stresses are subject to variation from fluctuating water levels in response to the tide. Piled structures may require design for negative friction in recent or deep reclamation.

(*g*) Underlying materials—the problems of construction on reclamation may be aggravated by considerable depths of marine 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.

Photolineaments 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 photolineaments 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.

Photolineaments 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 photolineaments 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. Narrow zones of weakness may pose problems to foundation construction and performance due to rapidly changing ground conditions across short distances.

Many of the photolineaments 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 photolineaments are often identified from preferential drainage caused by a weakness or strength of the adjacent rock mass. This may be due to variation in the rock itself or in its structure. Where the photolineament is evidence of a structural weakness, problems may be encountered in the founding of caissons and in the construction of rock cut slopes.

Small scale, as well as major, photolineaments may be associated with anomalies in the general pattern of weathering depth which may cause differential settlements of raft foundations.

Regular patterns of lineaments are evidence of the regional pattern of structure present at smaller scale. Engineering works 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.

Boundaries between rock types may or may not form photolineaments, partly depending on whether they are faulted or not. Identified rock boundaries are shown on the Engineering Geology Map. Changes in structure are likely at granodiorite/volcanic boundaries due to cooling stresses, and in strength and weathering due to contact metamorphism.

(iv) *Preferential Groundwater Flow*
The preceding engineering features of photolineaments are usually associated with preferential 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 photolineaments are identified on the Engineering Geology Map (after Allen & Stephens, 1971) as faults, and other major photolineaments may also indicate faults. Faults may extend laterally for short distances or many thousands of kilometres. The Government of the People's Republic of China has published a national seismic map which shows extensive fault-zones of NE or ENE trend in Guangdong Province and western Fujian Province. One of these fault-zones lies along the northern boundary of the Territory of Hong Kong, while others intersect the coast of Guangdong Province to the east of Hong Kong. Sources in China regard many of the faults of the region as active, the degree of activity being inferred from recent earthquake data and that derived from the historical geological record.

Throughout the world, even in seismically 'quiet' areas, many major faults are active to some extent. For example in the UK, which is classified as an area of low to moderate seismicity, a few hundred earthquakes occur every year, although they are rarely felt by individuals. Most of the earthquakes recorded by the Royal Observatory short-period seismograph network originated elsewhere in the Southeast Asian region. The few which actually have been felt by individuals in Hong Kong were mostly related to earthquakes in various parts of China. Nevertheless, minor seismic events originating within the Territory have also been recorded by the Royal Observatory, and these events may be attributed to minor movements on faults at depth giving rise to seismic waves but no apparent ground displacement. To date, no clear relationship is obvious between these local seismic events and known faults within the Territory.

On the basis of observations of the historical geological record and mapping work undertaken to date, it appears that, although minor crustal readjustments have been occurring in Hong Kong, the Territory is not characterised by local major fault movements or related severe seismic events.

D.3.5 *Colluvial Deposits*

Colluvium is a transported material, whose nature and engineering characteristics depend on the origin of the material, the conditions of its deposition and its subsequent history. Various types of colluvium exist 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 (Government of Hong Kong, 1972 a & b).

Engineering factors which are often associated with colluvium may be classified into the following:

(i) *Physical Properties*
Colluvium is subject to local variations of structure, density, strength and water content, both horizontally and vertically. In particular, concentrations of subsurface water flow may result in voids and pipes caused by the removal of fines, and in local piezometric variation. Stratification of these deposits may cause perched water tables and variations in the strength profile. Settlements under load may be unpredictable. Hence, heavily loaded structures should be founded on caissons through to bedrock. In situations 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 footslope terrain show zones of water seepage. Local instability in natural oversteepened colluvial slopes results from emerging groundwater. In cuts in colluvium, such conditions may lead to progressive collapse of a loose soil structure upslope with considerable debris flow.

(iv) *Site Investigation*

In heterogeneous deposits such as extensive recent colluvium and boulders, site investigation alone cannot reveal a comprehensive model of the ground, nor can appropriate strength values be accurately assessed. Carefully monitored trial caissons are often justified in colluvial deposits. Attention should be paid to variations in bedrock and its level in boreholes to ensure that foundations do not rest on boulders.

D.3.6 *Boulders and Rockfalls*

Boulder and rockfalls are a feature of the wet season in the Territory and have on occasion resulted in loss of life and considerable property damage.

Boulders are large blocks of rock which often result from wide joint spacing. They occur often in granodioritic rocks as the unweathered remnant corestones between completely weathered joints. If exposed on steep hillsides or in drainage lines, they may be liable to movement.

Adverse jointing and an exposed location may result in potential rockfalls in both granodioritic and volcanic terrain. In this case, weathering, except as a local weakening of the joints, is not a major contributing factor. In granodioritic 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 colluvium. Boulders may also exist in drainage lines where they are likely to be restrained and interlocked. However, high flows caused by torrential rain are liable to increase the likelihood of movement. Boulders in drainage lines may also trap detritus and torrential flows may cause mud or debris flows. In 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 granodiorite 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 (See Section 3.1.3).

D.3.9 *Cut Slopes*

Cut slopes and/or slope support structures are an aspect of most large-scale developments in the Territory Different considerations govern the use and design of slopes depending on the geological material, its state and structure. Hence, the overall form of a development should also relate to the engineering opportunities of the terrain.

The height and angle of a cut slope are a matter for design based on a model of the rock or soil strength and structure as determined by site investigation. Preliminary assessment of the size and form of slopes and retaining structures may be made on the basis of the engineering properties of the local rock type, as indicated on the 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. Photolineaments may indicate a degree of control of the landforms being exerted by the underlying geological structure. Structural control may indicate shallow bedrock, and the structure will influence the stability of cuts in rock. Photolineaments indicate a local structural feature which may influence the final slope design, probably requiring a shallower angle cut in the weaker rock zone.

In large developments on steep terrain, a more geotechnically economical use of the site can be made by providing a stepped site formation which follows the terrain, rather than a large level formation with very large cuts. The benefits of this approach occur in different ways, for each of the major geological materials occurring on steep terrain:

(i) *Volcanic Terrain*
Weathering depths of less than 15 m are generally noted for steep volcanic terrain in the study area, with rapid transition from weathered to fresh rock. In such terrain, structures can economically be founded at shallow depths and large fresh rock cuts avoided. Where fresh rock cuts are formed, the jointing of the rock may cause some surface ravelling, and net protection or a safety zone may be required to maximize slope angles. Locally persistent or unstable joints may require shallower angled cuts or support measures.

(ii) *Granodiorite Terrain*
Considerable depths of various grades of weathering are encountered in the granodiorite 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 granodioritic 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 weathered granodioritic rocks (greater than Grade III) may require empirical approximations to model the strengthening influence of boulders. In cuts in fresh rock, sheeting joints are likely to be encountered which require additional support or the draining of water. These local measures enable steep cuts to be made in fresh granodiorite, 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 to some extent in many of the areas suitable for development, as 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 alluvial and 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 (Government of Hong Kong, 1972 a & b, 1977).

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 is shown on the GLUM, EGM and PCM. 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.

(*b*) A field reconnaissance of the site and the surrounding area is a necessary preliminary to planning a site investigation. On undisturbed sites, much can be inferred with regard to the strength of underlying materials, the pattern of superficial deposits, and local weaknesses in rock from site observations of the contrasts in landform and the pattern of drainage on and around the site.

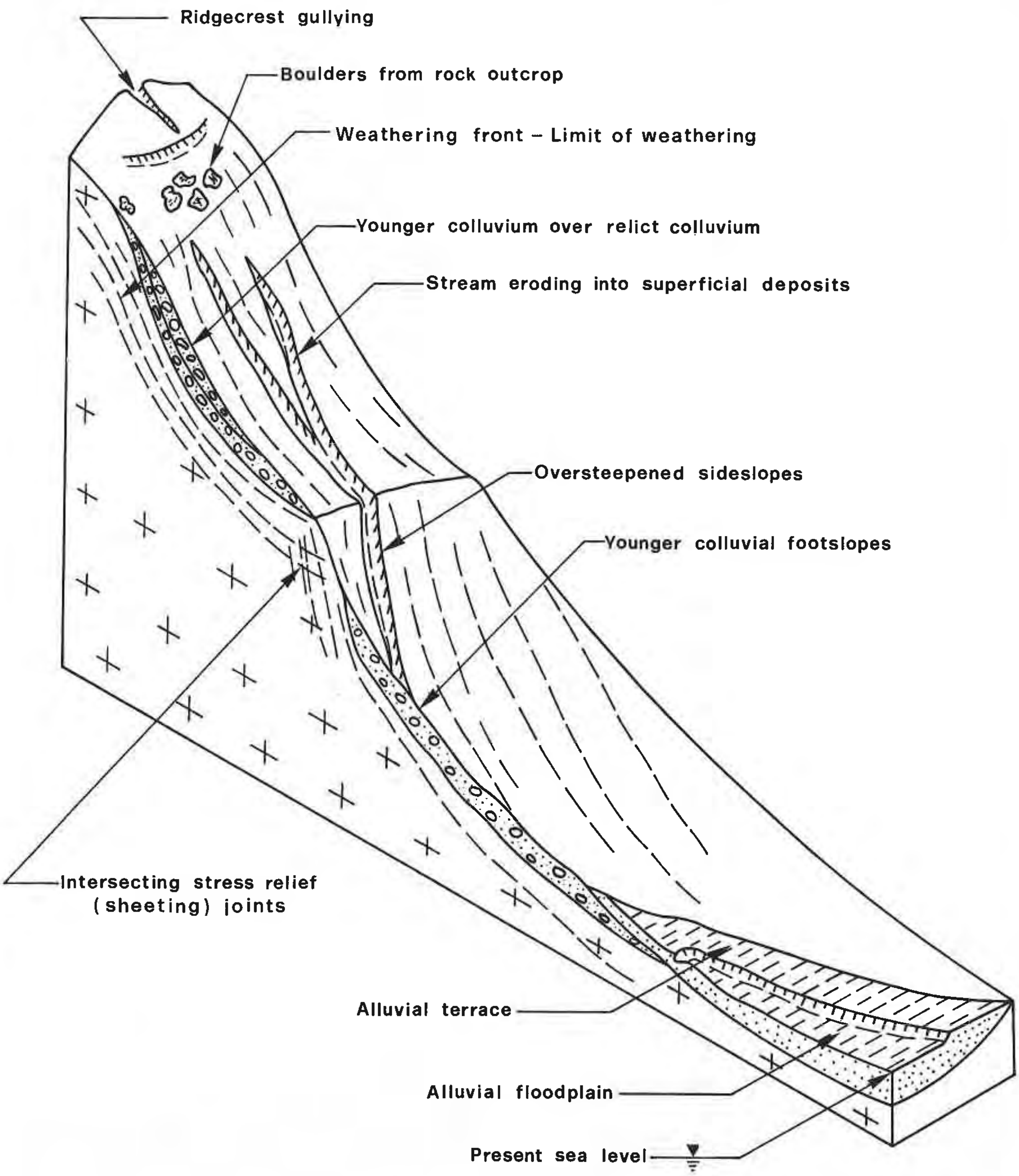
(*c*) The site investigation should be designed to highlight the scope of any available information, the anticipated material, its nature and variability, and the type and form of the engineering project.

D.4 Landform Model of the Terrain in Hong Kong

Landforms are the product of the local balance between weathering, erosion and deposition and are continually evolving. The mechanics of the system and its various components are shown in Figure D1 and described in Appendix D.3.1 (Hansen, 1984 a & b). This section discusses the significance of the sequence of landform evolution to the engineering properties of the materials within the 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 Pleistocene. During this period, the sea level fluctuated dramatically; there is evidence in southern China that stream incision occurred and produced oversteepened slopes adjacent to the channels. Gradually, the incision progressed inland, taking advantage of structural weaknesses in the underlying geology, with the result that many valleys are narrow with steep sides. The increased rate of erosion removed much of the weathered mantle adjacent to the streams. This, in part, explains the occurrence of shallow weathering depths and slightly weathered bedrock along the floors of many incised valleys in the Territory.

Drainage courses are the main axes of erosion within a valley. The density of drainage pattern responds to and is influenced by the materials and 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.

Instability will continue regardless of changes to the denudational system downslope provided that the debris resulting from the erosion of the oversteepened slope is continually transported away from the slope. 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.

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.

ALLUVIUM

Sediment transported and deposited by a river or stream.

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.

GEOTECHNICAL AREA STUDIES PROGRAMME (GASP)

Geotechnical study of a specific area by the GCO on the basis of systematic terrain classification using aerial photograph interpretation, fieldwork and engineering assessment.

GEOTECHNICAL LAND USE MAP (GLUM)

Map which delineates the general geotechnical limitations of the terrain for planning purposes.

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

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 or other waterbody.

RELICT

Term used to describe remnants of earlier landscapes or surface deposits. Also used to describe traces of lithological features in residual soil.

RESIDUAL SOIL

Soil resulting from the weathering of rock insitu.

RILL EROSION

Terrain attribute characterised by subparallel sets of small narrow channels formed by the concentration of surface runoff.

ROCK EXPOSURE (=ROCK OUTCROP as defined for Terrain Classification)

Discrete area of rock exposed at surface.

ROOF PENDANT

Mass of older country rock forming the roof of a major igneous intrusion (e.g. a granite batholith). On a map, a roof pendant is completely surrounded by the rock of the batholith.

SCREE (=TALUS)

Debris resulting from the mechanical weathering of rock which accumulates at the foot of a cliff or a steep slope.

SESQUIOXIDES

Oxides of iron and aluminium which are generally mobilized as ions in solution by groundwater and which, upon precipitation, often act as the cementing agent in the formation of duricrust.

SHEET EROSION

Terrain attribute, characterised by the removal of the surface layers of soil by wind or water.

SHEETING JOINT

Discontinuity produced by pressure release or exfoliation. Sheeting joints may separate large rock masses, e.g. of granite into tabular bodies or lenses, roughly parallel with the rock surface. Often persistent for large distances and generally following the shape of the landform.

SIDESLOPE

Terrain component, used to describe the terrain between footslope and hillcrest. This terrain unit is usually erosional.

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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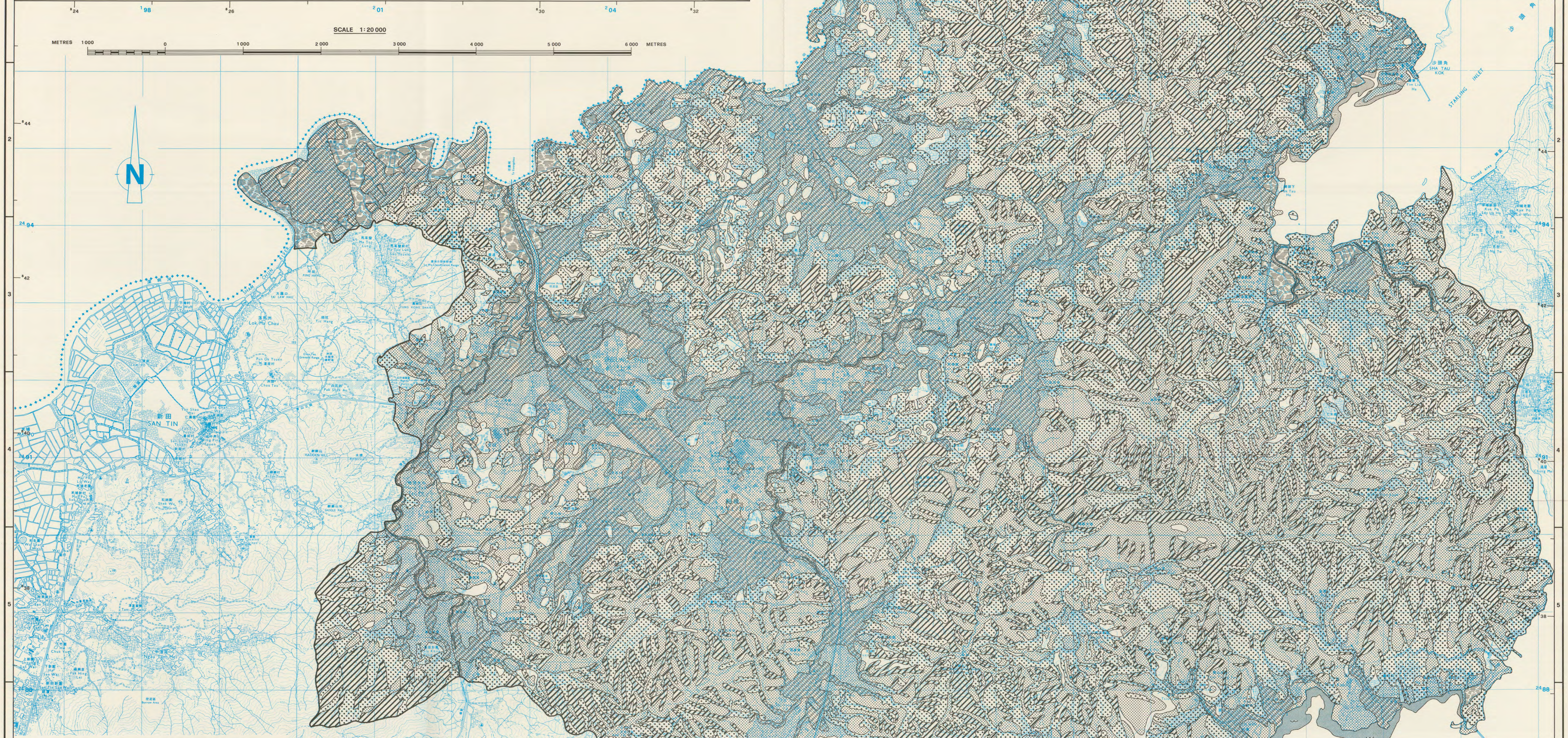
GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECHNICAL LAND USE MAP - NORTH NEW TERRITORIES



Note : The topographic base of this map is derived from Sheet 2 - Edition 2 of 1980, Sheet 3 - Edition 2 of 1980, Sheet 6 - Edition 2 of 1979 and Sheet 7 - Edition 3 of 1981 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)

$^{24}94$ Universal Transverse Mercator (UTM) Grid Reference

$^{8}40$ 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 North New Territories Geotechnical Area Studies Programme Report (GASP V) which discusses in detail the purpose, application and limitations of this Map.

Title : GEOTECHNICAL LAND USE MAP – NORTH NEW TERRITORIES	
Compiled : K.A.Styles / A.Hansen	Drawn : K.T.Chow / L.C.Tang
Scale : 1 : 20 000	Date : Original June, 1982 2nd Edition January, 1988
Map Ref. No. : GASP / 20 / V / 1 2nd Edition	Sheet :

Geotechnical Control Office

Civil Engineering Services Department

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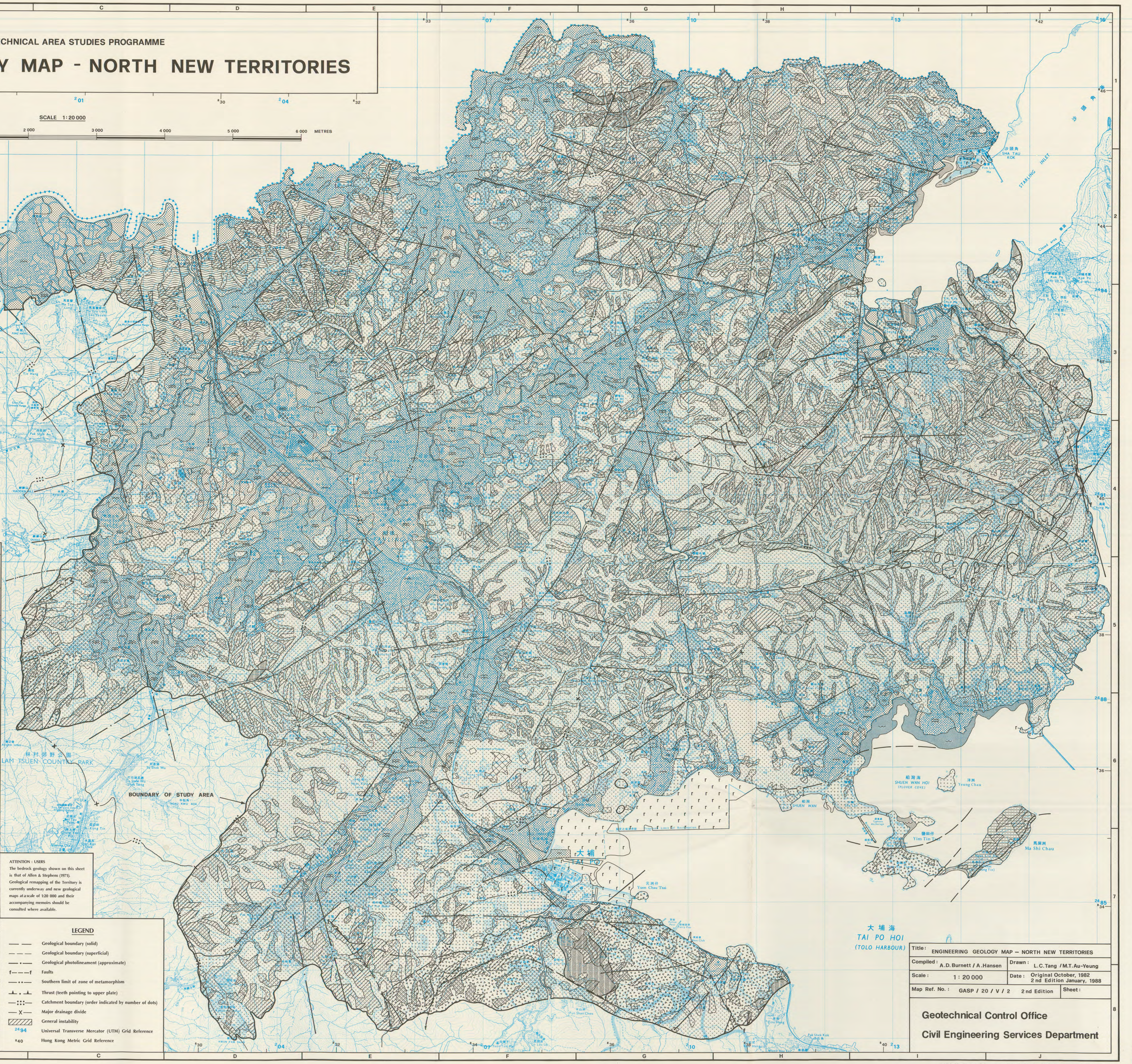
GEOTECHNICAL AREA STUDIES PROGRAMME

ENGINEERING GEOLOGY MAP - NORTH NEW TERRITORIES

SCALE 1:20 000

METRES 1 000 0 1 000 2 000 3 000 4 000 5 000 6 000 METRES



Note : The topographic base of this map is derived from Sheet 2 - Edition 2 of 1980, Sheet 3 - Edition 2 of 1980, Sheet 6 - Edition 2 of 1979 and Sheet 7 - Edition 3 of 1981 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.

Map Unit	Weathering and Soil Development	Engineering Comment (Stability, Foundation, Hydrogeology)	Material Uses and Excavation Characteristics
RECLAMATION / FILL	These materials placed by man have no soil (pedogenic) or weathering profile but may contain weather rocks or be underlain by natural superficial deposits and/or a pre-existing weathered profile.	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 pressure 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.
LITTORAL DEPOSITS	Nil	Materials are usually saturated and saline. Raised beaches may be leached by rainwater but may remain saline at depth. Groundwater extraction may induce incursion of saline water. Poor grading characteristics—low fines. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or pile foundations.	Main development potential is as beaches for recreational purposes. Excavation of these materials usually prohibited.
ALLUVIAL DEPOSITS: PONDS / UNDIFFERENTIATED / RAISED TERRACES	In subaerial locations very minor development of soil horizon. Relict deposits may be more weathered. Very old deposits may contain completely weathered boulders.	Locally low-lying terrain may be subject to flooding. Materials are usually saturated and of a low density— clay layers are normally consolidated. Buried channels may post local problems of high water flows into tunnels or excavations. Steep excavations require support. Groundwater may be saline if adjacant to coast. Incursion of saline groundwater following abstraction of fresh groundwater may occur. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or piled foundations.	Land deposits easily excavated. Marine deposits often form reasonable hydraulic fill. Excavation by cutter, suction or bucket dredger.
MARINE SEDIMENTS	Nil	Material is poor to unsatisfactory for hydraulic fill. It is also poor as a foundation because of settlement and bearing capacity problems. Will probably be susceptible to formation of mud waves if fill is end-tipped onto it. Consolidation may be aided by wick drains and/or surcharge loading.	Easily excavated using bucket or possibly suction dredger where necessary. Sandy deposits may be used in construction but silt and clay may pose problems of disposal.
COLLUVIUM: VOLCANIC DERIVED / GRANITIC/GRANODIORITIC DERIVED / SEDIMENT & METASEDIMENT DERIVED / MIXED	Colluvium can occur as independent deposits of a unique age such that one deposit overlies another. The older deposits may be subject to severe weathering and may be completely decomposed to a mottled, coloured sandy silt or clayey silt similar to the insitu residual deposits of their parent materials. The depth of such weathering may be in the order of 10 m or more.	This material has moved in its geologic past and is prone to reactivation if not carefully treated by such measures as low batter angles, drainage and surface protection, especially when saturated. Has low to moderate bearing capacity characteristics but should always be carefully drained because it may be susceptible to failure when wet. Voids may cause settlement of roads, services and buildings. Tunnelling probably difficult. Site investigation difficult and expensive.	May be used for borrow due to its ease of excavation by machine, broad grading characteristics and relative ease of access on hillsides. Some bouldery stream deposits will be of limited use. Large boulders may require blasting or splitting.
SEDIMENTARY ROCKS: PORT ISLAND FORMATION	Rock generally decomposed to a reddish brown silty sand with pebble traces. Weathering depths are usually small, less than 7 m.	Material has seldom been worked hence its characteristics are virtually unknown. The soil profile should be similar to the RBp. The rock profile stability aspects will be controlled by the existing discontinuities. No bearing capacity problems anticipated.	Material could be scraped for borrow when weathered. Fresh rock must be blasted. Not recommended for aggregate until further studied.
INSTRUSIVE IGNEOUS ROCKS (PLUTONIC): TAI PO GRANODIORITE	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.	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 asphaltic concrete.
SEDIMENTARY, VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS: REPULSE BAY FORMATION: SEDIMENTARY AND WATER-LAID VOLCANICLASTIC ROCKS	Shallow to moderately deep, reddish to brown, fine, sandy to silty clay, i.e. residual soil sometimes with ferruginous gravel and weathered rock fragments, overlying completely to highly weathered rock which grades (at bottom 5–20 m depth) into less weathered strongly jointed volcanic rock.	The sediments are bedded and fissile and weather relatively rapidly to a grey silt when exposed. 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.
REPULSE BAY FORMATION: COARSE TUFF / DOMINANTLY PYROCLASTIC ROCKS WITH SOME LAVAS	Rock sometimes produces a poor, thin (< 1 m) 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 18 m has been quoted. Weathering to produce corestones is common.	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.
METASEDIMENTARY ROCKS: LOK MA CHAU FORMATION	Metasediments generally weather to produce moderately deep (1–2 m), uniform or gradational, red to red-brown clayey metasediments. Marble (metamorphosed limestone) weathers in two forms: (i) Complete solution, originating along discontinuities; to produce interconnecting cavities which may exceed 1 m in size; (ii) Intergranular solution which produces a weak granular layer at the marble surface.	Considerable care is required during investigation, design and formation in materials of the Lok Ma Chau Formation. Bearing capacity characteristics are reasonable for low and moderate loads. Stability of this rock in cutting is dependent on the very closely spaced discontinuities, the strengths of which are generally low-considerable care is thus required. Roughness friction values of 0°–5° may be added to ø values. Discontinuity surveys are essential in cutting design. Metasediments may be prone to instability, especially along discontinuities when weathered and saturated. Bearing capacities are reasonable for low to moderate loads on metasediments and marble without large cavities. Interconnecting cavities within the marble provide excellent hydraulic conductivity. Whilst this may be beneficial for water supply wells, rapid fluctuations of the groundwater table can lead to the formation of either collapse sinkholes or gradual settlement in the overlying superficial deposits if hydraulic continuity exists, as soil is washed into the void system.	Material can be used as a source of bulk fill but may break down to silt if overcompacted. Excavation by machine is relatively easy.
BLUFF HEAD FORMATION	Only a thin (1–2 m) pedogenic horizon develops but the rocks are otherwise (5–25 m) moderately weathered to great depths as shown by the red colouration.	Metasediments may be prone to instability, especially along discontinuities when weathered and saturated. Bearing capacities are reasonable for low to moderate loads on metasediments.	Could be used as very localised source of fill. May break down to silt upon overcompaction. Only the sandstone members will require blasting otherwise machine digging may be possible.
TOLO HARBOUR FORMATION	Palaeosol developed beneath old alluvium. Weathering may be up to 40 m thick extending to –90 mPD.	If encountered in foundations the weathered material will be of low strength and contain sulphares. Acid attack on steel piles may occur.	Location precludes borrow activities. Excavation by machine digging with some blasting.

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.

LEGEND

- Geological boundary (solid)
- Geological boundary (superficial)
- Geological photolineament (approximate)
- f——f Faults
- Southern limit of zone of metamorphism
- Thrust (teeth pointing to upper plate)
- Catchment boundary (order indicated by number of dots)
- —X— Major drainage divide
- General instability
- 24 94 Universal Transverse Mercator (UTM) Grid Reference
- 8 40 Hong Kong Metric Grid Reference

Title: ENGINEERING GEOLOGY MAP – NORTH NEW TERRITORIES	
Compiled: A.D. Burnett / A. Hansen	Drawn: L.C. Tang / M.T. Au-Yeung
Scale: 1 : 20 000	Date: Original October, 1982 2 nd Edition January, 1988
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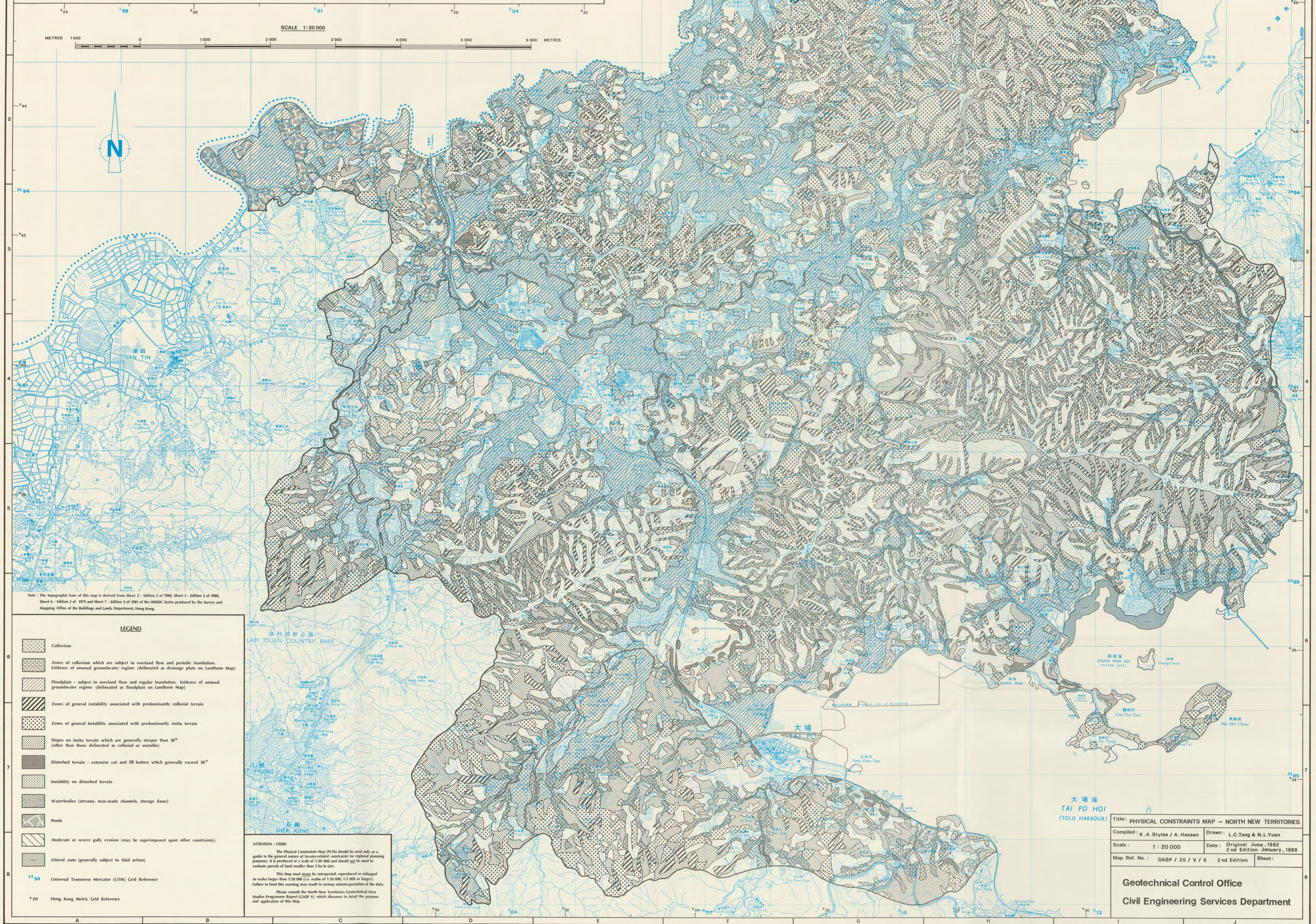
GEOTECHNICAL AREA STUDIES PROGRAMME

PHYSICAL CONSTRAINTS MAP - NORTH NEW TERRITORIES

SCALE 1:20 000



Note : The topographic base of this map is derived from Sheet 2 - Edition 2 of 1980, Sheet 3 - Edition 2 of 1980, Sheet 6 - Edition 2 of 1979 and Sheet 7 - Edition 3 of 1981 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.

LEGEND

- Colluvium
- Zones of colluvium which are subject to overland flow and periodic inundation. Evidence of unusual groundwater regime (delineated as drainage plain on Landform Map)
- Floodplain - subject to overland flow and regular inundation. Evidence of unusual groundwater regime (delineated as floodplain on Landform Map)
- Zones of general instability associated with predominantly colluvial terrain
- Zones of general instability associated with predominantly insitu terrain
- Slopes on insitu terrain which are generally steeper than 30° (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)
- $^{24}94$ Universal Transverse Mercator (UTM) Grid Reference
- $^{8}20$ Hong Kong Metric Grid Reference

ATTENTION : USERS

The Physical Constraints Map (PCM) should be used only as a guide to the general nature of terrain-related constraints for regional planning purposes. It is produced at a scale of 1:20 000 and should not be used to evaluate parcels of land smaller than 3 ha in size.

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