EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

COST Short Term Scientific Mission (STSM) TU1206-21279

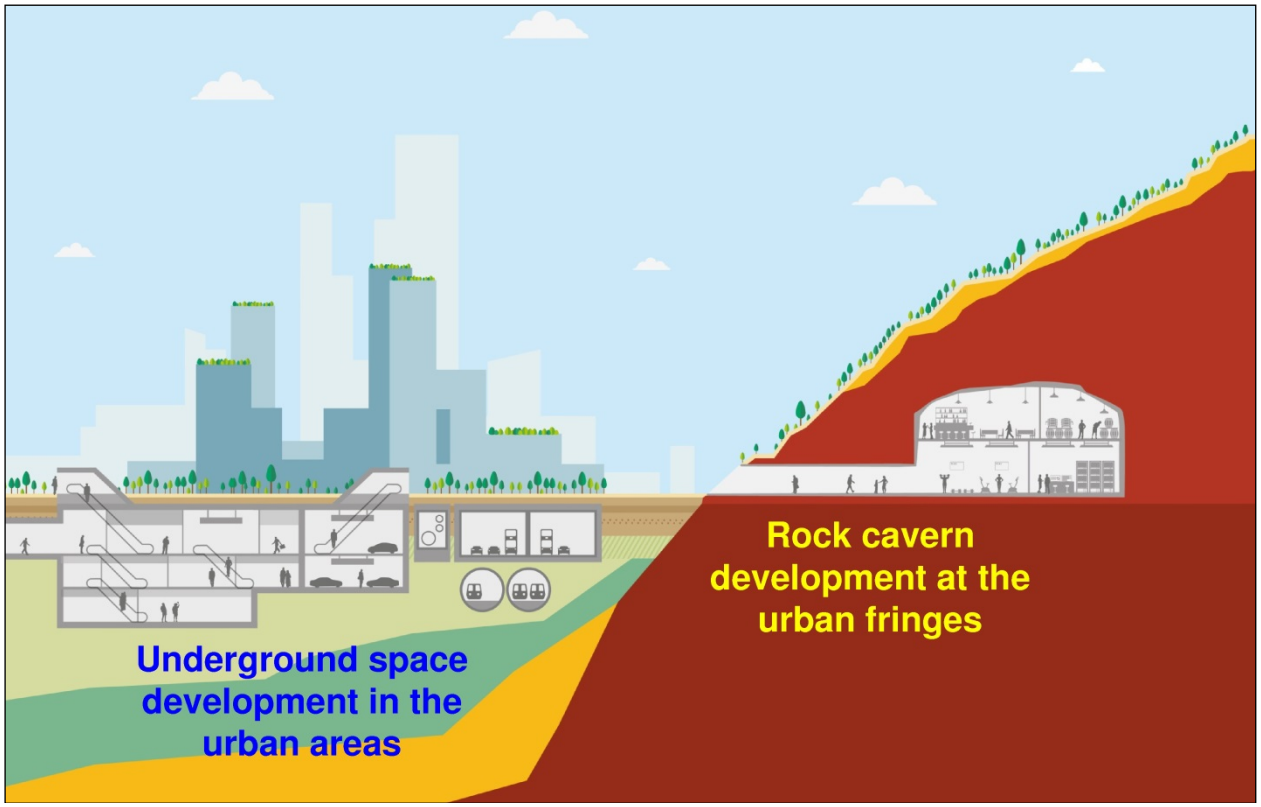
The subsurface in planning and decision-making - shared issues in Hong Kong and Glasgow

STSM Report to COST MC Chair

The subsurface in planning and decision-making - shared issues in Hong Kong and Glasgow

STSM author: Dr S. D. G. Campbell
(BGS, Edinburgh UK)

STSM Host: Mr H N Wong, Head, Geotechnical Engineering Office, Civil Engineering and Development Department, Hong Kong SAR Government (HK)



British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

BGS report reference: IR/15/004

STSM report submitted to:

COST MC Deputy Chair (Mr Johannes de Beer)
Team Leader, Groundwater and Urban Geology
Geological Survey of Norway
PO Box 6315 Sluppen
N-7491, Trondheim
Norway

STSM reference details:
COST STSM Reference Number: COST-STSM-TU1206-21279
STSM Applicant: Dr S. D. G. Campbell, British Geological Survey, UK
STSM Topic: The subsurface in planning and decision-making - shared issues in Hong Kong and Glasgow
Host: Mr H N Wong, GEO, CEDD, Hong Kong SAR Government, Hong Kong SAR

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Acknowledgements

A large number of individuals have contributed to this Short Term Scientific Mission (STSM), and have helped as a result to promote knowledge exchange between the Hong Kong SAR and the City of Glasgow, and to support the aims and aspirations of COST Action TU1206 – Sub-Urban.

Particular thanks go to my host, Mr H N Wong and to colleagues of the GEO, CEDD, and especially Dr Roderick Sewell. Colleagues in the Drainage Services and Planning departments of the Hong Kong SAR Government are also thanked for generously giving their time, and the benefits of their expertise.

Mr Johannes de Beer at NGU (Norway) and Mr David Lawrence at BGS (UK) are also thanked for their advice and support in developing the STSM application.

Finally, the author thanks the COST Action Sub-Urban for the financial contribution provided through its STSM programme.

Contents

1.	STSM rationale and purpose	5
2.	Work carried out within the STSM	6
3.	Lessons learnt from the STSM	8
4.	Applicability of lessons learnt – transfer of best practice	23
5.	Future collaboration and outputs	23
6.	Summary	24
7.	STSM Host institution approval / sign-off	25
8.	APPENDIX 1	26
9.	APPENDIX 2	30
10.	APPENDIX 3	31

1. STSM rationale and purpose

This Short-term Scientific Mission (STSM) was a contribution to COST Action TU1206 (Sub-Urban), and specifically between the British Geological Survey (UK) and the Geotechnical Engineering Office, Civil Engineering and Development Department, of the Hong Kong SAR Government (HK). The objective was to expand the scope of the current Working Group (WG) 1 city studies of the Action, and the reviews of good practice underway as part of WG2, by undertaking detailed assessments for both in Hong Kong. The subsurface is extensively exploited in Hong Kong, and there are very ambitious plans to expand its utilization, under the control of an advanced planning regime that takes considerable cognisance of the subsurface. The results will contribute to: the reporting of WG1; will have direct relevance to the subgroups of WG2, dealing with planning, data management and geohazards; and will contribute to the Action's Toolbox (WG3).

1.1 Rationale

Working Group 1 of Cost Action TU1206 will deliver a report on the current capabilities in the management and modelling of subsurface data by GSOs and other researchers, and to assess the related needs of City-partners by compiling inventories of the following:

- Existing management of subsurface data and legislation and practice related to the sharing of, and access to, these (including key geotechnical and groundwater data);
- Methodologies and workflows related to, and applications of, urban subsurface 3D /4D modelling - the representation of subsurface conditions depends fundamentally on the comprehensive availability, and quality, of input data;
- City-scale 3D/4D models and their uses, with case studies relating to specific needs of City-partners;
- Interactions between GSOs, researchers and urban decision-makers;
- Relevant directives and design codes

Working Group (WG) 2 will focus on establishing good practice and appropriate methodologies in relation to subsurface planning, data management, 3D modelling, groundwater monitoring and modelling, and geohazards. The good practice and methodologies will ultimately form the basis of the Toolbox which the Action will assemble, test and disseminate within Europe and further afield under WG 3.

Given the composition of the SUB-URBAN network, studies of cities, and identification of good practice and methodologies have so far only been carried out / established for European cities. The opportunity presented itself through this STSM to broaden the Action's scope geologically, geographically, and in terms of current good practice, by reviewing an Asian 'World City' - Hong Kong. The Hong Kong SAR has a highly developed infrastructure, in which the subsurface is extensively and increasingly exploited, and is considered in detail in relation to its urban planning and decision- making. As such there is considerable scope for knowledge exchange.

1.2 Purpose

The purpose of the STSM was to facilitate knowledge exchange between specialists in GEO, CEDD Hong Kong, and BGS, with a key emphasis on its experience in relation to Glasgow, so that the subsurface data management practices developed by both parties could be learned and understood as a best practice example within the COST Action. Of particular importance was the gaining an understanding of how the subsurface is planned and developed in the Hong Kong SAR.

This was achieved through a visit to the Hong Kong SAR, hosted by the Geotechnical Engineering Office of the Civil Engineering and Development Department of the Hong Kong SAR. The visit was focused around discussions with, and presentations to, the host Office/Department, other departments of the Hong Kong SAR (especially the Drainage Services and Planning departments), and selected private sector consultants, and through the examination of relevant publications and literature provided by the host Office/department(s).

The key objectives were to:

1. document the incorporation of the subsurface in the planning system in Hong Kong,

2. gauge the current extent of subsurface infrastructure, that under development, and plans for future uses of the subsurface in Hong Kong and how this is to be achieved,

3. present and exchange knowledge from Glasgow in relation to the use of 3D and 4D static and dynamic models, and related visualization, and similar ideas from colleagues within the COST Action TU1206, and

4. prepare a draft stand-alone City Study for Hong Kong as a contribution to the COST Sub-Urban Working Group 1 report, and for use also by its Working Group 2 subgroups in relation to Hong Kong's use (past, present and future) of the subsurface and its related planning, data acquisition and management, multiple use, and provision for geohazards and related recommendations for use also by its Working Group 3. This reporting is intended to be shared freely with the STSM host, and other HKSAR Government Departments.

2. Work carried out within the STSM

2.1 Work Plan

The STSM involved a visit spanning 24 days by the STSM applicant (Dr Diarmad Campbell [BGS]) to the Geotechnical Engineering Office of the Civil Engineering and Development Department of the Hong Kong SAR Government from 15 September to 8 October 2014. The visit was split into two parts, as the applicant had other commitments between 17 September and 28 September 2014). The preliminary phase of the STSM (15-16 September), was followed by the main phase of the STSM (29 September to 8 October 2014).

A series of meetings was held in relevant sections of the Geotechnical Engineering Office, and with relevant sections of the Drainage Services, and Planning Departments of the Hong Kong SAR Government. These were spent in discussions (applicant – host and relevant Hong Kong colleagues), making presentations, reviewing available documentation and writing.

Meetings focused on the Hong Kong SAR's ambitious plans, and the extent to which these had

already been implemented, for increased use of the urban subsurface for a variety of uses, and especially its intentions to develop caverns around the urban fringe in particular.

The work was undertaken as follows:

Between 15th September and 8th October 2014,

15-16 September 2014: the preliminary phase of the STSM

On 19th September 2014, initial results of the STSM were discussed in a plenary session of the COST Sub-Urban Action meeting in Santiago de Compostela, Spain.

29th September to 8th October 2014: Main Phase of the STSM: meetings with Geotechnical Engineering Office personnel, and meetings and presentations with/to Drainage Services Department (6.10.14) and Planning Department (6.10.14), http://www.pland.gov.hk/pland_en/tech_doc/hkpsg/full/index.htm

Discussions were also held during the STSM with private sector consultants engaged in studies on behalf of the Hong Kong SAR Government.

In addition, the STSM was reported on to the COST SUB-URBAN Working Group 2 subgroup meeting in Edinburgh on the 19th November 2014.

The main topics of meetings and discussion held in the week were:

- The Territory-wide study on underground space development in the urban areas of Hong Kong
- Enhanced use of underground space in the Hong Kong SAR
- Recent Studies into the feasibility of developing rock cavern facilities, including the Long-term strategy for cavern development in the Hong Kong SAR
- Recent and planned transfer of existing Drainage Services facilities to caverns including the Sha Tin Sewage treatment Works
- Present and future requirements for planning of Hong Kong's sub-surface, including revision of the Hong Kong Planning Standards and Guidelines in relation to Rock Cavern Development
- Revision of the geological map coverage of Hong Kong, the potential for 3D model development, and related metadata issues

Key meetings (and presentations) and discussions were held with, amongst others, a series of specialists:

- Dr Sam Ng, Chief Geotechnical Engineer/Planning, Head of the Planning Division of Geotechnical Engineering Office (GEO), Civil Engineering and Development Department (CEDD)
- Mr Tony Y K Ho (tonyykho@cedd.gov.hk) Senior Geotechnical Engineer/Marine Geotechnology (GEO, CEDD)
- Mr Keith Roberts, Senior Geotechnical Engineer/Engineering Geology (GEO, CEDD)
- Dr. Roderick Sewell (jsewell@cedd.gov.hk), Head, Hong Kong Geological Survey (HKGS, GEO, CEDD)
- Mr Benjamin Chan Ka-ho, Senior Engineer, Sewerage Projects Division, Ms LAM Yu Ha, Ms Agnes Yiu Po-fung, Drainage Services Department
- Ms Helen So, Senior Town Planner, and Ms Stella Ng, Planning Department, Hong Kong SAR Government
- Mr Mark Wallace, Director, Ove Arup & Partners Hong Kong Ltd., lead in various Underground Rock Cavern and Urban Underground Space studies in Hong Kong
- Professor John Endicott, Executive Director, Geotechnical, AECOM Hong Kong

3. Lessons Learnt from the STSM

3.1 Background

Hong Kong is a world city with a population of more than 7 million people. Through a combination of its steep-sided topography, prone to landslides, and many islands, and an effective moratorium on further land reclamation, the area of developable space is very restricted and population density is exceptionally high. Coupled with the considerable financial success of Hong Kong, and the very considerable collective wealth of its community, land prices are amongst the highest in the world. High-rise housing is therefore commonplace.

Hong Kong has had a very long history of making use of its sub-surface, and is now heavily reliant on its extensive network of tunnels and other buried infrastructure for transport (road, railway, Mass Transit Railway, underground walkways and shopping malls), water supply, sewerage, drainage, electrical cables, and other services. 430 km of tunnels have been constructed to date,. The construction of roads and railways in tunnels has significantly reduced the amount of road side slopes that need to be formed; a significant contribution to slope safety management. Underground works have also been specifically implemented for slope safety purposes. The hillside at Po Shan area, where a major landslide in 1972 took 67 lives, is susceptible to development of high groundwater levels and prone to large-scale, deep seated failure. An innovative and sustainable regional groundwater regulation system, comprising drainage tunnels and a network of sub-vertical drains, has improved the stability of this very sizeable hillside against the risks of major landslides and enhanced public safety. Recently, several tunnels and shafts have been constructed to intercept storm water flow from upland catchments for direct discharge into the sea, which will reduce the amount of rain water infiltrating into the natural hillsides. A substantial part of this network is offshore. Considerable expansion of the existing network is under development, and there are ambitious plans to extend this further (180 km of tunnels are planned up to 2020 (Pang and Woodrow, 2009)), including the innovative use of caverns. Housing service reservoirs within caverns has already eliminated the need for extensive cutting of the natural hillsides as part of the open-cut site formation option. In addition, the numerous high-rise buildings which so typify Hong Kong, which are typically piled to rock, often have many basement floors (for shops, storage, car parking etc.), and subsurface interconnections are common.

The key drivers of subsurface development are therefore the extreme shortage of developable space, the dense population, and exceptionally high values of land. This combination of drivers, and their extreme nature, is comparatively usual, and there are few parallels in cities across Europe and elsewhere. However, Hong Kong is essentially pioneering the use of the urban subsurface and other cities can learn much from the way it is doing so already, and intends to do so more extensively, imaginatively, and sustainably in the future.

3.2 Policy Background

Enhanced use of the urban sub-surface in the Hong Kong SAR has greatly gained momentum in recent years. This has been promoted through, and explicitly acknowledged in, the Hong Kong SAR Government's policy:

1. In October 2009, the Chief Executive of the Government of the Hong Kong SAR presented his 2009-10 Policy Address on "Breaking New Ground Together". A new initiative was put forward under the Policy Agenda of 'Developing the Infrastructure for Economic Growth' to launch strategic planning and technical studies to facilitate planned development of underground space. These were aimed at promoting the enhanced use of rock caverns as part of Hong Kong's pursuit of sustainable development.

2. In his 2013 Policy Address on "Seek Change, Maintain Stability - Serve the People with Pragmatism", the Chief Executive highlighted that rock cavern development is a viable source of long-term land supply and stressed the need to conduct a study on the long-term strategy for cavern development with a view to preparing rock cavern master plans and formulating policy guidelines.

3.3 Strategy and Implementation

In light of the high-level policy support for Hong Kong's subsurface development, the potential of rock caverns is recognized as a valuable land resource for Hong Kong, and work is in progress to realise this potential. Hong Kong is unusually well placed to undertake subsurface development as it has both the resources and technical capabilities to do so. Technical standards on cavern engineering and fire safety design, as well as planning guidelines to establish the ground work for rock cavern development, have been developed and published by the Government in Hong Kong since the 1980s. The details are outlined by Chan and Ng (2006). Hong Kong is therefore an exemplar urban community in many respects, and much can be learnt by others, including those in the COST Action Sub-Urban, as to how they implement the policy, and plan and construct their subsurface developments.

In achieving its current high level of urban sub-surface development, very considerable knowledge of the sub-surface has been accumulated in Hong Kong, supported by vast amounts of ground investigation and construction data, and civil and geotechnical engineering, and (engineering) geological expertise. This technical expertise resides both in the private sector, and in various departments of the Hong Kong SAR Government; the Government's geotechnical and (engineering) geological expertise resides principally within the Geotechnical Engineering Office of the Civil Engineering and Development Department.

The Geotechnical Engineering Office of the CEDD is therefore taking the lead with the implementation of Government policy in relation to the subsurface, and undertaking the studies that have been called for. Its Planning Division is very much at the forefront of this work, which includes the management of consultancies which are actually carrying out the feasibility and other studies.

The Planning Division of the GEO falls within its Planning and Standards Branch, and provides geological and other earth science services to the Hong Kong SAR Government and the public. It also carries out research and development aimed at improving knowledge and understanding of the geological framework for Hong Kong and on its implications for, and applications to, engineering activities. The Planning Division is divided into five Sections; these specialise respectively in geological mapping, engineering geology, terrain evaluation, marine geotechnology, and cavern and underground space developments. The five Sections (Figure 1) are closely inter-linked with many tasks and multidisciplinary studies involving teams of expertise. Of particular relevance to subsurface development are the following:

- The Marine and Land Geotechnology (MG) Section has amongst other duties undertaken a feasibility study of the long-term strategy for cavern development in Hong Kong and a territory-wide feasibility study on underground space development in the urban areas of Hong Kong.

- The Engineering Geology (EG) Section provides engineering geological input to various investigations and studies on government development projects, and technical support to strategic technical and planning studies related to rock cavern development in Hong Kong.

- The Hong Kong Geological Survey (HKGS) Section is responsible for geological mapping, geological reporting, archiving geological information, and providing geological advice to the Government, the private sector, and the general public. The HKGS section has the most detailed information on the geology of Hong Kong and offers an advisory service, supporting

for example the planning and development of tunnels (see Technical Guidance Note No 24).

- The Planning and Terrain Evaluation (PTE) Section provides input into the Government's land planning system by reviewing the geotechnical feasibility of planning proposals and providing advice for better land planning and utilization.

- A new Underground Space Development (UD) Section (which was in the process of being established at the time of the STSM) provides input to promote enhanced use of underground space in urban areas of Hong Kong. The UD Section is preparing a pilot study on underground space development covering four selected strategic areas; Tsim Sha Tsui West, Causeway Bay, Happy Valley and Admiralty/Wan Chai.

  Meetings focussed during the STSM with the Planning Division of the Geotechnical Engineering Office, and with the Senior Geotechnical Engineers, and staff, of three of its sections; Marine Geotechnology, Engineering Geology, and the Hong Kong Geological Survey. Discussions addressed existing provision for planning of the urban subsurface, and studies (present and recent past) for improved planning and innovative uses of the subsurface, and especially in relation to caverns.

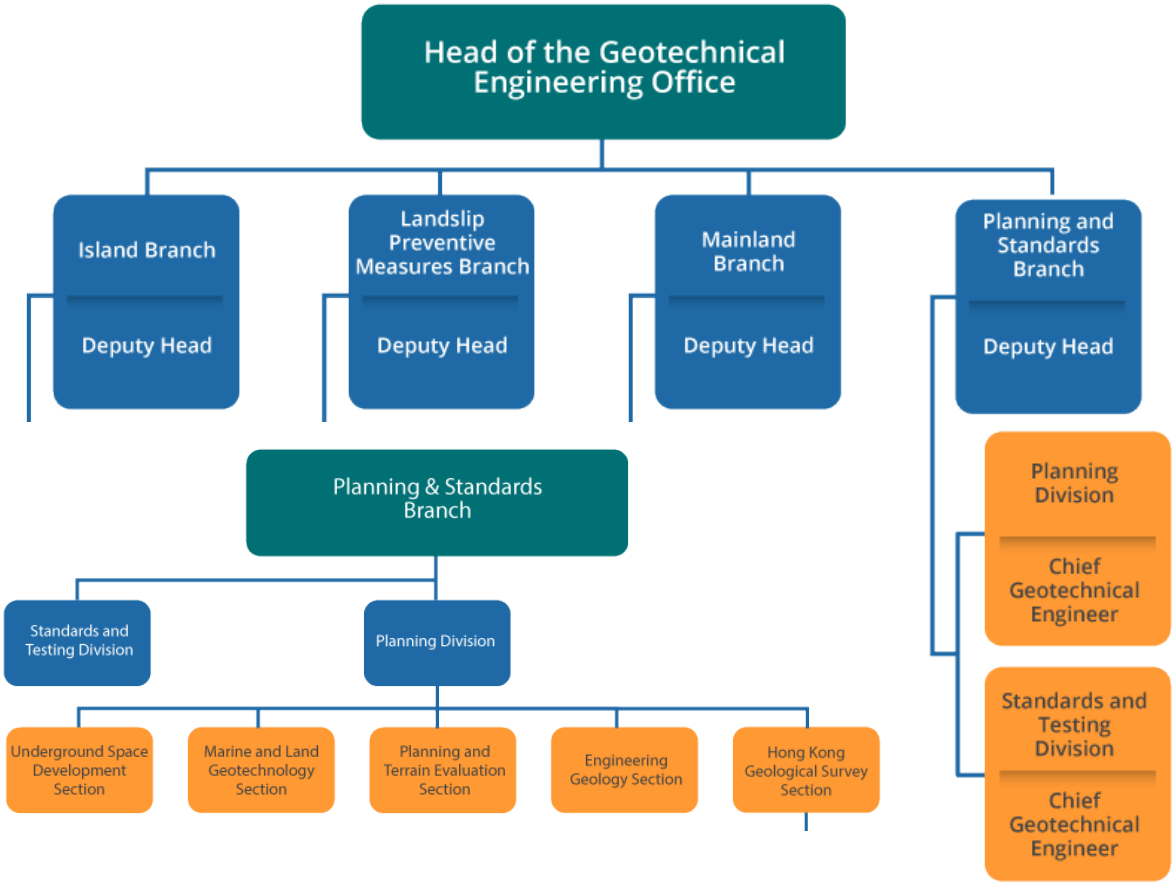


Figure 1 – Schematic representation of the internal organisation of branches within the Geotechnical Engineering Office with particular relevance to its Planning Division.

3.4 Existing provision for Planning, and Planning of the Subsurface

There is an extensive and sophisticated system of integrated planning in Hong Kong and it is well beyond the scope of the STSM to review this. However, a brief overview is provided here, to provide the context

to subsurface planning.

The Planning Department (PlanD) of the Hong Kong SAR Government is responsible for:

- formulating sustainable development strategies and plans
- monitoring, reviewing and guiding the use and development of land at the territorial and district/local level
- facilitating suitable development and redevelopment
- encouraging community involvement and support
- topical studies, and
- undertaking actions against unauthorised land uses.

Given the limited land resources in Hong Kong, there is a need to strike a balance in land utilisation to meet the competing demands for housing, commerce, industry, transport, recreation, nature conservation, heritage preservation and other community needs.

The principal body responsible for statutory planning in Hong Kong is the Town Planning Board (TPB), formed under the Town Planning Ordinance (TPO) and served by the PlanD. The TPB oversees the preparation of draft statutory plans, and considers applications for planning permission and amendments to plans.

Extensive consultation is undertaken across Government in relation to draft plans, and plan amendments, and views are sought from its various departments. With regard to the subsurface, the expert views of the CEDD, and the GEO in relation to geotechnical and geological issues, are key.

Planning System: Hong Kong's planning system comprises development strategies at the territorial level and various types of statutory and departmental plans at the district/local level. Guiding the preparation of these plans is the Hong Kong Planning Standards and Guidelines, relevant development related policy and principles and community views.

Territorial Development Strategy: The strategy aims at providing a broad planning framework to guide future development and the provision of strategic infrastructure in Hong Kong. It also serves as a basis for the preparation of district plans. The findings and recommendations of *Hong Kong 2030: Planning Vision and Strategy (the HK2030 Study)*, a study to formulate the planning framework for Hong Kong up to 2030, were promulgated in October 2007. The HK2030 Study has adopted sustainable development as its over-arching goal. The recommended strategy aims to help Hong Kong achieve its vision as "Asia's world city".

Statutory Plans: Two types of statutory plans are prepared:
1. The Outline Zoning Plan (OZP) shows the land use zones, development parameters and major road systems of an individual planning area. Areas covered by OZPs are in general zoned for uses such as residential, commercial, industrial, green belt, open space, government / institution / community uses or other specified purposes. Attached to each OZP is a Schedule of Notes showing the uses which are always permitted, and others for which prior permission from the TPB must be sought.

2. The second type is Development Permission Area (DPA) Plan. DPA Plans are prepared to provide interim planning control, and development guidance for rural areas in the New Territories until more detailed OZPs are prepared.

Departmental Plans: Outline Development Plans (ODP) and Layout Plans are administrative plans

prepared within the framework of the statutory plans. These departmental plans show more detailed level planning parameters e.g. site boundaries, location of access points and footbridges, specific types of government or community uses to facilitate the coordination of public works, land sales and land reservation for specific uses. Public engagement in the form of public forums, workshops, exhibitions, etc. has become a very important component of the planning process.

Hong Kong Planning Standards and Guidelines: This is a reference manual setting out the criteria for determining the scale, location and site requirements of various land uses and facilities. It is used in the preparation of town plans and planning briefs and is a tool that helps to regulate development.

Urban Renewal and Regeneration: The Urban Renewal Authority (URA) is a statutory body established to speed up renewal of old urban areas.

New Town and New Development Areas: Large-scale new town development in the New Territories began in the early 1970s. The PlanD's District Planning Offices have worked closely with the Civil Engineering and Development Department's Development Offices to prepare plans and oversee the development of these new towns. At present, nine new towns are in various stages of development and will accommodate about four million people. To meet the acute housing demand, a multi-pronged approach including extensions to existing new towns, and new developments are being pursued.

3.4.1 Land ownership issues and subsurface development rights

In Hong Kong, the owner of the surface land also owns development rights vertically upwards, and has the right to develop its underground space. Underground development for public purposes can be developed underneath private lots; however, this is subject to compensation to the land owner, and privately orchestrated underground development cannot be developed beneath private lots under the ownership of others. To avoid complicated and potentially contentious land ownership issues, it is preferable to develop caverns to house Government facilities beneath areas where there is no private ownership. In this respect, the hillsides in the urban fringes are particularly suited for cavern development. To facilitate optimal underground development, it is considered (Ng et al., 2015) that a revised regulatory framework would be required. Components of these amendments would include the ability to create separate ownership between surface and underground developments.

3.4.2 Specific examples of existing provision for subsurface planning and development

Some notable examples of planning and control of use of the urban subsurface in which the GEO, CEDD takes the lead in implementation, are in relation to Scheduled and Designated areas related to areas of geological complexity, and hazard, and tunnels.

Scheduled and Designated Areas

Scheduled Areas No. 2 (North-western New Territories) and No. 4 (Ma On Shan) are defined in the Fifth Schedule of the Hong Kong SAR's Buildings Ordinance. Geotechnical control measures [overseen by the GEO] apply in these areas in respect of building works, and apply to submissions relating to ground investigation, foundation design and construction in these Areas, and to any groundwater pumping proposed. The recommendations are based on practice developed since the discovery of cavity problems associated with concealed deposits of marble, and have been accepted by the profession.

Marble which occurs in the two Scheduled Areas, usually has a karstic upper surface with solution features; large cavities occur within the marble in some locations. The planning, design and construction of works which involve ground investigations, excavations, foundations or groundwater pumping may encounter significant difficulties as a result of these ground conditions, hence the need for geotechnical control.

The Designated Area of Northshore Lantau (GEO Technical Guidance Note TGN12) is also underlain by

locally complex geological conditions that require that attention is given to the potential problems associated with high-rise buildings and other structures involving deep foundations. The complex geological conditions include for example anomalously deep rockhead, locally in excess of 160 m below ground level.

Tunnels

Technical Guidance Note (TGN) 24 provides guidance on site investigation (SI) for tunnel works in Hong Kong. This states that the Hong Kong Geological Survey (HKGS) should be consulted, especially at the planning stage of new projects involving tunnel works, in the formulation of geological models, anticipation of difficult areas, and the verification of significant geological features (faults, dykes, contact zones between geological units, etc.). This consultation process in actual projects also allows feedback of important geological information from the project to existing geological archives maintained by HKGS.

3.5 Past and Present Studies in relation to the Urban Subsurface

3.5.1 Previous Studies of Underground Space in Hong Kong (Arup, 2011)

Study of Potential Use of Underground Space (SPUN)

Investigation of potentially viable uses for large man-made underground spaces in rock caverns was an early Metroplan initiative, for the 1990s, being a new response to the continuing demand for usable land supply. Concern about the growth of various environmental problems made this option even more attractive. Many kilometres of tunnels had already been constructed in Hong Kong for the use of road and rail traffic, and caverns had also been formed as part of the Mass Transit Railway (MTR) system and for water supply. The technology involved in this process had been well tested in Hong Kong, but had not yet been applied to the formation of underground space on as large a scale, or for as wide a variety of uses as was already common elsewhere in the world. It was recognised widely for the first time during the Metroplan Study, that rock cavern development could help to ease the demand for usable land, the supply of which is severely limited in Hong Kong Island and Kowloon. In order to establish the opportunities that existed for this new form of development, whilst taking the constraints unique to Hong Kong into account, the Study of the Potential Use of Underground Space (SPUN) was initiated by GEO in 1988 under the aegis of the Metroplan Study focusing on four main issues: 1. The physical opportunities provided by Hong Kong's topography and geology. 2. The existence of suitable sites compatible with planning needs. 3. A likely range of viable uses. 4. Environmental problems and opportunities.

The SPUN study confirmed that the development of underground space in Hong Kong was a viable alternative to conventional above-ground development and one which could offer significant environmental benefits.

Cavern Project and Cavern Area Studies

Following SPUN, Cavern Project Studies (CAPRO) were initiated in 1990 including ground investigations for two schemes. The studies included: • Refuse Transfer Station in Mount Davis, and • Government Warehouse in Chai Wan In parallel with the SPUN and CAPRO studies, the Guide to Cavern Engineering, the Guide to Fire Safety Design for Caverns and Hong Kong Planning Standards and Guidelines (HKPSG) on rock cavern development were issued to provide designers and regulatory authorities with a guide to good cavern engineering practice. Several Preliminary Engineering Geology Studies (PEGS) were carried out by CEDD between 1990 and 1993 and more recently to assess the potential for relocating various existing and planned facilities to rock caverns, including sewage treatment, fuel storage, abattoir & service reservoir facilities. Cavern Area Studies (CAS) were also carried out by CEDD between 1992 and 1998, to classify the suitability of land for rock cavern development based primarily on general engineering geological information

3.5.2 Rock Cavern Projects Successfully Implemented in Hong Kong (Arup, 2011)

Cavern development is by no means a new idea in Hong Kong. The following successfully implemented projects highlight that the use of rock caverns is a viable option in Hong Kong.

Hong Kong University has recently relocated two Water Supplies Department (WSD) salt water service reservoirs (12,000 m3 capacity) within rock caverns to accommodate the development of their Centennial Campus. The two rock caverns are 50 m long, 17.6 m wide and 17 m high. This has set an unprecedented local example of constructing service reservoirs in rock caverns. The cavern scheme preserved the three historic graded buildings nearby, minimised tree felling and reduced the amount of construction waste generated.

The Stanley Sewage Treatment Works serves a population of 27 000 inhabitants. The design capacity of the facility is 11 600 m^3/day. The facility, designed with a process that minimised the size of the sewage treatment facility, was completed in 1995. The underground facility comprises access tunnels, a 130 m long service cavern of 15 m span and 17 m high, and two treatment tunnels about 90 m long, 15 m span and 11 m high. These house aeration tanks, sludge pumps and final settlement basins. The cavern scheme was chosen because no suitable surface land was available.

The Kau Shat Wan Explosives Depot was completed in 1997 and has since been the principal store of explosives in Hong Kong. Due to the large urban development planned on the West Kowloon Reclamation close to the then explosives complex on Stonecutters Island, a new explosive storage facility was planned. The selected site at Kau Shat Wan offered a remote, secure site with limited accessibility by land. The Kau Shat Wan explosives magazine facility comprises one loop access tunnel with 10 No. explosive chambers that are 21 m long, 6.8 m high and 13 m wide running off the access tunnel.

The Island West Transfer Station involved the construction of a waste transfer facility in a rock cavern in the Central and Western District of Hong Kong Island. It was successfully procured through a build, operate and transfer contract with private sector involvement. The cavern scheme was adopted based on the work undertaken in the SPUN & CAPRO Studies as there were problems in identifying a suitable site for the refuse transfer station within the Central and Western District. The cavern layout and arrangement include a 27 m span cavern that is 60 m long and 12 m high. This is the largest span rock cavern constructed in Hong Kong to date.

The MTR West Island Line Explosives Magazine at Victoria Road was constructed to store explosives for the construction activities relating to the West Island Line. The magazine is designed in a horseshoe shape, with eight small niches, each to hold a small amount of explosives. The excavation totals approximately 325 m in length and the niches are 4.2 m high and 5.5 m wide, and 8.6 m long.
It appears to be possible to expand the use of underground space into large-scale development with minimal impact to the surrounding communities and general public. Indeed some of the new MTR projects are building caverns and underground space in close proximity to densely populated residential areas. There are numerous examples of use of underground space in Hong Kong not only as caverns but as deep basements in the city. Integration of some of these facilities into a connected underground city can be achieved as demonstrated by the successful integration of Tsim Sha Tsui and Tsim Sha Tsui East stations with connections to various shopping and retail complexes further expanding the feeling of a connected underground city space.

3.5.3 Enhanced Use of Underground Space in Hong Kong

A study was commissioned by the GEO, CEDD to undertake a strategic planning and technical study on ‘Enhanced Use of Underground Space in Hong Kong’ in March 2010. It was intended to take forward

the policy initiative of rock cavern development as laid out in the 2009-10 Policy Agenda. The study, undertaken by Arup, and supported by Norconsult and Urbis, was completed in March 2011. It explored the opportunities to enhance the effective use of land resources in Hong Kong from the perspective of planned development of underground space. The study is summarised by Chan (2011) and the Executive Summary of the study has been made publicly available (Arup 2011).

The study assessed potential land uses in Hong Kong and potential land uses for rock cavern development, and undertook a review of underground planning, useage strategy and practice in Hong Kong, as follows.

Potential Land Uses in Hong Kong

The review of cavern schemes overseas has identified that there are a variety of reasons for the development of caverns and underground space such as land supply, economy, environment, climate and security. Not only are the impact elements important to assess but also the political and public perception in accepting and valuing this type of space.

There are a variety of uses that have been developed in rock caverns mostly around the NIMBY (Not In My Back Yard) or Bad Neighbour type facilities. However, there are more land uses and facility types that have been recognised internationally that could also be considered as being relevant to Hong Kong. These land uses are listed in the table below:

Potential Land Uses for Rock Cavern Development

Commercial Retail Food / Wine storage Warehousing Industrial Industry LPG bulk storage Oil bulk storage Storage / Warehousing Dangerous goods Data centre Research laboratories Science park Government, Institution & Community (GIC) Civic centre Columbarium / Mausoleum / Mortuary Incinerator Indoor games / Sports hall Refuse transfer facility Sewage / Water treatment plant Service reservoir Slaughterhouse Transport connections & networks Wholesale market Archives Bicycle park-and-ride Car / Vehicle parking Crematorium Refuse collection point Maintenance depot for rail and others Underground quarrying Public Utilities Power station Substation.

Review of Underground Planning, Usage Strategy, and Practice in Hong Kong

In order to implement an underground planning strategy, there needs to be specific consideration of local requirements and demands. Underground planning and usage strategy and underground development practices are strongly linked. Where the framework to build, operate and maintain underground space has not been developed there is potential for the above-ground based legislative and regulatory framework to hinder the development of underground space.

Legislative and administrative issues concerning cavern development often include the limits of surface property ownership, the right to develop underground space, application of surface land use regulations to underground space, environmental controls, major permits required and potential development restrictions due to surface and underground structures.
While the use of underground space is quite common in Hong Kong in relation to the MTR and associated underground retail complexes, Hong Kong currently only has five purpose-built cavern developments. In Hong Kong the drivers for cavern development are high land values and limited surface land for development. The hilly, steep terrain and strong granitic and volcanic rocks of Hong Kong provide excellent conditions to develop underground space. Advantages and opportunities for underground development in Hong Kong include:

Lack of Available Land: Key sites that are occupied by government uses can be considered for reprovisioning in rock caverns to free up land in densely populated areas. Prime land areas that have become vertically constrained are likely to adopt underground options in the future, particularly if incentives are available to the private sector.

Urban Redevelopment: As existing older urban areas deteriorate and new infrastructure or redevelopment is required, underground development provides a method whereby essential services can be constructed concurrently beneath new facilities with minimum disruption to the surface and public.

Environmental Impact: Underground developments can reduce the impacts on urban sprawl and provide for the requirements of economic growth whilst preserving the natural environment.

Bad Neighbour Uses: Locating above-ground undesirable or "bad neighbour" uses, e.g. refuse transfer stations and sewage treatment works, can be a contentious aspect within an existing community. Adoption of underground facilities for this type of land use could reduce the impacts on the environment and communities living nearby.

Low Visual Impact: A major benefit of cavern developments is their relatively low visual impact as only shafts and portals are visible at the surface.

Security: Experts regard the use of rock caverns for data centres and storage of some dangerous goods such as natural gas and fuels as improving and increasing the security of storage as it reduces the risk of accidental impact, blast and acts of terrorism.

Innovative Usage: Other innovative design schemes, e.g. development of multi-facility caverns and integration of cavern formation and underground quarrying or underground infrastructure development could be explored.

Energy Efficiency: The insulating mass of the surrounding earth usually means that underground caverns typically use 50–80 percent less energy for heating and cooling than a surface building. From the perspective of uniform temperature control, exploiting underground caverns in Hong Kong could be beneficial.

Economics: The construction cost of underground caverns can sometimes be cheaper than that of an above-ground alternative if the land value is taken into account.

Future Expansion: Provision must be made to allow future expansion of facilities by reserving nearby space. To further maximise the use of underground space, it would be prudent for Hong Kong to take the following planning steps:

Identify and Plan for Future Underground Usage

1. A clear policy steer is needed. To address the lack of incentive to actively seek cavern development as a potential development option, it is proposed that Technical Circulars could be issued by relevant bureau to mandate the consideration of cavern options in the early project planning stage for all appropriate government projects.
2. In new land parcels, identify those that can adopt caverns to ensure that no beneficial opportunities for cavern development are missed in the public sector.
3. Identify existing land parcels that could be used for underground space development. A system to reserve them for suitable land uses without being compromised by future development project is required.
4. Shortlisting of government facilities of land uses with potential to be placed in caverns that are currently located on valuable surface land parcels, for re-provisioning underground.

5. To formulate a programme and implement the reprovisioning of the shortlisted government facilities with potential to be placed underground.
6. Explore innovative design schemes such as archives, data centres and underground quarrying.
7. Incorporate the planning strategy for underground space development into relevant future territorial/ regional development strategies, where appropriate.
8. To build up an underground land reserve based on the identified strategic cavern areas and sites.
9. Explore improved connectivity of existing underground space areas in Hong Kong with MTR stations and other transport hubs.

Legislative and Administrative Issues:
There are a number of planning and legislative aspects that place restrictions on the ability for Hong Kong to be flexible with its underground development locations and planning.

Firstly, in Hong Kong the land ownership on the surface extends underground as well. As the current development model for many of Hong Kong's projects is a mixed-use development, the ownership of the land is often amongst multiple parties. From an administrative viewpoint, it would be difficult to organise all of the owners to consent to trigger underground development beneath these land plots.

Secondly, Hong Kong's current land practice only allows underground development below other parties land (without ownership) in the case of public need, such as the development of the MTR system. Therefore the surface land would need to be owned by the same party that wanted to develop underground.

Thirdly, the statutory planning currently dictates that land use on the surface also governs the land uses underground, which could potentially be restrictive to the development of differing uses. However, the current statutory planning system has the flexibility to accommodate underground development.

To facilitate optimal underground development, a revised regulatory framework would be required. Components of these amendments would include:

- The ability to create joint ownership between surface and underground developments. This however, would require detailed feasibility study and would only be an option in case of newly disposed land.
- Legislative amendments required for the interfacing between joint landowners.

With regard to the proposed revisions to the statutory and legislative framework, there is the potential to introduce an overarching Cavern Ordinance to assist this aspect. This would:

- Consolidate all of the various development stakeholder aspects under one Ordinance.
- Specify the rights and obligations of all parties with respect to the underground developments.
- Make provision for the private sector involvement much easier in underground developments.

Private Sector Involvement: Hong Kong is a city that has minimal government involvement in business. This "hands off" approach sees the private sector driving most of the industry and commerce in the city. It would therefore be beneficial to also enable private sector involvement in the development of underground uses. To generate interest and involvement from the private sector, incentives would be required to make the developments attractive. The incentives could comprise preferential land premiums, enhanced development potential or tax incentives.
Another potential approach to encourage private sector involvement is the Public Private Partnerships

(PPPs). In many local and overseas instances, PPPs have proven to be a successful model to deliver modern and high quality services e.g. the railway and property model adopted by MTR and the Hong Kong Government. For example, to encourage relocation of bad neighbour uses or incompatible public utilities underground, the Government can grant the private investor with property development rights of the released surface site as a means of financial support.

Underground Development Programme Fund: For the development and promotion of underground space in Hong Kong, the creation of an Underground Development Programme Fund could assist with the administrative aspect of development and also be utilised to provide funding for replacement of existing government facilities in caverns.

Key findings (Ng et al., after Arup. 2011)

- Hong Kong is particularly suitable for developing rock caverns from a geological perspective, and two-thirds of Hong Kong's land is of medium to high suitability for cavern development (Fig. 2). The hilly areas in the urban fringes of Hong Kong with strong rocks and convenient access are particularly suitable for cavern development.
- By reprovisioning suitable Government facilities inside caverns and releasing the original land as well as any adjacent sterilized land for housing and other uses, cavern development is a viable option to increase land supply.
- Cavern development could also accommodate new infrastructure facilities which would otherwise occupy surface land. Reserving underground space could cater for future projects and expansion of underground facilities.
- For those NIMBY (Not-In-My-Backyard) facilities like sewage treatment works and refuse transfer stations, the cavern option would help reduce adverse impacts on the local environment, remove incompatible land uses and alleviate the NIMBY sentiment.

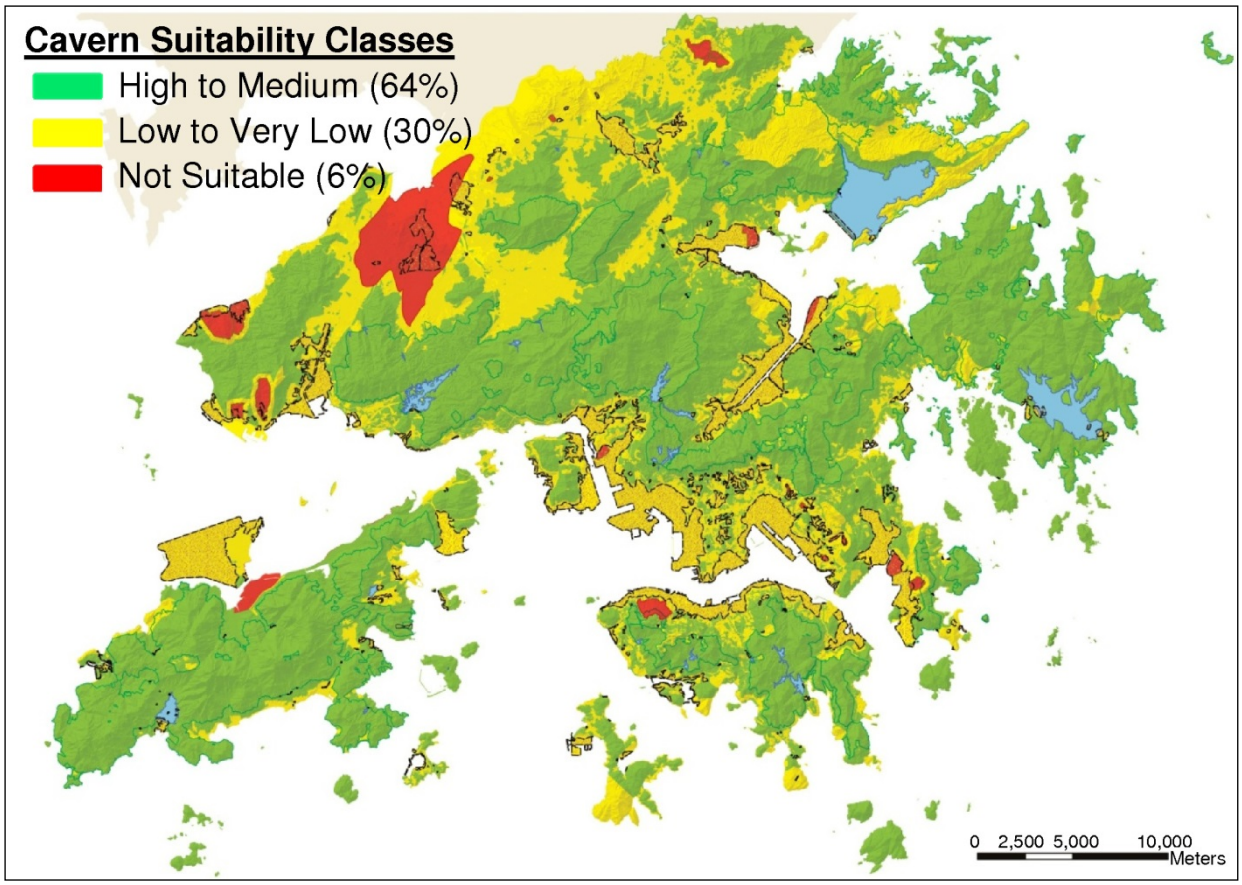


Figure 2 - Distribution of Cavern Suitability Classes (Arup, 2011)

Some 3,500 ha of land may therefore be formed from cavern development. As the Hong Kong SAR Government's existing facilities considered suitable for cavern development only occupy around 400 ha, there is considerable scope for developing new public and private sector facilities in caverns. The Study also recommended other potential land uses for cavern development for inclusion in the Hong Kong Planning Standards and Guidelines (PlanD 2008) (Table 1).

Land Use Category	HK Planning Standards & Guidelines (2008)	Additional Potential Land Use (Arup 2011)
Commercial	Retail	Food/Wine storage Warehousing
Industrial	Industry Storage/Warehousing Oil bulk storage LPG bulk storage	Dangerous goods Data centre Research laboratories Science park
Government / Institution / Community (GIC)	Civic centre Indoor games/Sports Hall Incinerator Refuse transfer facility Service reservoir Sewage/Water treatment plant Slaughterhouse Wholesale market Transportation connections & networks Columbarium/mausoleum/mortuary	Archives Bicycle park-and-ride Car/Vehicle parking Crematorium Refuse collection point Maintenance depot, e.g. rail and bus Underground quarry
Public Utilities	Power station	Substation

Table 1 - Potential Land Uses for Cavern Development (Ng et al., 2015, based on Arup, 2011)

3.5.4 Constraints on Cavern Development in Hong Kong

A number of key constraints have been identified for cavern development in Hong Kong (Roberts & Ng 2012) and these can be broadly grouped under two main categories, unfavourable regulatory mechanism and unfavourable financial assessment, as listed in Table 2. These lists are of broader applicability, and apply more generally to constraints on underground development in urban environments in many cities in Europe and elsewhere.

One of the key concerns (Ng et al., 2015) amongst potential end users is the general perception that caverns are more expensive in terms of both capital and operating/maintenance costs. It is likely that in some cases operating/maintenance costs can be expected to be higher, which is mainly a result of the additional energy costs associated with lighting and ventilation for an underground facility, depending on their nature. However, most buildings in Hong Kong also require lighting and ventilation. Furthermore, temperatures within caverns generally remain stable in the range of 20°C to 25°C all year round as compared to the mean surface temperatures varying between 15°C and 31°C. Therefore, a significant reduction in heating and cooling cost can be expected for a facility placed in caverns if a

uniform temperature environment is required for efficient operation. [Note: This same argument equally applies to the use of urban groundwater in both heating (ground source heat) and cooling in many cities in Europe and elsewhere with variable heating and cooling needs in winter and summer]

Only by overcoming the constraints can the full benefits of rock cavern development be realized, e.g. related to issues of land supply, land use compatibility and the environment. Many of the benefits of cavern development to the community are intangible, e.g. additional open space and reduced congestion or likely reduction in complaints in relation to NIMBY facilities.

Unfavourable Regulatory Mechanism	Unfavourable Financial Assessment
• Policy guidelines • Planning & zoning policies • Land ownership framework • Mechanism for valuation of cavern space • Project benefits may not reflect community benefits	• Cost of land formation excluded • Value of the land & adjacent sterilised land not considered • Land value enhancement by relocating NIMBY facilities not considered • Opportunity and intangible costs (e.g. less complaint handling) not considered

Table 2 - Constraints on Rock Cavern Development (Ng et al., 2015, based on Arup 2011)

3.6 Current Studies of Underground Space in Hong Kong

3.6.1 Long-term Strategy for Cavern Development

In September 2012, the Civil Engineering and Development Department of the Hong Kong SAR Government commenced a study on "Long-term Strategy for Cavern Development", to develop a holistic approach in planning and implementing cavern development and render it a sustainable means for expanding land resources. The study, being undertaken by Arup and due to be completed in late 2015, also places emphasis on private sector participation as facilities, such as storage, warehousing and data centres, can benefit from rock caverns' stable and secure setting. In parallel, four pilot relocation schemes, namely Sha Tin, Sai Kung and Sham Tseng Sewage Treatment Works, all for Drainage Services Department, and Diamond Hill Fresh Water and Salt Water Service Reservoirs, for Water Services Department, are being studied for their technical feasibility and financial viability. These facility specific studies together with the Strategic Study form the roadmap for cavern development (Figure 3).

Implementation of a long-term strategy for cavern development could provide a sustainable approach in easing the pressure of land shortage. Developing a systematic relocation programme for suitable Government facilities could release surface sites for other uses including housing, and placing nuisance facilities in caverns could remove incompatible land uses. Reserving rock cavern space to accommodate future public and private sector facilities underground could further reduce the land take.

Policy guidelines will be formulated to facilitate cavern development for both public and private sectors and encourage consideration of the cavern option at the initial project planning stage. An important element is to develop an appropriate method of economic analysis for comparing cavern and surface site options on an equitable basis, taking account of factors such as the value of the surface land, cost of land formation, value of excavated materials for re-use, value of sterilised land nearby, enhancement of land value in the vicinity, opportunity cost of the surface site, cost impact on maintenance and operation, and other intangible benefits.

Facilitating rock cavern development at the urban fringes and underground space development in the

urban areas could enhance Hong Kong's utilisation of land resources in pursuit of sustainable development. Therefore, a Hong Kong-wide Cavern Master Plan will also be prepared to delineate strategic cavern areas and outline the specific areas for Government facilities and areas suitable for private sector land uses. 60 strategic cavern areas have been delineated, so far, covering a total plan area of about 50 km^2 (5,000 ha). A systematic programme is being developed for relocation of suitable Government facilities (25 no.) to caverns in a planned manner, thereby gradually releasing the surface land for other uses. Enabling mechanisms to encourage private sector uptake will also be assessed, as will public and stakeholder views.

Figure 3 - Road Map for Rock Cavern Development (Ng et al. 2015)

3.6.2 Potential of Underground Space Development in the Urban Areas

The Hong Kong Government has also commenced an initiative to explore the potential of underground space development in the urban areas. Four strategic urban areas (Tsim Sha Tsui West, Causeway Bay, Happy Valley, Admiralty/Wan Chai, have been identified for the Pilot Study based on previous local studies. The prime objective of the study is to enhance the use of underground space resources more systematically by creating space for commercial and other uses and enhancing connectivity of facilities in these districts to meet the needs of the community, thereby improving the congested urban environment at ground level. The study will commence in early 2015 and will take about 2.5 years.

The key items of the Pilot Study, as described by Ng et al. (2015), are:

(a) Evaluation of overall merits and key issues of underground space development in the four selected strategic urban districts.

(b) Formulation of an Underground Master Plan for each selected district.

(c) Identification of priority projects within each selected district and proposing conceptual design schemes for the priority projects.

(d) Establishment of engineering feasibility of the priority projects by carrying out broad planning, technical and financial assessments and preliminary environmental review.

(e) Preparation of preliminary engineering design for each priority project.
(f) Recommendation of the way forward for implementation of priority projects.
(g) Public engagement and consultation with relevant stakeholders.

3.6.3 Availability of Geological Information to support subsurface planning in Hong Kong

An excellent and comprehensive interactive online account of the geology of Hong Kong, prepared by the Hong Kong Geological Survey, is available (***http://www.cedd.gov.hk/eng/about/organisation/org_geo_pln_map.html)***

A thorough revision of the geological map coverage of Hong Kong at 1:20,000-scale (15 map sheets originally produced in the 1980s and 1990s) is currently in progress. The maps for Shatin, Kowloon and Hong Kong Island have already been completed, and those for the NW New Territories are at an advanced stage of completion.

As yet, however, there is only very limited availability of 3D models/maps for Hong Kong. There is a clearly a major opportunity to develop potentially high resolution subsurface (engineering attributed) geological models, at least locally, based on the more than 100,000 boreholes held in archives by the Geotechnical Engineering Office. Knowledge exchange between partners involved in the COST Action Sub-Urban, and colleagues in the Hong Kong Geological Survey could help to facilitate the development of such modelling. This modelling could be further developed to assist decision-making in relation to the planning of Hong Kong's subsurface, and its programme of cavern development.

3.7 Key References

Arup. 2011. Executive Summary on Enhanced Use of Underground Space in Hong Kong – Feasibility Study. Ove Arup & Partners for Geotechnical Engineering Office, Civil Engineering and Development Department, the Government of the HKSAR. (Available at the CEDD website, www.cedd.gov.hk).

Chan, R.K.S, and Ng, K.C. 2006. Are we prepared for cavern development in Hong Kong? Proceedings of the Hong Kong Institution of Engineers Geotechnical Division 26th Annual Seminar, Hong Kong, 12 May 2008, 53-63.

Ling, K.K. 2011. Towards an Underground Development Strategy for Hong Kong. Proceedings of the Hong Kong Institution of Engineers and Hong Kong Institute of Planners Joint Conference on Planning and Development of Underground Space, 23-24 September 2011, Hong Kong, 45-51.

Ling, K.K. and Chan, M.H.Y. Learning from Successful Cases: Workable recipes for underground development. Proceedings of the HKIE Geotechnical Division Seminar 2013, 31 May 2013, Hong Kong, 1-18.

Ng, K.C., Roberts, K.J. and Ho, Y.K. 2013. Rock caverns – "unlimited space for future development". Proceedings of the HKIE Geotechnical Division Seminar 2013, 31 May 2013, Hong Kong, 19-31.

Pang, P.L.R. and Woodrow, L.K.R. 2009. A new era of tunnel works in Hong Kong: opportunities, challenges and geotechnical control. Proceedings of the Institute of Materials, Minerals and Mining (Hong Kong Branch) Conference on Hong Kong Tunnelling, 19 November 2009, Hong Kong, 37-46.

PlanD. 2008. Rock Cavern Development. Hong Kong Planning Standards and Guidelines, Planning Department, the Government of the HKSAR.

Roberts, K.J. and Ng, K.C. 2012. Long-term Strategy for Cavern Development in Hong Kong. Proceedings of the 30th Anniversary Conference, Recent Development on Geology and Engineering Geology, the Geological Society of Hong Kong, 29 June 2012, Hong Kong, 27-36.

Ross, S., Wallace, M.I., Ho, Y.K., Tsang, W. and Ng, K.C. 2014. Recent Studies into the Feasibility of Developing Rock Cavern Facilities in a Dense Urban City. Proceedings of the 14th World Conference of Associated Research Centre for the Urban Underground Space, 24-26 September 2014, Seoul, Korea.

Wallace, M.I., Roberts, K.J. and Lau, V. 2014. A Geographic Information Systems Approach for Regional Cavern Suitability Mapping for Hong Kong. Proceedings of the 14th World Conference of Associated Research Centre for the Urban Underground Space, 24-26 September 2014, Seoul, Korea.

4. Applicability of lessons learnt – transfer of best practice

The findings of the STSM are of considerable relevance, and applicability to COST Sub-Urban partners, and especially, but not exclusively, to its city-partners. These need to be promulgated widely therefore, to promote 'best' practice. The feasibility of transferring the subsurface planning culture and enhanced use of the subsurface as being practiced and implemented in Hong Kong to other COST cities will, however, be in part dependent on the different legislative frameworks existing in COST cities, and the different remits of city partners, and geological surveys. This will therefore require further discussion by COST Sub-Urban Working groups

The STSM confirmed that the work being carried out by Glasgow City Council in Glasgow, with the support of the British geological Survey (BGS), to develop statutory guidance for planning of Glasgow's subsurface, is following good practice. Visiting GEO/CEDD in Hong Kong, and other Hong Kong SAR departments, also gave a direct insight into the full potential of subsurface planning and enhanced use of the subsurface; something to aspire to on the basis of the work in Glasgow.

1. As a follow up to the STSM, a city study for Hong Kong is being prepared as a contribution to the series of city studies being undertaken for Working Group 1 of COST Action TU1206 Sub-Urban. This will cover city typology (Appendices 1 and 2), geology (Appendix 1), and subsurface planning system (Appendix 3 etc.).

2. The assessment of subsurface planning used in Hong Kong, and that being prepared for the next generation of the enhanced use of the urban subsurface, and associated cavern development in the Hong Kong SAR, will be provided as an exemplar of practice, to the Subsurface Planning Subgroup (WG2.1) of Working Group 2 of COST Action TU1206 Sub-Urban. This will be included in the toolbox to be prepared under Working Group 3 of the Action, for roll-out to city partners for testing, and wider roll-out in Europe and further afield.

3. In return, two presentations have already been given to wider audiences than those specifically targeted as part of the STSM, to share knowledge and experience gained from Glasgow to Hong Kong practitioners, to:

- The GEO/CEDD in an open GEO Seminar on "Geological and geotechnical characterisation of the shallow urban subsurface for planning and development"
- The Hong Kong Regional Group of the Geological Society of London on "From geological maps to 3D and 4D models - transforming the delivery and relevance of geological knowledge for practitioners"

4. Preliminary feedback has been provided to COST Action Meetings:

- 24-26.9.14 for Working Groups 1, 2 and 4, in Santiago de Compostela, Spain and
- 19.11.14 for Working Group 2-3 (3D modelling) in Edinburgh, UK.

5. Feedback, and a potential presentation, will be provided to colleagues in Glasgow City Council, UK, and especially to those engaged in developing statutory guidance for the subsurface of Glasgow.

5. Future Collaborations and Outputs

Continued knowledge exchange:

Continued discussions and knowledge exchange on planning of the urban subsurface, and on its enhanced use, particularly with respect to cavern development will continue from the STSM as work

in these areas in both Hong Kong and Glasgow proceeds, the latter including work by the British Geological Survey with its partners in the Glasgow-based ASK Knowledge Exchange network.

It is recommended that further visits by colleagues in Hong Kong and Glasgow are explored. This might include a potential STSM by a COST partner from Glasgow to Hong Kong, or vice versa, to assist with the development of statutory guidance for the planning of the urban subsurface, currently under preparation in Glasgow. This would also be shared with other COST partners, and especially those in Rotterdam, Oslo, but also others.

A reciprocal knowledge exchange by a colleague, or colleagues from Hong to Glasgow, could be coupled with a visit to the British Geological Survey in relation to 3D modelling of the urban subsurface. BGS has extensive experience of using the a range of 3D and 4D modelling software to create models of Quaternary deposits, and faulted bedrock, and would be able to provide training and knowledge exchange to GEO/CEDD colleague(s). This is will be followed up by BGS and GEO/CEDD in the coming months.

Hong Kong will be used to test the COST Toolbox, which will incorporate elements of the good policy, planning and implementation practice identified in Hong Kong

Engagement of a wider group of COST participants:
A wider group of COST participants will be engaged in discussions on subsurface planning and enhanced use of the urban subsurface, and on cavern development. This will be achieved during further COST Sub-Urban workshops, including those scheduled for Zagreb in March 2015.

Outputs:
Hong Kong provides a best practice example to the COST Action as to how the subsurface can be planned for and developed. The city study being prepared for Hong Kong as a follow-up to this STSM will be a contribution to the series of city studies being undertaken for Working Group 1 of COST Action TU1206 Sub-Urban.

The assessment of subsurface planning used in Hong Kong, and that being prepared for the next generation of the enhanced use of the urban subsurface, and associated cavern development in the Hong Kong SAR, will be provided as an exemplar of practice, to Working Group 2 of COST Sub-Urban, and will be included in the toolbox to be prepared under Working Group 3.

6. Summary

The STSM facilitated an invaluable, focused period of knowledge exchange between BGS and Glasgow on the one hand, and GEO, DSD and PlanD in Hong Kong on the other, centred on key issues of subsurface planning and enhanced use of the urban subsurface. The lessons learnt within this STSM are of benefit to all COST-participants, and not just BGS, Glasgow, and GEO. It is hoped the work of the STSM can be built upon to engage a wider group of COST participants and cities to become involved in the discussions.

The work by, and various studies carried out for, the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department (CEDD), Hong Kong SAR, and its sister government departments including Planning Department and Drainage Services Department, provide a benchmark example to COST city-partners and others to aspire to as to how the subsurface can be promoted, planned for in an integrated and sustainable way, and developed, especially in relation to the development of caverns intended for a wide range of uses.

7. Host Institution Approval /Sign-off

Mr H N Wong,

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

APPENDIX 1 Typology of Hong Kong

Socio-economic background

Hong Kong has, since 1997, been a Special Administrative Region (SAR) of the People's Republic of China. Under the principle of "one country, two systems", the Hong Kong SAR has a different political system from mainland China. It has an independent judiciary which functions under the Common Law framework. The Hong Kong Basic Law governs its political system and gives Hong Kong a high degree of autonomy other than foreign relations and military defence.

Hong Kong is a world city, and has one of the highest per capita incomes in the world, and ranks as the third most important international financial centre in the world, but it also has the largest income inequality among the advanced economies ("Hong Kong" International Monetary Fund (2.11.14).

Location

The Hong Kong SAR occupies an area of 2755 km^2, c.40% of which (1104 km^2) is land, and the remainder sea. The Hong Kong SAR lies on the south-east coast of China, at the mouth of the Pearl River (Figure 00). To the north (the New Territories, with the Kowloon Peninsula at it southern limit) it is joined to mainland China, and in particular to the Shenzhen SAR and Guangdong Province. In addition, there are two large islands, Hong Kong Island and Lantau Island, and 230 smaller islands.

Topography

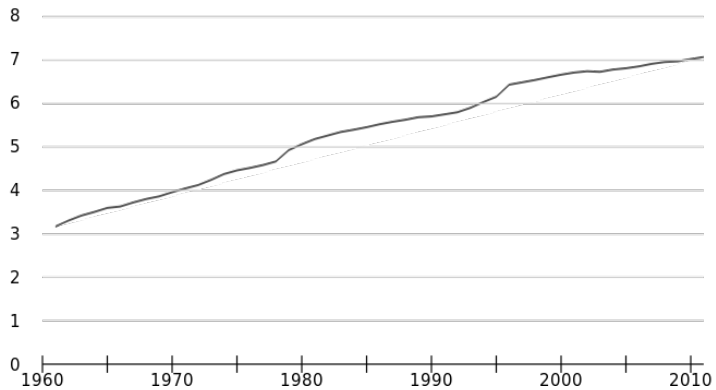
The topography of the area is rugged, comprising steep mountainous areas and deeply dissected valleys. The highest point is Tai Mo Shan (957 m) in the New Territories. Other high points include Victoria Peak (552 m) on Hong Kong Island, and Lantau Peak (934 m) on Lantau Island.

Climate

Hong Kong lies within the northern limits of the tropics and the climate is governed largely by the monsoons (Ramage, 1952). As a result, Hong Kong experiences a pronounced wet season in summer (May to mid-September), and a dry season in winter (November to February). The mean air temperature varies within a wide range of 13°C, from 15.6°C in January to 28.6°C in July (Chin, 1986). Such variation in rainfall and temperature has contributed to the presence of a deep weathering profile developed almost completely by chemical action (Fyfe *et al.*, 2000).

Population

The current population (as of 2013) is 7.188 million, and there has been strong population growth in recent decades (1970 3.959 million; 1980 5.063 million; 1990 5.704 million; 2000 6.665 million; 2010 7.024 million.



Population growth of Hong Kong in millions (y-axis) by year

However the Hong Kong SAR has one of the world's lowest birth rates— 1.11 per woman of child-bearing age as of 2012, far below the replacement rate of 2.1. As a result, Hong Kong has an ageing population and it is estimated that 26.8% of the population will be aged 65 or more in 2033, up from 12.1% in 2005.

Due to the steep and rugged topography, the intensity of urban development already achieved, and the restrictions on development in Country Parks, land suitable for development is in short supply As a result, the Hong Kong SAR is one of the most densely populated areas in the world, with an overall density of some 6,300 people per square kilometre. Most of the population is concentrated in central Kowloon, Hong Kong Island, and the central New Territories. More recently, new development areas/new towns have been focussed in the northern New Territories and on Lantau Island. Given the demand for land, within the limitations of the Hong Kong's natural landscape, has put increasing pressure on the need for a greater understanding of the nature of ground conditions and all other aspects of the onshore and offshore geology of the region.

Geology of Hong Kong

A comprehensive interactive online account of the geology of Hong Kong, prepared by the Hong Kong Geological Survey, is available at this link:
http://www.cedd.gov.hk/eng/about/organisation/org_geo_pln_map.html

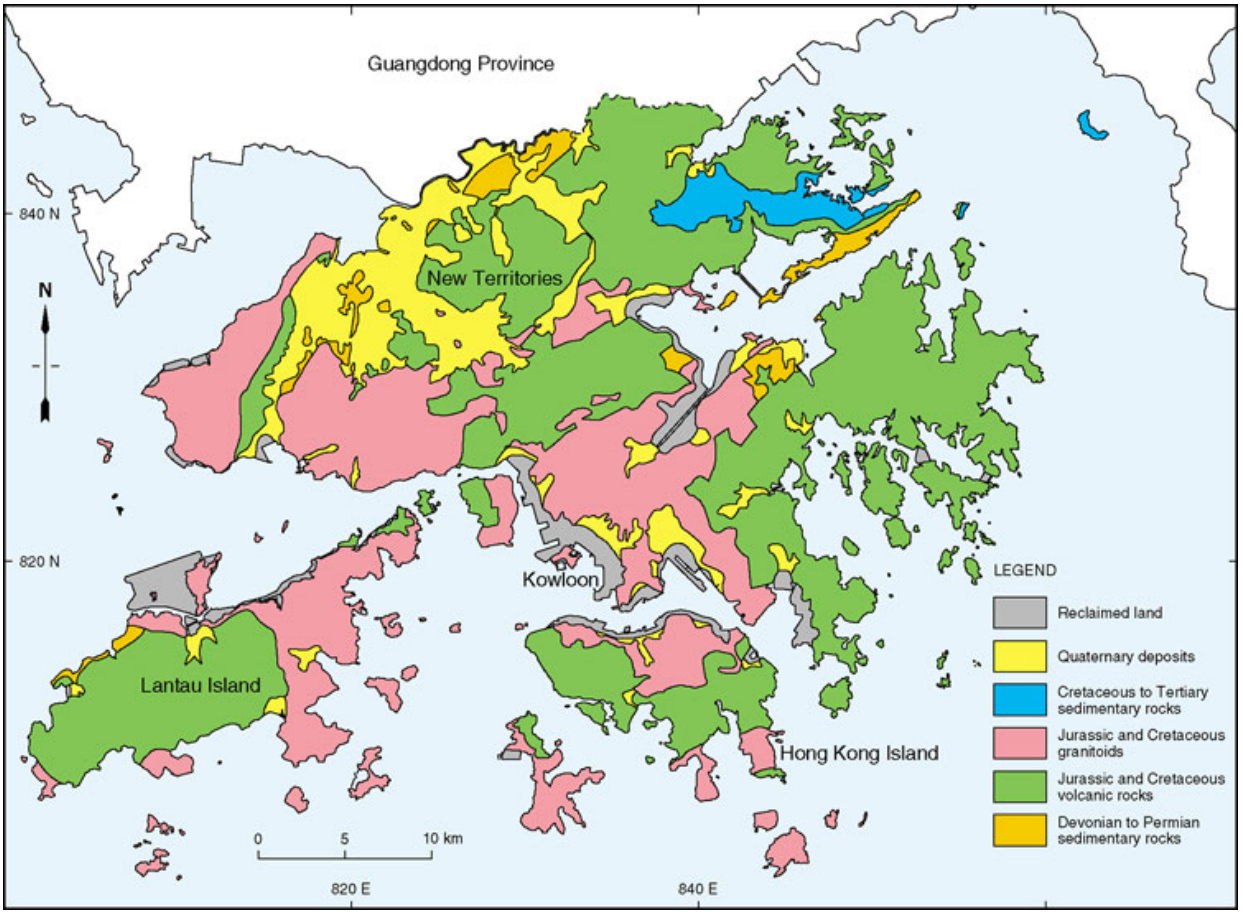


Figure 1 - Simplified geological map of Hong Kong

A simplified geological map of Hong Kong is presented in Figure 1. The oldest rocks are Late Palaeozoic non-marine and shallow marine sedimentary rocks. These Devonian, Carboniferous and Permian rocks crop out mainly in northeast and northwest Hong Kong and comprise 10% of onshore rock exposures.

A Triassic granite is present in subcrop offshore in the north-west of Hong Kong. Jurassic sedimentary rocks exposed over a small area of Hong Kong (<3%). They comprise Early and Middle Jurassic sandstones, siltstones and shales that were deposited in a deep marine shelf environment.

Mesozoic volcanic and plutonic rocks are the dominant rock types in Hong Kong, accounting for about 85% of rock outcrop on land. They comprise subvolcanic granite plutons, high level silicic dykes, and thick rhyolitic tuffs and lavas. Most of the igneous rocks are of Late Jurassic to Early Cretaceous age. The distribution and form of volcanic centres and related plutons are strongly controlled by east-north-east-trending and north-west-trending faults. Mesozoic sedimentary rocks younger than the main volcanic episode, and Tertiary sedimentary rocks are exposed mainly in northeast Hong Kong. They comprise non-marine red bed and evaporitic sediments that were deposited in fault-controlled basins that subsided rapidly, then were uplifted.

Faults in Hong Kong form many of the major northeast-trending and orthogonal north-north-west–trending valleys. Deformation, marked by folding and faulting, developed along periodically reactivated deep crustal structures. Microseismic activity continues to the present day on some of these faults.

Various metallic and non-metallic minerals have been reported in Hong Kong. Quantities of metallic minerals are generally small and few deposits have been exploited commercially. However, several quarries have provided aggregate. Three continue to do so, principally for concrete manufacture.

Weathering, mass movement, drainage and soil development, have shaped Hong Kong's present landscape and led to the accumulation of locally thick Quaternary superficial deposits. New land acquired through reclamation, which represents about 6% of the onshore area, has provided land for housing about 20% of the population. The distribution and nature of superficial deposits and the history of reclamation in Hong Kong are described in.

Geological Map revision and 3D modeling in Hong Kong

A thorough revision of the geological map coverage of Hong Kong at 1:20,000-scale (15 map sheets originally produced in the 1980s and 1990s) is currently in progress. The maps for Shatin, Kowloon and Hong Kong Island have already been completed, and those for the NW New Territories are at an advanced stage of completion.

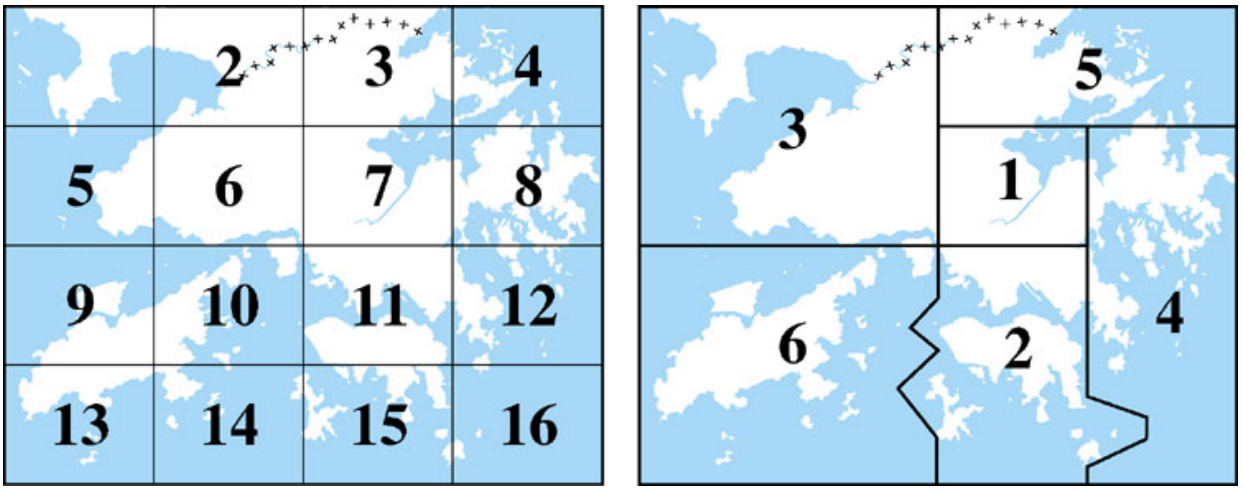


Figure 2 - Published 1:20 000-scale geological maps and memoirs (see text for details)

As yet, however, there is only very limited availability of 3D models/maps for Hong Kong. There is a clearly a major opportunity to develop potentially high resolution subsurface (engineering attributed) geological models, at least locally, based on the more than 100,000 boreholes held in archives by the Geotechnical Engineering Office. Knowledge exchange between partners involved in the COST Action Sub-Urban, and colleagues in the Hong Kong Geological Survey could help to facilitate the development of such modelling. This modelling could be further developed to assist decision-making in relation to the planning of Hong Kong's subsurface, and its programme of cavern development.

APPENDIX 2 Country Parks and The Hong Kong Global Geopark of China

Country Parks

Despite the extent of urban development in Hong Kong, about 75% of its land surface is varied and scenically attractive countryside. The Country Parks Ordinance provides a legal framework for the designation, development and management of country parks and special areas. The Ordinance provides for the establishment of a Country and Marine Parks Board to advise the Director of Agriculture, Fisheries and Conservation on all matters related to country parks and special areas. 24 country parks have been designated for the purposes of nature conservation, countryside recreation and outdoor education and there are 22 special areas created mainly for the purpose of nature conservation. The country parks and special areas cover a total area of 44 300 hectare and comprise scenic hills, woodlands, reservoirs and coastline in all parts of Hong Kong.

There are four marine parks and one marine reserve covering a total area of 2 430 hectares. They comprise scenic coastal areas, seascapes and important marine habitats.
In addition, there is a recently inaugurated Global Geopark.

The Hong Kong Global Geopark of China

The Hong Kong Global Geopark in China, inaugurated in 2009, covers an area of 50 km^2 across parts of the Eastern and Northeastern New Territories. The Geopark includes two regions covering eight geo-areas in the eastern part of Hong Kong, each with unique geological features.

Sai Kung Volcanic Rock Region: This region displays hexagonal volcanic rock columns, which are world class in terms of size and coverage:

- *High Island Geo-Area*: Hexagonal volcanic columns exposed along the coast.
- *Ung Kong Group Geo-Area*: These islands expose spectacular columnar joints and precipitous cliffs, including the high sea arches at Wang Chau and Basalt Island.
- *Ninepin Group Geo-Area*: These islands expose hexagonal columns and those on North Ninepin Island are particularly gigantic, with some measuring over two metres in diameter.
- *Sharp Island Geo-Area*: The coasts of Jin Island and southwest Kau Sai are dominated by columnar joints of tetragonal or pentagonal shapes. Sharp Island is covered by different volcanic rocks such as lava and eutaxite.

Northeast New Territories Sedimentary Rock Region: This region represents the most comprehensive stratigraphy of sedimentary rocks in Hong Kong, ranging from Devonian sandstone and conglomerate of about 400 million years of age to Tertiary siltstone of 65 million years old.

- *Double Haven Geo-Area*: As a result of the rise in sea level 6 000 to 8 000 years ago, the river valleys in Double Haven were flooded, therefore forming indented shorelines with headlands and bays.
- *Tolo Channel Geo-Area*: The rocks along the north coast of Tolo Channel are the oldest in Hong Kong. Ma Shi Chau comprise sedimentary rocks 280 million years old; various igneous rocks and sedimentary rocks at Lai Chi Chong of south coast were formed 140 million years ago.
- *Port Island and Bluff Head Geo-Area*: Bluff Head (Wong Chuk Kok Tsui) has the oldest rocks in Hong Kong, formed by deposits at estuarine deltas about 400 million years ago. Port Island (Chek Chau) comprises red conglomerate, sandstone and siltstone formed c.100 million years ago.
- *Tung Ping Chau Geo-Area*: Tung Ping Chau has the youngest rocks in Hong Kong which are 65 million years old.

APPENDIX 3 **Hong Kong SAR Miscellaneous Planning Standards and Guidelines (Chapter 12) Rock Cavern Development**

http://www.pland.gov.hk/pland_en/tech_doc/hkpsg/full/ch12/ch12_text.htm#2

2. Rock Cavern Development

2.1 What are Rock Caverns

2.1.1 Rock caverns refer to large man-made spaces in rock. Hong Kong's geological conditions offer excellent opportunities for the development of rock caverns for different land uses. The igneous rocks which underlie much of the metropolitan area and the New Territories provide an excellent excavation media below the weathered mantle and are ideal for forming man-made caverns. Caverns are designed on the principle of utilizing the strength of the rock mass to form the roof arch and sidewalls. Detailed guidance on site investigation, design and construction of caverns is given in Geoguide 4 - Guide to Cavern Engineering.

2.1.2 Although most cavern developments incur a higher capital cost and more lighting and ventilation costs than similar developments above-ground, the use of cavern space in an already well developed city such as Hong Kong can be an alternative, cost-effective form of development. Adopting rock caverns as a mode of development for particular land uses also has the potential to reduce or minimize the environmental impacts of such uses.

2.1.3 The cavern option needs to be considered at the early conceptual stage of the development process. For any new Government projects which concern land uses where rock cavern development is considered a possible alternative, and in particular those projects which may impose adverse environmental, social, health, safety or other impacts on the surrounding areas, pre-feasibility studies should be carried out at the initial planning stage to evaluate the cavern development option versus the non-cavern option.

2.2 Land Uses with Potential for Development in Rock Caverns

2.2.1 Table 1 shows those land uses which have the potential to be located in rock caverns. The table, however, is not exhaustive and should be used for general guidance only.

2.2.2 As changes in technology may help prevent or reduce the problems associated with any intended development in rock caverns, the suitability of each case should be assessed individually on the basis of a pre-feasibility study and planning assessment.

Table 1 : Land Uses with the Potential for Development in Rock Caverns

	Types of Land Uses
1.	Commercial Uses
	-Retail
2.	Industrial Uses
	-Industry -Storage/Warehousing -Oil bulk storage -LPG bulk storage
3.	Government/Institution/Community Uses
	-Slaughterhouse -Civic centre -Incinerator -Indoor games/Sports hall -Wholesale market -Refuse transfer facility -Sewage/Water treatment plant -Service reservoir -Transport connections & networks -Columbarium/Mausoleum/Mortuary
4.	Public Utilities
	-Power station

Note: Pre-feasibility studies and planning assessments should be conducted for the above land uses to establish their suitability for rock cavern development on a case by case basis.

2.3 Planning for Development in Rock Caverns

Identifying Cavern Opportunities

2.3.1 The steps that should be taken to identify opportunities for rock cavern development in the planning process are shown in Figure 1.

2.3.2 When conducting planning studies or preparing district town plans for any area, PlanD would normally circulate the land use proposals of the planning study or the draft departmental plans to concerned departments including the Geotechnical Engineering Office (GEO), for comments and agreement. For those proposed land uses with potential for development in rock caverns (see examples in Table 1), the GEO would conduct geotechnical-related studies to establish cavern development opportunities for these land uses. The GEO would also identify specific sites within the planning area and in the vicinity that are suitable for cavern development for further study. When conducting the geotechnical studies, it would not be necessary to exclude natural hillsides such as Green Belts.

2.3.3 Once the potential cavern development sites have been identified, these sites would be designated on the relevant Outline Development Plans/Layout Plans (ODP/LP) for departmental agreement and for approval by the Committee on Planning and Land Development. Suitable zonings would be annotated on these plans to indicate the normal above-ground and cavern development intentions as developments of very different nature could occupy the same site. At this stage, the potential site boundaries for the rock caverns should be taken as approximate boundaries only which would be subject to further refinements.

Project Planning for New Government Project Proposals

2.3.4 For any new government project proposals involving land uses with potential for development in rock caverns (see examples in Table 1), an assessment of the cavern option should be conducted by the Client Department at the initial project planning stage of preparing the Project Definition Statement and the procedures that should be followed are shown in Figure 1A. The main purpose of this step is to provide basic technical and planning information and facilitate an assessment of the pros and cons between the rock cavern and non-cavern development options. Conducting the assessment at the initial project planning stage would prevent a waste of manpower and resources at the works project planning stage.

2.3.5 The pre-feasibility studies would be conducted by the GEO with support from the Client Department. These are basically an initial appraisal of the geotechnical and other engineering aspects of the potential cavern sites for the proposed use. The studies should produce a preliminary design of the cavern accommodation and access arrangements as well as an estimation of the excavation, ground treatment and other relevant costs.

2.3.6 The planning assessment would be co-ordinated by Planning Department (PlanD) with input from relevant departments including the Fire Services Department, Transport Department, Lands Department, etc. The purpose of the planning assessment is to ascertain the viability and development parameters for the proposed use for both the non-cavern and cavern development option, including :

a. *Development Intensity and Compatibility*

To determine the broad development intensity of the proposed use and to identify any potential conflicts between the proposed use and its immediate environment.

b. *Safety*

The safety aspects of the potential cavern developments, particularly fire safety, provision of emergency vehicular access, means of escape and fire resisting construction should be adequately addressed in the planning assessment stage. The assessment should take into account the overall size of a cavern and the associated works which would have a direct effect on the ease of evacuation and on the overall safety of the development.

c. *Traffic*

A traffic impact assessment should be conducted to ascertain the impact of the proposed use at both the construction and operation stages. Interfaces and connections with the existing and planned roads, railway and other forms of transportation system should also be examined.

d. *Financial Viability*

The Client Department, in consultation with relevant departments, should submit a comparative cost/benefit analysis of the cavern and non-cavern development options taking into consideration the capital and recurrent costs. As part of the analysis, the potential financial and other benefits including the release of the originally reserved site for other uses should be evaluated.

2.4 Issues Concerning Implementation

Environmental Impact

2.4.1 The development of a rock cavern, for either a public or private project, is a designated project under the Environmental Impact Assessment (EIA) Ordinance, and the statutory EIA process is required to be followed by the project proponents. The EIA Ordinance provides the framework for assessing environmental impacts of a designated project defined under the EIA Ordinance and for enforcing the implementation of prevention and mitigation measures to be carried out by the project proponents through the Environmental Permit system under the EIA Ordinance.

Projects Proposed by the Private Sector

2.4.2 For projects which have the potential for development in rock caverns proposed by the private sector, the project proponent should also conduct an assessment of the pros and cons of the non-cavern development option versus the cavern option, in terms of the land use compatibility, safety, traffic and financial viability aspects. Should a rock cavern site be confirmed as a suitable mode of development, a planning brief should be prepared by PlanD in conjunction with the relevant departments to set out the development parameters and the various technical requirements of the project. The planning brief should also serve as the basis for drawing up the lease conditions for the rock cavern development.

Land Disposal

2.4.3 Due to the complexity of the space developed within rock caverns, there are practical difficulties in defining plot ratio and site coverage. The development content and relevant control on the cubic content of the development should ideally be specified in the form of a three dimensional development 'envelope' on the lease/engineering conditions. This 'envelope' should be developed in consultation with the GEO and should define an inner space within which cavern construction is permitted, and an outer surrounding space (for maintenance of cavern support) within which excavations or other works should not be permitted apart from access tunnels, drainage adits, and ventilation shafts. Relevant departments should be consulted on the maintenance requirements of the proposed development for incorporation in the engineering/lease conditions.

Protection Zone

2.4.4 To secure the operation and structural safety of rock cavern development, a protection zone covering an area surrounding the development should be defined according to the detailed design and construction of the cavern and the associated underground works. The GEO should be consulted on the proposed extent of the protection zone. The protection zone should be annotated on the ODP/LP and relevant departments, in particular GEO and Buildings Department, should be consulted for any future development proposals traversing this zone.