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土木工程拓展署
土力工程處
Geotechnical Engineering Office
Civil Engineering and
Development Department

CE 66/2009 (GE)

Executive Summary

Enhanced Use of Underground Space in Hong Kong

Feasibility Study

ARUP

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ARUP in association with: Norconsult & Mott

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Introduction to the Study

In October 2009, the Chief Executive presented the 2009-10 Policy Address entitled “Breaking New Ground Together”. A new initiative was included under Chapter 1 of the Policy Agenda – ‘Developing the Infrastructure for Economic Growth’ to launch strategic planning and technical studies to facilitate planned development of underground space aiming at promoting the enhanced use of rock caverns as part of Hong Kong’s pursuit of sustainable development.

Ove Arup & Partners Hong Kong Ltd (Arup) were commissioned by the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department (CEDD) to undertake the study on the Enhanced Use of Underground Space in Hong Kong under Agreement No. CE 66/2009 (GE). Arup were supported by sub-consultants Norconsult AS and Urbis Ltd and other specialist sub-consultants.

The objectives of this study are to review the history and current status of use of underground space in Hong Kong, benchmarking Hong Kong’s practice with that elsewhere, examining opportunities for underground space development in Hong Kong, evaluating the viability of zoning strategic cavern areas, identifying strategic planning and technical issues that need to be addressed and based on these findings, recommend the approaches and the way forward for planned development of underground space by promoting enhanced use of rock caverns in Hong Kong so as to release land for other uses.

Whilst the emphasis of this study is particularly related to rock cavern development, the term ‘underground space’ is used to encompass not only purpose-built rock caverns but also large basement-type excavations formed by cut and cover methods.

This Executive Summary outlines the major issues and findings under the assignment as well as the recommended approaches and way forward for the enhanced use of underground space in Hong Kong.

Previous Studies of Underground Space in Hong Kong

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.

Other Relevant 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.

Review of Major Rock Cavern Projects Worldwide

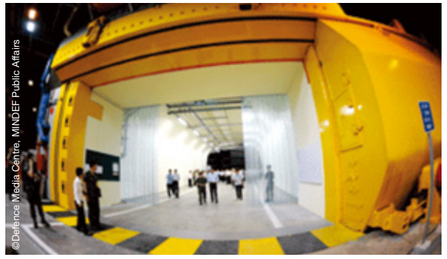
The advantages of the development of underground space are being recognised internationally. This study has unveiled numerous both practical and innovative cavern developments that have been successfully implemented across the globe. The most notable are introduced below:

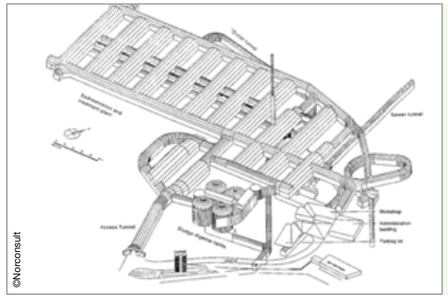
Gjøvik, Norway

In 1975, the first underground swimming pool to international standards was completed in the city centre of Gjøvik, Norway. In 1993, this underground facility was extended to become a spectacular cavern for public use. The Gjøvik Mountain Hall was built to accommodate the ice-hockey matches of the Lillehammer Winter Olympic Games in 1994. It has the largest known cavern span excavated worldwide and is 61 m wide, 91 m long and 25 m high. A wide variety of activities and concerts are also held making it an excellent, well used public facility, which is capable of accommodating 5,500 people and is the largest underground arena in the world to date. It is feasible that similar sized facilities could be considered for Hong Kong where good rock mass conditions could be identified.

Singapore

The Underground Ammunition Facility (UAF) was completed in 2008. This reduced the land area required to be sterilised from development due to the smaller safety buffers around the underground facility, releasing some 300 hectares of land.





Veas, Norway

With the increased needs for sewage treatment and tighter controls on the discharge standards into the sea, large sewage treatment plants have been constructed in rock caverns since the 1970s. The first underground treatment plant in Oslo was the VEAS Sewage Treatment Plant commissioned in 1982. It handles residential, commercial and industrial waste water for a population of approximately 565,000 people. The plant initially had a capacity of 400,000 m^3 and adopted a mechanical/chemical process, which was later extended to include a fixed film biological removal system.
An extension for six of its eight caverns commenced in 1991 to improve the quality of the discharge.

Oset, Norway

Globally, water treatment facilities have also been developed within rock caverns. One of the largest facilities for water treatment is the Oset Water Treatment complex in Oslo, Norway. The original plant was constructed in 1971 and consisted of 5 parallel caverns. This was enlarged and upgraded in 2008 and now produces over 391,000 m^3 of potable water per day whilst meeting EU standards. Oset is now Europe's largest plant located within rock caverns and serves about 90% of Oslo's population.

Kansas City, USA

Underground quarrying of limestone for construction road-base materials and aggregates has produced more than 2.3 million m^2 of developed underground space. Since the 1960s, this has been used extensively for warehousing, manufacturing, offices, retail and service operations.

Itäkeskus, Finland

Itäkeskus Swimming Complex opened in 1993 and is an underground two-storey facility. It consists of a 50 m swimming pool, a learner's pool, children's pool, jacuzzi, waterslides, diving towers, saunas and a gymnasium. The facility can handle 1,000 visitors at one time. When circumstances require, it can be converted into an emergency shelter for 3,800 persons.

Rock Cavern Projects Successfully Implemented in Hong Kong

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 m^3 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.

Others

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.

Update of 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

Land Use Category	Potential Land Uses in the Current HKPSG	Potential Land Uses Proposed to be Added to HKPSG
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 the Financial and Economic Aspects of Rock Cavern Schemes

The costs of the various rock cavern schemes previously presented within the SPUN and CAPRO studies have been reviewed and updated. The costs, excluding the land costs overall, for the cavern options have generally increased by a larger proportion than the above-ground facility costs. This is primarily because permanent linings have been included in all assumptions to meet improved operational requirements. Shotcrete and dowel rock mass support could be used in less critical areas to reduce costs.

For the cavern option, project benefits could be derived from the potential release of the surface land. The approach for this study is to allocate land as a cost rather than revenue. For example, the above-ground option includes costs for land, capital and operation, while the underground option does not incur costs for land. The comparison would then be on a least cost basis and land would be an avoided cost, or saving.

There is significant variation in cavern construction costs with current contract estimates suggesting an upper cost range of HK$1,500 to 2,000 per m^3 for the excavation and temporary support. With a final concrete lining installed the total cost of the construction is likely to range from around HK$2,500 to 3,500 per m^3. It should also be noted that these costs are for excavation and support only and do not include all the necessary associated preliminaries.

The review has identified that underground facilities are generally more costly to run than the above-ground facilities. However, when non-monetary benefits and land costs are taken into account, the rock cavern schemes become more attractive.

Reasons why some of the schemes studied under SPUN/CAPRO were not implemented could be broadly categorised under four main headings as follows:

Economic / Financial

- Feasibility stage does not include an accurate comparison of above-ground and underground options, particularly the land cost savings that are captured by rock cavern development options. The savings in land and the ability to use it for some other use that benefits the community needs to be included in future analysis.
- Potential cavern option will always appear more costly if land costs are not included due to possibly higher operational requirements (ventilation, lighting, safety, etc).
- Project-based benefits may not adequately reflect overall benefits to the community.

As discussed above, the development of caverns relative to an above-ground location needs to include land costs.

Policy and Strategy Issues

- Lack of policy steer for cavern development.
- Cavern option may be examined too late in the works projects implementation process.

- Lack of planning of underground usage.
- Lack of incentives for government departments and private developers.
- Fire safety and ventilation requirements / approach thought to be too onerous.

Operation and Maintenance Issues

- Initial capital costs considered to be higher than above-ground development.
- Life cycle costs and operation / maintenance costs considered to be higher than above-ground facilities.
- Limited experience of government departments to work in, and maintain underground space.

Perceptions

- Availability of suitable above-ground land to build surface options.
- No driver to consider cavern options for existing facilities due to limited need for expansion.
- Low value placed on public benefit schemes.

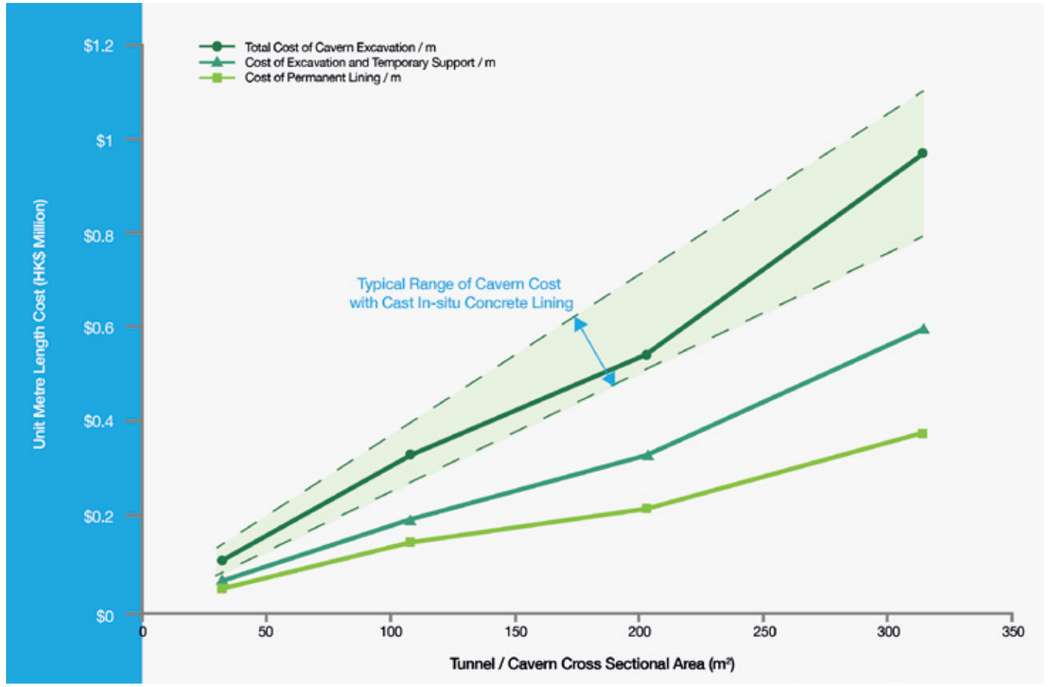
Other benefits such as public relations and government image could also be an important consideration for underground schemes. Success factors that do not necessarily relate to cost and financial aspects of the project should also be considered to ensure that an appropriate balance is considered for public benefit.

Current Cavern Costs

In the SPUN studies the previous Norwegian practice of shotcrete and rock dowel support was adopted. The current MTR approach in Hong Kong is to build tunnel and cavern linings that meet a higher threshold level of performance with regard to water tightness. If future schemes consider providing tunnel linings that are comparable to the MTR approach, then the costs of construction will be greater.

The adjacent graph outlines the typical costs per linear metre that could be considered for different range of tunnel and cavern cross sections. These costs are for typical tunnel support and a range of typical rock mass conditions found in Hong Kong. It should be noted that the excavation of these caverns is assumed to be within an urban environment. It should also be noted that these costs are for excavation and support only and do not include all the necessary associated preliminaries.

Typical Cost per Unit Metre Length for MTR Type Tunnels and Caverns



Review of Underground Planning, Usage Strategy and Practice in Other Countries

In order to implement an underground planning strategy, there needs to be specific consideration of the local requirements and demands of each country, region or city. The 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. The general underground development of selected countries in relation to their underground planning and usage strategy is summarised below.

Finland

In 2009, the Helsinki Underground Master Plan was introduced with an objective to ensure the utilisation of the bedrock resources is retained for the construction of public long-term projects and underground spaces are well-connected with important traffic infrastructure and significant commercial projects. The master plan illustrates more than 400 current underground spaces and reserves over 200 underground spaces for future uses. The locations, space allocation, importance, connection and mutual compatibilities of underground spaces are taken into account.

The Helsinki Underground Master Plan is a legally binding plan for land owners and authorities. Today, over 400 premises are located in underground locations in Helsinki, totalling a volume of approximately 9,500,000 m^3.

The comprehensive underground master plan has had a significant influence on underground space development. Many of the dual-purpose cavern facilities are partly funded by the National Civil Defence Department that provides another incentive for facilities to be developed as dual-use facilities.

Norway

Norway has effectively and strategically placed the majority of their NIMBY type facilities below ground and has valued the land that has been released for other uses. The concept has great public acceptance and there has been commitment from all government and district levels in implementing this strategy. Despite the lack of a central or specific legal and administrative framework for planning and regulation of underground space, Norway has a long history of developing a large number and variety of underground facilities.

Accommodating previous restrictions on underground development, in that surface buildings in urban areas were only allowed to extend to shallow depth may have inadvertently freed up the rest of the deeper underground space for other uses. Construction of underground development beneath private lots is also allowed subject to appropriation and compensation to the surface land owner.

A major driver in the development of caverns appears to have been the policy to develop and provide civil defence shelters for the majority of the population. This combined with financial assistance to provide for the construction of civil defence shelters has also promoted the construction of dual-purpose rock caverns for public use.

Singapore

Singapore has a land area of 650 km^2 and land reclamation has been carried out extensively in the past. In the 1990s, Singapore began their journey of exploring the opportunities of developing underground space. With a growing population reaching nearly 5 million, land availability is a key issue. Land owners in Singapore also own the underground space of the land that they own subject to the specific area being defined on a government plan or gazetted. In 2010, the Economic Strategies Committee reported that in the next 10 years, the government should seek to catalyse the development of underground space as a means to intensify land use. Singapore should put in place enablers for underground development such as by developing a subterranean land rights and valuation framework, and develop an underground master plan to ensure that underground and above-ground spaces are synergised, and invest in the creation of basement spaces in conjunction with new underground infrastructure projects (e.g. rail), so as to add to the 'land bank'. There is likely to be a greater push in underground space development in Singapore in the near future to aid economic growth.

Other Countries

Key items noted regarding underground planning and usage in other countries around the world are:

- In **Canada**, the Underground City of Montreal is known as one of the largest and oldest underground pedestrian networks in the world. This case demonstrates that rather than the development of a master plan to guide the growth of underground development, the use of appropriate incentive tools can also encourage successful underground development within the private sector.
- In **China**, it has been reported that more than 20 cities including Beijing, Shanghai, Shenzhen and Hangzhou have or are compiling plans for their urban underground space. These plans show the size, layout, function, development depth and timing of the underground space, and have defined the guiding theory for urban underground space development of key development areas.
- The **United Kingdom** has a long and varied use of underground space, the development of which appears to have occurred according to local needs and on an ad-hoc basis.
- **Japan** has a long history of developing underground pedestrian and retail space that has been mostly promoted by government incentives. Oil storage, hydropower and other land uses have also been placed underground.
- **South Korea** has developed an extensive network of oil and fuel storage facilities for strategic and security reasons.
- The **Netherlands** has two cities (Arnhem and Zwolle) that have prepared non-binding zoning plans that divide the subsurface into three layers that target the types of uses that those layers would be subject to. The surface layer accommodates buildings and near surface development. The next lower layer targets underground transportation systems and the bottom layer targets groundwater resources.

Underground Planning, Usage Strategy and Practice in Hong Kong

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.

Benchmarking the Extent and Rationale for Underground Uses

	Extent of Underground Use	Underground Planning strategy	Main Reasons for Underground Use
Finland	Extensive	Yes	Security, Economy, Environment & Climate (also Land Supply in Helsinki)
Norway	Extensive	No	Security, Economy, Environment & Climate
Singapore	Minimal	No	Land Supply & Security
South Korea	Moderate	No	Economy & Security
UK	Moderate	No	Ad Hoc
Hong Kong	Minimal	No	Land Supply & Environment

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 the 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

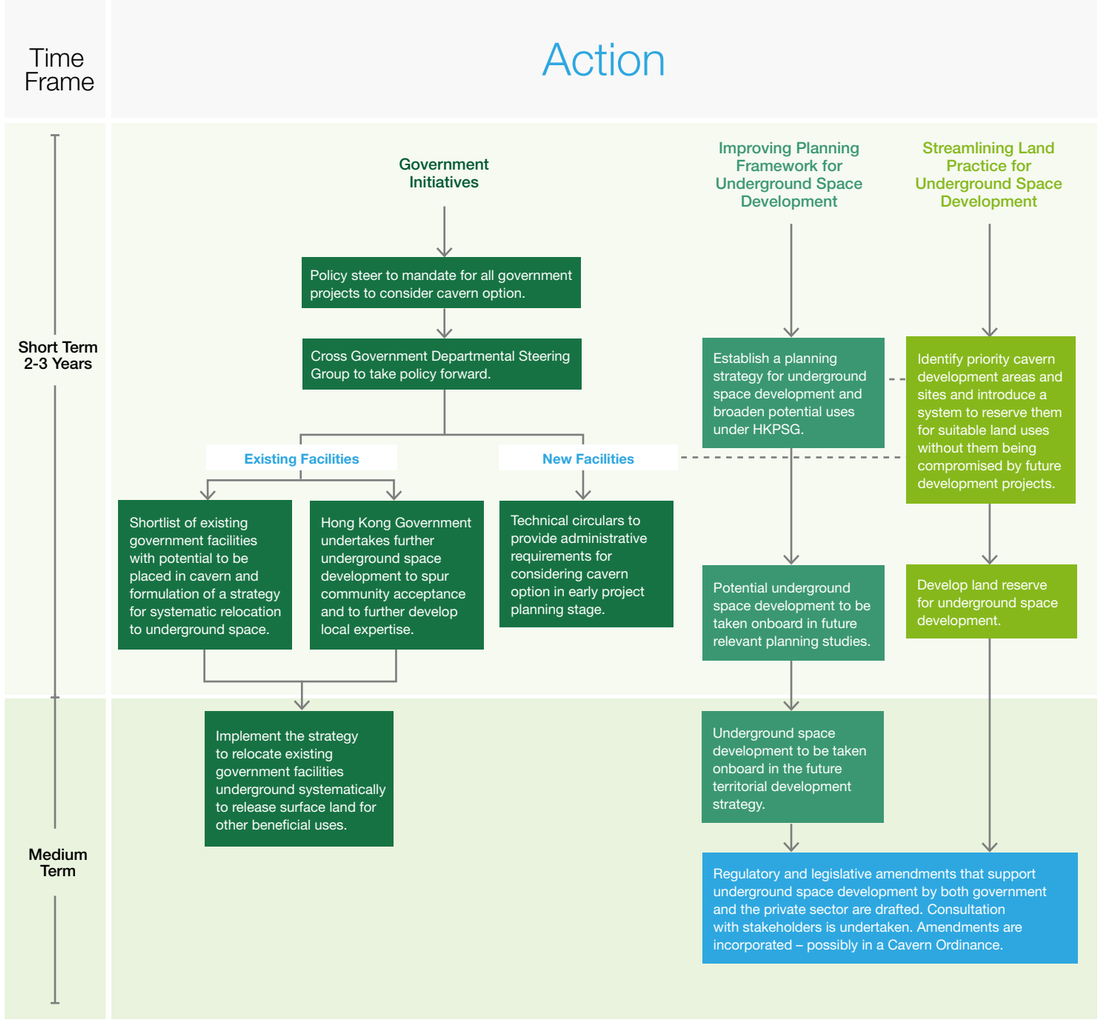
Hong Kong is a city that has minimal government involvement in business. This "hands off" approach sees the private sector driving most of the industry and commerce in the city. It would therefore be beneficial to also enable private sector involvement in the development of underground uses. To generate 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 underground space, releasing land for other beneficial public uses.

Suggested Steps to Improve Hong Kong's Use of Underground Space



Strategic Environmental Assessment for Cavern Development

Reprovisioning of Western Salt Water Service Reservoirs (HKU) - Cut-slope Option

Reprovisioning of Western Salt Water Service Reservoirs (HKU) - Cavern Option

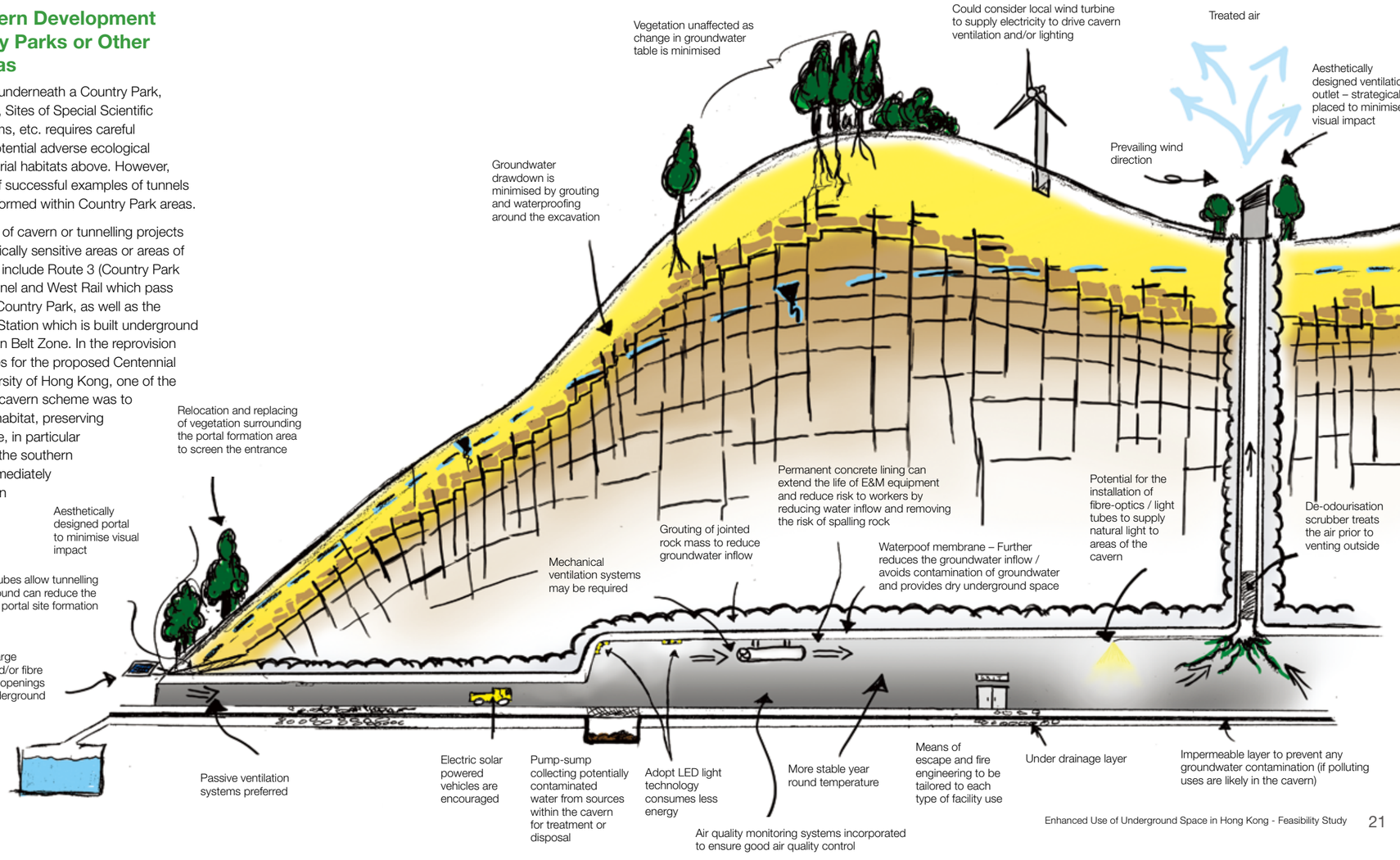
A Strategic Environmental Assessment (SEA) has been carried out to evaluate at a strategic level the potential environmental impacts that may be caused by various potential uses of underground space, in particular rock cavern development in Hong Kong. It highlights the most prominent strategic environmental impacts from cavern construction and suggests broad mitigation measures to limit the impacts. Overall, it is concluded that with due care and diligence during construction, and effective management and maintenance during operation, cavern developments can have limited negative impacts on the environment, and potentially provide benefits.

The development of a rock cavern is a Designated Project under the Environmental Impact Assessment Ordinance (EIAO) and hence a statutory EIA is required for construction and operation of the cavern. Potential land uses such as sewage treatment works, refuse transfer station, power station, etc. would also be Designated Projects under the EIAO.

Potential Cavern Development within Country Parks or Other Sensitive Areas

Developing a cavern underneath a Country Park, secondary woodland, Sites of Special Scientific Interest (SSSI), streams, etc. requires careful assessment of the potential adverse ecological impacts to the terrestrial habitats above. However, there are a number of successful examples of tunnels and cavern projects formed within Country Park areas.

Successful examples of cavern or tunnelling projects located within ecologically sensitive areas or areas of high landscape value include Route 3 (Country Park Section), Tai Lam Tunnel and West Rail which pass through the Tai Lam Country Park, as well as the Island West Transfer Station which is built underground partially within a Green Belt Zone. In the reprovision of waterworks facilities for the proposed Centennial Campus of the University of Hong Kong, one of the major benefits of the cavern scheme was to retain the woodland habitat, preserving the ecology of the site, in particular the natural hillside at the southern portion of the site immediately north of Lung Fu Shan Country Park.



Examination of the Opportunities for Enhanced Use of Underground Space

A territory-wide stock taking exercise was undertaken to identify existing and future government facilities that could be located in rock caverns. The aim of the stock taking was to:

- identify the existing and planned above-ground government facilities that have the potential for rock cavern development, and
- to collect information on these facilities including: location, site area, capacity and plans for expansion/reprovision.

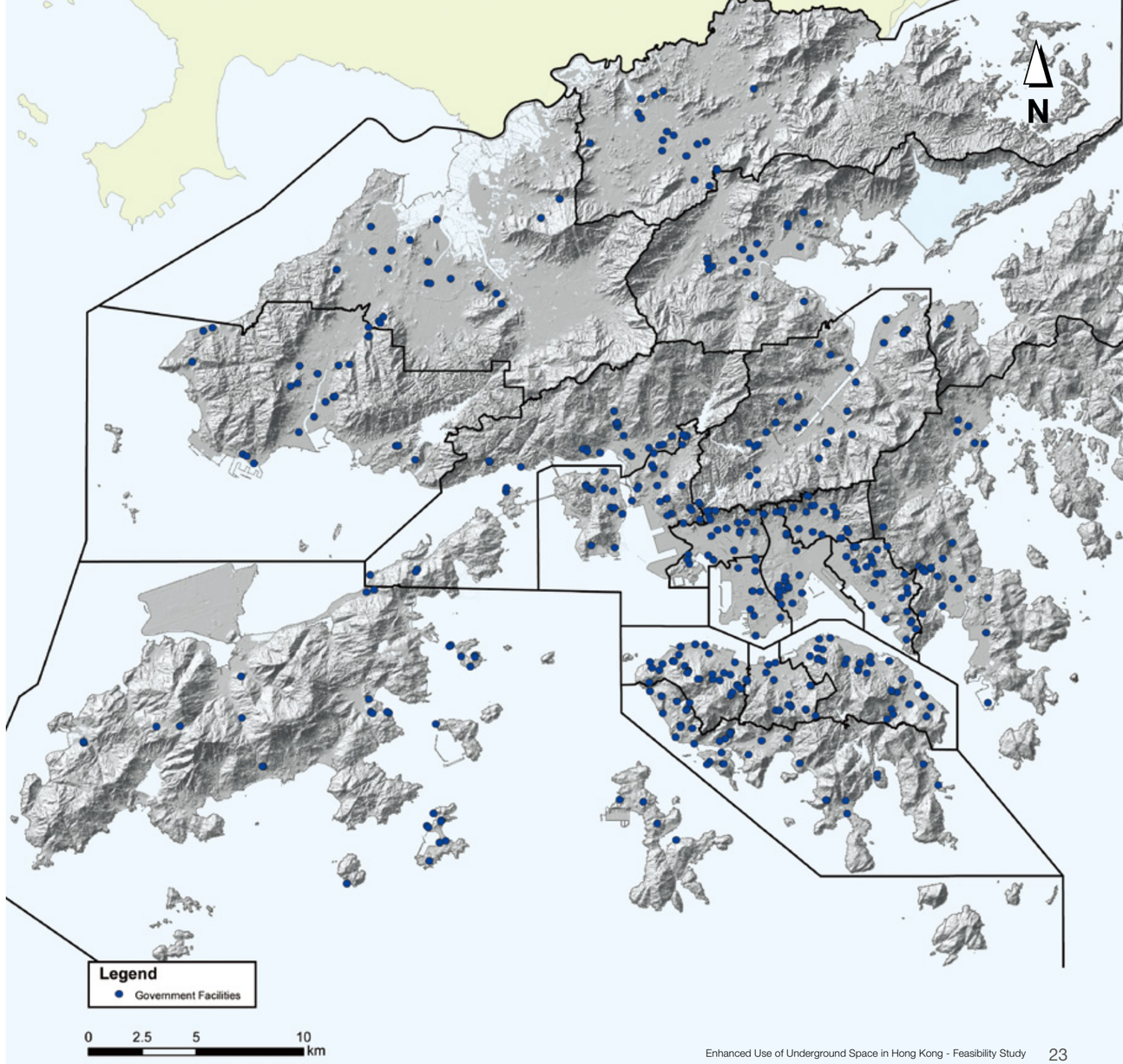
Only Government/Institution/Community Uses listed in the Hong Kong Planning Standards and Guidelines were included in the stock taking exercise.

A qualitative ranking system for some 400 facilities was developed to identify specific existing government facilities that could be relocated to rock caverns. The selection criteria have been chosen to generally identify the type of facility and whether it needs to be replaced or upgraded, its size and whether there are examples in Hong Kong or overseas to demonstrate that it can be built in rock caverns. It also includes the general suitability of land nearby to house the original facility and whether there are good connections and environmental benefits of transferring the facility underground.

The parameters used in the selection include facility status, existing location, site area, multi-facility opportunities, precedent case, location requirements, ground condition and environmental benefits.

The selection criteria have been divided into 3 grades defined as A, B or C. These grades provide a simplified basis for the ranking of the facilities. The more grade A's that are identified for the facility then the more suitable it is likely to be for cavern development, subject to further review.

The current preliminary screening only covers basic parameters and assumptions that characterise, in general, the physical location and suitability of the facility for cavern development. Other factors such as planning issues, land zoning, facility specific technical issues, local needs and other criteria that may have a more strategic relevance for a facility or a geographic area have not been included in this study. It is recommended that a future study should further develop the criteria and the ranking and incorporate such additional factors and weighting as necessary for the existing or other proposed criteria that are likely to be required to suit a systematic and comprehensive relocation strategy for various facilities. The potential to relocate or locate any individual facility shall be confirmed by detailed feasibility study.



Potential for Government Cavern Development in Hong Kong

The stock taking exercise has identified that numerous government facilities could be considered for placement or reprovisioning in rock caverns. The NIMBY type facilities are typically more suited to this type of transfer, especially where they are located near urban or urban fringe areas.

The types of land uses that have a high preference for cavern development are noted below. The additional potential land uses identified have been reviewed with respect to their relevance to Hong Kong.

Preference for Cavern Development	Government Land Uses Recommended in the Current HKPSG	Government Land Uses Proposed to be Added to HKPSG
High	• Sewage / Water treatment plant* • Refuse transfer facility • Service reservoir • Transport connection & networks • Storage / Warehousing	• Archives • Bicycle park-and-ride • Car / Vehicle parking • Refuse collection points • Maintenance depot for rail and others • Underground quarrying
Moderate	• Indoor games • Sports hall • Columbarium • Mausoleum • Mortuary	
Low	• Civic centre • Wholesale market • Slaughterhouse • Incinerator	• Crematorium

Note: * Treatment Technology adopted could affect the order of preference

Development of a Territory-wide Cavern Suitability Map for Future Selection of Potential Areas for Cavern Development

A preliminary territory-wide cavern suitability map has been developed using a Geographical Information System (GIS) based approach to aid in the future selection of potential areas for cavern development during the planning stage.

The original CAS studies outlined a series of attributes that were considered relevant for cavern suitability and were based upon those outlined on the right.

Original CAS Suitability Criteria	Description of Suitability Criteria
Existing and proposed surface developments	Type of suitable land use to be generally below government land.
Existing and proposed underground installations	Located away from existing and planned tunnels and caverns.
Engineering geological conditions	Located away from faults or potential areas of poor rock mass.
Topographic constraints	Upper elevations to allow for sufficient ground cover.

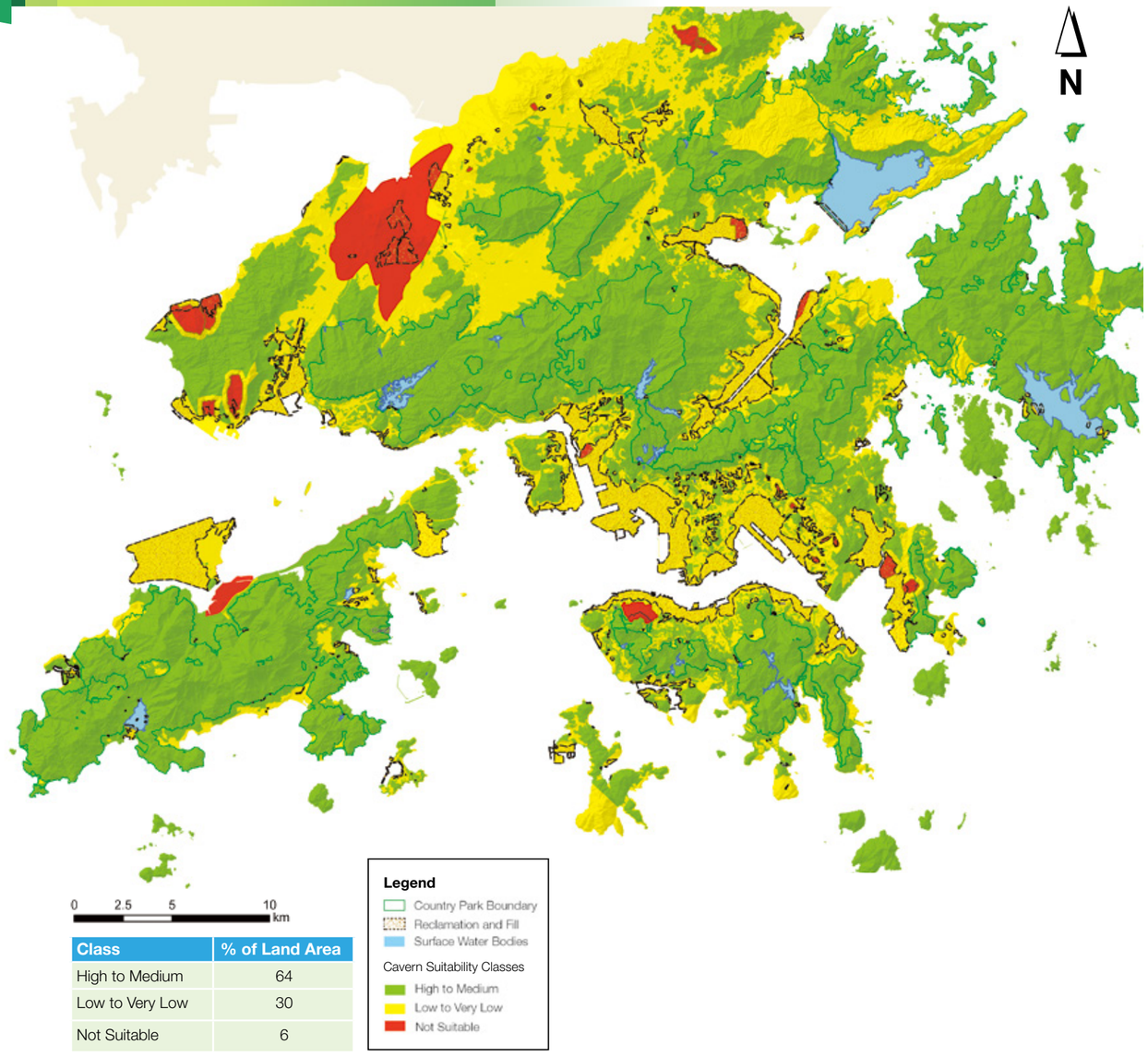
High suitability areas are those areas that are considered to be more easily developed with reduced overall construction cost.

The attributes of the original CAS were reviewed and additional attributes added to fit with a territory-wide study. The other additional suitability criteria are listed on the right. A broad classification for whether a cavern would be generally above or below +10 mPD was also introduced to identify direct entry caverns to those that were generally in low lying areas subject to more geotechnical constraint.

The GIS analysis identified various suitability classes from high to very low and some areas that were considered to be not suitable.

The suitability classes were used to generate cavern suitability maps in both detailed and simplified format. A simplified map is shown on the next page.

Additional CAS Suitability Criteria	Description of Suitability Criteria
Poor Geology	Sedimentary and metamorphic rocks have very low suitability and caverns are considered to be more difficult and more expensive to construct in these rocks.
Scheduled Areas	Not suitable if within a scheduled or designated area due to significant geotechnical constraint.
Landfill Areas	Not suitable if below a landfill site or low suitability within 250 m buffer due to methane gas hazard.
Reclamation / Fill Areas	Low suitability for major fill or reclamation areas.
Country Parks	Considered suitable to place caverns below Country Parks but to place portals wherever possible outside the Country Park areas.
Drillholes	Medium suitability within 50 m radius of a drillhole with suspected or confirmed poor ground.
Impounding Reservoirs	Not below a surface reservoir to avoid excessive seepage into the cavern.



Class	% of Land Area
High to Medium	64
Low to Very Low	30
Not Suitable	6

Preliminary Feasibility Studies

Following the stock taking exercise and ranking system, 3 facilities were selected to carry out Preliminary Feasibility Studies (PFS) to demonstrate whether a cavern scheme could be successfully implemented.

The selection of the facilities for the PFS was made based upon some general principles and requirements to showcase the approach and to cover various expected needs and requirements of government as well as the benefit to the general public and communities that lie close to those facilities.

Mount Davis & Kennedy Town Fresh Water Service Reservoirs

The fresh water service reservoirs were selected at Mount Davis to illustrate the suitability of transfering the existing facilities below ground. Some considerations for selection and key issues for the proposed facilities are summarized below:

- Existing cavern facility and other nearby underground facilities successfully completed.
- Land (2 ha) can be released for other uses including potential private and public residential development.
- Traffic impact is an important aspect of any proposed construction and redevelopment taking into consideration the Pokfulam Moratorium.
- Future expansion can be provided for underground rather than extensive open-cut works.
- Improved security and integrity of the tanks.

Mui Wo Integrated Cavern Scheme

Various existing bad neighbour facilities are grouped along the southern waterfront of Mui Wo. Some considerations for selection and key issues for the proposed facilities are summarised below:

- Waterfront land (2.5 ha) can be released for other uses.
- Complements Mui Wo Facelift Study by providing revitalization of 500 m of waterfront area.
- Existing refuse transfer station, sewage treatment works, bus depot and some other facilities can be relocated underground to provide greater amenity uses for the general public.
- Traffic impact is considered to be minimal.
- Marine access needed for some of the facilities.
- Interface with some external initiatives such as mountain bike trail required.
- Improved environment for the area.

Sha Tin Sewage Treatment Works

The existing facility occupies a large footprint, prime location at the mouth of the Shing Mun River. Some reasons for selection and key issues for the proposed facilities in this area are summarized below:

- Large footprint site area (28 ha) in prime waterfront location can be released for other beneficial uses.
- Known similar large-scale overseas underground sewage treatment plants.
- Improved visual and environmental impacts of the area.
- Land value can be improved in the area.
- Future expansion can be provided for underground in a planned layout.

Selection of Strategic Cavern Areas and Strategic Cavern Sites

A strategic area is defined as being greater than 20 hectares in area and having the ability to accommodate multiple cavern sites. Relative ease of access with regard to the surrounding infrastructure network and the ability to realise some public benefit whilst tying in with Hong Kong strategic planning initiatives were the predominant objectives of the strategic areas.

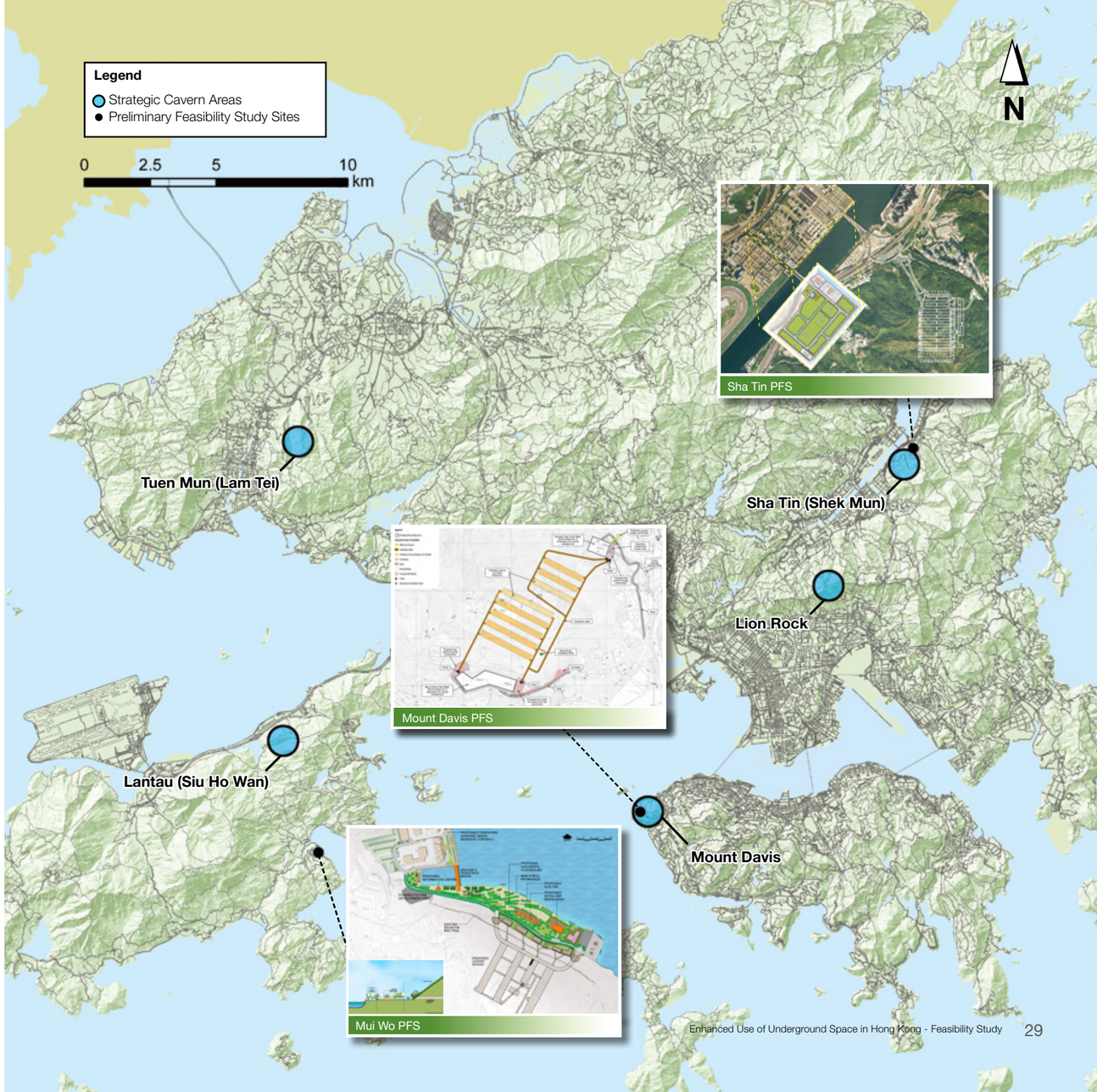
The strategic areas were required to be located in different regions of Hong Kong, namely Hong Kong Island, Kowloon and the New Territories. A preliminary screening of the areas suitable for cavern construction led initially to 12 areas that could be considered. From these, five strategic areas were selected after considering the merits of review. The preferred area to be proposed for Hong Kong Island is Mount Davis while the preferred area for Kowloon is the Lion Rock area. In the New Territories the three areas of interest are Tuen Mun (Lam Tei), Sha Tin (Shek Mun) and Lantau (Siu Ho Wan).

From the stock taking and preliminary ranking exercise, several strategic facilities with the potential for being relocated in rock caverns were identified. The facilities are distributed throughout Hong Kong Island, Kowloon and the New Territories. These facilities were broadly reviewed in terms of site suitability, land use context of the surrounding area and their relative benefits. During the review, any lower ranking facilities that were in close proximity to the selected cavern site were included in larger cavern schemes when compatible. This could lead to significant areas of developable land being released, and often the removal of potential multiple bad neighbour uses from an area.

Further refinement of the ranking methodology and more detailed study will be required within each of the potential cavern sites in order to confirm that the facilities are technically feasible to be relocated without significant impact to the service, community, surrounding landscape, environment and traffic network.

In order to preserve the land identified for the strategic cavern areas and sites, suitable plans such as outline cavern development plans would need to be developed. Strategic cavern areas and sites could be marked on these plans as dashed lines and labelled as “Proposed for cavern developments subject to further detailed study”, to alert government departments that the land has been reserved for future cavern development.

The technical circulars recommended to mandate that all government projects consider cavern options at the early project planning stage to promote the use of caverns for suitable land uses, could also mandate government departments to reference the Cavern Suitability Map whilst considering the cavern option for their proposed facility.



Recommendations and Way Forward

This study has identified numerous additional land uses that are considered suitable for rock cavern development and it is recommended that these be included in the relevant section of the Hong Kong Planning Standards and Guidelines.

A stock taking exercise has identified some 400 government facilities that have potential for rock cavern development. A preliminary ranking system has been developed to highlight the relative merits of relocating these facilities in rock caverns. It is recommended that these criteria should be further developed to incorporate additional factors and weightings as necessary. This will ensure that those facilities offering the highest benefits to the community will be identified for future relocation in rock caverns.

Three preliminary feasibility studies were undertaken to demonstrate the broad viability of cavern development for a range of facility types and to identify key issues that would need to be addressed. Further detailed feasibility studies are recommended to be undertaken to address the issues raised.

A territory-wide cavern suitability map has been developed to aid in the future selection of potential areas for cavern development. This has identified that 64% of the land area has high to medium suitability for large-scale cavern development. Given the large land area identified as being suitable, there is good potential for many other areas to be outlined in addition to the five strategic areas identified. It is recommended that a mechanism be established such that these areas will not be compromised by future development projects and also not prevent or limit any future surface development.

The strategies employed by other countries to develop underground space have been benchmarked against Hong Kong's practice. It is recommended that:

- Policy steer be provided through the issue of technical circulars to provide administrative requirements for government departments to consider the cavern option in the early project planning stage. Similarly, a policy framework be developed to encourage private sector involvement in development of underground space.
- An Underground Development Programme Fund should be established to assist with the administrative aspects of development and also be utilized to provide funding for replacement of existing facilities in underground space, releasing land for other beneficial public uses.
- Consideration be given to develop a Cavern Ordinance to specify the rights and obligations of all parties with respect to underground space developments and to make provision for private sector involvement.

It is recommended that the Hong Kong SAR Government formulates a strategy to systematically relocate existing government facilities underground. This will facilitate development of a comprehensive programme to gradually release land occupied by existing government facilities, for inclusion in a land reserve for other beneficial uses.

To encourage private sector involvement, incentives would be required to make the developments attractive, such as preferential land premiums, enhanced development potential or tax incentives. Another approach would be to explore more Public Private Partnerships. It is recommended that suitable mechanisms should be evaluated and established to encourage involvement of the private sector in this initiative.

Hong Kong should create an environment in which the cavern development option is not overlooked or treated as unconventional. The planning and execution of these spaces should become part of the mainstream development process to create the optimal living environment. Creating signature schemes that are world beaters in terms of scale and efficiency of the facility would promote the use of underground space and raise Hong Kong's profile as Asia's World City.