HELSINKI EXPERIENCE WITH MASTER PLANNING FOR USE OF UNDERGROUND SPACE

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Abstract

This paper examines the continued growth in the use of underground space beneath the city of Helsinki and the continued widespread lack of significant and broad planning efforts for its use. The particular focus of this paper is on sustainability issues related to urban underground space use including contribution to an environmentally sustainable and aesthetically acceptable landscape, anticipated structural longevity and the maintenance of opportunity for urban development by future generations.

Since the 1960s, the City of Helsinki has been adept at widely utilizing the opportunities for underground construction. More than 400 premises and over 200 km of tunnels have already been built underground. Furthermore, there are more than 200 new reservations in the register for long-term underground projects. Demand for underground facilities in central Helsinki has grown considerably and, at the same time, the need to control construction work has increased substantially.

The underground master plan of Helsinki reserves designated space for public utilities and important private utilities in various underground areas of bedrock over the long term. The master plan also provides the framework for managing and controlling the city's underground construction work, and allows suitable locations to be allocated for underground facilities.

When selecting these resources, the survey took into account their bedrock conditions, accessibility, the present and planned ground-level uses of these areas, traffic connections, land ownership and possible recreational, landscape and environmental protection values.

Keywords
Land Use Planning, Underground Resources, Master Plan, Sustainability, Urban Development

1. Introduction

Since the 1960s, the City of Helsinki has been adept at widely utilising the opportunities for underground construction. More than 400 premises and over 200 km of technical maintenance tunnels have already been built underground. Demand for underground space in the central city area has grown rapidly as the 21st century was approached and begun, and at the same time, the need to control construction work has increased substantially.

As the city's structure becomes more dense, more and more facilities suited for different purposes are being placed underground. There is also a growing demand for connecting underground premises to each other to form coherent and interrelated complexes, whilst the safety of the functions and operations of the facilities has become a major factor.

While planning and carrying out new construction projects, it is important to make sure that the space reservations for public long-term projects, such as tunnels and ducts for traffic and technical maintenance, are retained for future construction. Similarly the use of the valuable and unique rock and ground must be practical and done without wasting any future resources.

The growth in underground construction and planning and the demand to co-ordinate different projects has led to a requirement to prepare an underground master plan for Helsinki. Having legal status, the master plan also reinforces the systematic nature and quality of underground construction and the exchange of information related to it. The underground master plan is a general plan that allows the control of the locations and space allocations of new large significant underground rock facilities and traffic tunnels and their interconnections [HELSINKI CITY, 2009]. The master plan will also safeguard already existing spaces because there are for example certain minimum distances for any future plans or constructions regarding those spaces.

Efforts have been made to alleviate the great demand for central city area underground space by allocating new rock resource areas suited for underground construction outside the inner city. Changing the purpose of rock facilities that have already been built is difficult, which further emphasises the importance of underground master planning. The Helsinki underground master is administrated by the Helsinki City Planning Department. The City Real Estate Department's Geotechnical Division qualified the areas and elevation levels in Helsinki which are suitable for construction of large, hall-like spaces.

2. Helsinki Conditions and Land Ownership Strategy

Finland has 336 independent municipalities as in 2011. Helsinki is the capital city with 591,000 inhabitants and is clearly the biggest city in Finland by population. However, the surface area of Helsinki is only 215 km^2 whereas the average size of municipalities is 585 km^2. The population density of Helsinki is 2,755 inhabitants per km^2. Helsinki spreads across a number of bays and peninsulas and over a number of islands. The inner city area occupies a southern peninsula. The population density in certain parts of Helsinki inner city area is high, reaching 16,500 inhabitants per square kilometre.

The Helsinki metropolitan area is the world's northernmost urban area among those with a population of over one million people, and the city is the northernmost capital of an EU member state. Altogether 1.3 million people, approximately one in four Finns, live in the Greater Helsinki area.

Helsinki is located in southern Finland, on the shore of the Baltic Sea. Helsinki has a climate that is between sea and continental. Owing to the mitigating influence of the Gulf Stream, temperatures in winter are much higher than the far northern location might suggest, with an average in January and February around −5 °C (23 °F). However, because of the latitude, days last less than six hours around the winter solstice. Conversely, Helsinki enjoys long days in summer, close to nineteen hours around the summer solstice. The average maximum temperature from June to August is around 19 to 21 °C (66 to 70 °F).

Helsinki's landscape is quite flat; the highest natural spot is only 60 m above sea level. One third of Helsinki´s ground is clay where the thickness of clay is over 3 metres and shear strength commonly around 10 kPa. The average depth of soil material upon bedrock is 7 m, but variation is from 0 to almost 70 m. Bedrock quality is ideal for tunnelling and for building underground spaces. The average price of underground space is only 100 €/m^3 (including excavation, rock reinforcement, grouting and underdrainage). For the time being only the drill and blast method has been used for rock excavations. The use of Tunnel Boring Machine has not been competitive in Helsinki so far.

Finnish people are used to having lots of green areas around, even in cities. That is also a good reason for using underground as a resource for those functions that do not need to be on surface. The unofficial motto of the Finnish Tunnelling Association is "Always examine the underground alternative". Among other reasons, safety is also a major aspect for using underground instead of building infrastructure near ground surface. Earthquakes are not a threat in Finland, but in case of those, underground solutions would be advantageous. Prof. Tetsuya Hanamura studied the effects of a natural disaster which took place in Japan in March 2011 and found out that the earthquake caused little if any structural damage to the metro tunnels. Moreover, the tsunami swept off almost everything on the ground - but caused only minor damages in tunnels.

The City of Helsinki consists of 215 km^2 of land and 500 km^2 of sea. Within its administrative boundary, the City of Helsinki owns 65% of its land (Fig.1) [HELSINKI CITY, 2010]. According to Real Estate Department´s Land Division the city tries to buy the needed land areas as greenfield land (viz. undeveloped land either used for agriculture, landscape design, or left to naturally evolve) before city planning (zoning). As greenfield land is getting scarce, the city is, in spite of previous strategies, today more and more facing redevelopment of brownfields (previously used for industrial purposes), especially when

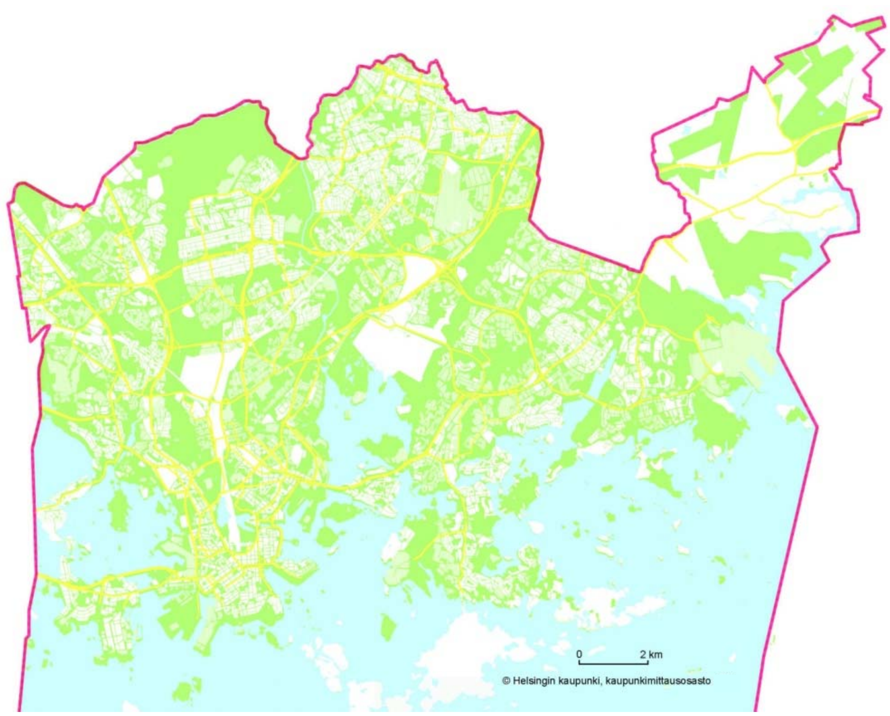


Fig 1. Map of Helsinki
(The green areas of land are owned by the City of Helsinki and the white areas are owned by others)

developing waterfront areas. It is also easier to develop underground resources under your own real estate, compared to building under somebody else's property.

3. Statistics of Underground Helsinki

Underground resources have an extremely important and central role in the development of the city structure of Helsinki and the adjoining areas, helping to create a more unified and eco-efficient structure (Fig. 2 & 3). Underground planning enhances the overall economy efficiency of facilities located underground and boosts the safety of these facilities and their use.

For the time being there are 10,000,000 m^3 underground spaces (parking, sports, oil- and coal storages, metro etc.), more than 400 premises, 220 km technical tunnels, 24 km raw water tunnels and 60 km utility tunnels "all in one" (district heating and cooling, electrical and telecommunications cables, water) [HELSINKI ENERGY, 2011]. Some quite unique examples are shown in Figures 4 and 5.

It is maybe easier to comprehend these statistics by

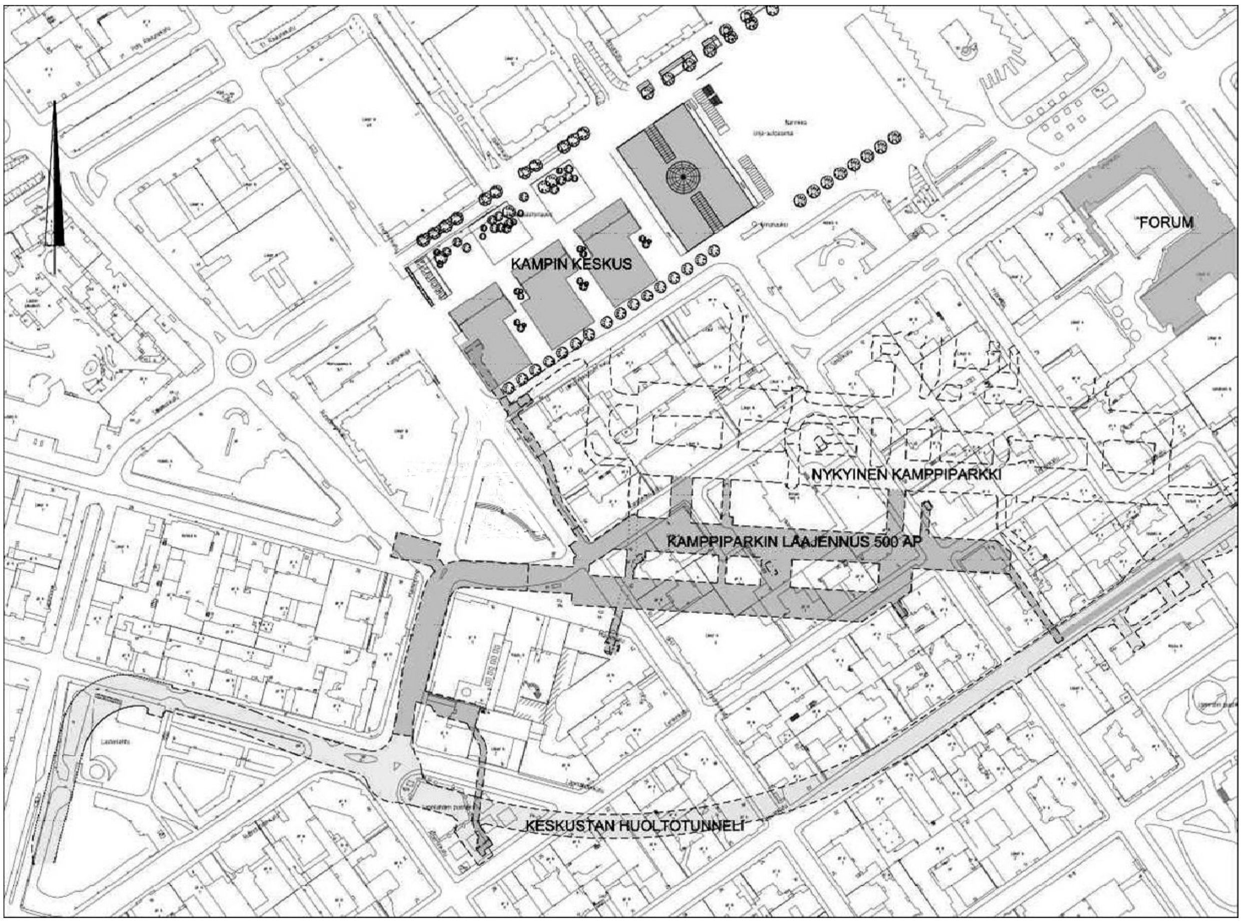


Fig 2. An Example of the Development of the City Structure of Helsinki
(An old car park (shown with dashed line) is connected to an extension and a new City Service Tunnel)
(Image: Helsingin Väylä Oy)

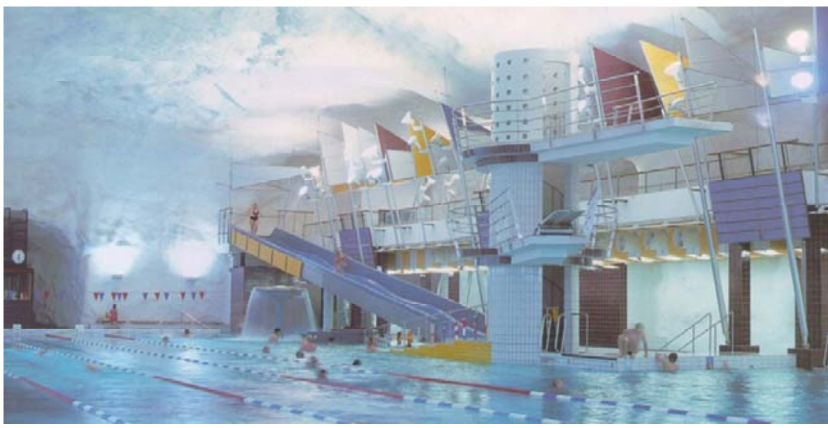
Aerial View (red line showing tunnel alignment)

Longitudinal Profile

Cross-section

Fig 3. Jokeri 2: Central Park Tunnel for Public Transport (Under Planning) to Connect Two Residential Districts

Fig 4. Temppeliaukio Church Built into Solid Rock
(Photo: Pertsaboy)



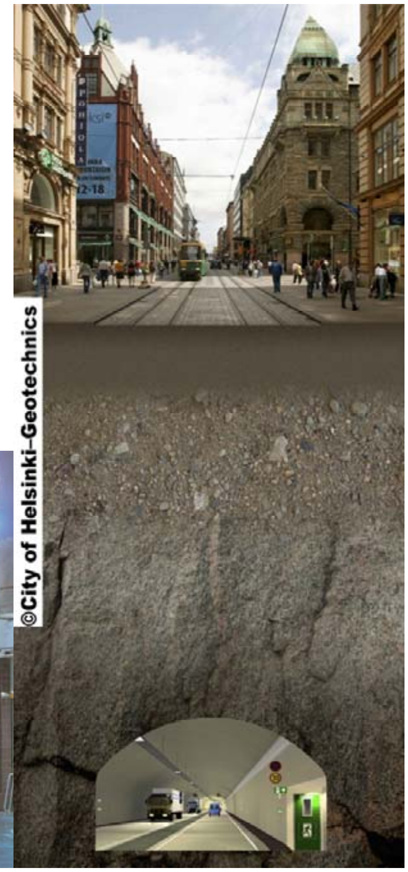


Fig 5. Underground Swimming Pool in Itäkeskus (left) and City Service Tunnel in the City Centre (right) and
(Photo: Erkki Makkonen)

comparing Helsinki´s surface area and the total area of underground spaces that are in use. As an average, under each 100 m^2 surface area there is 1 m^2 underground space. So, within the whole city area there still are lots of underground resources for future needs. This statistic is explained more clearly in Sections 4 and 5.

The underground swimming pool in Itäkeskus (Fig. 5) has facilities on two floors and can hold about 1,000 visitors at a time. The hall has about 400,000 visitors a year. Quarried out of solid rock, the hall can be converted into an emergency shelter for 3,800 people if necessary.

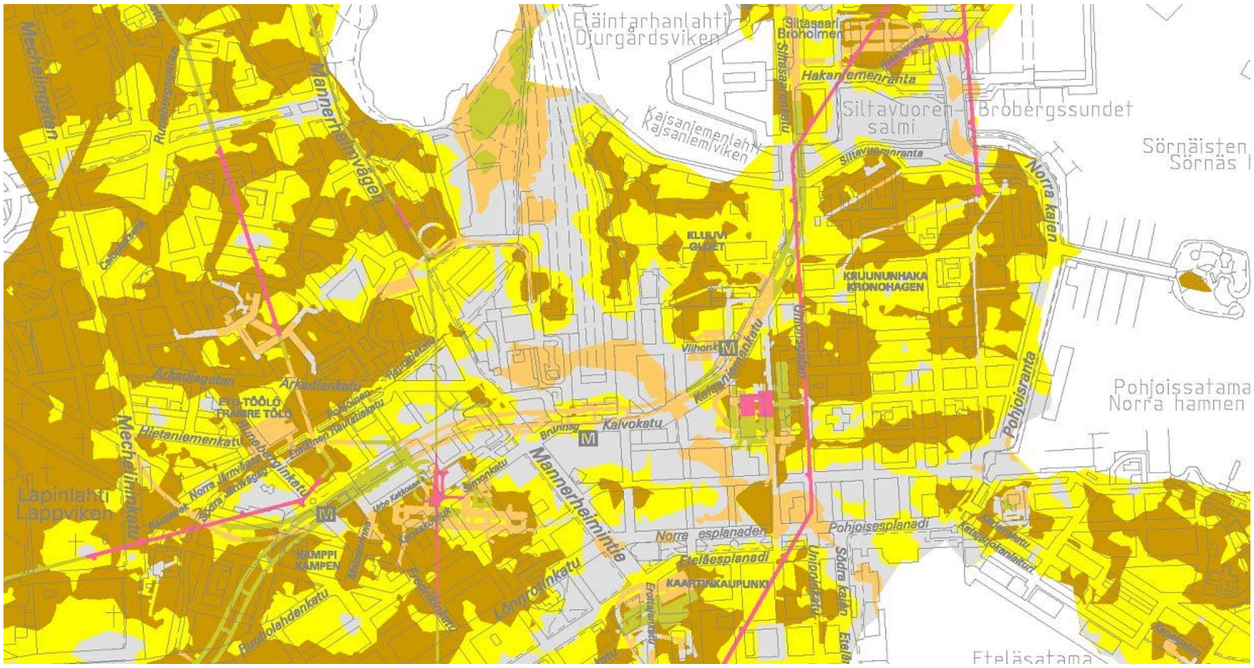
4. Rock Surface Model

An initial survey examined the areas and elevation levels in Helsinki which are suitable for construction of large, hall-like spaces. A model based on rock surface data was used applying a standard-sized measurement cave (width 50 m, length 150 m, height 12 m). The model of the bedrock is based on base map data for exposed rock and land surface elevations and point data obtained using drill machine borings (Fig. 6). The survey also took into account local weakness zones and rock resources that have already been put to use.

In general, it can be said that the bedrock in Helsinki is not far below the ground surface, and that there are plenty of reasonable and safe locations suitable for construction of underground facilities. Outside the city centre, the survey found 55 rock areas that had a sufficient size for accommodating large underground facilities near major traffic arteries. In many areas, future underground projects can make use of entrances to existing underground facilities, which have been marked with triangles on the master plan map. It is worth mentioning that thermal energy from bedrock is also a noticeable resource.

5. The First Underground Master Plan and Rock Resources Reserved for Unclassified Future Use

Space allocations for long-term projects such as traffic tunnels must be maintained for future construction. The same applies to those resources that are worth conserving for future projects. The exploitation of such resources must be carried out according to plan (Fig. 7). Excavating bedrock is a one-off action. Underground master planning



Legend: 1 - 3 m | 3 - 10 m | 10 - 20 m | 20 - 30 m | 30 - 40 m | > 40 m

Definition: Deepest public underground spaces have been taken into consideration when presenting free rock resources. Estimated rock surface is based on bedrock confirmation drilling.

Fig. 6. An Extract of the Rrock Surface Model

Notes:

Dark grey	Existing underground spaces and tunnels
Grey =	Planned underground spaces and tunnels
Light grey =	Rock resources reserved for the construction of as yet unnamed underground facilities
Lightest grey	Rock surface less than 10 m below ground surface

(Courtesy Helsinki City Planning Department / Strategic Urban Planning Division)

Fig. 7 An Extract of Helsinki Underground Master Plan

in Helsinki is today a significant part of land use planning process.

City of Helsinki has also reserved rock resources for unclassified future use for the construction of as yet unnamed underground facilities, with the aim of identifying good locations for functions suitable for placing underground and which would also reduce the pressures on the city centre's rock resources. The suitability of rock areas for different purposes will be studied when preparing the town plan. There are now about 40 unnamed rock resource reservations without a designated purpose (Fig. 8). The average area of these reservations is 30 ha. Unnamed reservations have a total

Fig 8. Unnamed Rock Resources Reserved for Underground Construction Outside Central Helsinki as Shown in the Official Underground Master Plan of Helsinki (Approved by the City Council on 8th of December 2010)

area of almost 1,400 ha, representing 6.4% of the land area of Helsinki. When selecting these resources, the survey took into account their accessibility, the present and planned ground-level uses of these areas, traffic connections, land ownership and possible recreational, landscape and environmental protection values. Selection of unclassified resources is purpose driven and in addition rock-resource driven.

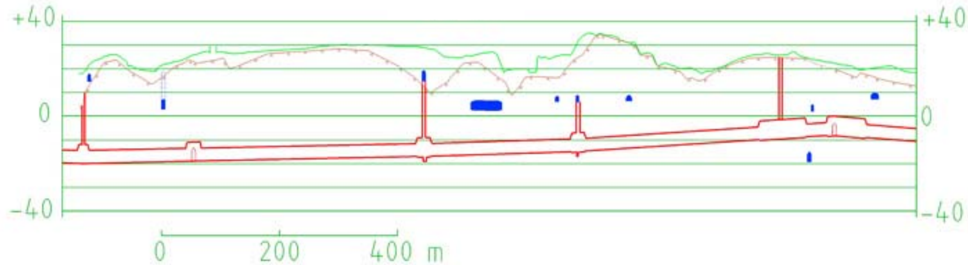
6. Reliable and Optimised Large-scale Networks in Bedrock

Underground facilities for municipal and other technical services (such as energy, water supply and telecommunications) are, by nature, large-scale closed networks. These facilities comprise a number of different functions together with the utility tunnels connecting them. Utility tunnels are located at such a depth that space reservations for them do not have a significant effect on other underground facilities (Fig. 9 & 10).

The City of Helsinki has more than 200 km of technical maintenance tunnels, 45 km of which are utility tunnels used by a number of operators. Utility tunnels have been built since 1977. They house transmission lines and pipes for district heating, district cooling, electricity and water supply systems, as well as a large number of different cable links.

Fig. 9 Typical Utility Tunnel (Photo: Jorma Vilkman)

The Geotechnical Division of the City of Helsinki's Real Estate Department has been the main designer responsible for the preliminary and construction-phase planning required for the rock construction of the utility tunnels, the underground wastewater treatment plant and the treated



Note:

The darken objects are existing tunnels and underground spaces

Fig. 10 Longitudinal Section of the Newest Utility Tunnel Contract
(Showing the principle of locating utility tunnels at such depths that there are rock resources also for future needs)

wastewater discharge tunnel. The facilities designed by the Geotechnical Division have included tunnel lines, halls, vertical shafts and the necessary access tunnels.

The raw water for the Helsinki region comes from Lake Päijänne, to the north of Helsinki, via a rock tunnel measuring more than 100 km. Its main investor and designer was Metropolitan area Water Company PSV. Thanks to the good quality of water reserve and constant low temperature during transport in the deep tunnel there is just a small amount of bacteria in raw water and only minimal processing is required before use. Tunnel construction started in 1972 and was completed in 1982 at a cost of about €200 million (adjusted for inflation in 2011). The original tunnel design was based on minimum reinforcement. In 1999 a small part of the tunnel was repaired due to rock falls (Fig. 11). In 2001 and 2008, the tunnel did undergo an extensive renovation. It was bolted and shotcreted in two portions in order to prevent cave-ins.

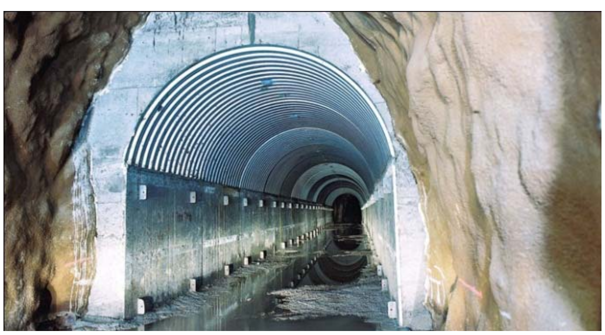


Fig 11. Tunnel from Lake Päijänne was Repaired the First Time in 1999 (Photo: Photo Mannelin)

Waste water treatment is carried out in a centralised manner at the Viikinmäki underground waste water treatment plant (Fig. 12 & 13). Waste water arrives at the plant via an extensive tunnel network. The treated waste water is discharged into the sea via a rock tunnel whose discharge outlet is at a distance of 8 km from the coast. The tunnels in the treatment plant have a capacity of more than 1 million cubic metres.

The Viikinmäki waste water treatment plant is the central plant for treating wastewater from six towns and cities. It

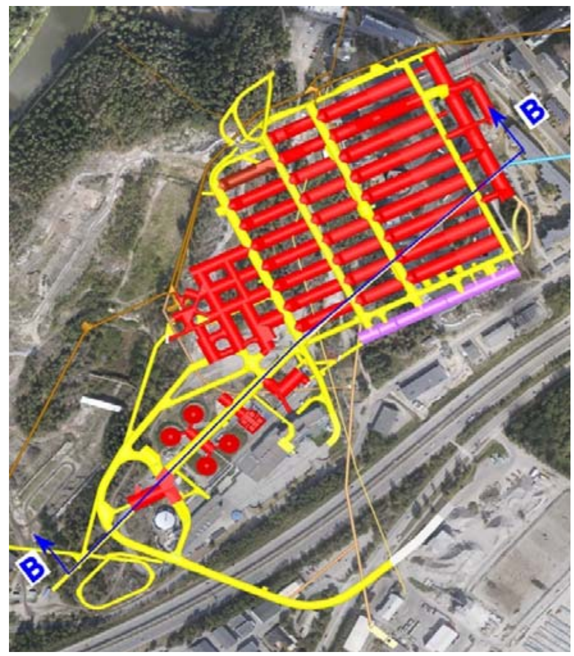


Fig. 12 Aerial View of the Viikinmäki Waste Water Treatment Plant

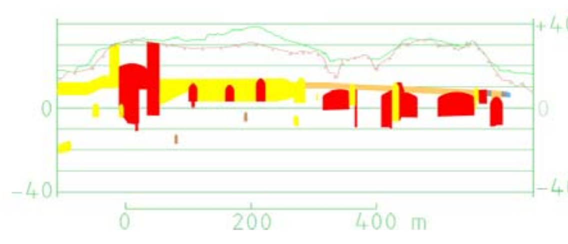


Fig 13. Longitudinal Section of the Viikinmäki Waste Water Treatment Plant

is less than 10 km off the centre of Helsinki. The plant treats 280,000 m^3 of wastewater from about 750,000 people daily. Completed at a cost of approximately €180 million, the treatment plant began operating in 1994. It replaced more than 10 smaller treatment plants, all above ground, thus allowing these sites to be zoned for more valuable uses. The construction of the underground waste water treatment plant took place simultaneously with the construction of ground-level infrastructure and residential buildings. Above the tunnels is the Viikinmäki residential area with 3,500 inhabitants. There is also plenty of zoned area for future residential blocks.

Technical services and utility tunnels in Helsinki are reliable and optimised large-scale networks in bedrock which have several advantages such as:

- There is reliable energy supply via a network with multiple links (allowing alternative routes as necessary)
- Optimisation of energy generation with major transmission networks, i.e. power needs met by generating energy using the cheapest source at any one time
- Expenses are shared by several users
- Land is released for other construction purposes
- The city's appearance and image are improved as the number of overhead lines can be reduced
- Construction work carried out on underground pipes and lines has significantly fewer disadvantages than similar work carried out at street level
- Blast stones resulting from construction of the tunnels can be utilised
- Pipes and lines in tunnels require less maintenance; they are easier to maintain than pipes and lines buried under streets and the tunnel routes are shorter than those of conventional solutions
- Any breakages in pipes, lines and cables do not pose a great danger to the public
- Tunnels are a safer option against vandalism

7. Underground Property Ownership in Helsinki

According to the Finnish law, the owner of a property has control over the underground part of the property, though the vertical extent of ownership is not specifically defined in legislation. When interpreting the extent of ownership, the lower boundary of a property has been limited to the depth where it can be technically utilised. In practice this means the depth of 6 m from the lowest point of the building lot. This allows the owner to build a cellar under a building.

City of Helsinki charges all private and public companies using underground space. The rent of "the underground building lot" is about 50% of the corresponding ground-level rent.

8. Further Information

Further information and international examples of the use of underground is given by the International Tunnelling and Underground Space Association www.ita-aites.org

Detailed and accurate online geographic information about Helsinki City region by various maps, aerial photography, plans and real estate data can be found at http://ptp.hel.fi/index_en.html.

Technical services and large-scale utility tunnel networks in bedrock are described more detailed in *www.geotechnics.fi > CaseBank.*

Finnish Geotechnical Society SGY maintains website www.sgy.fi/ for professionals that actively participate in ground engineering.

9. Conclusions

The underground master plan of Helsinki shows both existing and future underground spaces and tunnels, as well as existing vital access links to the underground. It also includes rock resources reserved for the construction of as yet unnamed underground facilities, with the aim of identifying good locations for functions suitable for placing underground and which would also reduce the pressures on the city centre's rock resources. The suitability of rock areas for different purposes will be studied when preparing the town plan. Thanks to the systematic planning process and good experiences among citizens, underground developing has not led to a depreciation of the property on ground. An initial survey examined the areas and elevation levels in Helsinki which are suited for construction of large, hall-like facilities. A model based on rock surface data was used applying a standard-sized measurement cave. The model of the bedrock is based on base map data for exposed rock and land surface elevations and point data obtained using drill machine borings. The survey also took into account local weakness zones and rock resources that have already been put to use. In general, it can be said that the bedrock in Helsinki is not far below the ground surface, and that there are plenty of locations suitable for construction of underground facilities. Outside the city centre, the survey found 55 rock areas that had a sufficient size for accommodating large underground spaces near major traffic arteries. In many areas, future underground projects can make use of entrances to existing underground tunnels. When selecting underground resources, the survey took into account also their accessibility, the present and planned ground-level uses of these areas, traffic connections, land ownership and possible recreational, landscape and environmental protection values.

The means of land acquisition in Helsinki are briefly the following: The primary goal of the city is to acquire the (greenfield) land needed for zoning by voluntary transactions (purchases or land switches) before the zoning begins. Thus the value increase of the zoning is fully usable for the implementation of the town plan; i.e. building streets, parks, communal service properties such as schools, playgrounds etc. Owning the land also gives the city the power to decide on the implementation timetable (without having to negotiate with land owners). The Finnish legislation allows the city to expropriate the land if the voluntary negotiations fail. Helsinki has, however, been reluctant to use this possibility. Especially when rezoning private land, the city also negotiates

”zoning agreements” with the land owners involved. These agreements stipulate how much of the public rezoning implementation costs are to be paid by the land owner. The payment is linked to the land value increase generated by the new town plan (additional and/or more valuable building rights). The land owner pays his share in form of land and/or money. The payment is due within a few months after the town plan is approved and valid.

There are several benefits of locating technical networks in bedrock such as: Energy supply is reliable via a network with multiple links (allowing alternative routes as necessary). Optimisation of energy generation with major transmission networks, i.e. power needs met by generating energy using the cheapest source at any one time. Expenses are shared by several users. Land is released for other construction purposes. The city’s appearance and image are improved as the number of overhead lines can be reduced. Construction work carried out on underground pipes and lines has significantly fewer disadvantages than similar work carried out at street level. Blast stones and also construction aggregates (sand, gravel, crushed stones) resulting from excavation of the tunnels can be utilized. Pipes and lines in tunnels require less maintenance; they are easier to maintain than pipes and lines buried under streets and the tunnel routes are shorter than those of conventional solutions. Any breakages in pipes, lines and cables do not pose a great danger to the public. Tunnels are a safer option against vandalism.

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