COST European Cooperation in Science and Technology

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Sub-Urban

TU1206-WG1-012

Oslo

TU1206 COST Sub-Urban WG1 Report

I. Eriksson, J. Borchgrevink, M. M. Sæther, H. K. Daviknes, S. Adamou & L. Andresen

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Municipal agencies at the municipality of Oslo:

Agency for Planning and Building Services

Cultural Heritage Management Office

Agency for Urban Environment

Agency for Real Estate and Urban Renewal

Agency for Water and Sewerage Works

Content

1 Sub Surface Oslo

Oslo is the capital of Norway. It is a small town by global standards, but still a rapidly growing city. The population of Oslo is the fastest growing in Europe, a tendency giving both challenges and opportunities. The city will require large investments in communication systems, new dwellings and an integrated land use and transportation planning. Underground space is already widely used for transportation, storage, extraction of heat and for foundations of buildings and infrastructure. Due to the rapid growth of the city the underground use is expected to develop further. The city of Oslo also deals with geological challenges such as deep horizons of organic-rich clay, quick clays and alum shales that contain enhanced levels of radium and uranium.

Figure 1: Photo over the central parts of Oslo with Vippetangen and the fortress of Akershus. To the right the currently developing area of Bjørvika can be seen: the Opera house is the white building right at the seafront, behind it is the central station and the "Barcode", a series of steel and glass towers housing some of the major companies in Oslo (Photo by Rolf Sandnes, Agency for Planning and Building Services, Municipality of Oslo).

1.1 Size

The overall area of the municipality is 453.7 $km^{2.}$ Only one third (approximately 150 km^2) of this is urbanised areas. The rest (approximately 300 km^2) is the so called “Oslomarka”, a forested recreational area protected against urban development by Norwegian law[1]. The municipality of Oslo can be seen in Figure 2.

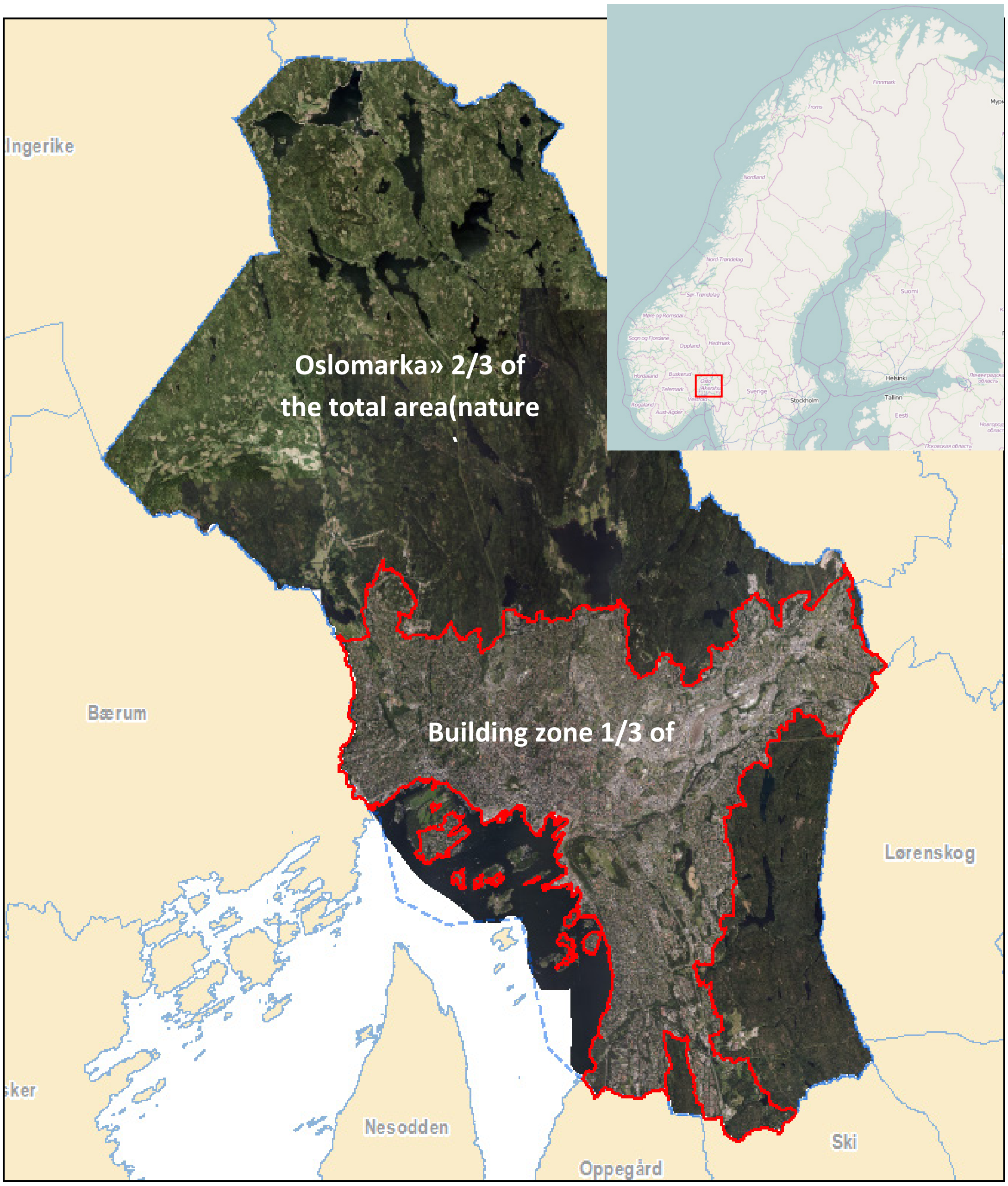

Figure 2: Map showing Oslo municipality with the building zone and the "Oslo marka" map provided by the municipality of Oslo, map over Norway in above right corner from OpenStreetMap.org.

[1] This is called the law of Marka or «Markaloven» LOV-2009-06-05-35.

1.2 History

Although the oldest registered settlements in the region date back to around 11000 BC, the city of Oslo was only founded around the year 1000. The oldest part of the city was located in the eastern part of Bjørvika – at the foot of the green hill called Ekeberg (Figure 3). During the middle ages, the town developed into one of the most important centers of trade and commerce in Norway.

Oslo thrived until the disastrous fire of 1624, which reduced much of the city to ashes. The fire gave rise to the establishment of the new town at the opposite side of the Bjørvika bay, on the north side of Akershus castle and fortress[2]. The new town, named Christiania after King Christian IV of Denmark and Norway, was built on a grid plan in the typical European fashion. As a consequence of the great city fire, a ban on wooden houses was introduced in Christiania, allowing only solid brick, and half-timbered brick houses. A map over these can be seen in Figure 4. At the time of the first official census in 1769, Christiania had 7469 inhabitants.

Facts about Oslo municipality:

Founded: Year 1000

Size: 453.7 km^2

Urban area: 150 km^2

Population 625 000

Administration: The City Council has 59 members, headed by the Mayor of Oslo. Elections are held every four years.

Underground use:

- Railroad tunnels
- Metro tunnels
- Road tunnels
- Waste water tunnels
- Cables
- Foundations
- Storage
- Energy wells for heating and cooling

Underground challenges:

- Settling
- Deep clay horizons

[2] Akershus castle and fortress was originally built as a royal residence in 1299, and was later developed into a fortress in the 16th century.

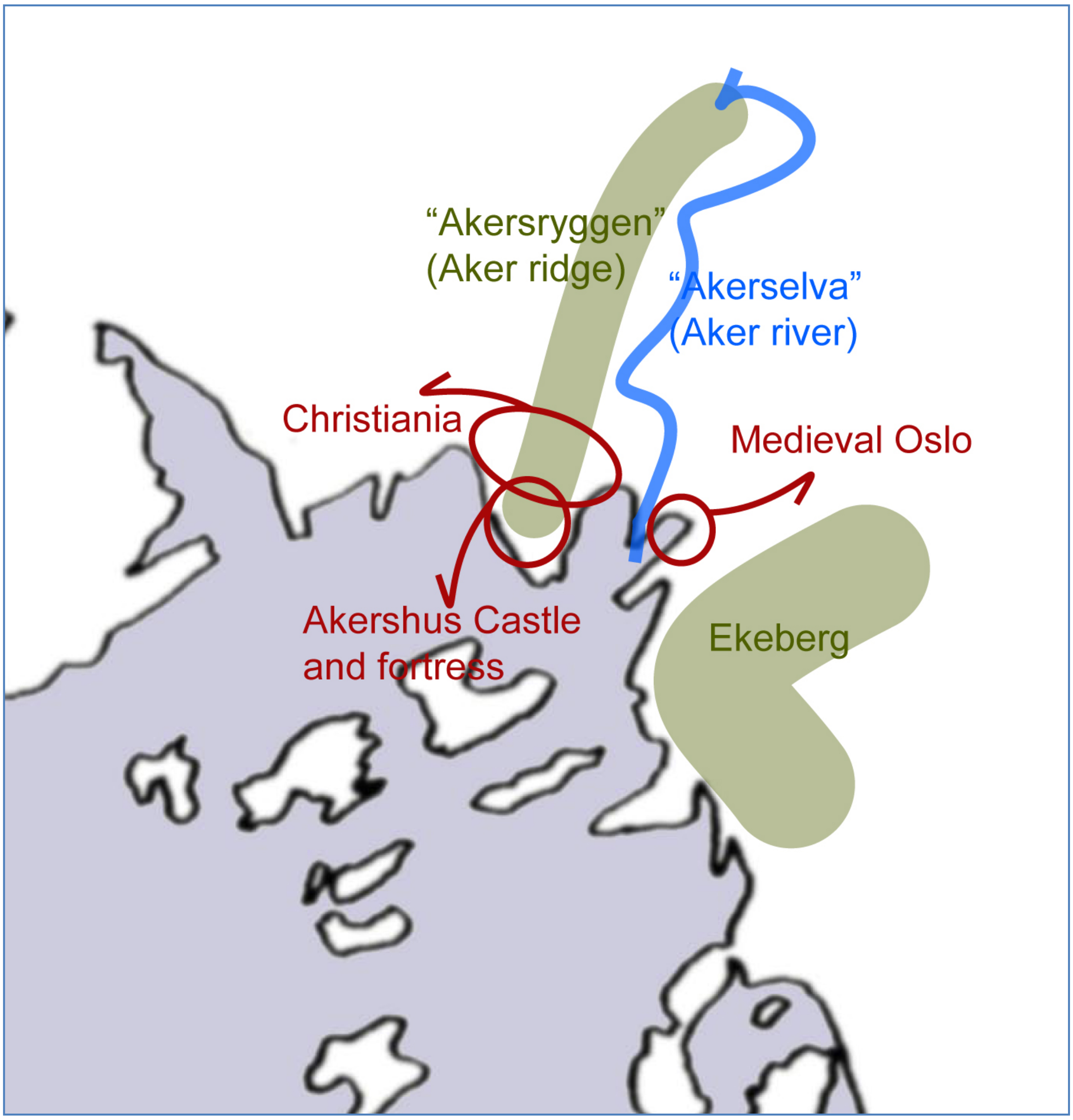

Figure 3: Map showing the location of Christiania, the early parts of Oslo. Map provided by the municipality of Oslo.

The wood trade played a crucial role in Christiania's development and economic growth for years to come. Internationally, the demand for wood rose rapidly from the 1600s onwards, and Christiania was a strategically located harbor town close to rich forest areas.

Outside the city's borders, suburban areas with small wooden houses would soon develop, some of which still remain today.

Figure 4: Map showing multi storage brick tenements which constitutes the main part of Oslo's central cityscape. Map provided by the municipality of Oslo.

When Norway gained independence in 1814, Christiania was chosen to be the nation's capital. Still, the 1624 city limits remained largely unchanged, and only minor expansions were made. The Royal Palace, built between 1825 and 1849, was located on a hill on the west side, just outside the town. Independence also saw the construction of numerous monumental buildings to suit the needs of a young nation, such as the University (1811) and The National Gallery (1849), both located near the Royal Palace.

With the rise of the industrial era from around 1840, factories were built along the main river Akerselva. The industrial revolution led to a massive process of urbanization. By 1859 the population had increased to 113000 inhabitants. The economic upturn in the late 19th century, especially the 1880s-90s, set off a building boom, and a vast number of multi-story brick tenements were constructed. These areas still make out the main part of Oslo's central cityscape. Building activity ground to a halt after the financial collapse in 1899.[3]

In 1925 the city reverted its name back to the original name 'Oslo', and the modernist planning principles made way for a new kind of development. The municipal city planner Harald Hals drew the Oslo Ring Road – a boulevard-inspired road to efficiently lead traffic around the city. The areas north and south of the Ring Road were a mixture of traditional block structures and free standing multi story apartment buildings, all with a simplified modernist look.

A shortage of housing following World War II sparked yet another building boom, but this time under slightly different circumstances: As Oslo's borders were once again expanded in 1948; large areas to the east, west and north became connected with the city center by a new subway system. Situated closer to the surrounding countryside, these "Sprawl developments" of the 1950s-1970s took on a much more suburban character.

1.3 Population

1st of january 2016 Oslo had a population of 658 000 citizens and is the largest economic, cultural and knowledge based hub in the country. By 2040, the population of Oslo is expected to grow with almost 300,000 people to 926 000.[4].

The population increase is partly a result of a large net migration and a high excess of births. Twenty eight percent of the population of Oslo is immigrants.

1.4 Infrastructure

Oslo acts as a hub for the national and the regional transportation system. Despite the large population growth, Oslo has experienced a lower car traffic increase than the national average. This is partly a result of the strengthening of the public transport system, which had a 20 percent increase in the same period. The population increase is expected to lead to a 50 percent freight transportation increase by 2030.

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[3] There were a few large building projects conducted by the municipality in the early parts of the 1900s mainly inspired by the Garden City movement in England.

[4]

2 Regional setting

Oslo is a city surrounded by rocky hills in the north, west, and east, and by a fjord in the very south. Over the last 390 years the City of Oslo shoreline has seen dramatic changes. Since the great fire of 1624, the city's waterfront has been pushed further and further out into the fjord.

2.1 Regional geology

The Oslo Region is a graben structure which extends geographically northwards from Langesundsfjorden to the northernmost part of the Mjøsa district, a distance of approximately 115 km north and south of Oslo (Figure 5). The width of the Oslo Region varies between 40 to 75 km, and the area is bordered to the east by major normal fault-zones. The areas to the east are dominated by Precambrian rocks, while to the north the allochtonous Caledonian nappe units are preserved.

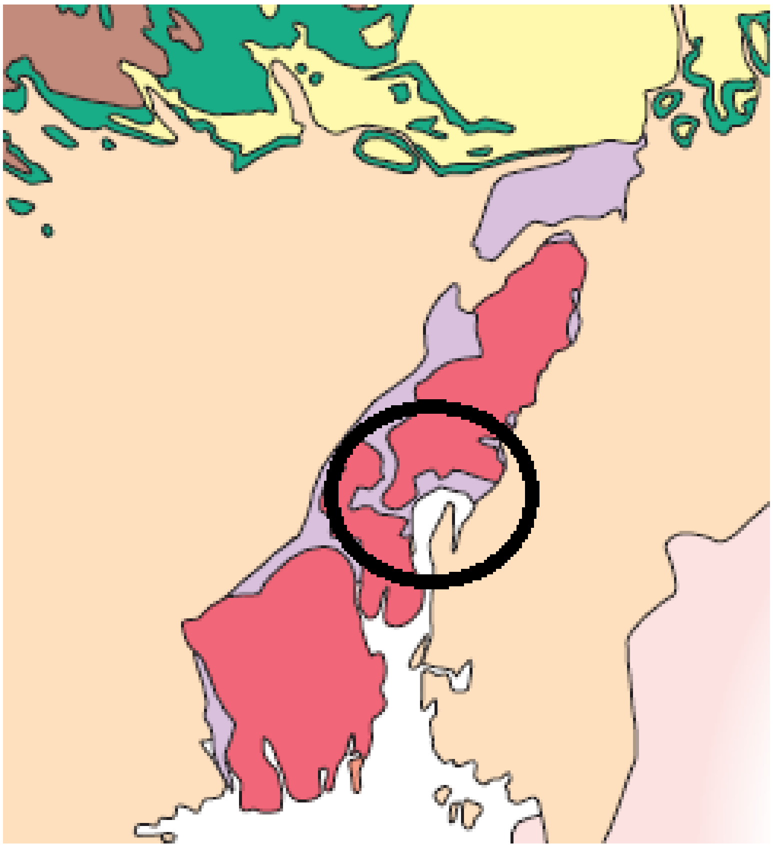

Figure 5: The Oslo Region. The city of Oslo is marked by a black circle (source: NGU).

The Lower Palaeozoic rocks in the Oslo Region are preserved due to the graben-structure that formed during the Carboniferous - Permian extensional rifting of the supercontinent Pangea. The region subsided about 1000-2000 m, burying the Lower Palaeozoic sediments with first erosional material from the surrounding horst area and then by volcanic rocks.

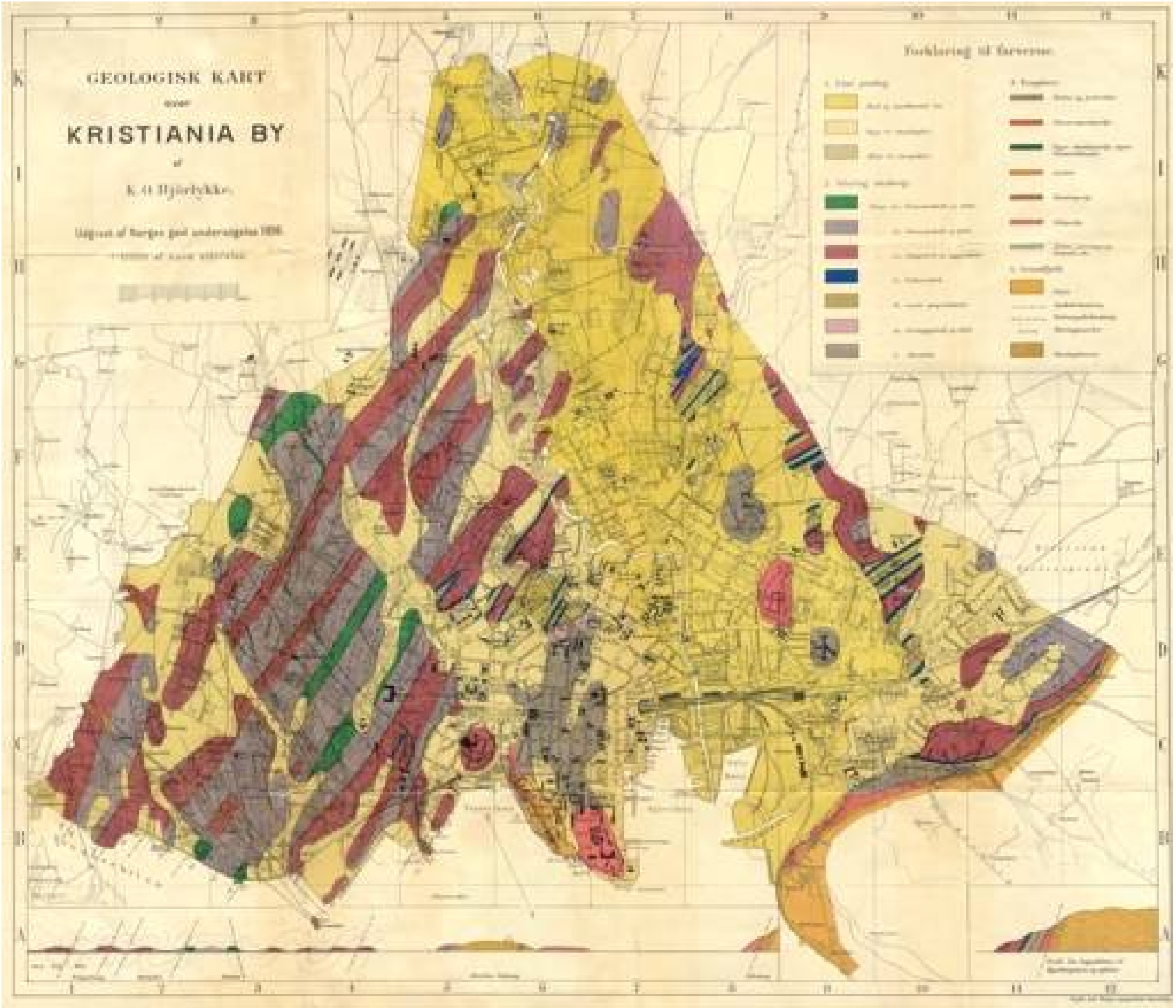

Figure 6: Map of the City of Oslo approx. 1890 (source: K.O. Bjørlykke).

In the Tertiary and Quaternary a still continuing uplift of the land started. The uplift has been up to approx. 200 meters, which caused, together with glaciers, the huge erosion during the last glaciation which formed the Oslo fjord.

2.2 Geology of Oslo

The city of Oslo is situated at the northern end of the Oslo fjord, in a sedimentary basin formed during the last glaciation period. These glacial structures have since then been covered with marine sediments, mostly clays. Moraine from the glacier dammed up lakes, from which 8 main waterways in Oslo stems from.

The thickness of the sediment layer I Oslo varies from 0 up to 100 meters. The map displayed in Figure 7 shows that the topography of the underlying bedrock is variable and includes several deep valleys. The deepest areas are located close to the central train station where the depth to bedrock has been measured to be 94 meters at the deepest geotechnical borehole. The sediment layer is dominated by marine clays, but at the outlet of especially Akerselva the layer contains a lot of organic materials. Like in most modern cities the top most layer is strongly anthropogenic. The currently available mapping of the quaternary layers in Oslo is very poor, although detailed information about these layers is found in the large number of geotechnical reports available in the municipals Sub Surface archive and Geotechnical archive.

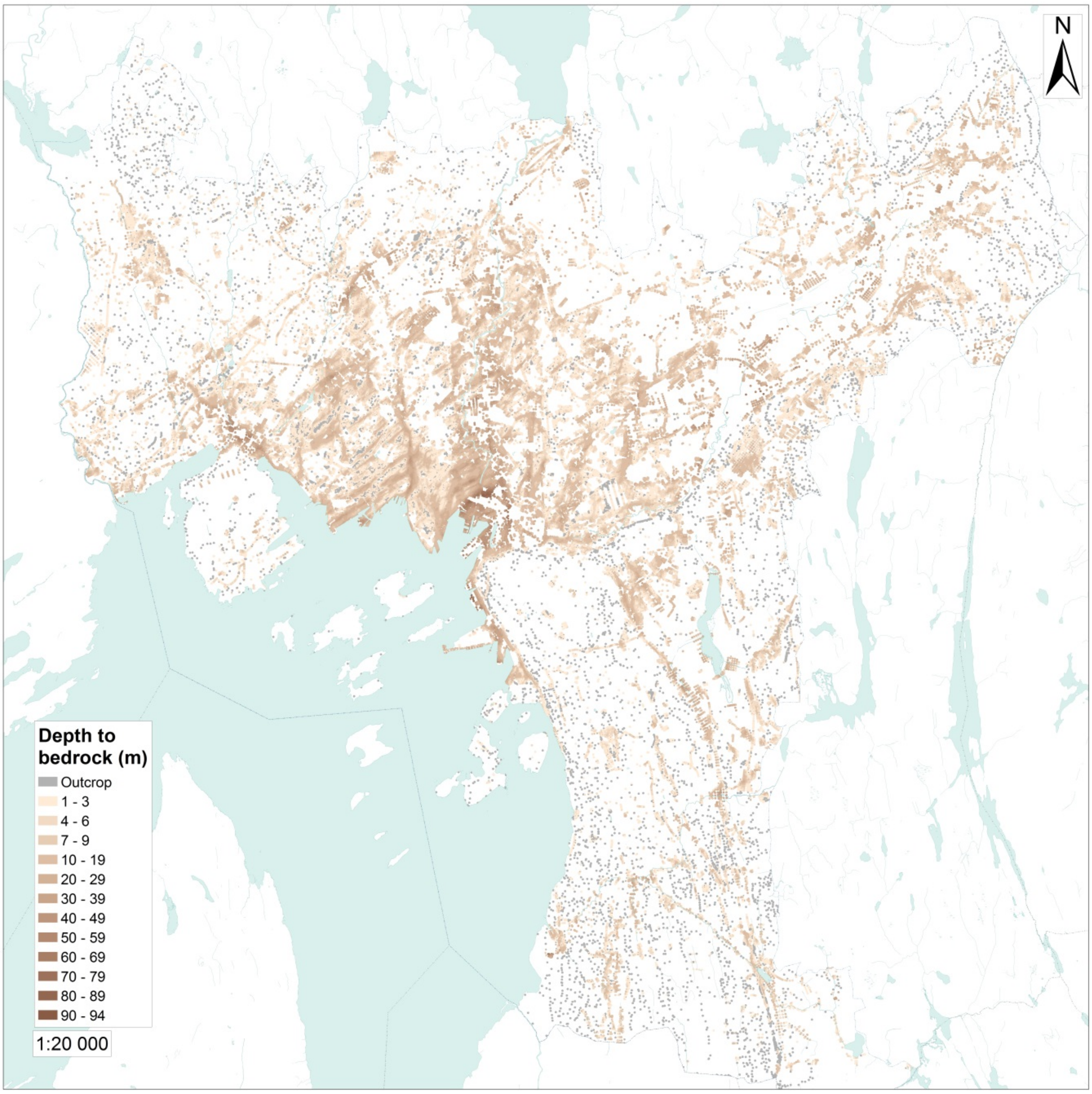

Figure 7: Map over depth to bedrock showing the interpolated depth to bedrock in Oslo. Only the colored parts have information about depth to bedrock. The area that provides most information is the central parts of Oslo, located near the fjord. Produced by the Sub-surface project, Andresen 2014.

2.2.1 Particular challenges related to the geology of the city

2.2.2 Subsidence

Oslo has been rising from the sea since the end of the last ice age due to isostatic uplift. The result is a thick set of marine and fluvial sediments that are still undergoing natural compaction. However, the main settling is occurring within the anthropogenic fill material that has been used to expand the harbour area over the last centuries. This subsidence affects infrastructure and buildings in the area, including the Oslo Central railway station.

While most modern buildings are founded on piles that reach down to bedrock, many historic buildings, including the station, are built upon wooden foundations. Even if new buildings are stable, settlements in the surrounding areas may affect infrastructure connections, such as water pipes and electric cables. Recently, it has been claimed that the Barcode development could have accelerated subsidence in the area by altering the groundwater table and reducing pore pressure in the sediments. A lowered groundwater table could also lead to degradation of wooden foundations that are now exposed to an oxidizing environment (see satellite image using Interferometric synthetic aperture radar (InSAR) to measure settling rates from the central parts of Oslo in Figure 8).

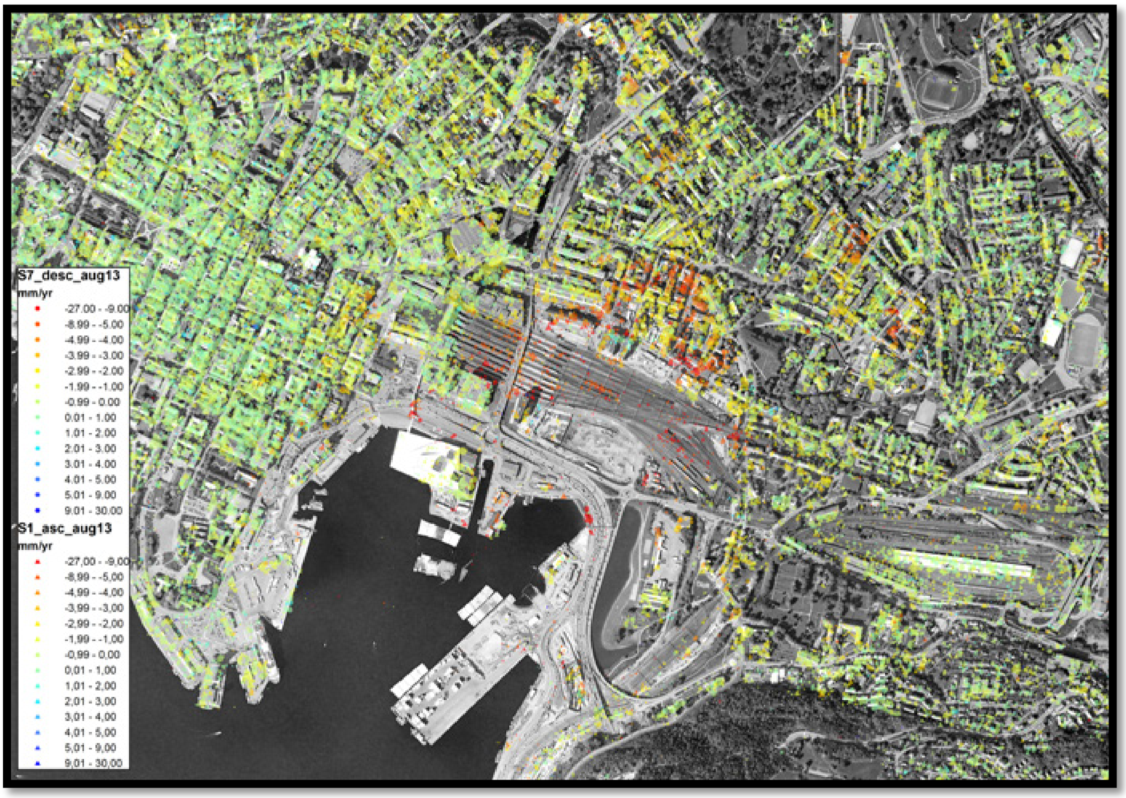

Figure 8: Settling rates measured from satellites with InSAR technology in the Björvika area. Red dots show areas with high settling rates (John Dehls, NGU, August 2013).

2.2.3 Quick clay

Along some of the waterways, salt has been washed out of the clay by fresh water creating so called quick clay. Quick clay can be very dangerous as it can become liquid if it is disturbed and the water content gets too high. There is a low risk for quick clay landslides in the central parts of the city, but pockets of quick clay have been confirmed along the Alna River.

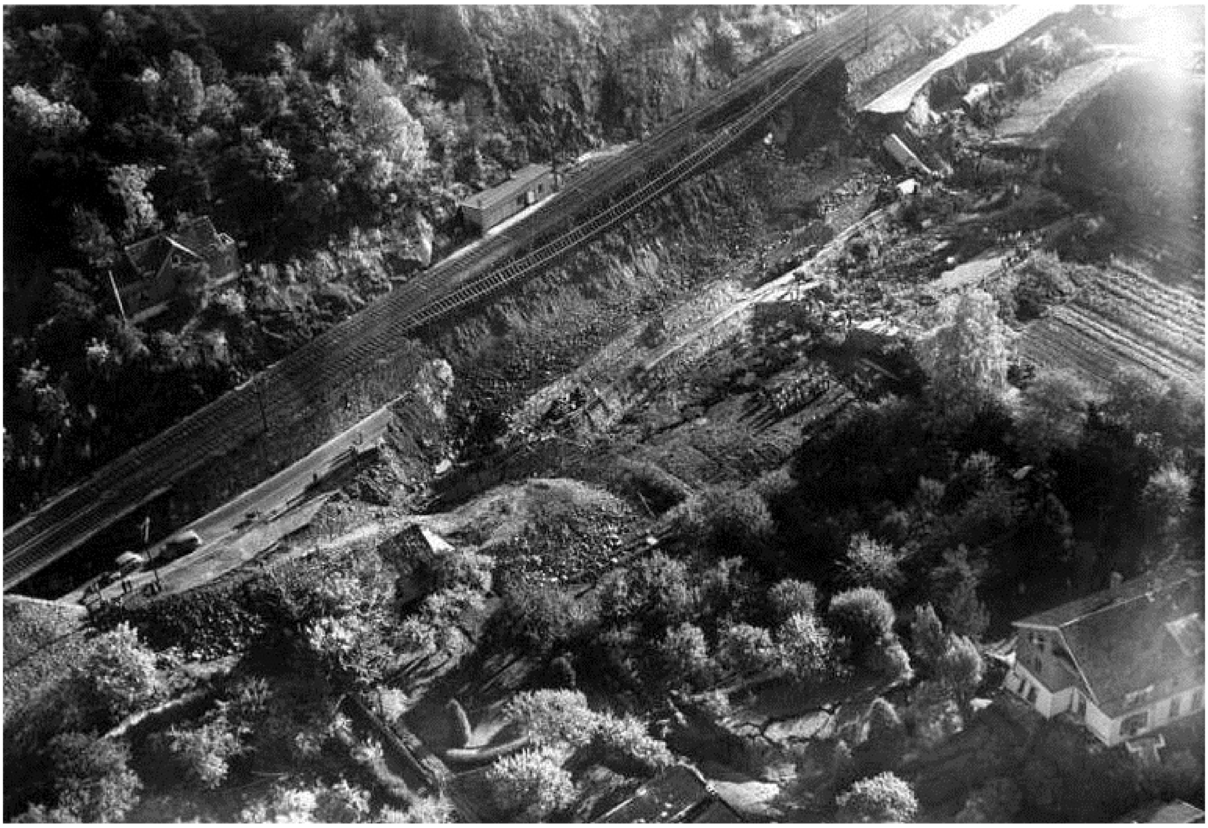

Figure 9: Quick clay mass movement in Bekkelaget in Oslo on 7th of October 1953 at 7:37 h. Cutting of the main road and railroad line going south from Oslo, the local train managed to stop in time but a bus with 45 commuters followed the masses down and four people died.

2.2.4 Alum shale

Alum shale consists of black carbon and sulfurous shale materials, deposited about 500 million years ago. Alum shales are found frequently in the Oslo area and are considered as a nuisance to public health. They swell when disturbed from their natural deposition setting, resulting in damages to buildings, deterioration of steel and concrete, sulfur and heavy metal contamination of groundwater as well as emissions of carcinogenic radon gas. In addition, there is a concern about the best solution for sound disposal of masses containing alum shales.[5]

[5] http://ngi.no/no/Prosjektnett/Blackshale/

2.3 Groundwater distribution in Oslo

There is no systematic mapping of the groundwater levels in Oslo. However, pore water pressure is often monitored during developments in the underground. Lowering of the groundwater levels has been proven at several sites in the city. The groundwater level is lowered by natural forces (isostatic up-lift) but the anthropogenic factor is quite important. The anthropogenic influence is caused by actions such as the use of impermeable surfaces by paving. But drainage of groundwater into subsurface constructions or during excavations can locally have a high impact on the groundwater level. Due to very compact marine clays the infiltration capacity is generally very low.[6]

2.4 Sub surface land use

The underground land use in Oslo is widespread. Roads, train lines and metro lines are frequently directed through tunnels. Other sub surface uses are:

- Infrastructure tunnels
- Interest of national security
- Air raid shelters
- Parking facilities
- Water storage
- Water treatment centre
- Sewage tunnels
- Drinking water transportation
- Energy wells
- Storage
- Pipes
- Cables

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[6] Oslo municipality, Agency for Water and Sewerage Works

The use of energy wells for heating is developed more and more. There is a widespread use of closed loop systems drilled down to depths between 150 and300 meters. The variation is quite remarkable. Many private persons install energy wells in their gardens but there is also a significant number of large scale systems that are heating hospitals, schools and large office buildings. The current distribution of energy wells in the Oslo area can be seen in Figure 10.

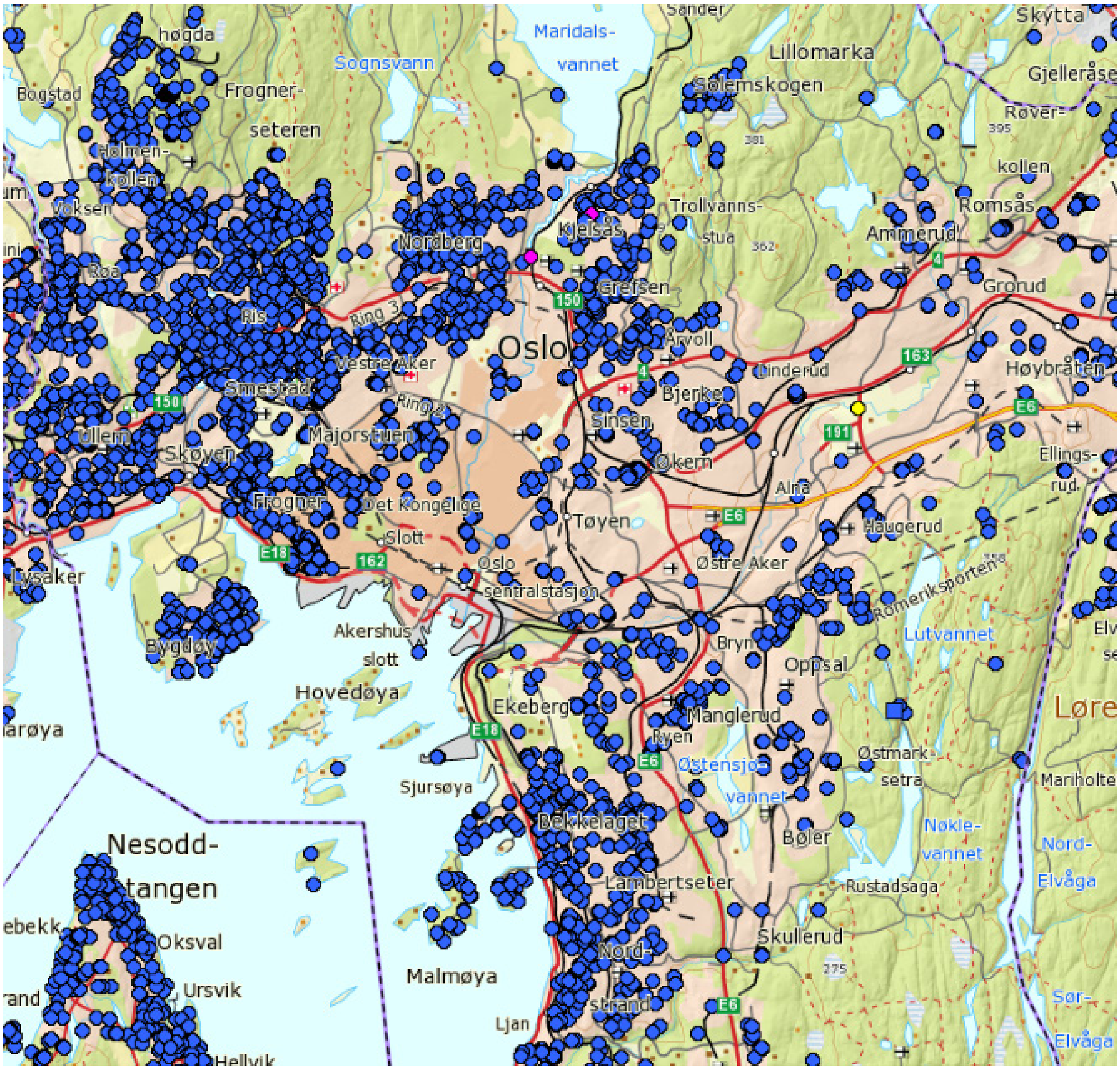

Figure 10: Distribution of energy wells in the Oslo area in April 2016. The drilling companies are obliged to report new holes to NGU (National Geological Survey). However, most probably this is not always done. Note the high amount of energy wells in the more wealthy western parts of the city (http://geo.ngu.no/kart/granada/).

2.5 Major sub surface developments in Oslo

2.5.1 Bjørvika

Bjørvika is a major re-development area located between the railway station and the seafront. Since a few years ago the area used to host the harbour and a highway. The highway is now going through a tunnel beneath the fjord, and the harbour has moved a couple of kilometres south, a major action which has freed large surfaces for redevelopment in the central parts of the city. Many new high-profile buildings are now being built or planned in the area; the Opera house, the Barcode, a new art museum hosting the city's collection of the famous painter Edward Munch to mention some of them. As mentioned in chapter 2.2 the geotechnical conditions in the area are quite difficult. One way of overcoming these difficulties can be seen in Figure 11. Dronning Eufemias gate which is running parallel to the seafront looks like a road at the surface but it is actually a bridge built upon 1100 pillars of steel and concrete**.**

Figure 11: Dronning Eufemias gate in the newly developed area of Bjørvika is more like a bridge than a road. To deal with the deep horizons of clay, often containing a large amount of organic matter, the road is constructed on more than 1000 piles of steel and concrete (Statens Vegvesen).

2.5.2 Follobanen

Follobanen will be a 22 km new double track line from Norway`s capital to the public transport center of Ski. It compromises a 20 km long tunnel partly under residential areas and is designed for speeds up to 250 km/h. The main construction phase started in May 2014 and it is scheduled to be completed in 2021.[7]

2.5.3 Fornebubanen

Fornebubanen is a new metro line that is currently planned to go partly through a tunnel between Fornebu and Majorstua. The area is sensitive to underground changes; earlier underground infrastructure has caused major settings and important damages to 18th century brick buildings.

2.5.4 Lørenbanen

Lørenbanen is a metro tunnel currently under construction. It will provide 1.6 km of double rail between Sinsen and Økern as well as a new station underground. The completion is scheduled for 2016.[8]

2.5.5 Midgardsormen

Midgardsormen is the largest sewage project in the modern history of Oslo. The sewage system partly consists of a nearly 3 km long rock tunnel and 6.5 km of pipes of which the internal diameter is up to 2.7 m. The system was taken into use in May 2014 and ensures that wastewater from the city centre is safely transported to the subsurface water treatment centre of Bekkelaget. [9]

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[7] http://www.jernbaneverket.no/en/startpage1/Projects/New-double-track-Oslo-Ski/

[8] http://intranett.ktpas.no/ikbViewer/page/inter/prosjekter/artikkel?p_document_id=2429991

[9] http://www.vann-og-avlopsetaten.oslo.kommune.no/aktuelt/prosjekter/midgardsormen/article225226-54556.html

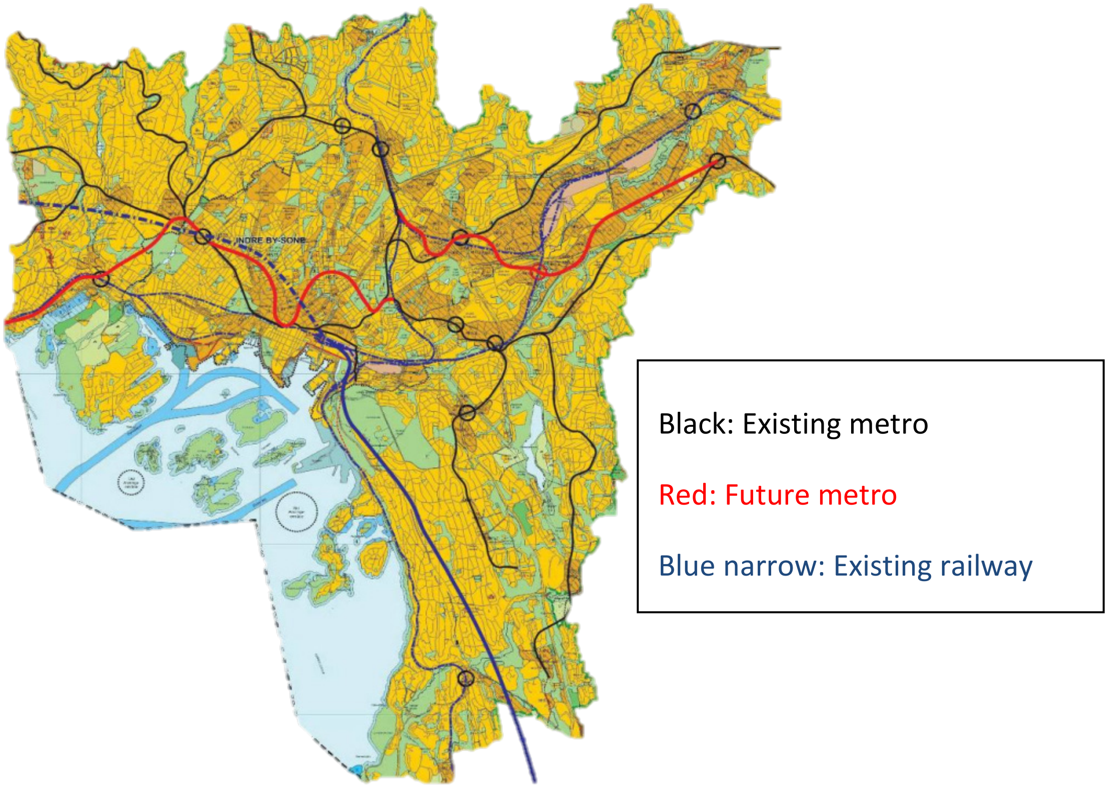

Figure 12: Map over the Municipal Masterplan showing major infrastructure that is existing, under construction and planned. Map by the Planning and Building Agency in Oslo.

2.5.6 KGrav – a sub-surface solution

In a city that develops rapidly, digging cannot be avoided. To avoid excessive digging the municipality of Oslo has developed KGrav, an internet-based system that obliges subsurface infrastructure owners to coordinate when the length of digging works-is longer than 40 meters and/or when the digging works crosses municipal roads. The system contains information about pipes and cables under the surface in Oslo Municipality. The infrastructure database makes KGrav a useful tool in project engineering.

In order to get a work permit for digging, the contractor needs to report future digging activities to K-Grav. Infrastructure owners in the municipality will then be notified. If they want to carry out any digging it needs to be coordinated. When the digging/works have been carried out in one area, permits to dig in the same area won't be handed out for the next three years.

KGrav has been developed in cooperation between the municipality of Oslo and a private company, and is now operated by the same private company. They also provide cable location service before drilling or digging works can start. This is organised as a service that the infrastructure owners pay for.

The system is now being implemented in other Norwegian cities and the system is in use in the miunicipalities of Asker, Bærum, Lørenskog, Drammen, Trondheim and Tromsø.

3 The sub-surface on a national scale

3.1 The Planning and Building Act

A number of laws, bylaws and local regulations set the legal framework for protecting existing underground structures as well as the planning and construction of new ones. The most important tool is the Norwegian Planning and Building Act[10]. The law was revised in 2008, a work that resulted in quite significant changes.

The Norwegian planning system has over the last decades moved from being *strong* to *balanced.* Local municipalities would earlier not only develop municipal master plans by themselves, but also carry out most of the detailed planning. Detail plans are now mostly developed by private interests and approved by municipal authorities (City Council).

Previously building controls were quite strict throughout the construction process. The responsibility for compliance with regulations is now to a much greater extent placed on the developer, while authorities carry out random controls and check reported violations of laws and regulations.

The planning system is designed to encompass underground structures, and a bylaw describes how planning in more than one level shall be shown on maps.

The law opens for planning in 3D, but so far 3D has only been used to illustrate plans and constructions. Methods for producing 3D plans are presently under development.

[10] http://lovdata.no/dokument/NL/lov/2008-06-27-71

The Norwegian planning and building hierarchy can be described as being structured in four levels:

1. Central government land-use plan
2. Municipal master plan
3. Municipal sub-plan
4. Detail plan
5. Building project

3.1.1 Central government land-use plan

The state can develop and determine plans according to the Planning and Building Act when national interests are concerned. This is seldom used but when it is used it is mainly done on a detailed plan level. Some examples are the main international airport (Gardermoen Airport) and the national hospital (Rikshospitalet) in Oslo.

3.1.2 Municipal master plan

The Municipal master plan is a plan developed for the entire municipality in two parts: One strategic plan which is descriptive and a land use plan, which is map based (2D) with related regulations.

The plan shall be revised every four years in rhythm with change of political leadership (elections every four years).

3.1.3 Municipal sub-plan

A municipal sub plan is a plan developed either for a geographical part of the city, or for a certain topic for the entire city. Over the later years a sub-plan has mostly been used for certain topics.

Urban planning in 3D is currently under development in Norway and has not yet been tested in full scale. Methods to store and build up a 3D plan as well as how to communicate a 3D plan with the public and decision makers needs to be investigated before a decision can be made.

3.1.4 Detail plan

A detailed plan is a legally binding land use plan for a relatively limited area, normally in scale 1:1000. According to the 2008 law there are two types of detail plans: One where plans are being worked out by the planning authorities and where the aim is to ensure public interests (this may also cover privately owned areas), and one type where plans are developed to govern specific buildings and constructions.

Detail plans will in principle have to comply with superior plans. Normally they will expand on superior plans in terms of level of accuracy, and include underground issues like pipelines and cables, car park facilities etc. Detail plans are approved by the city council.

3.1.5 Building project

The planning and building law lists a range of building projects and construction measures that need to go through a process of application and approval before realization. The list is detailed and further explained in bylaws. The effect of this is that almost everything that needs digging into the ground, moving of rock or soil, and/or implies constructing something on or underground needs be approved by the municipality before it can be carried out.

There are two challenges connected to this:

- If there is an application for a construction that is expected to be in conflict with a future (underground) measure like, for instance, a future metro tunnel which is not yet planned to an extent where it is governed by law binding land use plans, there is no legal base to refuse it.
- There are measures that are not subject to application and approval, although better control would be beneficial for the municipal management of the city. A typical example is drilling of energy or groundwater wells.

3.2 Particular challenges affecting underground planning

Ownership to land goes below the surface, and landowners are free to use the underground beneath their property. There is no fixed limit to how far down this right of ownership goes, and there have been trials in court where it is referred to “reasonable use” and phrases of similar nature. As long as this has meant basements and other constructions directly connected to buildings on the ground, the lack of accuracy in laws has represented few problems, but particularly with the accelerating number of private energy wells drilled (presently some 100 – 150 a year), being drilled to depths between 100 and 300 meters, this issue becomes important.

There is a long tradition for constructing road and railway tunnels in Norway. Though such tunnels often run through projections of private land, it has rarely meant problems as they often go so deep that it has been considered “no man’s land” (ground where the land owner has no interest of use for himself).

There is also a “first come first served “tradition”, meaning that if somebody wants to bring a new underground construction close to an existing, for instance a road tunnel, the road owner will have a strong position in keeping the newcomer at a distance, even if there is not established a defined buffer around the road tunnel by an approved plan (this delayed recently the project planning for a new railway tunnel out of Oslo which was proposed close to a main road tunnel).

Protection of ground water levels is somewhat insufficient in Norwegian legislation, though it is a common problem in several Norwegian cities, that construction works frequently alter ground water levels and pressure, causing damage to neighbouring constructions, often older buildings of preservation value. In a detail plan for parts of central Bergen that is presently under work, it is for the first time in Norway proposed in a detail plan regulations to control ground water levels. The outcome of the approval process can be of general importance to this issue.

3.3 National subsurface databases, organizations and standards

3.3.1 National Database for Ground Investigations in Norway (NADAG)[11]

A vast amount of data from ground investigations such as geotechnical drilling, bedrock drilling and ground water wells exists in Norway. In spite of the huge amount of existing data, these are not easy to access as they are spread between different data owners and users. A national database for ground investigations will, for the first time, give an overview over existing drill data for all of Norway. This will make the data easier to access, and re-use will lead to considerable savings for society. Within cities, in particular, the exploitation of the subsurface is growing, and the need for 3D knowledge about ground conditions is increasing.

The project about developing the National Database for Ground Investigations (NADAG) was started in 2012 as a cooperation between the Geological Survey of Norway and three other governmental departments (the Norwegian Public Roads Administration, the Norwegian Water Resources and Energy Directorate, and the Railway Services), and aims at collecting and making public available data important for the society. The development of the database is controlled by conceptual and standardized data models, and will be adjusted according to the needs of the various users. NADAG will contain various amounts of data, dependent on what is available – ranging from only metadata (location, drill type, drill depth, company, date, report no., etc.) to full reports and raw data. NADAG will firstly be populated by data from geotechnical investigations. The primary objective for NADAG in the future is to be able to show all ground investigations in Norway through a web application.

[11] Inger Lise Solberg, NGU, project manager NADAG

3.3.2 Granada[12]

The national groundwater database (GRANADA) provides information on wells and springs in soils and rock , groundwater quality monitoring of groundwater and reports of groundwater investigations. The database is available as a map service on the Internet. It is hosted by the Geological Survey of Norway (NGU).

3.3.3 Cooperation board for wires in the ground[13]

"Cooperation board for wires in the ground" (Samarbeidsforum for ledninger i grunnen) was established in 2013 and is a forum for relevant industry associations and government agencies with an interest in the coordination of pipes, cables and other infrastructure in the ground. This includes power, water, sewage, electronic communications , heating , gas and caverns .

The board shall fulfill the following purposes:

- Mutual exchange of information on topics of common interest and discussion of current challenges in Norway.
- Keep abreast of international developments.
- Contribute to developing new relevant knowledge, and propose solutions and initiate projects that can help solve issues.
- Be proactive and discussion partner for the development of regulations, standards and agreements for cooperation.
- Promote greater coordination through information campaigns, by conducting seminars, workshops and the like, and lectures on relevant courses and conferences.

[12] http://www.ngu.no/no/hm/Georessurser/Grunnvann/Grunnvannsdatabasen/

[13] http://www.regjeringen.no/en/dep/kmd/subjects/plan--og-bygningsloven/kart/samarbeidsforum-ledninger-grunnen.html?id=723667

3.4 National SOSI standard[14]

SOSI is a much used geospatial vector data format predominantly used for exchange of geographical information in Norway. SOSI is short for **Samordnet Opplegg for Stedfestet Informasjon** (literally "Coordinated Approach for Spatial Information", but more commonly expanded in English to **Systematic Organization of Spatial Information**). The standard includes standardized definitions for geometry and topology, data quality, coordinate systems, attributes and metadata.

There are several standards for underground objects, such as geology, soil, petroleum, pollution, geochemistry, pipes and cables (under development).

4 Urban planning and management in Oslo

4.1 City administration

The highest decision-making body in Oslo is the City Council, which has 59 members and is headed by the Mayor of Oslo. Elections are held every four years.

Eight political parties are presently represented (2014). The next election is in the autumn of 2015.

The City Council is divided into five Standing Committees: Finance, Urban Development, Education and Cultural Affairs, Health and Welfare, and Transport and Environmental Affairs. The committees prepare all matters for decision by the City Council.

The City Government consists of eight members, the so called Vice Mayors. The City Government heads the City's administration, makes recommendations to the City Council and is responsible for carrying out decisions made by the City Council. Once decisions are made in the City Council, it is the responsibility of the City Government to ensure that they are properly implemented.

City council decisions are carried out by Municipal Agencies and/or Undertakings.

4.1.1 Municipal master plan

Oslo is presently developing the first generation of a legally binding land use master plan, according to the 2008 law revision. The most significant achievement for the underground is that the plan proposal contains a demand to consult with infrastructure owners before drilling wells within a shown boundary. This is to protect future major infrastructure such as

[14] http://www.statkart.no/en/SOSI-Standard-in-English/SOSI/SOSI-Standard-in-English/

a new railway tunnel and a new metro tunnel through central parts of the city. These projects are currently in very early planning stages.

The municipal master plan is expected to be approved in the spring of 2015.

4.1.2 Municipal sub-plan

It may be relevant for Oslo to develop a municipal sub-plan for the underground, and the "Oslo Sub surface project" has passed a recommendation to start the development of such a plan, much like the one developed for Helsinki.

Main constructions to include in the planning process of a municipal sub plan for the underground are:

- future railway tunnels,
- future metro tunnels,
- future main road tunnels.

Other structures that we consider to include in the municipal sub plan for the underground are:

- expansion of the main district heating pipe system,
- major electricity cables,
- future development of the central water and sewage system etc.

Urban planning in 3D is currently under development in Norway and has not yet been tested in full scale. We are currently discussing whether a municipal sub plan should be partly or completely carried out in 3D. Methods to store and build up a 3D plan as well as how to communicate a 3D plan with the public and decision makers need to be investigated before a decision can be made.

4.2 Particular challenges affecting underground planning in Oslo

- Buffers between underground constructions are not established.
- Some constructions are not subject to approval (e.g. energy wells).
- For any master plan and detail plan that ”can have significant consequences for environment and society” a ”planning program” shall be developed requiring consequence analysis. Such analysis shall, e.g., cover consequences for cultural heritage wherever relevant, which may include how the construction phase can affect groundwater pressure and level.
- Law requirements to maintain groundwater pressure and level are vague.

5 Full case description; the Sub Surface Project

The city of Oslo has some major challenges related to the use and the planning of the underground:

- Increased use of the subsurface,
- Conflicts of interest, tunnels vs. energy wells,
- Alum shale,
- Deep horizons of clay,
- Increased building activity causing increased subsidence,
- Sinking groundwater causing damages on, or loss of historical buildings.

In 2011 a pre-project was carried out which resulted in the four-year "Sub Surface Project" or; Prosjekt for økt kunnskap om undergrunn i Oslo" in Norwegian, that started up in February 2013.

The project is owned and managed by the Agency for Planning and Building Services, and the project group is put together with employees from five different municipal agencies, including:

Agency for Planning and Building Services,

Cultural Heritage Management Office,

Agency for Urban Environment,

Agency for Real Estate and Urban Renewal,

Agency for Water and Sewerage Works.

The project group consists of 15 persons and is a truly interdisciplinary group; architects, counsellors, construction engineers, GIT engineers, geologists, 3D specialists, a geotechnician, a hydrogeologist and a hydrologist are working closely together in order to improve the knowledge and management of the city's subsurface.

The project is divided into four different subprojects: ***Groundwater, Geodata, Datacatchment and Urban Planning and Law.***

5.1 Aims and methods of the subprojects

5.1.1 Urban planning and law

Urban planning and law is a key group as the group members are investigating the means to regulate and manage the underground and will propose necessary changes on both local and national level. The subproject is defining weaknesses in national law that affects the municipality's management of the underground. An important step ahead will be to propose changes on national level (law changes). Another step is to propose local regulations to the local government as they can be adapted to the Oslo case. An important part of the work will also be to work out and implement internal guidelines.

The planning part of the group is defining where in the planning process different types of underground projects should be implemented. An important work ahead is to realize and implement our changes in the daily working process at the Agency for Planning and Building services. The aim is that the subsurface should be a part of the local planning process.

5.1.2 Geodata

The aim of the sub-project Geodata is to produce the outlines for a future digital 3D model over underground infrastructure and other sub-surface structures. The system will give access to relevant information about man-made structures in the subsurface, and could become a great help whilst planning future sub-surface use.

During the years 2014 and 2015 a pilot model in 3D over underground infrastructure and some geological features is being developed in three test areas at Majorstua, Bryn and Ekeberg, see Figure 16. Majorstua is the main pilot area where all types of underground infrastructure will be visualized. At Bryn and Ekeberg only major infrastructure such as road, train and waste water tunnels will be visualized.

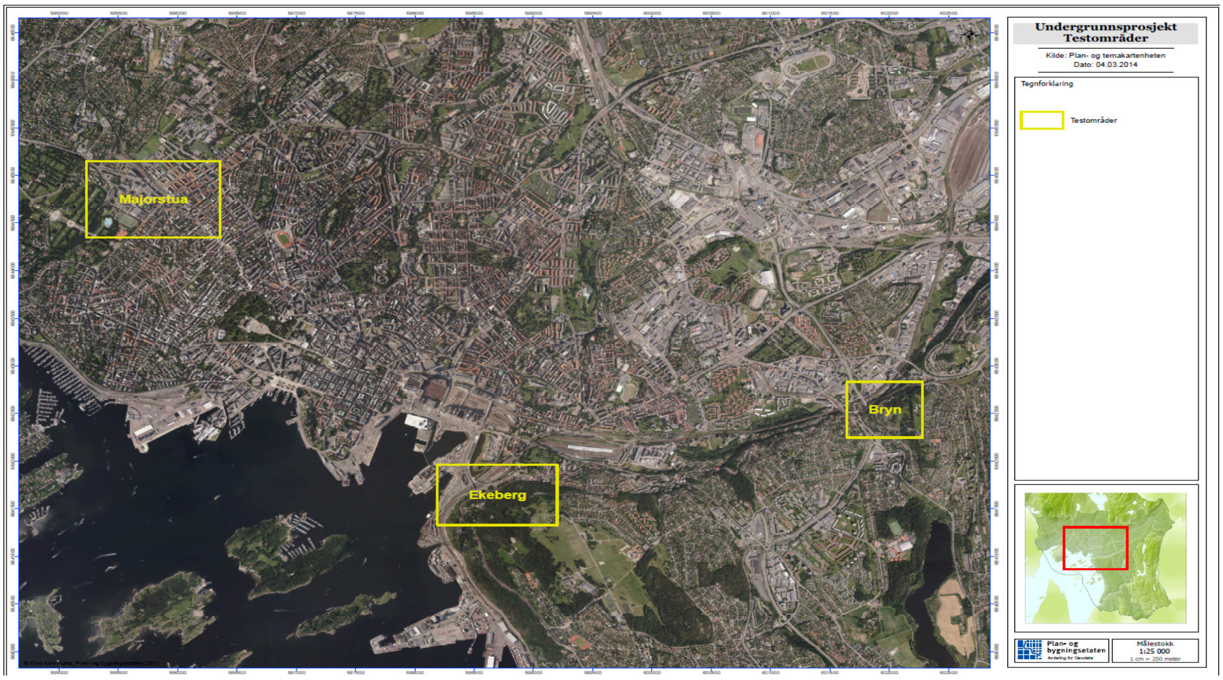

Figure 13: Map over three test areas where underground infrastructure will be modeled in 3D during 2014 and 2015.

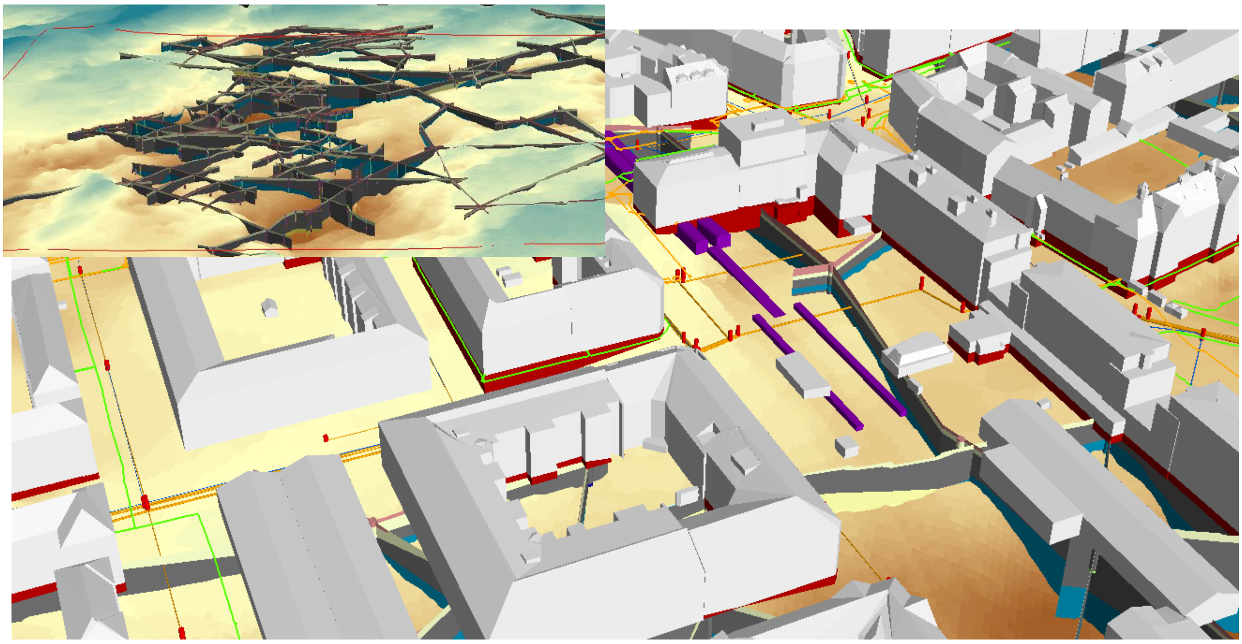

Figure 14: Part of the 3D modelling in the area of Majorstuen, December 2015. Showing existing buildings, depth to bedrock, soil profiles, manholes, sewage and waterpipes (Oslo Municipality).

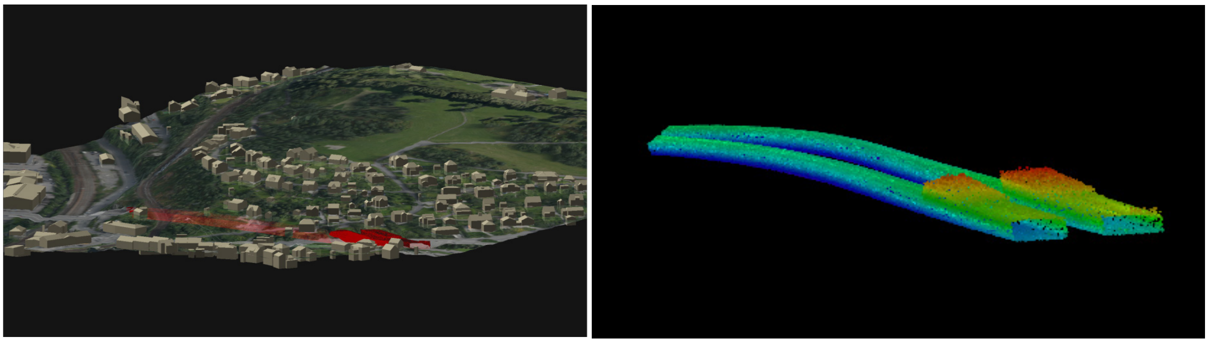

Figure 15: 3D model of the Bryn Tunnel (with thanks to Statens Veivesen).

Part of this groups work will be to evaluate the need for underground data, and the level of security measures needed whilst creating a model of underground infrastructure. The need for coordination and distribution of existing data will be investigated and methods to do so will be proposed.

A test project using Ground Penetrating Radar (GPR) to detect and visualize pipes and cables is realized during autumn 2014. The aim is to evaluate if this method is of any interest to the city.

The Sub surface project will also participate in the research project “Satellite InSAR for longtime surveillance of subsidence and mass movement prone areas”. The aim is to investigate possible use for InSAR measurements to survey subsidence.

5.2 Groundwater

The aim of the sub-project Groundwater is to deepen the municipality’s knowledge on groundwater related issues in Oslo. There is already a lot of information available but an overall vision is missing. Tests of modeling groundwater and geology will be carried out in the area of Majorstua. This is a major challenge as geotechnical data is not yet available in digital format. Further on the knowledge of geological and groundwater modeling is limited within the municipality. The subproject will also investigate the need of a groundwater monitoring system, as well as of identifying areas that are sensitive to groundwater changes. Further on the group will work together with the *Urban Planning and Law* group and will propose and work for better means, on local and national level, to manage the groundwater in the municipality.

5.3 Data availability

5.3.1 Geological and geotechnical data

5.3.2 Underground archive

The municipality of Oslo has the so called **Undergrunnsarkivet,** a large archive containing almost 200000 geotechnical drillings. The first drilling is from 1916. The archive can be described as "semi digitized", all reports have been scanned and are available in pdf, and each borehole is represented by a point in the map. However, there is currently a lack of metadata for many boreholes and many of them have not been connected with the correct report. The archive needs updating and digitalization.

There is currently one person working with the database, and new reports are reported in to the archive on an ad hoc basis.

5.3.2.1 Geotechnical archive

The remains of the former geotechnical office is a non-digitized paper archive with more than 3000 geotechnical reports and evaluations. There is an excel file that describes the content of the archive.

5.3.2.2 Database over polluted ground

Oslo has a database consisting of sites where polluted soil is confirmed or suspected. The database has two sources:

- Reports from sites where soil pollution has been investigated. The Municipal Agency for Urban Environment receives reports containing information about: the site of investigation, number of sampling points, analysis results and usually a map over the area. These rapports generally describe the measures taken by the Entrepreneur to prevent spreading of pollution and remediation of the site. The sites are then drawn in a map, which is distributed to other agencies.

- A register based on an historical investigation where the history of the site (e.g. former gas station, printing press, etc.) has been mapped.

5.3.2.3 Pore pressure database

The municipality of Oslo also holds the Pore Pressure Database ("Poretrykksdatabasen") that contains groundwater measurements from across the municipality. Approximately 1000 piezometers with in total 80000 measurements of hydraulic head are recorded. The data is usually recorded during development of underground constructions. That means that many of the piezometers are no longer active. The first recorded piezometer is from 1973. During the Underground Project work has been done to increase the availability of and the knowledge about the database. There are currently 54 measuring wells still being recorded, all of them being situated at Majorstuen.

Major infrastructure owners carry out groundwater measurements, but there is no coordination of the measurements and no external measurements are reported into the database.

5.3.3 Infrastructure

Water pipes and sewage is available through the web service *"Under Oslo".* In addition, pipes and cables are available through "*K-Grav*", with both services needing a log in. For obtaining the log in the user needs to be approved.

Data over infrastructure from the municipal agencies are being adapted for visualization in 3D in the test area of Majorstuen.

The National Road Agency (Statens Veivesen) is planning to laser scan all their tunnels in the municipality of Oslo. The data and the future models will be available to the municipality. They are also planning to register all their tunnels in the national cadastre in order to avoid problems with ownership of the areas where the tunnels are situated. This is still under development and buffer zones around the tunnels are yet to be established.

6 Results

Apart from the ongoing work described above the following results are available after nearly two years of the project.

6.1 Depth to bedrock

During the summer of 2014 a new map that shows depth to bedrock in the populated areas of Oslo was developed. The result can be seen in Figure 16. 186260 points with information on depth to bedrock, mostly from geotechnical drillings, have been used to create the map. The points are unevenly spread, with the highest density being found in the most central areas. To avoid the inclusion of areas with no information on depth to bedrock, only areas of 20 meters around each point were included in interpolations of data.

The map can be used as a tool to indicate areas that are sensitive to settling. A close up of the central areas of Oslo and the brick buildings can be seen in Figure 16. Through this method it is possible to detect buildings that might be founded partly on rock and partly on sediments. Such buildings are very sensitive to settling as those could actually break the whole building.

6.2 Master thesis in 2014

During the spring of 2014 a master thesis focusing on the underground conditions in the area of Majorstua was performed. The study area in Majorstua is influenced by a sewer installed in the 1970s and by the artificial infiltration of water into the ground starting in the 1990s. The infiltration of water was started because of drainage of groundwater into a large sewage tunnel. One of the tasks in the master thesis was to visualize the groundwater conditions in the area. Box plots that showed the annual progress of hydraulic head was created from 43 piezometers. The 43 box plots showed different patterns. Some showed great variations of several meters while others were more stable within a meter. One of the box plots is shown in Figure 17, it displays a pattern corresponding to drainage problems after the installation of the sewer. Water pumps to infiltrate water were installed in 1991 and 2003.

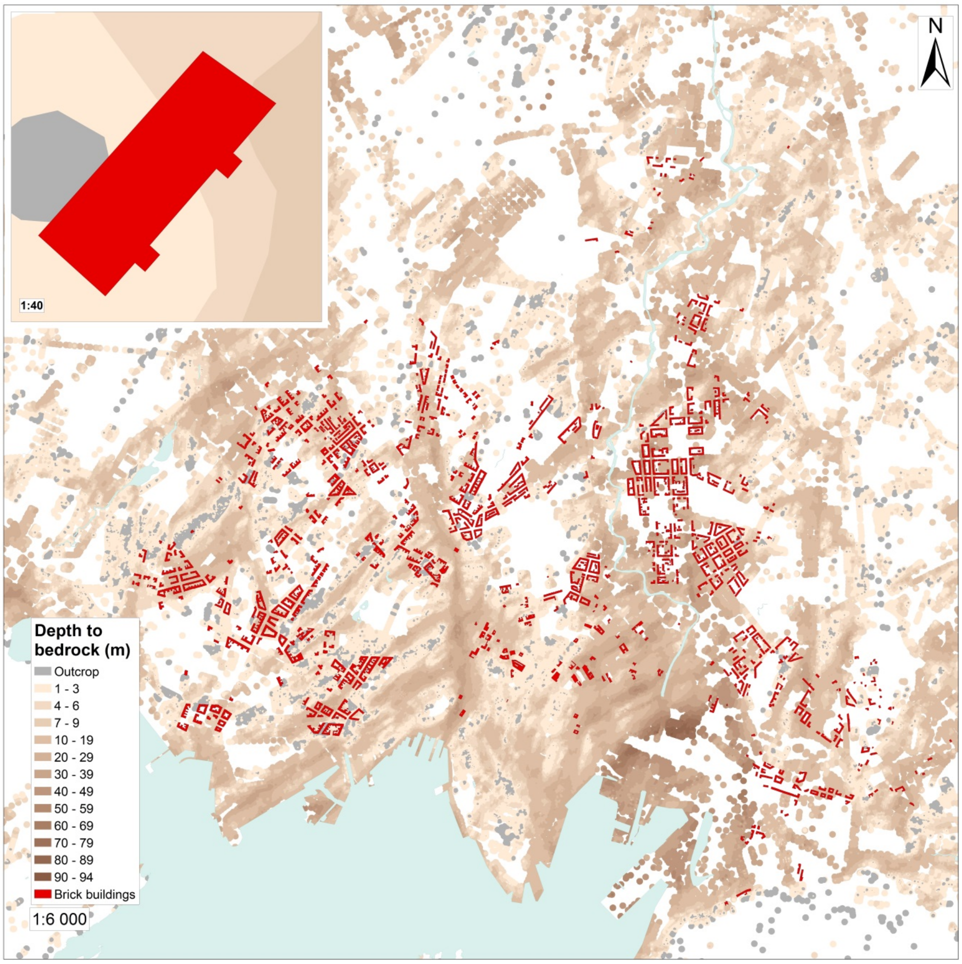

Figure 16: Depth to bedrock and brick buildings in the central parts of Oslo. The picture in the upper left corner shows a brick building that is partly located directly on bedrock and partly on up to 9 meters of soil.

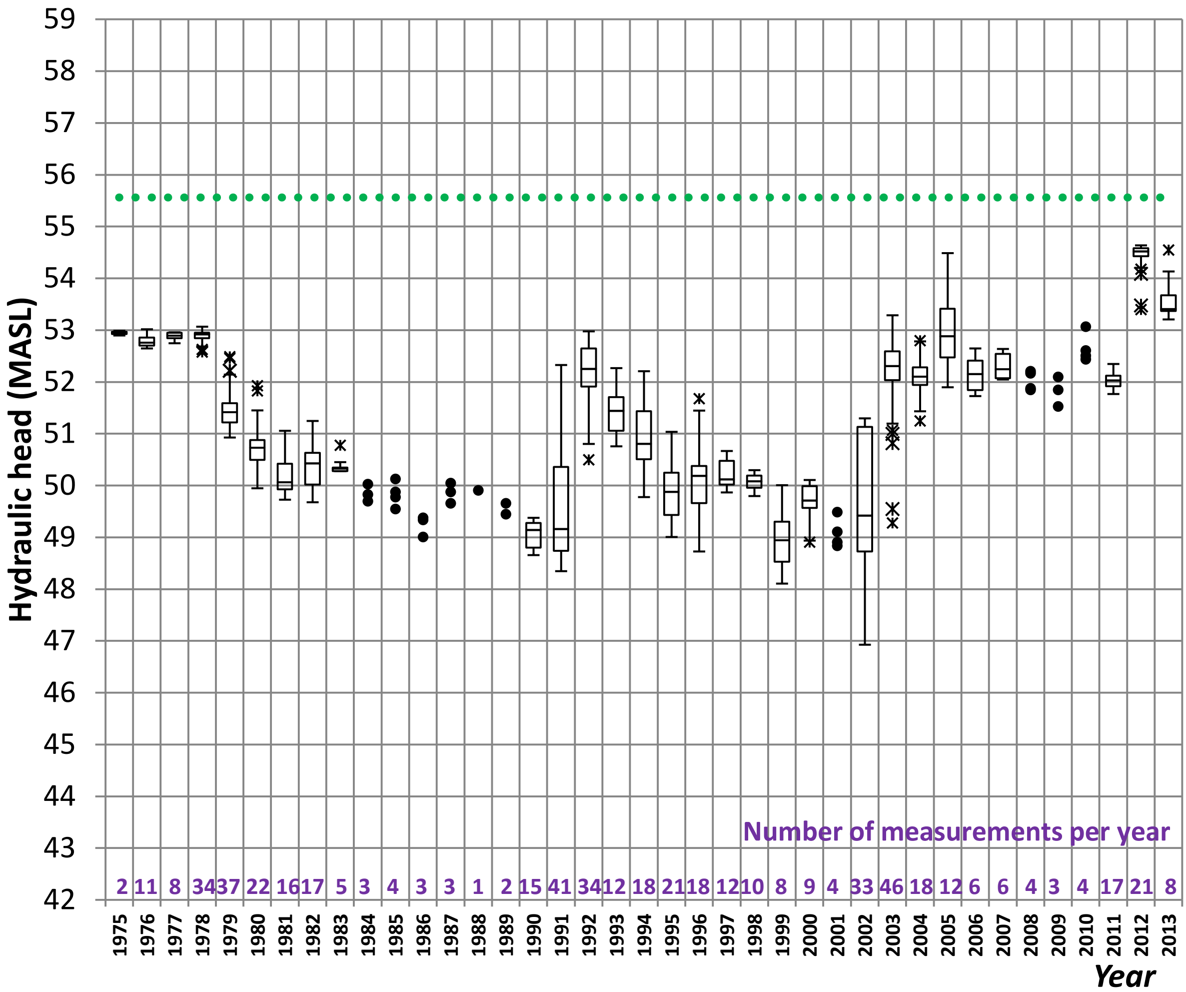

Figure 17:, The box plot above shows the variation of hydraulic head from 1975 to 2013 in Majorstua, measured from one piezometer. The plot shows an annual declining trend until 1991, when the first infiltration wells were installed. From 1992 to 2003 there is a new annual declining trend. In 2003 new infiltration wells were installed, as a result of an accident in 2002. From 2003 the hydraulic head has been significant higher. There is also large variation within certain years such as 1991 and 2002.

6.3 Foundations

About 1200 buildings at the test area in Majorstuan were investigated and mapped with information regarding the geology that the foundations rests upon, the type or material and the depth of the foundations. Further details that are digitalized include address, coordinates, building year, terrain height, type of soil and historical data about groundwater level and damages due to settlements. All the data is organized and mapped with a GNR/BNR number, which is a unique numbering system for all the buildings in the Norwegian cadaster.

The information comes from the Agency for Planning and Building Services, *"building matter archive".* The archive is not digitalized and the extraction of any information is time consuming, especially for older buildings, where the information is of lower quality and at worst unreadable. For nearly 7% of the total buildings investigated sufficient information could not be found, or the building file was lost. It is noteworthy that for most cases, especially older ones, the depth of the foundations is an approximation based on the information available in the building matter. Due to these circumstances, the information should be used as an approximate and in order to get a general view.

Figure 18; Foundation types relative to the geology that the foundation rests upon in the test area of Majorstuen.

7 Challenges during the project period

7.1 How to get our message through to the real decision makers?

The key words here are communication and education. It is essential to communicate facts and figures that are easily understandable. And the communication that has the most effect is through media with high credibility.

Whilst writing this underground issues have had quite a lot of attention in Norwegian media. The debate is held on two levels, difficulties and dangers due to the lack of control of new energy well and the settling rate at Bjørvika in central Oslo.

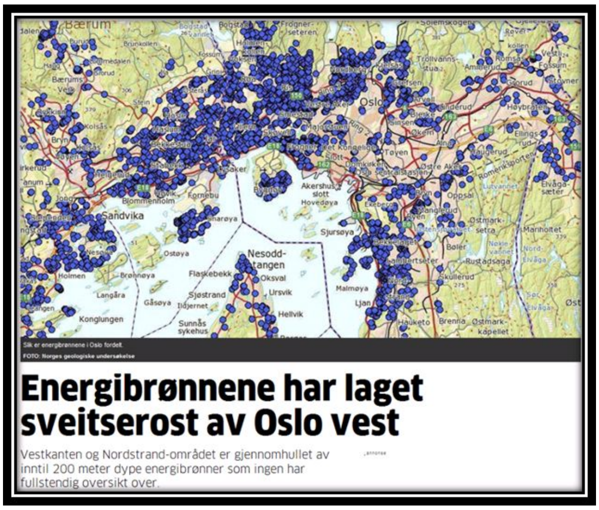

Figure 19: A major media discussion about settling, local geology, and geotechnical competences within the municipality is currently (May 2014) taking place in Norway's most important technical magazine; Tekniskt Ukeblad. A debate has also started in Norway's largest and most important paper, Aftenposten. There have also been several articles on the uncontrolled drilling of energy wells.*7.2 Data security issues*

Being a capital, Oslo holds underground infrastructure of national security level. How to handle this is a challenge for us. Questions that needed to be answered during the project period are:

- *How do we visualize enough information about the sub-surface without adventuring national security?*
- *What happens when we visualize a lot of different infrastructure in a 3D model, and does information about infrastructure that has a low classification move up a security step when it is put together?*

7.2 Access to Subsurface infrastructure data

It is proven to be difficult to access subsurface infrastructure data. Benefits from sharing data need to be communicated and security demands need to be fulfilled in order to motivate private data owners to share their data.

7.3 Geotechnical expertise within the municipality

Downscaling in combination with the difficulty of finding replacements for employees with geotechnical expertise who retired or went on to new jobs, have led to a lack of employees with relevant geotechnical competence within the municipality.

7.4 Quality of present geological maps

Present quaternary geological maps are out of date and need to be updated.

7.5 Accessibility of geotechnical data

There is a lot of geotechnical and geological data available in Pdf or paper reports. If this information could be digitized and modeled, the information that it contains could be communicated in an efficient way, leading to better informed decision makers and ultimately decisions including information about the sub-surface.

7.6 3D planning

For the use and the possibility to create 3D plans, there are both technical and communicational issues to be solved. The current approach is that we will do this step by step.

8 Sources

Commmunication with the following municipal agencies at the municipality of Oslo:

Agency for Planning and Building Services

Cultural Heritage Management Office

Agency for Urban Environment

Agency for Real Estate and Urban Renewal

Agency for Water and Sewerage Works

Communication with Mona Trøtscher, Geomatikk AS

Communication with Inger Lise Solberg, NGU, project manager NADAG

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http://intranett.ktpas.no/ikbViewer/page/inter/prosjekter/artikkel?p_document_id=2429991 http://www.vann-og-avlopsetaten.oslo.kommune.no/aktuelt/prosjekter/midgardsormen/article225226-54556.html

http://www.ngu.no/no/hm/Georessurser/Grunnvann/Grunnvannsdatabasen/

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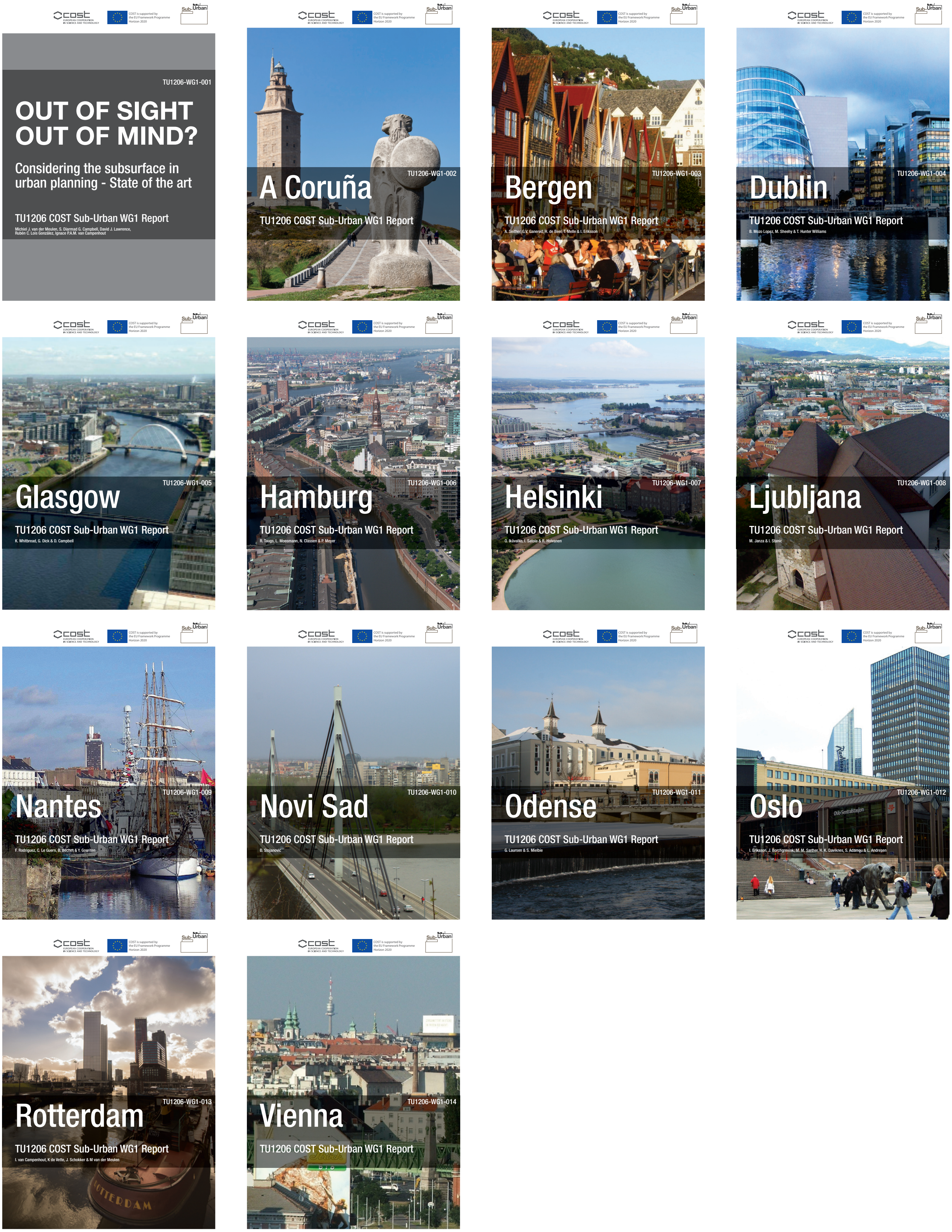

www.sub-urban.eu

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