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Sub-Urban

TU1206-WG1-011

Odense

TU1206 COST Sub-Urban WG1 Report

G. Laursen & S. Mielby

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COST TU1206 Sub-Urban Report
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Content

1 Introduction

The City of Odense is under big pressure – from above: because annual mean precipitation has increased by around 100 mm since measurements started 140 years ago. In addition, extreme rainfall events are occurring more often and are becoming more intense. There is also pressure from surface water: because of flooding due to extreme runoff in the rivers through the city or flooding from the Odense Fjord. Sometimes both types of flooding occur at the same time. Thirdly, there is pressure from the subsurface: due to a rise in groundwater level caused by increased recharge, diminishing needs for potable water / lesser water abstraction and the sealing of previous leaky sewers which hereby stop acting as drains.

During the last 100 years the area of the city has grown greatly. The water supply was primarily based on local groundwater abstraction sites. Today, it is still based on groundwater, but most of the groundwater abstractions within the urbanized areas have been stopped and the total amount of abstracted groundwater has been reduced by 50%. Furthermore, the majority of our potable water is being abstracted in the surrounding municipalities. As an effect of these changes the groundwater level within the city limits has risen dramatically over the past 25 years. In some areas the water table has risen 12 meters. Today the water level in some areas is close to the water level that was given at the turn of the last century (early 1900s).

The areas that are drained and urbanized are becoming increasingly waterlogged again. This is a major concern for the inhabitants and constitutes a major conflict of interest. In addition, the development in urbanization also causes other challenges. The natural seepage of rain into the ground is drastically reduced due to the increase of the total area of impermeable surfaces.

Historically, sewage pipes were established as common sewage systems for both rain run-off and raw sewage. Expanding sewage pipe systems to accommodate future heavy rainfall events/climate change is very expensive and sometimes an almost impossible task, but we try. Within the city limit we have used more than 1 billion Euro establishing large diameter sewage pipes for delaying or storing storm water during extreme rains, in order to meet the EU-legislation by hindering/decreasing the amount of sewage water that, though "overruns", is led untreated into the Odense Å and Odense Fjord (Å means river and Fjord means Inlet).

Instead of building larger storage pipes/pools there is a growing interest in securing local infiltration. The need for artificially/naturally enhanced infiltration of rainwater in urban areas is growing. This, again, is putting further strain on the water level and saturation beneath the city. New large-scale suburban infrastructure projects like tunnels and underground parking facilities also put further strain on the groundwater saturation challenge and may alter the nature of groundwater flow patterns, etc.

In order to meet the above mentioned growing demands, the Municipality of Odense together with VCS Denmark (one of the biggest water/waste water companies in Denmark), GEUS (The Geological Survey of Denmark and Greenland) and The Region of Southern Denmark have started building a detailed 3D geological and hydrogeological model. The purpose of this model is to study the groundwater resources, the climate change impact on the water cycle and to cover subjects of archaeological and historical interests.

2 City description

2.1 Size and population

Denmark is a small country that covers 43100 km^2 which is less than 10% of the area of Sweden. Denmark consists of the peninsula of Jylland (Jutland), and an archipelago of 406 islands of which 78 are inhabited.

The coastline stretches more than 7300 km in total length. The land includes mainly areas used for agriculture (67%) and forests (12%) and semi-natural areas (11%), and also urban areas and infrastructure installations (10%).

The Kingdom of Denmark also includes the Faeroe Island and Greenland. Denmark has a population of 5.6 million inhabitants and the population density is 130 persons per km^2. 85% of the population lives in cities and villages with more than 200 inhabitants and 15% live in the countryside and smaller villages. One third of the population lives in Greater Copenhagen.

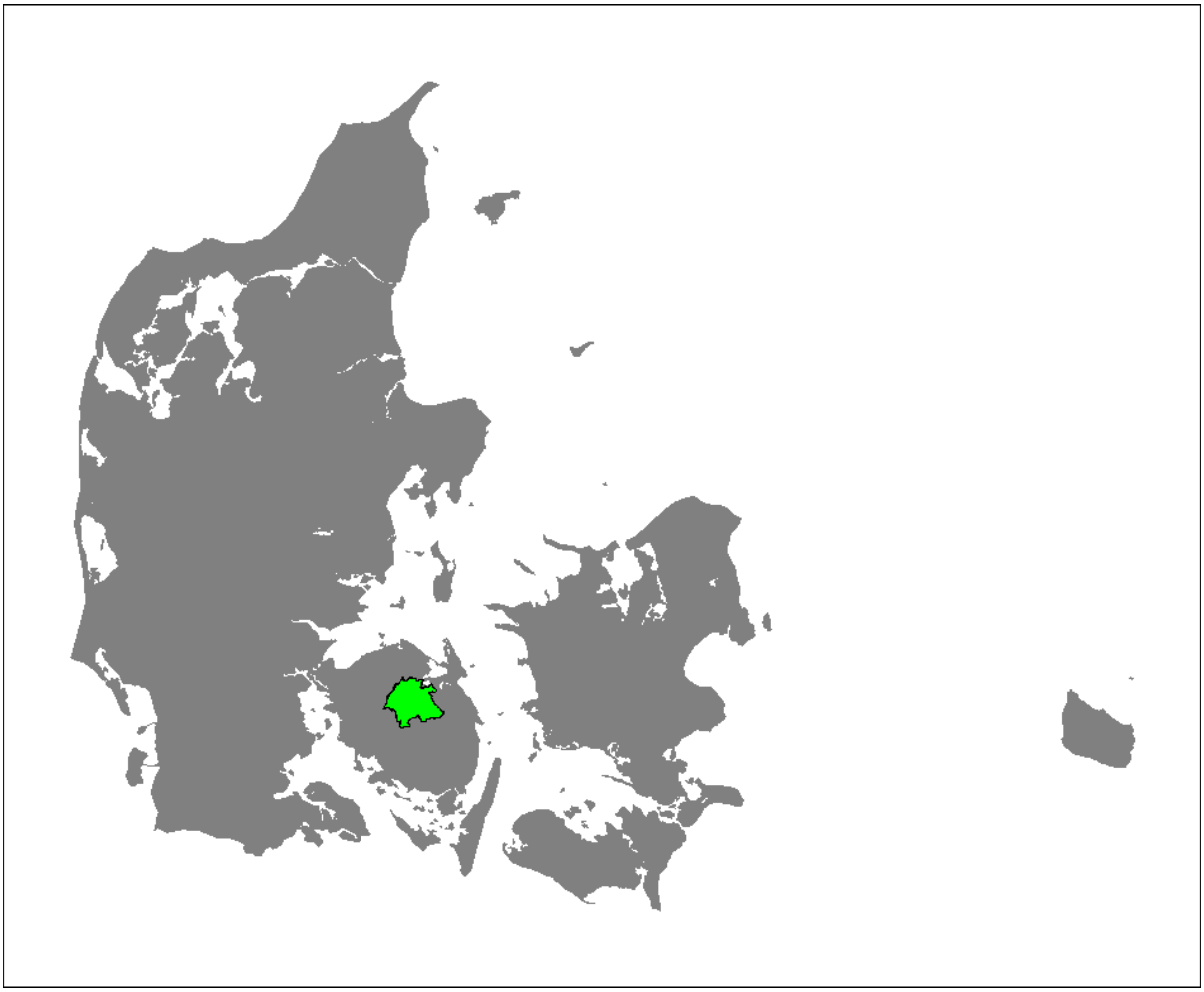

Figure 1. Denmark - with the Municipality of Odense in the middle

The Municipality of Odense covers an area of only 305 km^2. This place it in the central part of the 98 Danish municipalities –The municipality of Copenhagen – the Capital of Denmark – only covers 88 km^2, which is roughly the same area as the City of Odense (Figure 2).

The City of Odense is one of the oldest in Denmark, dating back to the Vikings and their ring fort "Nonnebakken" south of the Odense Å. Archaeological excavations have uncovered pavements, buildings and crafts dating back to the first millennium and the first time Odense is mentioned in a written reference is in the year 988. The oldest parts of St. Alban's Priory and The Cathedral for Canute the Saint are dating back to the 11th century. During the 12th century the building of another church, several monasteries and nunneries and a moat testifies strong urban growth.

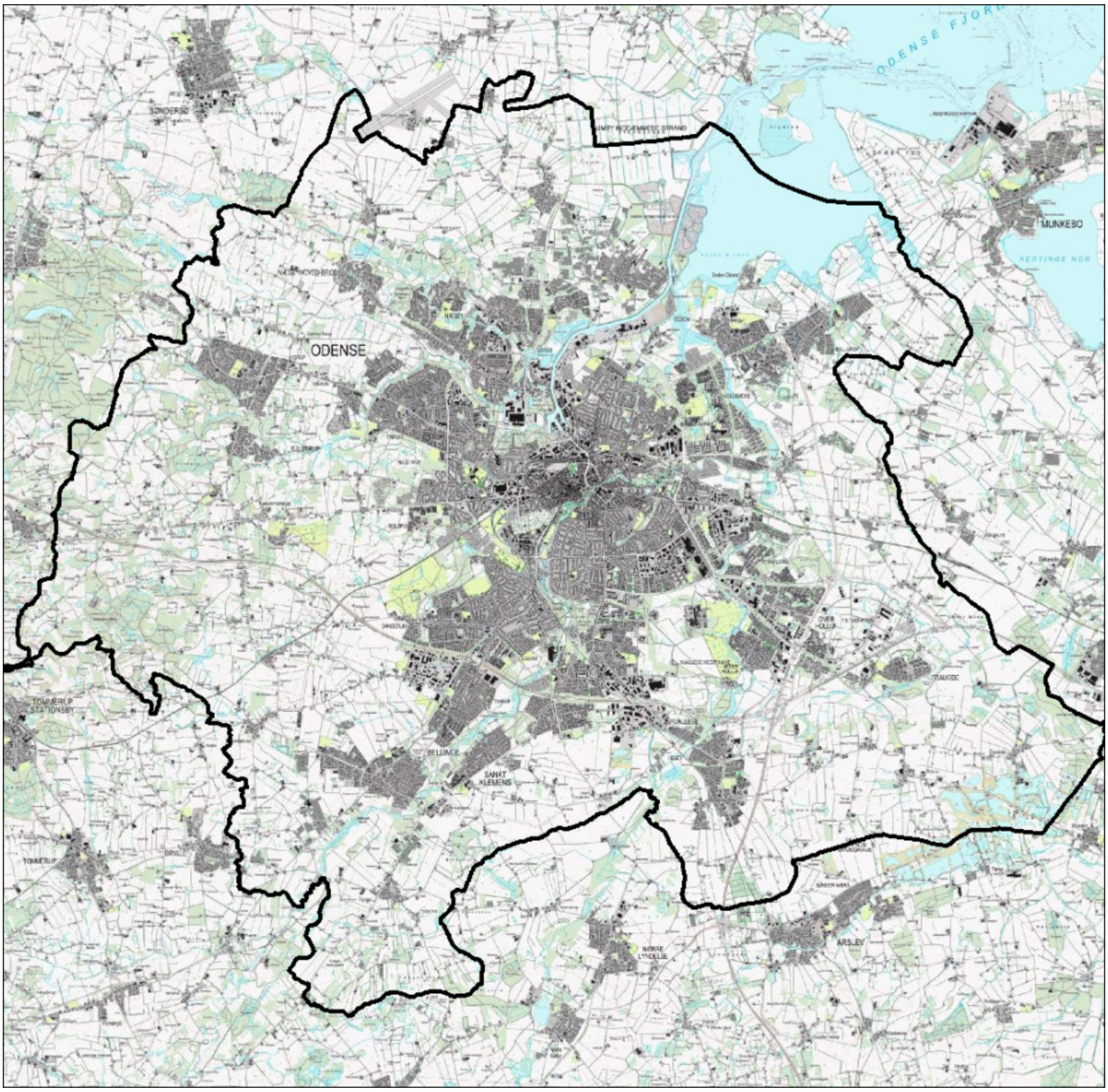

Figure 2. Municipality of Odense and the Odense Fjord (Copyright: KMS).

During the later centuries the construction work has intensified with all sorts of buildings including a town hall, and the city limit is defined by The City Stream (today defined by the streets: Skt. Anne Plads – Slotsgade – Gravene – Hans Jensen's Stræde – HCA Hotel – Pjentedamsgade) and the Odense Å. During the 14th century the city limit moved to Pantheonsgade and north to Østre Stationsvej, an extension which roughly defined the size of medieval Odense (Figure 3).

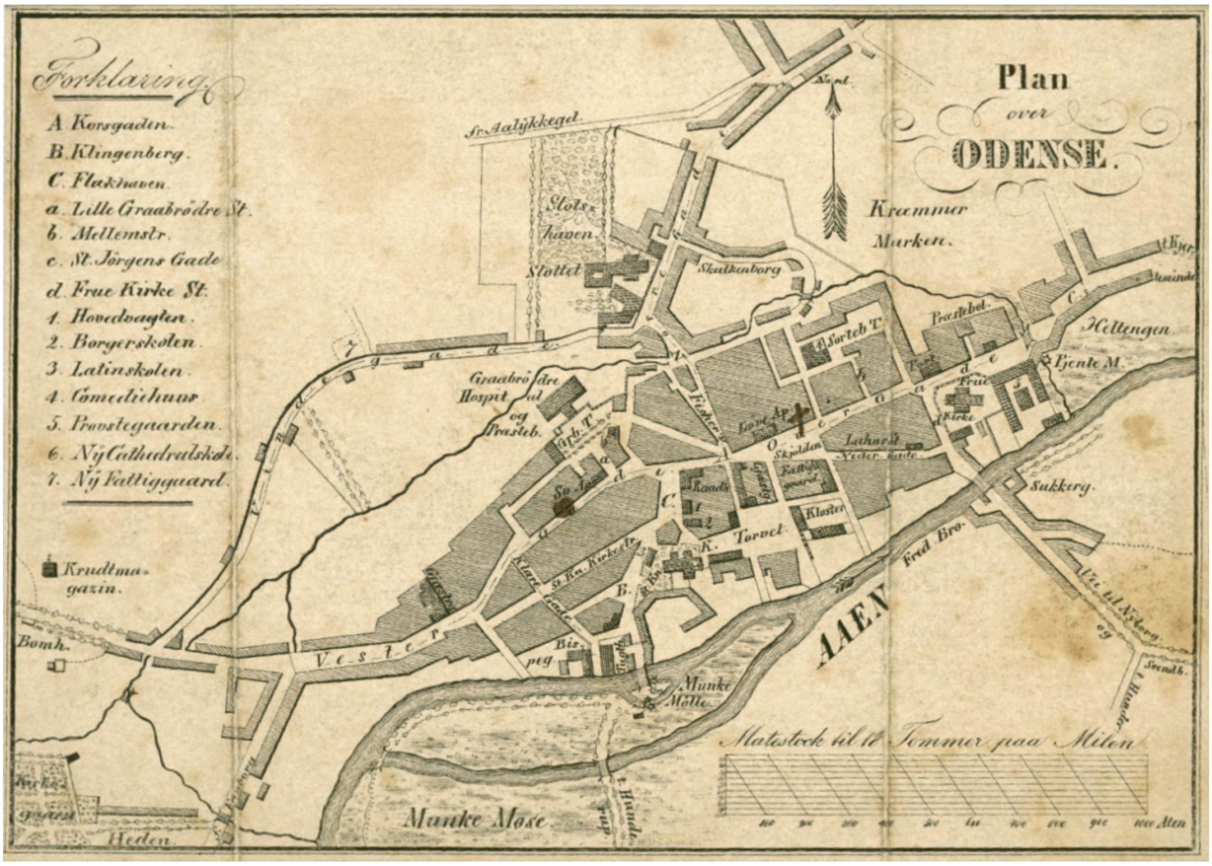

Figure 3. The City of Odense anno 1839 (Copyright: Det Historiske Hus).

The streets running east-west are thought to be as old as the city itself. The streets “Vestergade” and “Overgade” are mentioned in written references in 1285 and 1433, respectively. Until the big Thomas B. Thriges-street breakthrough (discussed later) in the 1960s, the streets in the central part of Odense all had a very medieval touch.

Since the founding of the city, Odense has been one of the leading cities in Denmark, and until the end of the 18th century it was the second largest city in Denmark, only surpassed by our Capital, the city of Copenhagen. In the year 1805 our famous poet and story teller Hans Christian Andersen was born in Odense, and at that time there were about 6000 inhabitants in the city. Half of them belonged to the poorest and 10% of them was homeless with no home at all.

The City of Odense has developed from a small borough of 11000 people, covering only 2.5 km^2 in the 1850s to more than 172512 inhabitants today (1st of January, 2014), covering an area of 78 km^2.

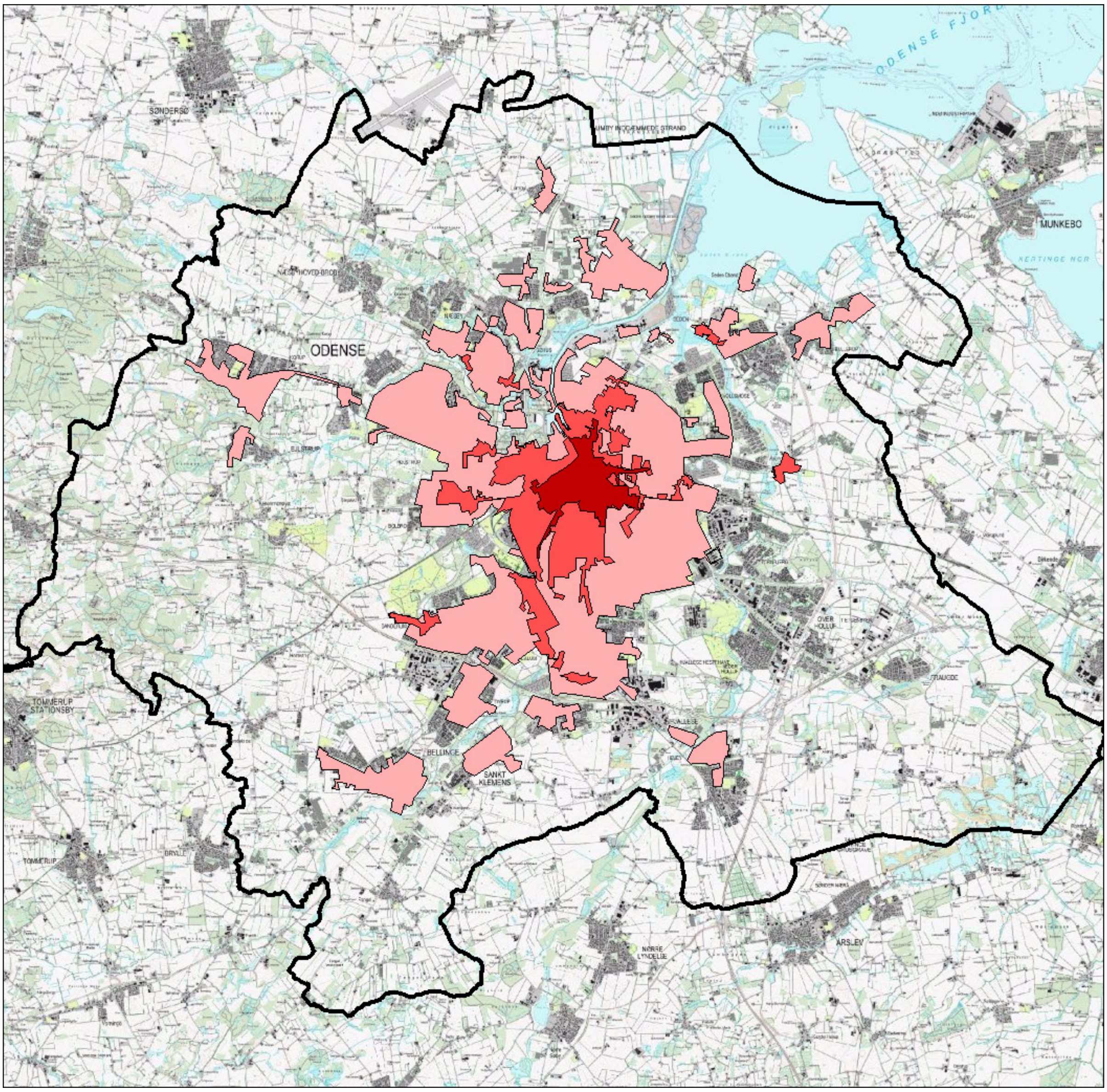

Figure 4. City growth within the Municipality of Odense (Copyright: KMS). Dark red - anno 1892, red - 1928, pink - 1977 and the city of today - dark grey.

Figure 4 shows the size of the city at different times during the last 125 years. Especially during the Industrialization in the middle part of the 20th century the city limit changed dramatically and extended in all directions. The documented growth (taken from old city maps) of the City of Odense from the 18th century until today is presented in Figure 5.

From around 1830 untill today (more or less) we can observe an exponential growth of 3.2% per year. This means that the size of the city doubles every 22 years, also meaning that if this growth rate would continue the City of Odense would no longer fit into the municipality of Odense by the year 2045.

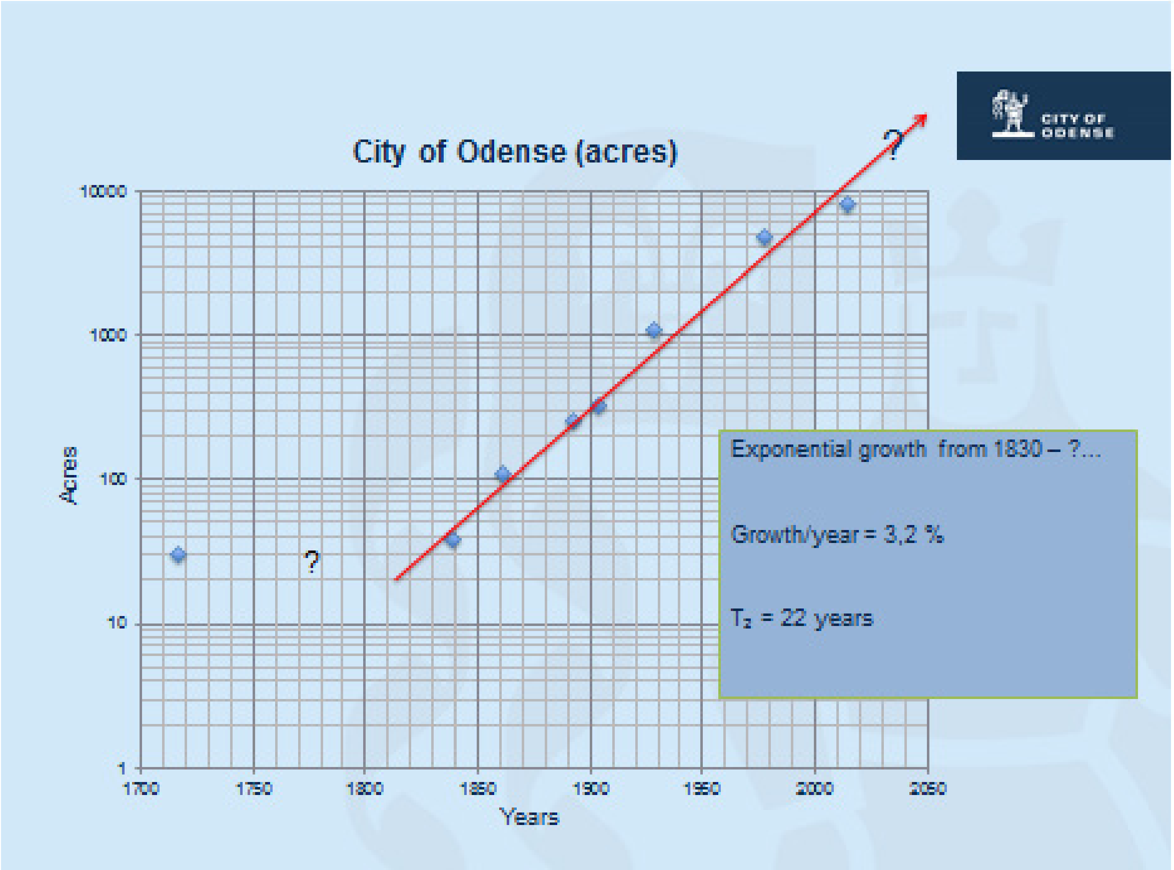

Figure 5. Exponential city growth of Odense.

2.2 Density and land use intensity

Having experienced an intensified growth of population between 1.5 and 3% per year during the 19th century and the first half of the 20th century, the growth has later diminished or even stopped (in some years it was even negative) (Figure 5).

From the 2nd half of the 21st century the population growth has resumed with an average of 0.5 – 1% per year, in some years above 4% corresponding to a doubling in population within 17-18 years. In 2010 we passed a population of 190000 and according to the "Statistics of Denmark" we can expect to pass 200000 inhabitants just before 2020 and 210000 in the beginning of the year 2030.

Figure 6 shows the growth of the population in the City of Odense from the year 1672 until today.

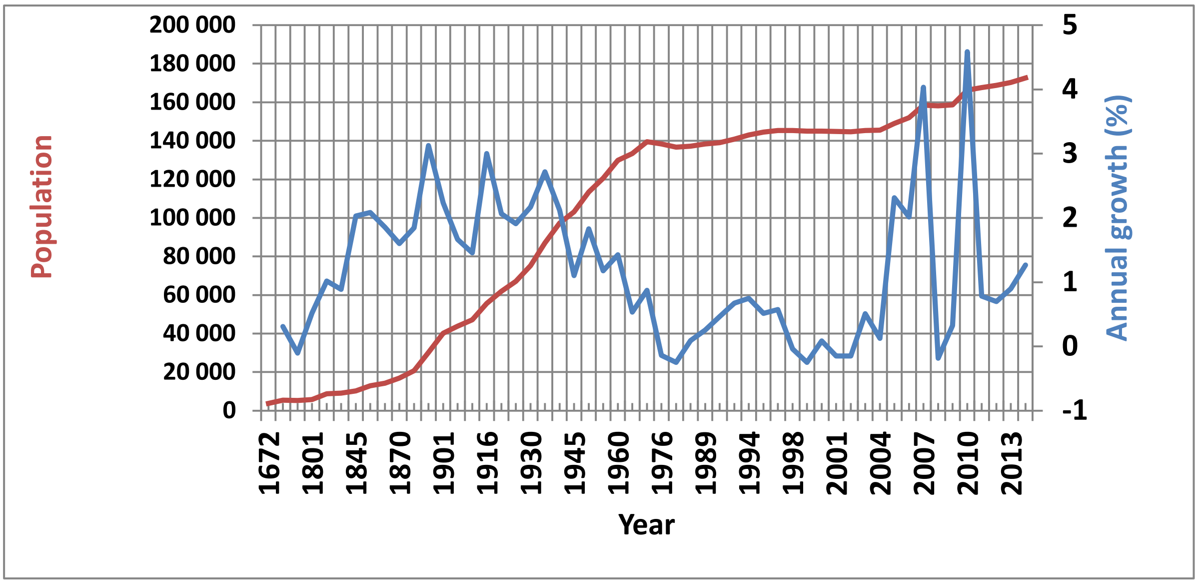

Figure 6. City-population growth from 1672 until today. Please notice the x-axis being non-linear.

As by 1st January 2014, 88% of the municipality population (195797) lives within the city limit of Odense, but 3/4 of these people live outside of the city centre – maybe this is the reason why Odense sometimes is called the "the city of residential neighbourhoods". Almost half of the inhabitants "own" their house/apartment.

Outside of the big city areas, the municipality of Odense also has a significant amount of arable land (50%) and forests (6-11% depending on the definitions). Natural areas (meadows, bogs, swamps and lakes) cover around 5% and quarrying areas (sand, gravel, clay, etc.) occupy around 1-2% (see Figure 7).

The municipality of Odense is poor in forested areas and we are intensively involved in afforestation and the restoration of wet lands.

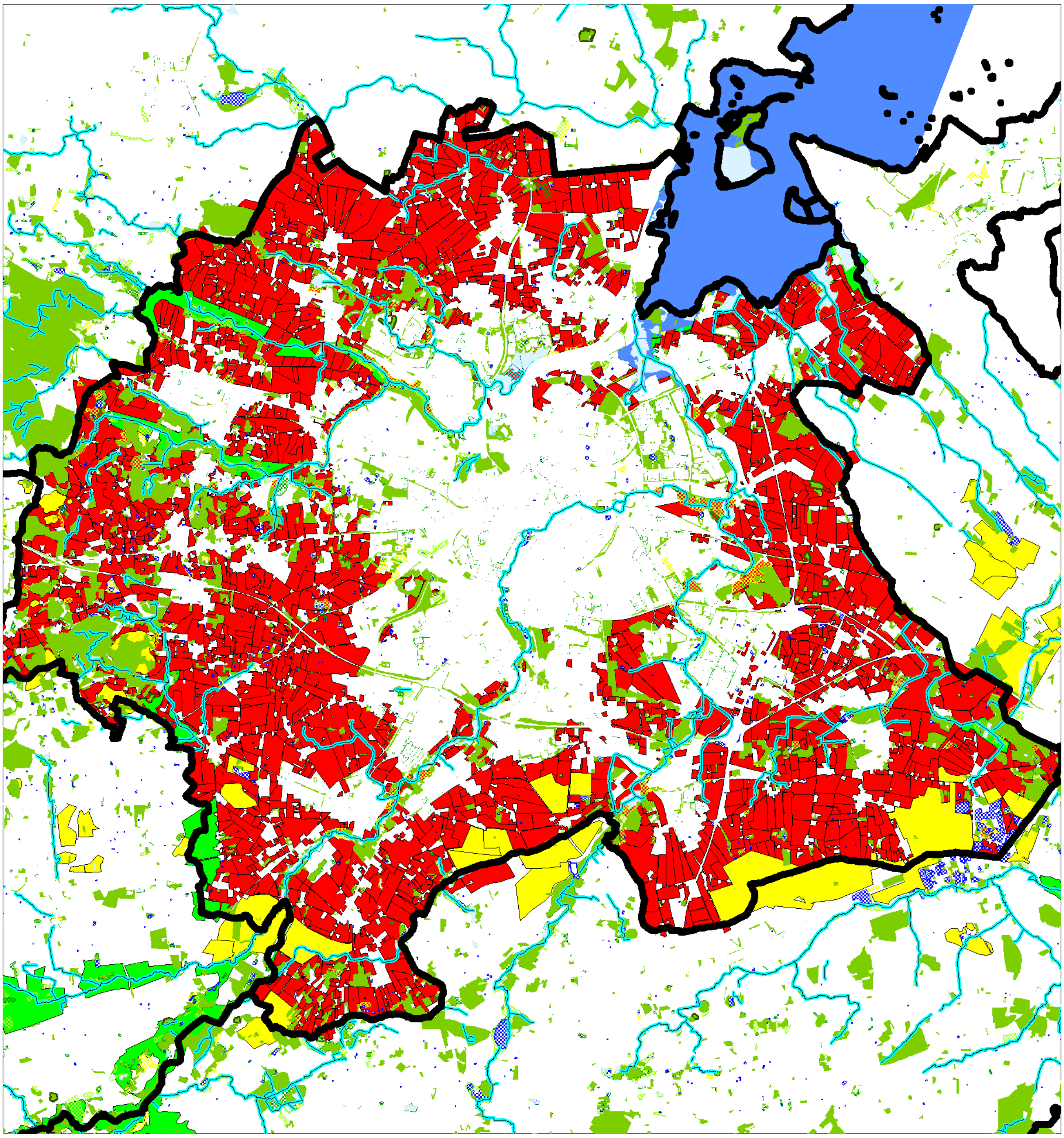

Figure 7. Land use in the Municipality of Odense (Copyright: KMS). Red – arable land, green – nature/forest, yellow – quarrying areas and blue – the Odense Fjord area.

2.3 Infrastructure

The infrastructure of Odense is influenced by “The Odense Canal” that connects the old harbour in the central part of the city with the Odense Fjord (inlet) area north of the city. The Canal is 5 km long and “man-made”, excavated with shovels and wheelbarrows between 1796 and 1806. Upon completion the Canal provided a passage for goods that could be loaded / unloaded from ships in the center of Odense leading to city growth and increasing prosperity. The Industrialization got another boost by the establishment of the railway in 1865 and the associated growth of city areas north, east and west of the city centre.

The 2nd industrialization from 1950 to 1970 led to the seizure of new industrial settlements outside the city and in the small neighbouring municipalities, most of them being a part of our municipality today. The university of Odense (today: The University of Southern Denmark) was established in 1965 and from 1975 to 1990 a new part of town (Odense South) was developed between the city centre and the highway. From 1990 until today new homes were built in the city centre and lots of townhouses and block of flats popped up in the suburbs.

In the year 2012 the City Council of Odense decided to develop a new Municipality Plan in order to ensure a sustainable urban development. One of the main goals is that 70% of all urban development shall happen inside of the current city limit through urban densification and renewal. This is also the reason why only a few urban growth areas are chosen to be situated in the suburbs.

The location of Odense in the middle of Funen has made the city a major traffic hub. The location also includes that all trains and road traffic until recently had to pass through the central parts of the city. The highway bypassing the city (the European Route E20) was finishedin August 1985. The bulk of traffic has used Thomas B. Thrigesgade, the main artery running north-south through the central parts of the city. The average traffic count was 25000 cars per day.

Decades of political discussions on how to diminish the traffic load have now stopped and “the big dig” in Odense has started this summer. This will be a transformation of Thomas B. Thrigesgade from four traffic lanes to a townscape with a tramway system, new buildings, city squares, streets and parks mainly for pedestrians, and 1-2 floors of underground parking garages for containing 700-800 cars.

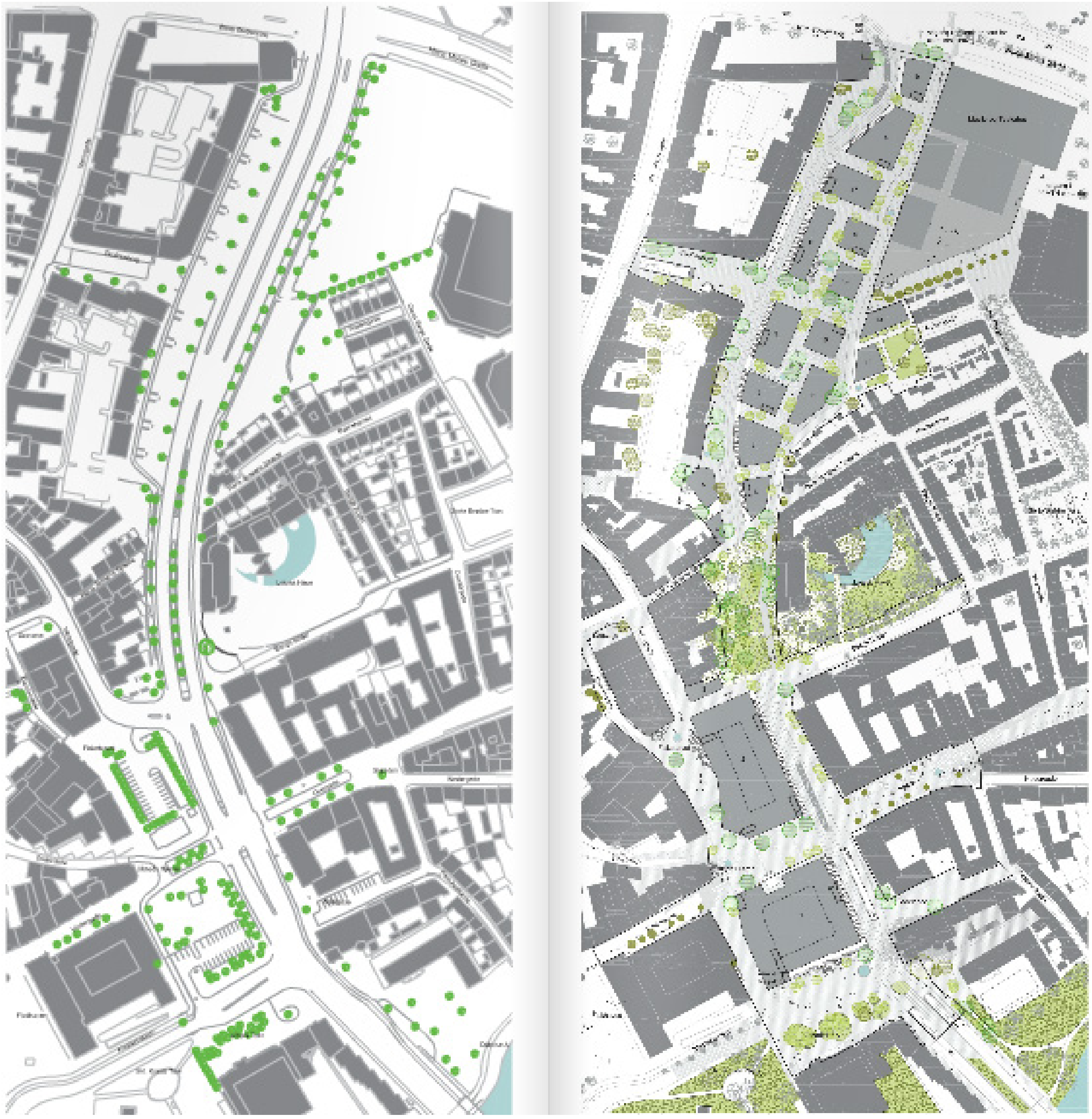

Figure 8. "The Big Dig in the city centre" Thomas B. Thriges Gade: today (left) and around the year 2020 (right).

In general the municipality of Odense continuously tries to develop more sustainable transport systems focusing on pedestrians, cyclists and passengers to public transport, and on the use of cars in a smarter way. Among other things, Odense for many years has been known as a city for cyclists - both nationally and internationally.

As already said Odense is a very flat (low) city - “the city of residential neighbourhoods”. The old parts of the city centre are typically characterized by 3-4 floors but the new plans, among other things, accept higher buildings on the harbour area and in the central part of the town. One of the goals of the city is to create a great big city centre to reinforce the impression of Odense of being a town transforming from a large city to a metropol.

In Odense exist approximately 114000 buildings of different kinds. Odense is one of the very few municipalities that have made a digital connection between the geographical location of a building and a Building/Residential database. By combining these data (GIS), we know that a little more than 60500 buildings are actual houses for living, production, storage, offices and buildings for sports and cultural purposes – 52100 are located within the city limit and the rest (8400) are situated in the rural areas. More than 1/3 (21600) of these buildings has a basement and 92% of these are situated within the city limit. In other words, Odense may be flat (seen from the surface) but it contains many subsurface areas, and why that's interesting, we'll come back to later.

In addition to the above-mentioned basements, other examples of suburban infrastructure or suburban impact beneath/within the city of Odense are:

- Sewers: More than 2100 km of all sorts of pipes, from very small up to 300 centimetres in diameter, and 1700 pumping stations.
- District heating/(cooling in the near future?): Fyn Power Station supply central heating to more than 85000 households, and about 7000 companies and institutions distributed through a network of more than 2000 km of pipelines.
- Communication: All sorts of electric wires and optical fibers.
- Garbage: Underground waste collection systems.
- Natural gas: All sorts of pipe sizes for transmission of natural gas from the North Sea and distribution to end users. Diameters from 2 to 90 centimetres.
- Wells and pipes for potable water: Our 13 waterworks have around 100 active abstraction wells and within the municipality we furthermore have 233 individual household wells/dug wells and 195 wells for all sorts of industrial purposes. Probably near to 1500 km of water pipelines.
- Wells/boreholes: More than 3200 investigation wells made for other purposes – geotechnical, (hydro) geological, archaeological, lowering of groundwater, etc. Average and maximum depths respectively are around 18 m and 200 m
- Ground source heating/cooling system: Until today we only have 210 horizontal installations (closed loop systems), but we are planning for a big Aquifer Thermal Energy Storage (ATES) installation in the central part of the city and hope there will be more in the near future.
- Underground storage tanks: Around 600. The majority are between 6000-100.000 l and are being used for the storage of oil or gas
- Underground artificial structures: Parking lots, waste water and storm water basins of all sorts and sizes (see Figures 9 and 10).

Figure 9. Inauguration of a new storm water basin (3500 m^3).

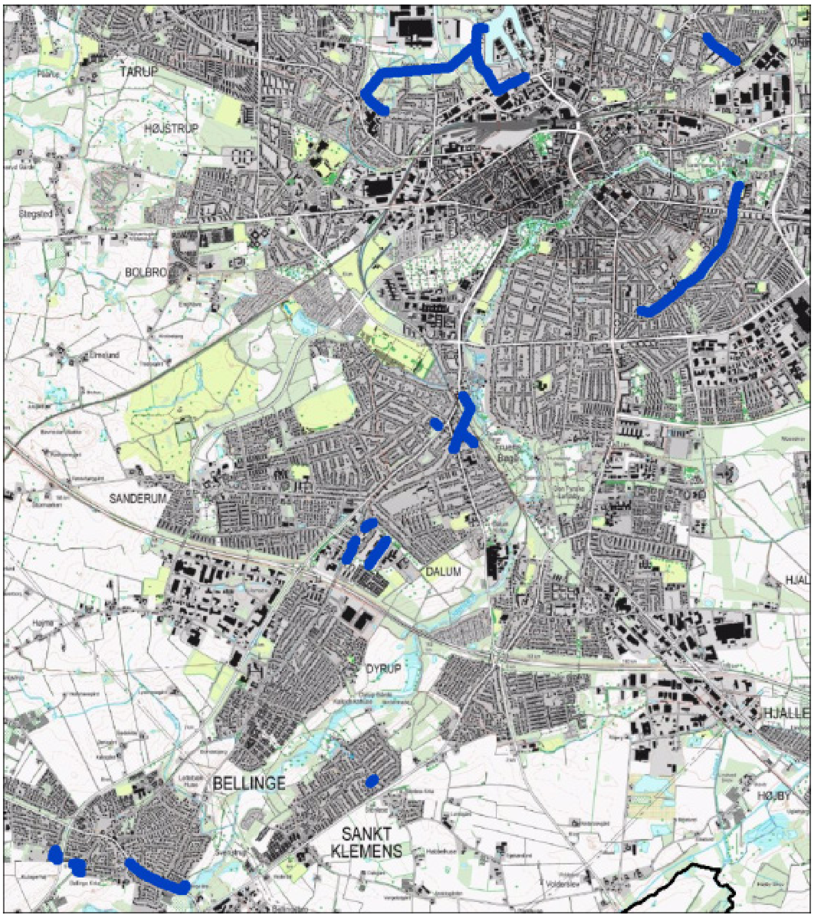

Figure 10. Location of the large-diameter "Basin Pipes" for the storage/delaying of storm water (Copyright: KMS).

- Drains and gabions: For the extraction or infiltration of surface or rain water.
- Quarrying areas: Lots of old abandoned gravel deposits within the city limit of today are refilled with all sorts of garbage and waste materials and in most cases with green areas, city parks or houses on top.
- Contaminated sites: "The sins of the past" also include present and past industrial sites with possible polluting activities placed all over the municipality which have led to pollution of more than 1100 sites and in many cases also to pollution of the groundwater below or the indoor climate above (see Figure 11 as an example).

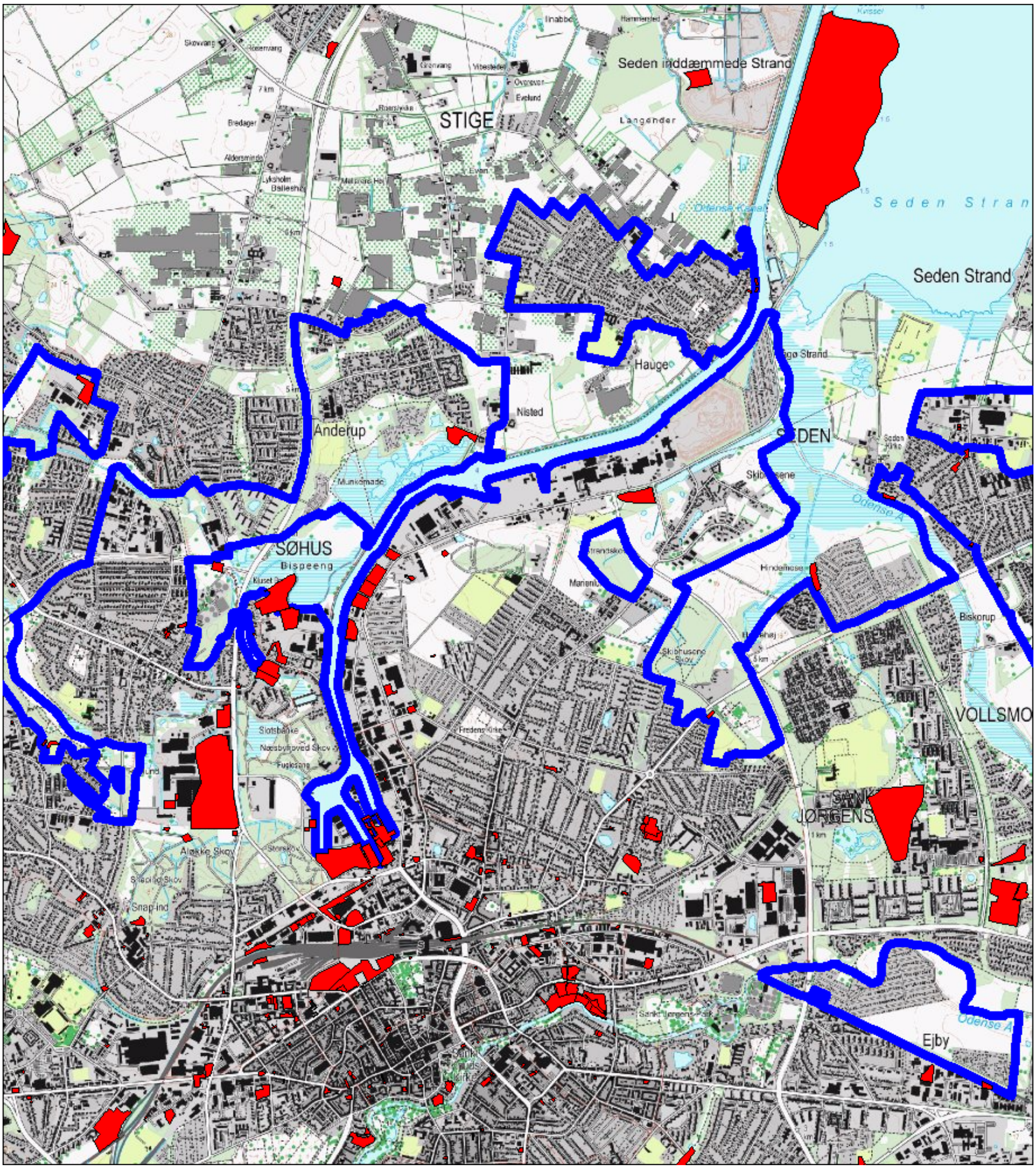

Figure 11. Examples of contaminated sites (red) in the centre and in the harbour areas (Copyright: KMS).

Of special interest in this infrastructure context is the history of the waterworks. There were three times more water works as we can see today (see Figure 12). Most of the water works were built during the period from 1920 until the early 1970s. Historically, many of the water works in Denmark are privately operated on a cooperative basis with voluntary management. The general increase in complexity due to legislation, service and due to public demand has caused that many of these voluntary cooperatives had to give up. The larger and municipality-owned water companies have taken over the facilities/network. Many of the small production facilities were deemed unprofitable and have been closed and dismantled. There is a national trend of general consolidation in the business so that these small water works will grow even scarcer in the future.

By today most of these earlier water works in Odense have disappeared. Some of them due to pollution, gravel quarrying and other activities, when the need for large refurbishment or maintenance constituted a great increase in water price.

It is important to notice that not a single one of these water works were built inside of the city limit, when they started. They were all established in rural areas outside the city of Odense.

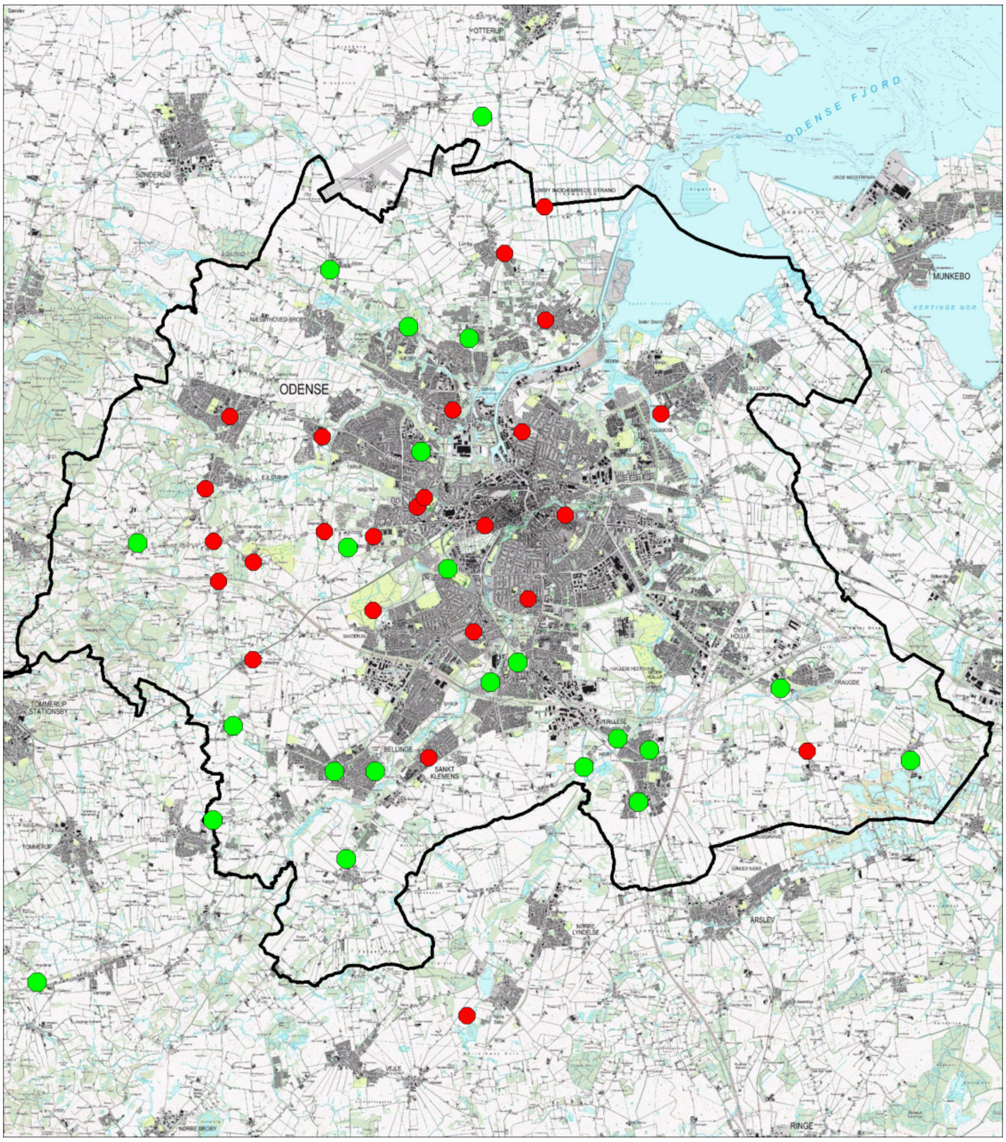

Figure 12. Water works or well fields: Green spots indicate the active ones and red the abandoned (Copyright: KMS).

3 Geological and physical geographical setting

The landscape of Denmark has been created by glacial deposits of tills, sand and gravel from at least three different ice ages. Tills from all three ice ages are present on Funen. The thickness of glacial deposits on Funen reaches from 10 to 150 meters. Beneath the glacial deposits are pre-quaternary deposits of Caenozoic age. The upper 300 meters consists of clays, marl, limestone and chalk. Faulting and folding of these strata affects the major terrain-forms weakly.

The hydro-geological model of Funen mirrors this above-mentioned stratigraphic evolution, with three levels of glacial sand-aquifers separated by thick till-deposits. The lower sand-aquifer is more scarcely distributed than the middle and top aquifers, due to erosion and tectonic activity by the two younger glaciations.

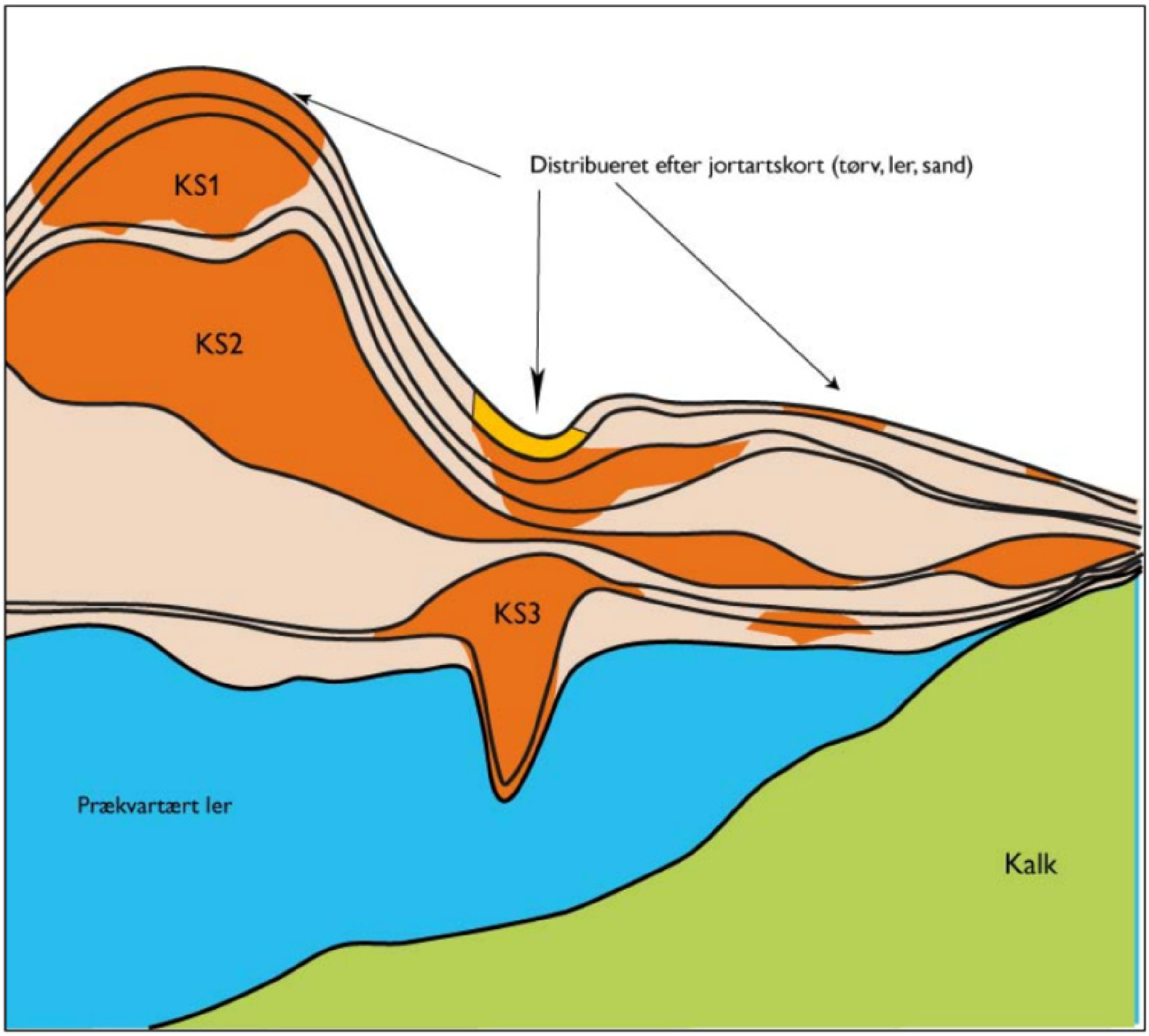

Figure 13. Simplified diagram showing the hydro stratigraphic units in the Funen-model. GEUS (2010).

Beneath the glacial series are chalk and marl deposits of Palaeocene age, which form the lowermost groundwater aquifer in most of Fyn. In several places we find buried valleys, which were cut into the underlying deposits, sometimes as deep as the pre-quaternary deposits. These buried valleys are often filled with thick sand and gravel deposits, interbedded with tills.

The land surface is mainly sculptured by the latest glaciation. In the central part of Funen wide areas of hummocky terrain are created by deposits from till covered dead-ice, with a hilly appearance. In the southern and western parts of the municipality are several lateral moraines, with some of the most marked hills on Funen. Between these landscapes relatively flat moraine plains and melt water deposits, and minor areas with alluvial clay deposits from ice dammed lakes are found.

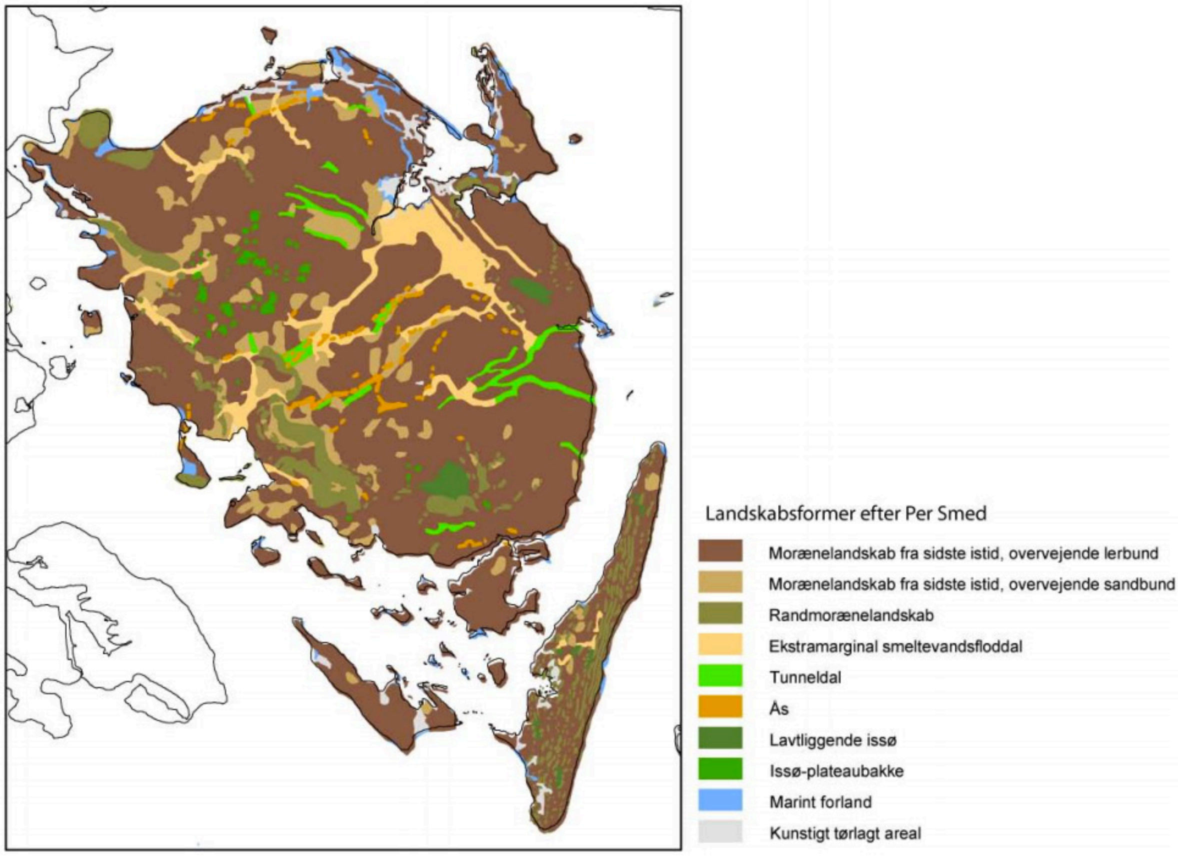

Figure 14. The landforms of today. Brown: Weichsel-moraines, Yellow: diluvial sediments. GEUS (2010).

In the Odense area the landscape is dominated by a moraine plain to the south and east, with some larger areas of alluvial deposits to the east. In the west there is a transition zone to a dead-ice landscape. In the north the Odense Fjord dominates.

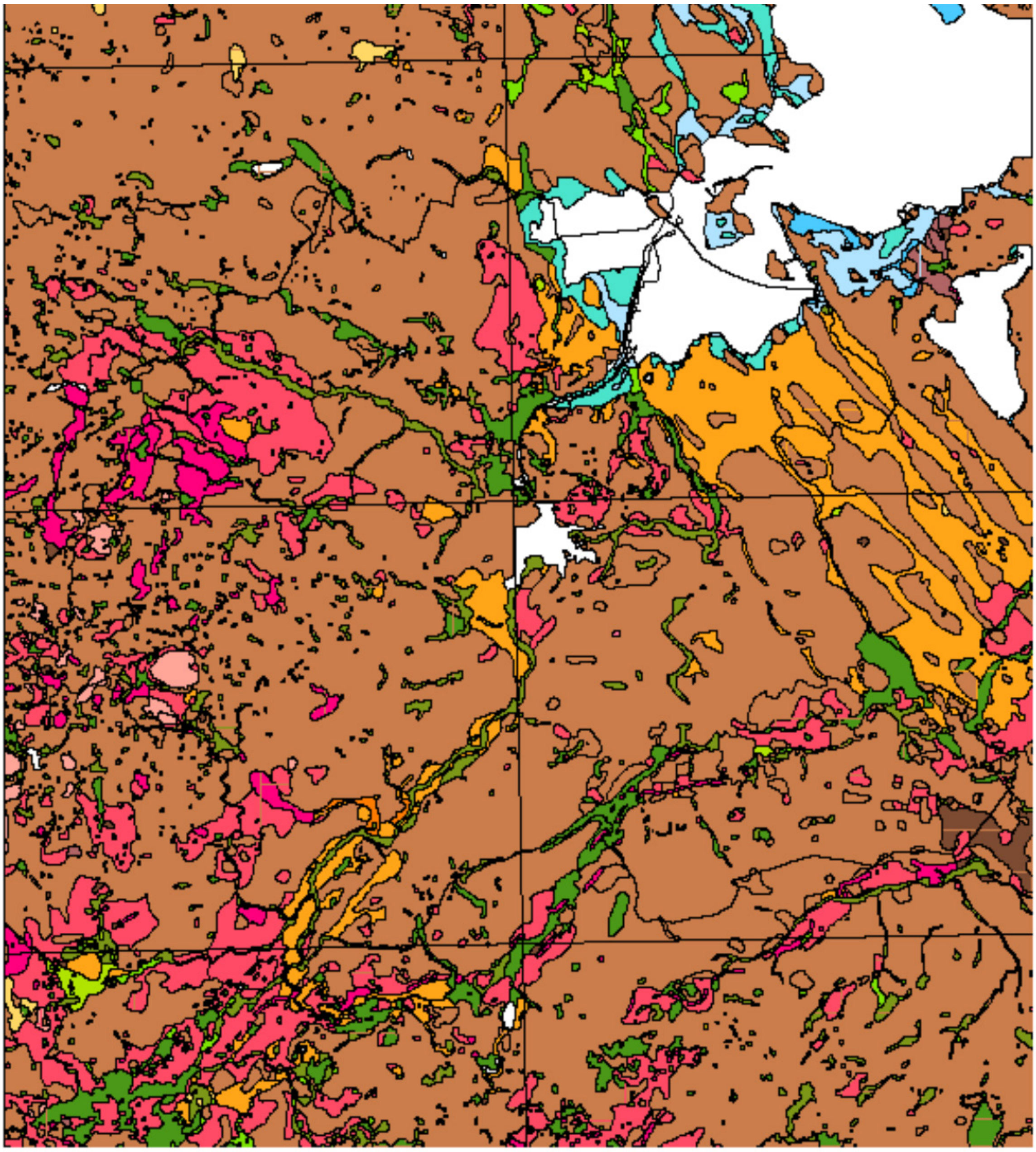

Figure 15. Surface geology: Till/boulder clays (brown), diluvial deposits (red/pink), Holocene fresh water deposits (green/yellow) and diked/drained areas (blue). Copyright: KMS/GEUS.

Through this landscape, the Odense Å (Å means river) and its tributaries (the rivers Lindved Å, Stavis Å, Ryds Å) have cut in more or less marked valleys. Especially the Odense river valley is very significant in places. In the urban area of Odense the river formed a marked valley through the central part of the city centre. Adjacent to the river valley are bogs, which have been drained and urbanized. The higher ground is made up of moraine plains with a complex geological composition consisting of embedded alluvial deposits and tills. Organic-rich deposits from paleo-bogs can be found, especially along the river valleys. The difference in elevation between the valley-floor and the higher grounds is not more than 10-20 meters (see Figure 16).

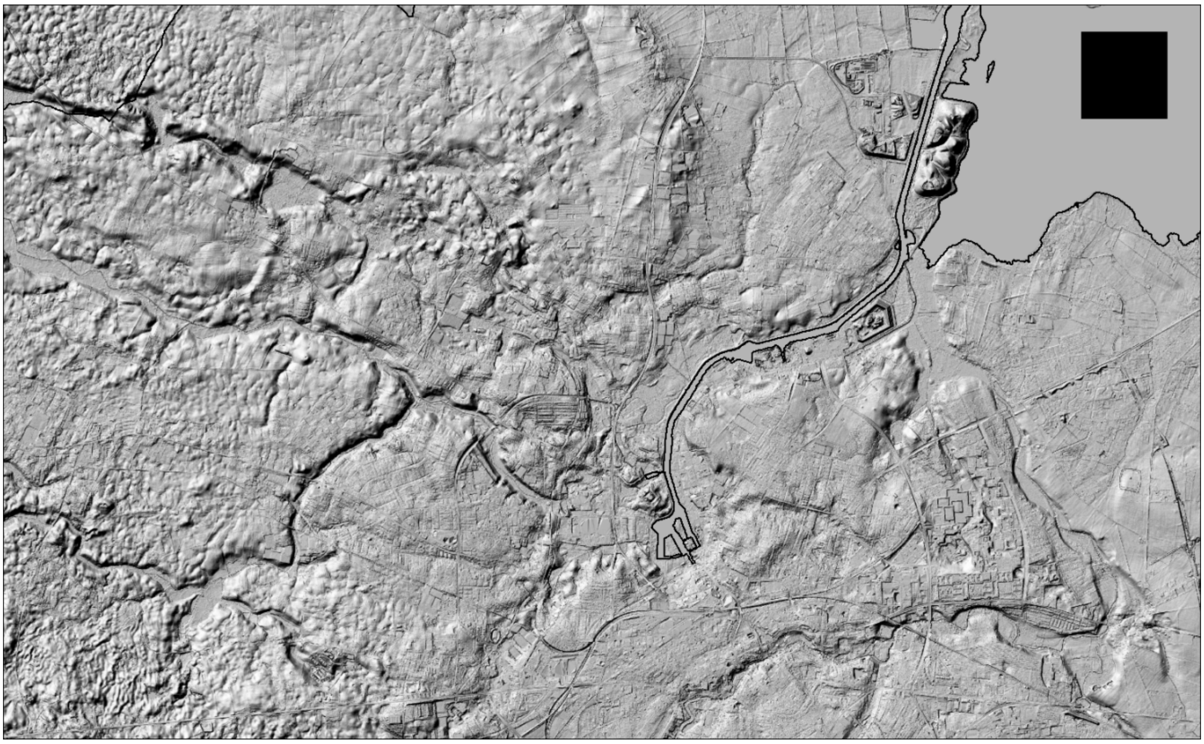

Figure 16. Hill shade map showing the topography of the northern part of the municipality (Copyright: KMS).

To the north, larger parts of Odense city are situated around 1-10 meter above sea level (see Figure 16). To the south the terrain rises generally to about 20-25 meter above sea level. The northern part around the harbour and the inner parts of the Odense Fjord area are therefore vulnerable to sea-level rise, both as short-term events during storm floodings, and as long-term event due to climate changes.

The last glaciation (The Weichselian) ended some 11500 years ago when the thick ice sheet melted and Denmark was characterized by an isostatic uplift (a process that is still going on) causing the surface to rise between 0.3 and 2.0 mm/year (with a minimum in the south and a maximum in the northern parts) (see Figure 17). The iso-curve running through the Odense area is showing an uplift of around 1 mm/year. This cannot cope with or eliminate the observed sea-level rise of around 2 mm/year (1971-2010) but maybe it can alleviate the negative effects for many years to come.

The small relief of the urban landscape leads to vulnerability due to flooding during rain storms and melting of snow in late winter or during spring time. The city of Odense therefore also has an important challenge in handling the growing amount of surface water that has occurred in the latest decade and may occur to an even larger extent in the future.

Generally seen, the subsurface of Odense is geotechnical stable. However, deposits rich in organic material may cause problems, if they are de-watered during or after construction work. In some parts of the city centre the foundation of older buildings probably consists of wooden piles, which tend to decompose if the groundwater table is lowered too much for longer periods of time.

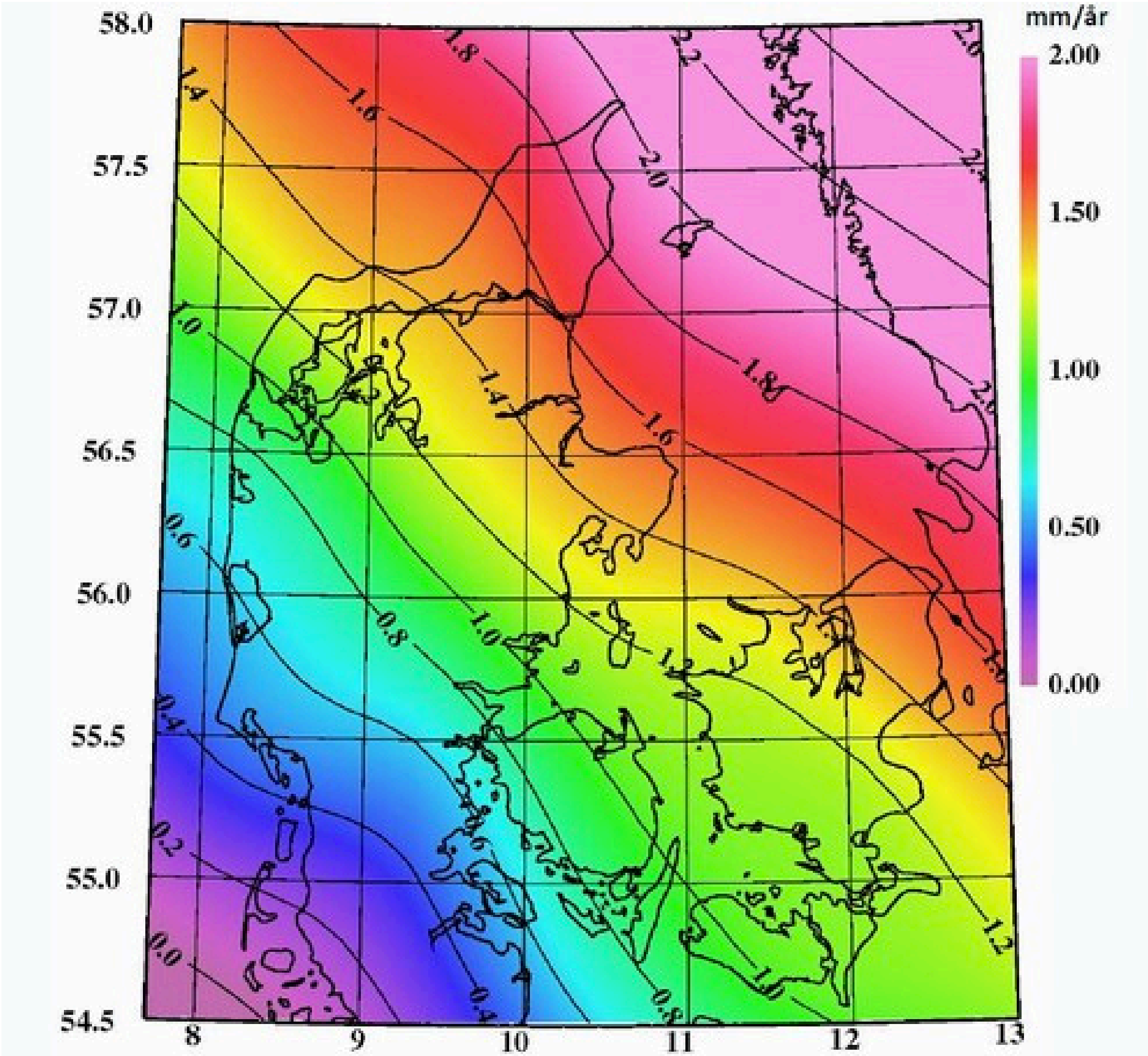

Figure 17. Absolut rates for uplift in Denmark (Copyright: The Danish Coastal Authority).

Besides the basic uplift shown in Figure 17, we can see local examples of more uplift or extreme subsidence of up to 10 mm/year. The origin of such strong subsidence can be related to the underlying geology – e.g. the consolidation of sediments or the underground being geotechnical dominated by a harbour, a dike or a building subsidizing.

4 Urban planning and management

4.1 City Government and Administration

The municipality of Odense is governed by a city council with 29 members and five specialist committees. Each committee is chaired by a counsellor and the Finance Committee is chaired by the mayor. The city council is elected for a four-year term.

4.1.1 Services

Odense City administration has a total of around 17000 employees, working in five services:

- Mayors Department
- Department of Culture and Urban Development
- Department of the Elderly and Disabled
- Social Services and Labour Department
- Department for Children and Youth

Regarding ”suburban infrastructure” the most important services are the Mayor´s Department and the Department of Culture and Urban Development. The latter has more than 1000 employees and they have the following responsibilities:

- Administration of libraries, museums and other cultural activities
- Environmental, energy and refuse disposal planning
- Urban Planning
- Environmental and building authority
- Land supply, including purchase and sale of real estate
- Rental, running and maintenance of council property
- Construction and management of roads, public spaces, churchyards and parks, public transport
- District heating supply

4.2 The Planning System

The planning system in Denmark has three levels:

1. The National level dealing with national policies and directives.

For example the jurisdiction concerning “big infra-structure”: highways, high voltage power lines, transnational pipes for the transmission of natural gas and off shore wind farms.

2. The Regional level with the ”regional growth and development strategy”.

There are five Regions in Denmark. They run the hospitals, the raw material planning, and the planning of clean-up activities on polluted industrial sites. The regional growth and development strategy includes a strategy for the future development in the region regarding infrastructure, business development efforts, including tourism, education and employment activities, the development of urban and remote areas, nature and the environment, culture, etc.., as well as the initiatives the Regional Council will carry out in the strategy.

3. The Local level with:

The Plan Strategy, that ”translates” politics into planning. It deals with the visions of the City Council – the dilemmas, challenges and opportunities.

The Municipality Plan, that act as the City Council`s ”deal” with the citizens. It defines the frames for the local planning and plans for large physical structures and is binding for the politicians – not for the citizens. The Government, the Region and the neighbouring municipalities all have the possibility to object against the Municipality Plan.

Local Plans are very exact local “laws” that plan for small(er) physical structures. They regulate the usage of specific areas, building volumes and appearance, and are binding for the citizens. The Local Plans have to comply with frameworks and regulations established in the Municipality Plan.

The departments of Culture and Urban Development have their own specialized divisions to administrate the relevant set of laws. On local planning and project planning we have an interdisciplinary collaboration and an ongoing dialog with the land owners, project planners and developers for urban areas, to identify and apply relevant legislation and premises and on this basis negotiate the disposition of some areas.

Concerning the suburban planning we have plenty of challenges. We don’t have any sort of suburban Local or Municipal Planning and we are just about to start a collaboration among city planners, hydro-specialists, engineers and archaeologists.

4.3 The Legislation

As a fundamental principle of the Planning Act and its management, Denmark is divided into two types of areas – rural and urban areas, and we have a strong tradition for a clear division between the town and the countryside, and the protection of river valleys, historical values and the medieval urban structures.

Concerning the spatial planning in Denmark, the Planning Act is the most important tool: It delegates the responsibility for spatial planning to the Minister for the Environment, the five regional planning authorities and the 98 municipal councils. The Planning Act decentralizes decision-making authority and promotes public participation in the planning process based on the reformed planning legislation of the 1970s.

In this context the biggest problem is that The Planning Act does not work beneath the soil surface. We do not have any special “municipality plan” or “local plan” dealing with subterrainian (surface-near) conditions.

We have a number of laws and directives dealing with the underground. Starting from the bottom we have ”The Underground Law” that aims at an appropriate use of raw materials. In general it only comes into action in depths greater than 250 m below the surface, regardless of the purpose. All parts of Denmark beneath 250 m below sea level belong to the State.

When dealing with the uppermost 250 m of our underground it’s important to notice that our Constitutional Law in §73 defines that the ownership of the private property shall be inviolable. It's all nice words without much legal meaning and it is the following words in the paragraph that are crucial: no one can be forced to transfer his private property except where the public interest requires it. It can only be done by statute and against full compensation. The idea behind article 73 is such that the individual does not have to bear extra burdens because of interventions carried out in the interests of the public.

Usually for instance, the drilling of tunnels is tolerated as long as the utilizations of the private property aren’t changed. In practice the involved owners of the relevant private property lose their right to drill wells or establish all sorts of foundation by expropriation.

Water abstraction: Groundwater is not ”private property” but the owner of the land has a preference to exploit/abstract the aquifer AFTER he has been given the permission from the municipality. Usually this permission is very hard to get, especially if the private property is situated within areas already designated to supply the public with water, i.e. well field for public waterworks.

Due to conditions described elsewhere in this note most of the abstractions of groundwater have moved away from the city centre. Today we actually abstract more than 60% of the potable water outside of the municipality of Odense.

The mining legislation (Mineral Resources Act?) defines that raw materials such as stone, gravel, sand, clay, limestone, chalk, peat, etc. are ”private property”, but commercial quarrying of these materials needs a licence from the municipality.

The combination of a dense population and the large quarrying of raw materials – actually the largest deposits of sand, gravel and stone on Funen are situated within the municipality in an elongated zone south of the city - is giving rise to some conflict of interests between the local inhabitants and the contractors.

Most of the gravel pits are situated close to larger approach roads to the highways. The municipality attempts to keep the smaller roads and school-roads clear from the heavy lorry-traffic.

The permit to extract raw materials is an assembled permission. This means that the permit consists of different adjudications. For example, a permission to extract groundwater, dispensation to work in an area classed "environmental preservation", dispensation to remove protected dikes, constructing crossings and perhaps the permission for the re-establishment. Most of the partial permissions are made by the municipality, but must be assembled within one comprehensive permission in which the region will be the authority.

The authority for extraction of raw materials and Environmental Impact Assessment (EIA) has been transferred from the municipality to the region on the 1st of July, 2014.

5 Full case description

In Odense we have several and very different cases dealing with suburban planning. We have, e.g., just started the transformation of the central part of Odense – from 4 traffic lanes (Thomas B. Thrigesgade) to a townscape with 1-2 floors of underground parking garages for 700-800 cars. This piece of suburban infrastructure will cut off the hydraulic connection in the valley sediments around a very old stream (The Rose Stream), buried long time ago, and will prevent the groundwater flowing from west to east, unless we are able to prevent it by installing some sort of remedial solutions.

5.1 A short story of a town getting wetter

Of special interest in this infrastructural context are the geographical locations of waterworks for the abstraction of potable water. Maybe it's a very typical picture - but remarkable anyway. As far back as in 1586 the inhabitants could get (fresh?) tap water at three different localities in the city. The water at these pumping stations was delivered through hollowed logs from springs west of Odense. Most people had to get their water from these tap places, but a few were privileged to have a pipeline installed at their house where they received the unfiltered water within their houses.

This water distribution lasted more or less unchanged for nearly three centuries. By the mid 1800s the situation was almost intolerable and the city council took steps to establish a public water work based on British principles of groundwater filtration through sand filters. In August 1853 the first real water work in Denmark was put into service. By the way, in the fall and through the early summer of the following year of 1854 a severe cholera epidemic outbreak ravaged many cities in Denmark. In Copenhagen 3809 people died, and also 66 in Aarhus, 39 in Aalborg and 22 in Svendborg died due to cholera. In Odense no one died. Copenhagen did not get their water work up and running until 1857.

From the start the water was taken from springs situated further west from the city. The demand for water exceeded the natural flow from these springs which meant that there was a need to establish drilled wells. In 1876 the water work started abstracting water from wells in an artesian aquifer from a well field called Eksercermarken (a sort of playground for the soldiers - exercise) west of the, at this time still small, city. This well field is still active, producing potable water, and through time it has become the most utilized of all our well fields.

But everything has a price. Figure 18 provides an excellent example of the consequences of the aforementioned growing demand – first mining and afterwards drowning.

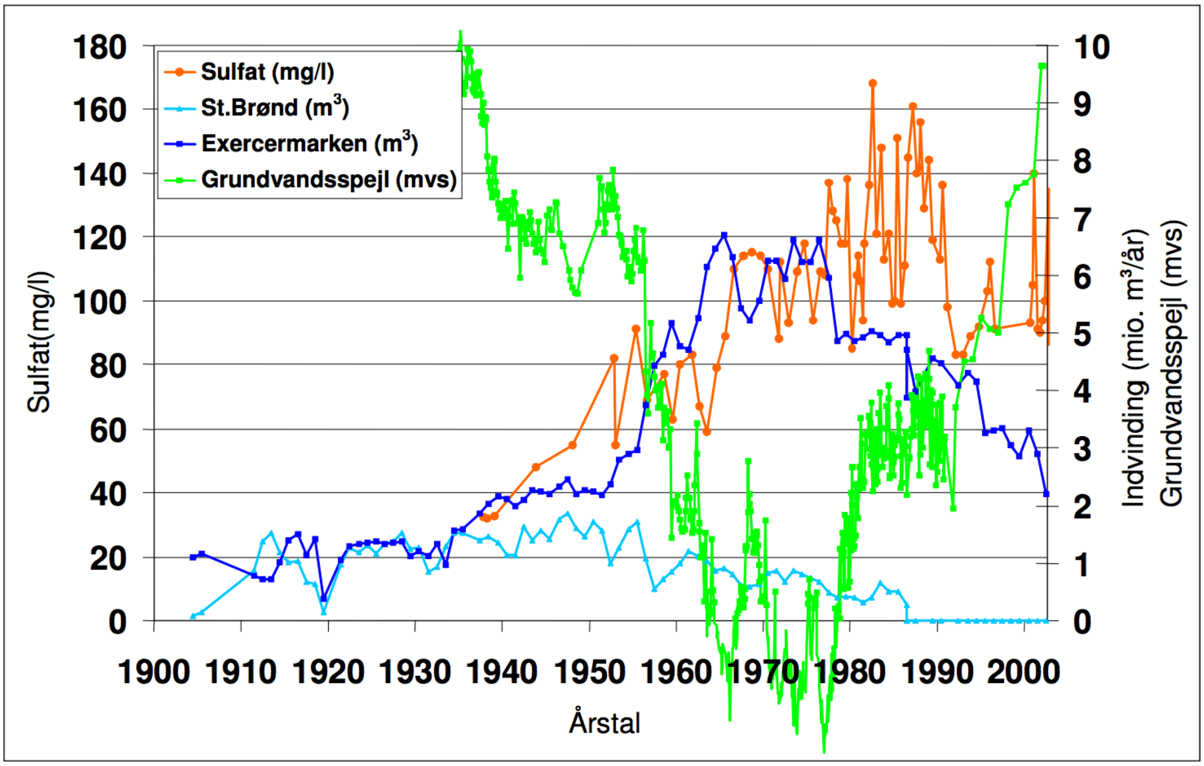

Figure 18. The abstraction of water from The Eksercermarken Well Field (Data: J. Linderberg, Vandcenter Syd).

The abstraction from wells at that particular well field was initiated late in the 19th century and at the start of the last century the yield was around 1 million m^3 per year. At the same time the piezometric head was at least 10 m above sea level (ASL). The increase in abstraction is relatively slow until the mid-1960s. From that point and the following 10-15 years the abstraction was growing exponentially to an absolute maximum of close to 7 million m^3 per year, resulting in a severe drop in piezometric head to 2 to 3 m below sea level and a dramatic and unsustainable increase in the sulphate concentration, from 20 to 170 ppm – a process often associated with groundwater mining.

Due to deterioration in water quality (mainly sulphate and the occurrence of detected pesticides) and a wish for a more sustainable abstraction from that particular well field, the abstraction of today has been reduced dramatically in the last decade. It is now almost back at the same level as during the first half of the 20th century, that means at around 1-2 million m^3 per year, and the piezometric head have risen to around 10 to 12 m above sea level. The main reason why the above-mentioned lowering of the abstraction of groundwater is becoming a problem is very simple – city growth.

In Figure 19 three different maps show the land use in that specific area anno 1870, the time when the groundwater abstraction was initiated, in the 1950s, and in the 1990s.

Figure 19. The land use of the Eksercermarken well field - anno 1870, 1950 and 1990. Copyright: KMS.

The area is also called Sanderum Tørvehave (tørv = peat, have = garden) and during the 19th century the peat bogs were intensively ditched, drained and excavated. From 1870 when the abstraction of groundwater started until 1890 the wells were artesian up to +14 m (ASL) and the water was flowing by itself.

There were only a few small houses in the area at that time and those were only situated at the highest places. As earlier mentioned, a large part of the area served as a military training ground right up to the start of the 2nd World War. Because of the fact that the area was being used for military purposes it is believed that this is the reason why the city expansion was "delayed" in the south-western part of Odense.

Until the 1950s the piezometric head was lowered further from more than +10 to +2 m ASL and the area became suitable for allotments and a horse-racing track. Through the next decades the groundwater abstraction increased from 2 to more than 7 million m^3 per year. The water quality started to deteriorate and the piezometric head hit "rock bottom" at – 3m BSL.

Today the actual water work (VCS Denmark) has reduced the abstraction to approximately 2 million m^3 per year and the piezometric head has gone up and is at present equal to the level of the year 1940 (Figure 18). This unfortunate combination of the rising of the water table and the fact that the annual mean precipitation has increased by around 100 mm since we started measuring in 1876 is a case of conflicting interest. Several drained and urbanized areas are now becoming waterlogged again and the situation is of increasing concern for the current inhabitants.

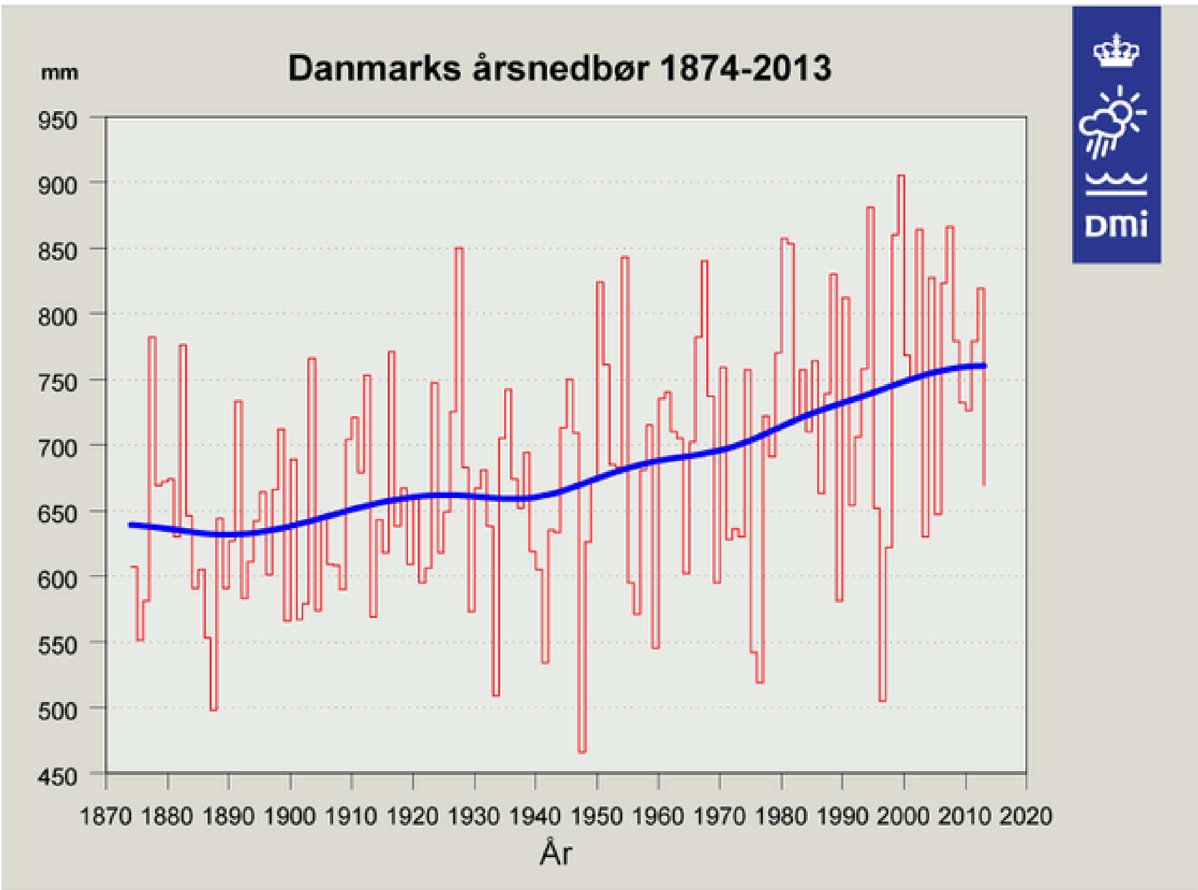

Figure 20. Mean annual precipitation for selected Danish meteorological stations, from 1874 until today (Copyright: Dmi.dk).

Water works and all other activities are by law responsible for damages caused on buildings etc. by lowering the water table. However, this is not liable the other way around when the water table rises to previous levels.

Figure 21 is showing our best bet on the hydraulic conditions occurring in case we would stop all the abstraction of groundwater in this area - a situation similar to the conditions of the year 1900.

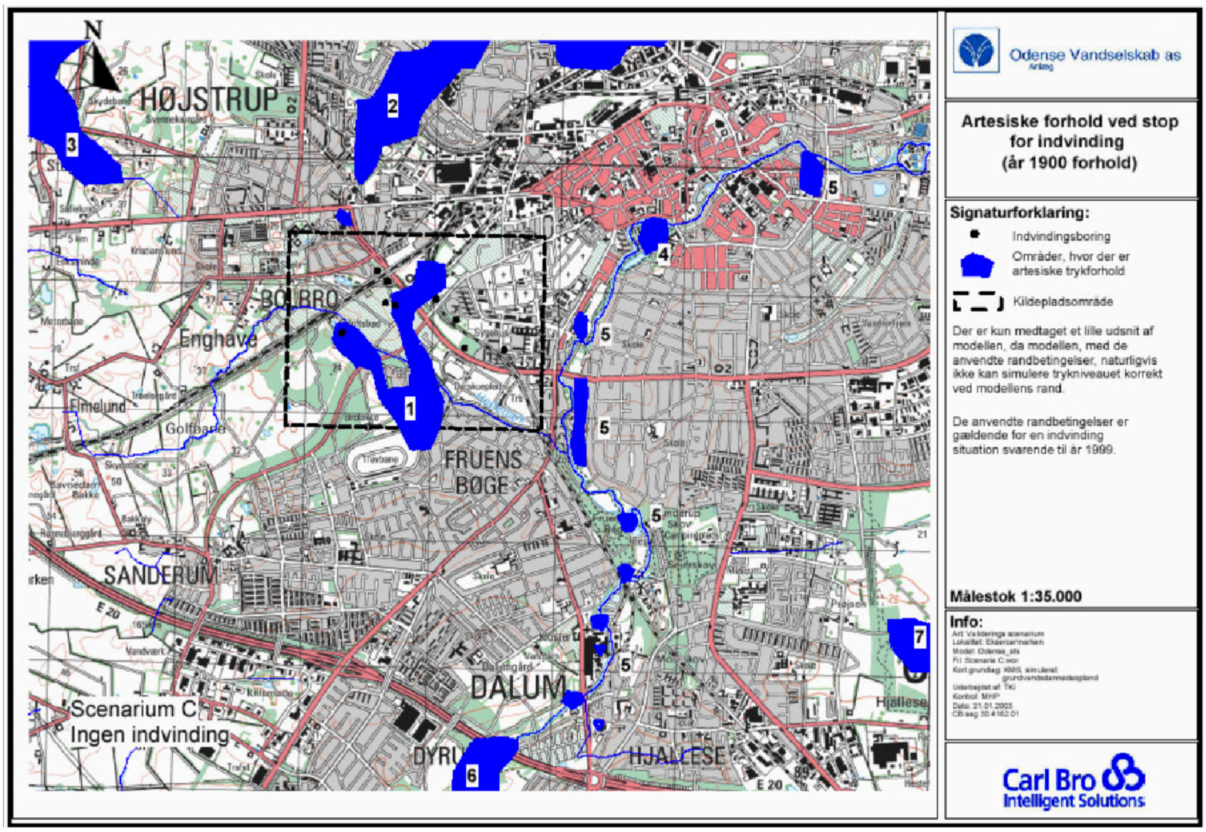

Figure 21. Areas (blue) with artesian condition if abstraction is stopped. Area no. 1 is the Eksercermarken well field. Odense Vandselskab et al (2003).

Despite the legislation, the VCS Denmark is very much aware of this conflict of interests in that specific area and they conduct a major annual monitoring programme of the water level in this area.

VCS Denmark is the sole operator on sewage transport and treatment. It is in their interest to minimize unnecessary surface and groundwater entering the sewage system. The municipality is also advocating the possibility to handle as much rainwater from rooftops/impermeable surfaces as possible, locally, by trying to make the public willing to establish seepage systems, soak ways in their own back yards. Those who do can get an economical refund on the properties connection charge. This is of course a major challenge because of the great geological heterogeneity and the close proximity of the water tables to the surface. Soak ways (gabions) in till clays are not necessarily efficient to cope with the current or future rainfall.

The increase in the annual precipitation sums and the increasing frequency and intensity of extreme rainfall events make it very challenging to cope with all this water locally. Therefore one drastic way to cope with reoccurring flooding in a suburb area of Odense has been to expropriate these vulnerable properties. The owners were offered a reasonable compensation for their houses. Seven owners agreed and VCS Denmark acquired these houses with the associated properties. The houses were demolished and the resulting area was turned into a local park, capable of storing a large amount of water that can be stored for a while before directing it to treatment when there is sufficient capacity in the system (see Figure 22).

Figure 22. The previous area of seven private properties. Now the houses are removed and the area has turned into a combined recreational area and a storm water basin.

As mentioned in the beginning of this report, the City of Odense is under big pressure – due to an increasing amount of water from all directions. Odense is situated at the innermost part of the Odense Fjord, one of the most manipulated estuaries/inlet areas all over Europe. At the river mouth of the biggest river on Funen "Odense Å" with a drainage area covering 1/3 of Funen, and remembering that the municipality only covers 1/10 of the island, so the administration of the recharge area is distributed to most of the municipalities on Funen, and we are working closely together to manage these inter-municipal problems and relationships.

It is very uncertain whether the observed increase in yearly precipitation in the long term will result in a rise of the groundwater level. Some models predict this, while other models indicate that the increase in evaporation due to warmer and longer summers combined with an increase in winter precipitation (where a large proportion drains to the rivers / recipients and does not beneficent the groundwater), will result in a decrease in infiltration to the groundwater, thus resulting in a decreased piezometric head of the groundwater. A summer with drought can also increase the need for artificial irrigation of fields.

The level of the near-surface groundwater reservoirs are increasing, which is already observed at several places in the city and will gradually cause more damp/moist or even wet basements. This phenomenon is more or less linked to an increased recharge, diminishing needs for potable water / lesser water abstraction and the sealing of previous leaky sewers which hereby stop acting as drains.

The climate-related rise in sea level could probably give rise to a corresponding and equivalent rise in the piezometric heads of the aquifers. If this happens the drainage of the low-lying fjord areas will become even more problematically and economically disadvantageous. The risk for the intrusion of salt water into the cost-near aquifers will rise. However, the changes, if any, will occur very slowly.

In the EU Flooding Directive, the Odense Fjord area is one of ten Danish areas that are defined as more vulnerable to flooding and we are about to deal with this problem. Initially this will happen by defining an action level in the risk screening work yet to come and then by implementing robust and future-related solutions from there.

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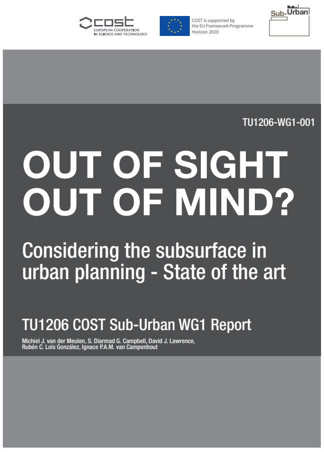

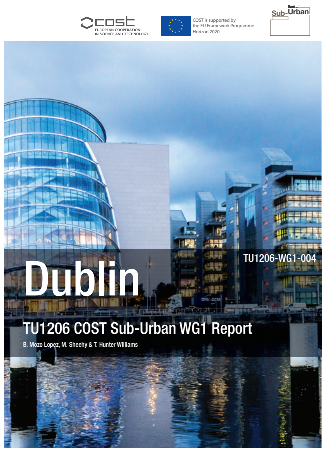

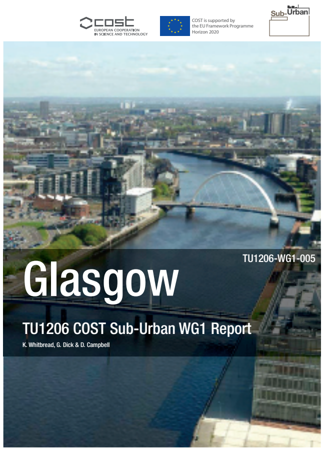

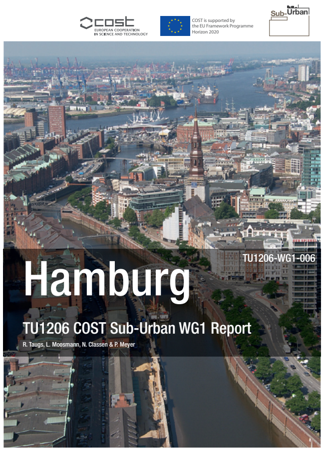

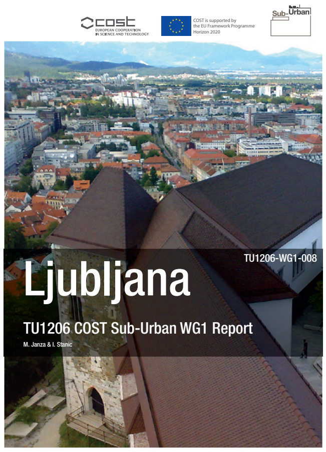

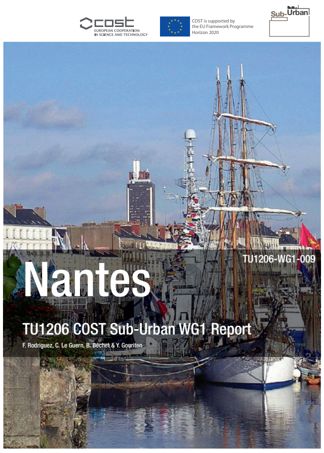

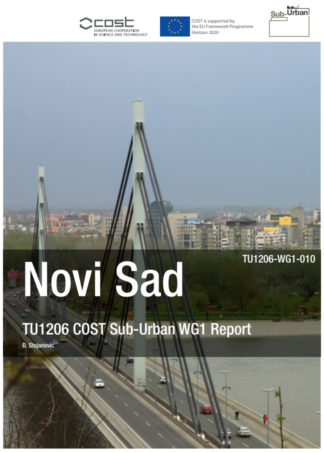

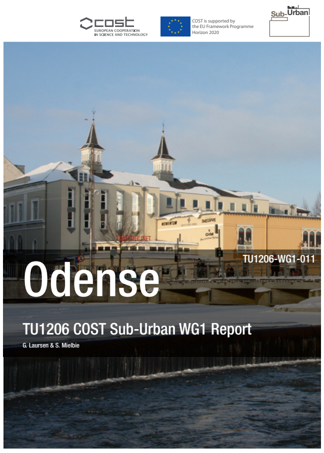

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