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STORM-WATER MANAGEMENT IN MALMÖ AND COPENHAGEN WITH REGARD TO CLIMATE CHANGE SCENARIOS

Dagvattenhantering i Malmö och Köpenhamn med avseende på klimatförändringsscenario

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Abstract

The current status of storm-water management in the neighbor cities of Copenhagen and Malmö was studied with respect to present measures and the implemented systems in both cities. Application of blue-green solutions in the outer parts of Malmö started in the 1990s; hence collaboration between different departments in the municipality is more structured in the city of Malmö while in Copenhagen the process is still based on traditional pipe systems and CSO management with the exception of Ørestad. However, more blue-green solutions are to be applied in Copenhagen in the coming years. Concerning the climate adaptation plans in regard to the Three Points Approach (3PA), Copenhagen has determined the required framework for adaptation of the inner parts of the city with regard to extreme rainfalls (Cloudburst Management Plan in Copenhagen) while Malmö has focused on implementation of open systems in the suburbs taking design rain criteria into account.

Key words – Cloudburst, BMP, Three Points Approach, Climate change, Storm-water

Sammanfattning

Aktuell status för dagvattenhantering i grannstäderna Köpenhamn och Malmö studerades med avseende på befintliga åtgärder och genomförda systemen i de båda städerna. Tillämpning av blå-gröna lösningar i de yttre delarna av Malmö började på 1990-talet och följaktligen är samarbete mellan olika avdelningar inom kommunen mer strukturerat i Malmö medan processen i Köpenhamn fortfarande är baserad på traditionella rörsystem och CSO-hantering med undantag av Ørestad. Fler blå-gröna lösningar kommer emellertid att tillämpas i Köpenhamn under de kommande åren. När det gäller klimatanpassningsplaner med tanke på Three Points Approach (3PA), visar det sig att Köpenhamn redan har fastlagt det nödvändiga ramverket för anpassning av de inre delarna av staden vid extrema regn (Cloudburst Management Plan in Copenhagen), medan Malmö har fokuserat på genomförandet av öppna system i förorterna som främst tar designregnkriterier i beaktande.

Introduction

As illustrated in the IPCC 5th assessment report, global warming (i.e. higher average temperature), along with other consequences, would cause more frequent intensive rain events in specific regions following the elevated water vapor content in the atmosphere (Figure 1). This would however make serious problems in urban areas where the surfaces are mainly covered by impermeable materials, such as concrete, asphalt, buildings, etc. On the other hand, the existing storm-water management systems are not designed to face extreme events. Tack-

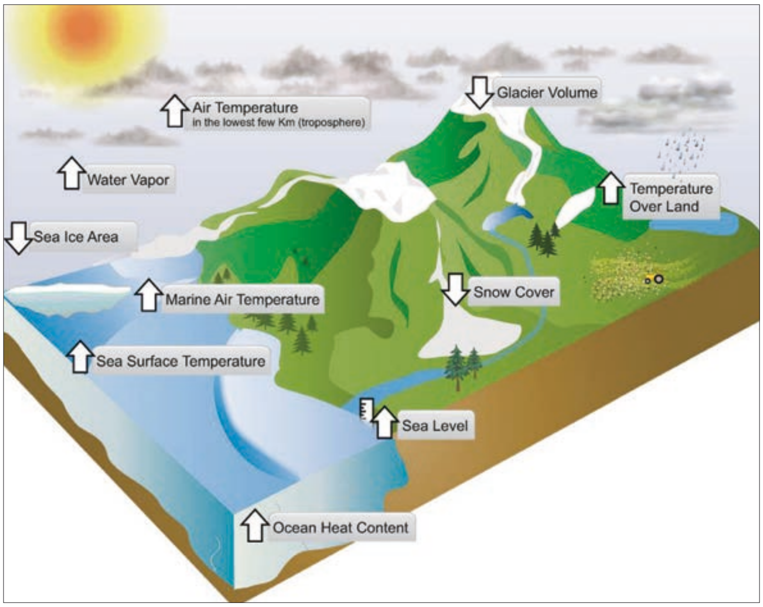

Figure 1. *Effect of global warming on many different components of the water cycle. Arrow direction shows the expected change; i.e. higher (up), lower (down). Adopted from Climate Change (2013) with permission.*

ling the storm water problem has to be done from different aspects in order to be able to move towards sustainable development. The pattern of sustainable development in which social progress, economic development and environmental responsibility are interacting within a well-balanced equilibrium can be severely disturbed by mismanagement of storm water in urban areas regarding both its quantity and quality.

Climate change is believed to lead to more intense precipitation trends in the future in Scandinavian countries (Collins et al., 2013). Moreover, Denmark and Sweden are amongst those countries which are expected to be exposed to intensive storms as well as sea level rising according to the latest IPCC report. Four strong storm events struck Sweden in 2013 of which the storms Simone and Sven (known as Allan and Bodil in Denmark) occurred in the Öresund region – where the densely populated cities of Copenhagen and Malmö are located. These storms have cost Sweden about 700 million Swedish kronor paid by insurance companies while the costs in Denmark by the same storms mounted up to 4.2 billion Danish kronor, according to Insurance Sweden (Svensk Försäkring, 2014). More recently the cloudburst on 30th–31st August 2014 in Malmö and Copenhagen, corresponding to a 100-year rain (SMHI, 2014), caused household flooding as well as serious damages to the transportation networks of the cities.

Tabel 1. *Information about the storm events causing considerable damages in Sweden since 1999 according to Svensk Försäkring (2014).*

Storm	Year	Registered damages (Number)	Cost (Million SEK)
Anatol*	1999	22 365	970
Gudrun*	2005	90 220	3965
Per	2007	16 334	551
Simone*	2013	13 196	428
Hilde	2013	1 794	59
Sven*	2013	8 314	264
Ivar	2013	5 114	186

* Storms by which the Öresund region was affected severely.

Existing storm-water handling systems in Scandinavian countries are mainly dominated by pipe networks which can be regarded as the traditional approach towards management of urban runoff. As cited by US EPA the pipe-oriented systems may have been originated based on the idea that *dilution is the solution to pollution.* Consequently quick transport of wastewater to farther locations from the city was believed to be the answer to waste problems. Combined sewer networks are normally associated with severe problems with combined sewer overflows (CSO) or increased influent to the wastewater treatment plant (WWTP) in case of intensive precipitations; while separate sewers, though more convenient in many ways, is regarded as an expensive solution mostly insufficient in case of extreme rainfalls.

Best management practices (BMPs) are the alternatives to the traditional pipe-oriented systems. BMPs (open systems, blue-green solutions) are also known as key actors within sustainable urban development systems (SUDS) and low impact development (LID). The idea with the alternative approach is to mimic the natural processes in the urban areas in order to handle the storm water. Slow transport, detention ponds and lakes, green roofs, etc. are considered to be methods within the context of BMPs. The definition of sustainability in storm-water management in Sweden, and especially southern Sweden, is to a great extent influenced by Peter Stahre who made intensive studies in this field. His books "Sustainability in urban storm drainage" and "Blue-green fingerprints in the city of Malmö, Sweden: Malmö's way towards a sustainable urban drainage" shaped the framework of a sustainable approach towards urban drainage. The definition of "blue-green" has to be discussed further since it is not well-developed. Basically all the storm drainage techniques that blend the following three aspects can probably be called "a blue-green" solution:

1 Hydraulic control of storm water
2 Quality control of storm water regarding organics, pathogens, biocides, micro-pollutants, heavy metals, etc.
3 Added value of the system i.e. storm water shall play an aesthetic role in the urban landscape and contribute to biological diversity.

Traditional piping network for handling the storm water on some occasions does not have the capacity to handle the flows. This causes flooding of urban areas (in separate networks), discharge of untreated combined sewer overflows or flooding of buildings (in combined sewer systems) or a combination of these problems. Even development of open solutions for enormous volumes of storm water, such as the 1000-year storm in Copenhagen 2011, is an ongoing process with lots of debates on unsolved problems concerning technical, social, legislative, economical, and political aspects. The quality of storm water varies a lot depending on the surface the drops land on. Storm water flowing over industrial areas has different composition from that of a real-estate accommodation area. Heavy-metals, biocides and polycyclic aromatic hydrocarbons (PAHs) are the most problematic fraction of the pollutants in storm water compared to organics and nutrients. The combination of the pollutants in storm water and relatively large volumes of urban runoffs make efficient treatment very challenging with respect to technique and economy. There is no in-depth evaluation of all the current open solutions systematically applied in cities i.e. retention ponds, swales and wetlands regarding nutrients uptake, organics reduction, heavy metals, biocides etc. in such systems. Considering the serious problems regarding management of quantity and quality of storm water, application of an aesthetic function seems to be far more problematic where the risk for human contact with the collected storm water is high.

Regardless of the techniques and methods used for handling of storm water in urban areas, urban flood risk management can be done at three different levels known as the Three Points Approach (3PA) as suggested by Fratini et al. (2012). The 3PA classifies rain/storm events into three different categories: 1) Design rain, 2) Extreme rain, 3) Little rain based on their impacts on urban life quality and likely risks associated. The three levels of 3PA are shown in Figure 2 while further expla-

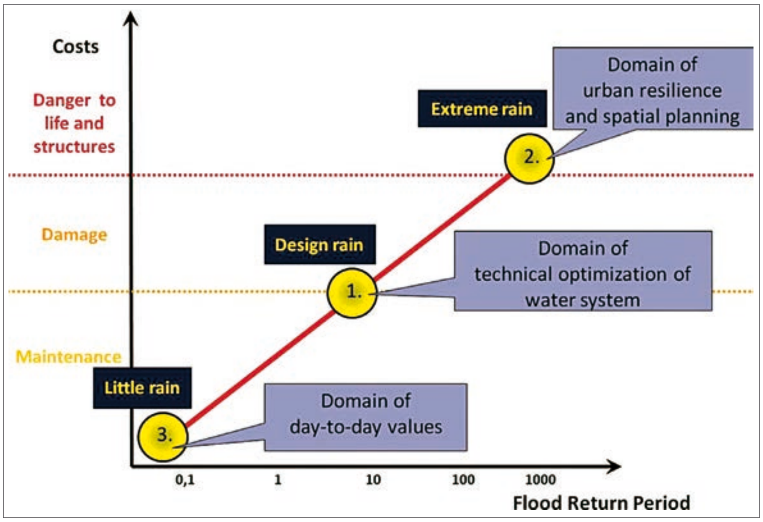

Figure 2. *Three Points Approach (3PA) as introduced by Fratini et al. (2012) classifying the rainfall events according to rain intensity (flood return period) and their associated costs.*

nations and elaboration can be read through Fratini et al. (2012). Appropriate adaptation of the entire storm-water handling system for meeting the needs in case of all three rain categories, as classified in 3PA, would be a considerable step towards a sustainable urban drainage. It should be considered that it is the combination of all levels that could result in systematic efficiency in case of more intense rainfalls. For example, maintenance of storm-water handling systems which is underlined in case of little rain has a significant role in efficiency and functionality of the system in case of design rain and extreme rain. Therefore development of new methods and techniques for management of rain events at different intensities is one of the missing loops of the sustainable management chain.

Moreover there is a high degree of uncertainty regarding the future climate conditions which leads to less determinacy level in the selection of an appropriate act that in turn makes the decision process very sophisticated. Rare occurrence of extreme storms which cause catastrophes is another reason making it more difficult to realize the necessity of implementation of preventive-adaptive measures in urban areas. This is true for extreme storms which so far have been seen as too rare and/or uncertain events; hence relatively less focus has been allocated by politicians and other decision makers on alleviation of the storm water/flooding problems, especially when no serious extreme rainfall and its consequent damages have been experienced.

Meanwhile legislations are passed, at both European and national levels, delimiting the water, wastewater, and storm water sectors within tighter requirements. European Flood Risk Directive (2007/60/EC) asks the member states to evaluate and assess flood risks with respect to flooding and its impact on public health and life, the environment, cultural heritage and economic activity. According to the plan all member states are required to generate flood risk management plans including assessments, risk maps and measures regarding prevention, protection and preparedness by 2015. The latest EU Bathing Water Directive (2006/7/ EC) is another example stipulating stronger requirements on E. Coli and Enterococci levels in the receiving waters used for bathing. Such legislations bring up an important discussion among different actors of the city regarding responsibilities.

In order to be able to tackle such discussions it seems necessary to know the current management system in an urban area. Malmö, the largest city in southern Sweden, and Copenhagen, capital of Denmark, are chosen for this study as the neighbor cities in the Öresund region with similar climate but different history of storm-water management.

Storm-water management in Malmö

The storm-water management in Malmö is driven by an official document (Storm-water Strategy for Malmö) generated through a mutual agreement between VA SYD and Malmö City (municipality). The initial version of the document was published in 2000 where some basic principles were underlined regarding the storm-water management:

- The natural water balance should not be affected negatively by urbanization.
- Sources that contribute to pollution of storm runoff should be limited.
- The storm-water handling system shall be designed in order to avoid harmful flooding in case of intensive rainfalls.
- The storm-water handling system shall be designed so that a large part of the pollution in the urban runoff is removed on its way towards the recipient.
- Storm water shall be used as a positive resource in urbanization.
- Open solutions for storm water shall be prioritized as much as possible in the new developments.

The latest version of the policy, published in 2007, in which the above stated principles are deepened and practical approaches are explained. The major part of this policy is dedicated to explanation of the responsibilities of different departments of the municipality as well as VA SYD. Severe difficulties were faced in the late 1980s regarding cooperation of city actors which made it almost impossible to implement a storm-water handling project with sustainability fingerprints. However the policy has been the outcome of about 10 years of experience in negotiation, collaboration and cooperation between different actors of the city from 1989 to 2000. Today it seems that different departments of the municipality in Malmö have realized the importance of the storm-water management as it is taken into consideration at very early stages of city planning. Consequently a framework for responsibilities associated with each department/actor is generated, clarifying the role of different actors all the way from planning to maintenance of the system in addition to some other acts such as classification of runoff quality with respect to urban land-use as well as classification of recipients based on their sensitivity to flow, nutrients and pollutants.

Moreover, the Swedish parliament has passed a bill targeting the pressure reduction on the environment by 2020 and the climate change in 2050. The bill is known as Sweden's Environmental Quality Objectives which consists of 16 goals. The bill aims to be the main driving force in achievement of a decent environmental quality in Sweden by initiating a holistic integrated movement

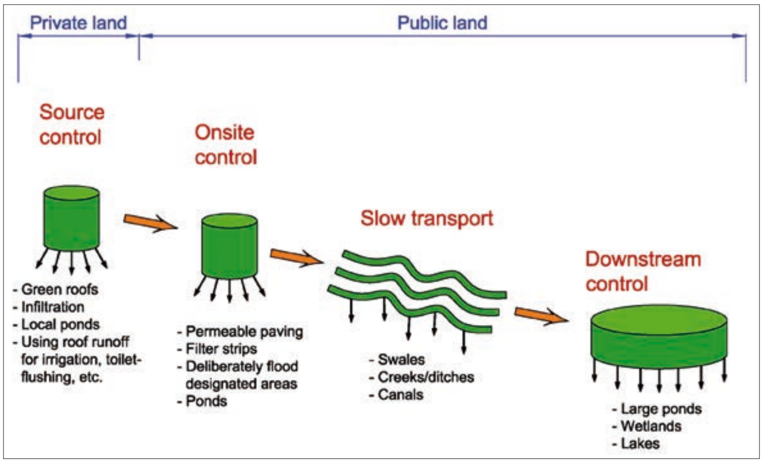

Figure 3. *Implementation levels of open storm drainage systems and their applicable techniques [redrawn according to Stahre (2006) with permission].*

through different governmental agencies, public agencies, NGOs, enterprises as well as individuals. A specific agency is assigned as the main responsible for each goal while it is utterly understood that fulfillment of the goals requires public care and sometimes international collaboration. The Ministry of Environment is the supreme responsible and the main supervisor of the status of the drawn vision.

A closer look into the objectives could reveal that fulfillment of some of the objectives will lead to better storm-water quality. Achievement of goals such as Clean Air, Natural Acidification Only and A Non-Toxic Environment would influence the storm-water quality positively while control and management of storm-water quality would contribute to other goals such as Good-Quality Groundwater, A Balanced Marine Environment, Thriving Wetlands especially in urban areas.

Since the early 1990s there has been a shift towards open solutions in storm-water management in Malmö. These solutions are mainly considered as Best Management Practices (BMPs), Sustainable Urban Drainage Systems (SUDS) or Blue-green solutions for urban drainage. The process of the transformation from traditional urban drainage towards a sustainable approach, with all the hurdles and difficulties faced at the time, is well described by Peter Stahre in his book "Blue-green Fingerprints in the City of Malmö; Sweden". As a result, Malmö is one of the leaders in application of sustainable urban drainage systems in Sweden. The main objectives of the BMP are to decrease and slow down the runoff flow in the urban areas so that the existing piping network does not get overloaded. These measures can be implemented on private lands (known as source control methods) and on public lands. Figure 3 shows the different levels of implementation of open storm drainage together with some examples of the techniques and methods applicable at each level. It should be noted that the mentioned techniques under each level in Figure 3 are not specifically unique for that level but are the most frequently implemented techniques. This means that for instance permeable paving or ponds can be a source control technique if implemented on private land. In many cases it is not easy to assign the project singly to one of the four levels of implementation since most of the projects could be multi-functional in this respect (e.g. meandering creeks leading to a recipient can be a "slow transport" implemented at "downstream control" level).

Figure 4 shows the distribution of combined and separate sewer networks in the city of Malmö. About 35 % (~2800 hectares) of the Malmö city has combined sewer systems of which about 20 % (~550 hectares) is non-effective separate systems. A non-effective separate storm-water system is a duplicate system which is not diverted to the recipient directly so the storm water eventually flows into the combined system and is then led to wastewater treatment plants. The combined sewer is traditionally present in the older parts of the cities which are normally tightly constructed and highly populated. These circumstances make the application of new solutions such as open systems almost impossible; moreover substitution of a combined sewer with a separate sewer seems to be an extremely costly and complicated process. However the outskirts of the city and relatively recent developments in Malmö city have been supplied with duplicate sewer systems together with open solutions in certain areas. Additionally over 20 projects within the context of sustainable urban drainage has been defined and implemented in Malmö (pointed out in Figure 4) as listed in Table 2 which is adopted from the book "Blue-green Fingerprints in the City of Malmö; Sweden" and has been updated based on information from VA SYD.

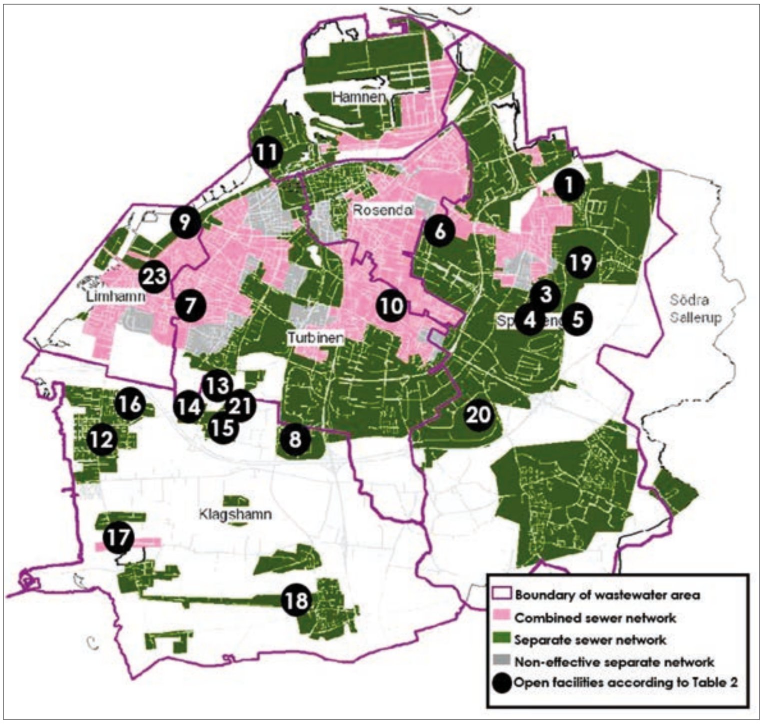

Figure 4. *Different storm water collection networks as well as implemented open solutions in the urban areas of Malmö, Sweden. Measure No. 22 according to Table 2 is implemented within the combined sewer area wherever applicable. The basic map for generation of this figure is adopted from VA SYD (2009) with permission.*

Table 2. *List of the BMP implementations in the city of Malmö and their characteristics (Expanded from Stahre, 2008).*

ID	Name	Year of implementation	Type of facility	Level of implementation
1	Toftanäs wetland park	1989–1990	Wetland, controlled flooding	Downstream control
2	Sallerupsvägen	1992	Pond, meandering creek, root zone	Slow transport/ Downstream control
3	Kasernparken	1992–1993	Pond, reed bed	Onsite control
4	Amiralsgatan	1995–1996	Ponds	Onsite control
5	Husie lake	1996–1997	Detention lakes	Downstream control
6	Olof Hågensens wetland	1997	Wetland, controlled flooding	Downstream control
7	Vanåsgatan	1999	Swales, inverted traffic bumps	Slow transport
8	Svågertorp	1998–2001	Soakaways (dry wells), ponds	Onsite control
9	Limhamnsfältet	1998	Swale	Slow transport
10	Augustenborg	1998–2005	Green roofs, canals, swales, ponds, permeable paving, controlled flooding	Source/onsite control
11	Bo 01 housing exhibition	2000–2002	Open canals, rain gardens, water artwork	Source control
12	Fjärilsparken	2000–2004	Eco-corridor (regional swale)	Slow transport/ Downstream control
13	Elinelund recreation area	2001–2002	Ponds, filter walls	Downstream control
14	Gottorpsvägen	2001	Ponds, filter walls	Downstream control
15	Vintrie	2001–2003	Detention ponds in series	Downstream control
16	Annestad	2005	Detention canal, controlled flooding	Onsite control
17	Växthusparken	2005	Eco-corridor (open watercourse and pond)	Slow transport
18	Tygelsjö eco-corridor	2004–2007	Eco-corridor (wetland, watercourse and ponds)	Downstream control
19	Gyllins trädgård	2009–2010	Green roofs, controlled flooding	Source control
20	Skogholms meadows	2011	Detention ponds in series	Downstream control
21	Hyllie Water Park	2014 (expected)	Detention pond	
22	Disconnection of roof drains from CS	–	Infiltration, controlled flooding	Source control
23	Choking of storm drains in CS (Limhamn)	2007	Controlled flooding	Onsite control

However, despite all the implemented open systems in Malmö the storm Sven (5th–7th of December 2013) showed that the city was still prone to critical damages in case of severe rainfall events. During the storm the water level in the city canals of Malmö raised about 1.5 m while the three year-old metro network of Malmö was only 15 cm (in water level) away from being flooded (Westerberg, 2014). The most recent cloudburst on 31st of August 2014 was another clue demonstrating the need for an efficient storm-water handling system in Malmö.

Studies have been done regarding the sea level rising concerning the coasts of Malmö which has led to re-consideration of a course of action for all new constructions to be at least 3 m above sea level (Dialog-pm, 2008:2) if no other measure of flood protection is implemented in the area. The previous guideline stated a minimum level of 2.5 m above the sea level for new constructions.

Storm-water management in Copenhagen

Copenhagen is mainly dominated by combined sewer systems with the exception of Ørestad and a narrow strip along the harbor which have separated sewer networks (Figure 5). Water quality in the Copenhagen harbor has always been an important issue for the Copenhageners. As reported by Lindegaard (2001) it was in 1930 that the local council representatives reacted against the environmental water quality in Copenhagen putting the blame on the city of Copenhagen (municipality) for releasing 370 000 tons of waste including wastewater from households into the Sound. This argument brought up the demand for treatment of the municipal wastewater from Copenhagen (Lindegaard, 2001). The municipality decided to build a WWTP at Kalvebod and implemented chlorine disinfection to the treated wastewater from Helgoland. It was in 1932 that the municipality closed down the bathing locations in Kalvebod and Helgoland due to high bacterial content in the water.

Since the 1990s improvement of water quality in the Copenhagen harbor has been a driving force to control flooding and sewer overflows into the harbor. Heavily polluted water caused by industrial impacts and combined sewer overflows had made it completely impossible to use the harbor for water-based recreational purposes for decades. In total 93 outlets released CSO into the harbor and its neighboring coasts in case of heavy rainfalls.

The aim to achieve a water quality suitable for swim-

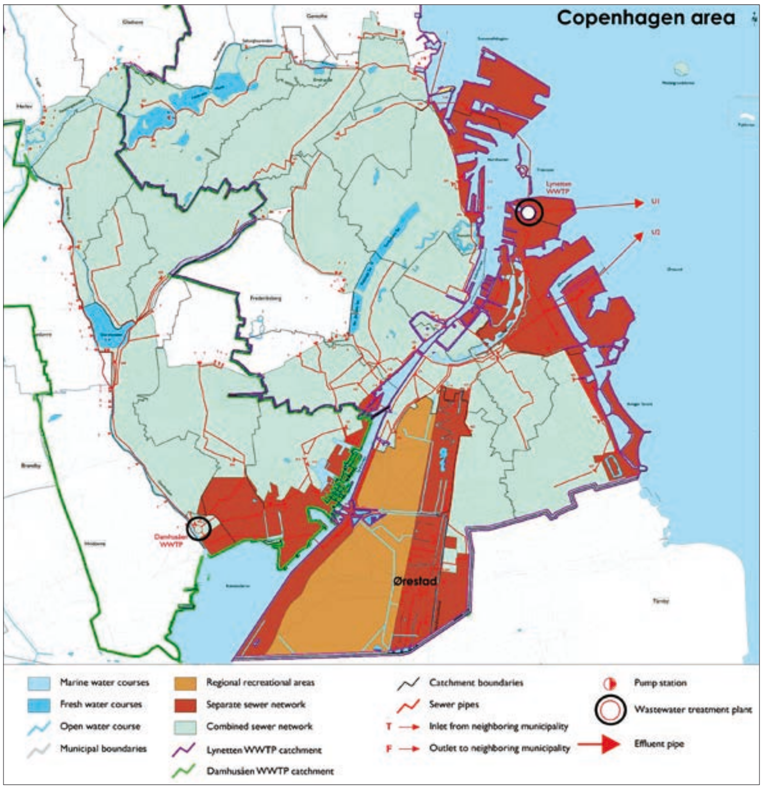

Figure 5. *Overview of the Copenhagen area illustrating locations of separate and combined sewer networks. This map is adopted from Københavns Kommunes Spildevandsplan, 2008 (with permission).*

ming in the harbor initiated a plan in the municipality of Copenhagen in order to decrease the release of pollutants into the harbor. Many retention basins were built at the overflow points which could detain the overflow water for a certain time until the network could handle it back. Construction of retention basins was a great progress in line with the defined aim which decreased the number of the outlets down to 38. Now CSOs occur at very extreme rainfalls (i.e. overflow takes place at higher hydraulic gradients in the pipe system compared to the original conditions). Also an online warning system controls the bathing water quality in the harbor.

The intense storm on the 2nd of July 2011 in Copenhagen has probably been a turning point in the history of storm-water management in Denmark. About 150 mm rain in about 2 hours, corresponding to a 1000-year rain, led to approximately one billion euros insurance claims in the Copenhagen area (Fink, 2014). Moreover, critical infrastructures were damaged, hospitals were close to be evacuated and the emergency services were threatened seriously. Since then the storm-water management has been considered as one of priorities in the urban planning in Copenhagen.

The Cloudburst Management Plan (October 2012) can be regarded as the guideline and policy for storm-water management in Copenhagen. Cloudburst Management Plan has been worked out by the City of Copenhagen via cooperation with Copenhagen Energy (Københavns Energi), the city of Frederiksberg, Frederiksberg utility company (Frederiksberg Forsyning) as well as neighboring local authorities whose storm water is diverted to the common water courses through Copenhagen. The collaboration of different city actors and their mutual agreement on the Cloudburst Management Plan makes it more convenient to plan, design and implement storm-water management projects with a holistic perspective in the city of Copenhagen. The document is an offshoot to the Copenhagen Climate Adaptation Plan (August 2011) with some changes initiated from the experiences of the 2nd of July 2011 extreme storm. The Climate Adaptation Plan suggests two measures in order to mitigate flooding in case of extreme events: a) Changing the current combined sewer network to separate network (long-term plan), b) Using public surfaces with low sensitivity e.g. parks, sport fields and open spaces for temporary storage of storm water (known as Plan B). However the 2nd of July 2011-event proved that the maximum volume contained on such surfaces in Copenhagen area would only cover a minor proportion of the flood during the extreme rainfall events. Therefore, the Cloudburst Management Plan is issued by introducing additional measures which could lead the storm water to the sea via roads, canals, urban waterways and underground tunnels. The legal problems for financing such inter-institutional provisions are identified and asked to be solved by the Danish Ministry of Environment. Moreover, environmental impacts of such water outpourings into the water courses are planned to be investigated.

The Cloudburst Management Plan also recommends a new risk dimensioning criteria. The suggested criteria allows the sewer water level reach the ground surface once in a 10-year course (i.e. the former criteria) as well as 10 cm flooding above ground level once every 100 years. The100-year storm is selected based on economical evaluation of different approaches. Controlling the flood level of maximum 10 cm above ground level in case of a 100-year storm would be done via combined adoption of storage measures, fast transport via designated surfaces and tunnels all together with public awareness and preparation of their properties against 10 cm of water above the ground level. This means that in future every individual should be prepared to manage 10 cm flood without any substantial damage to the properties.

On the way towards large scale adaptive measures for the city of Copenhagen, as discussed above, blue-green solutions are one of the major available alternatives. The City of Copenhagen has expressed its determinacy for implementations of blue-green solutions concerning storm-water management for alleviation of urban flooding problems. Unlike the situation in Malmö, Copenhagen does not have as many large-scale open storm-water implementations. The only example is available at the Ørestad area in Copenhagen where a series of interconnected canals is recipient to the storm-water runoff from the roofs of the surrounding buildings. There are several projects in the planning phase in Copenhagen which address the common use of urban surfaces, e.g. streets and parks for storm-water control in case of intensive rains. H.C. Andersen's Boulevard, Sankt Annæ Plads, Istedgade, Sankt Jørgens Sø and Sønder Boulevard are some of these conceptual plans under consideration for the Copenhagen area. Figure 6 shows one of the future solutions transforming the street to a storm-water runway in case of intensive rain (Visit http://tredjenatur.dk/portfolio/indre-by-skybrudsplan/ for more graphical illustrations).

Summary and discussion

The nature of storm-water management in the two compared cities is completely different. In Malmö, many large-scale open storm-water handling implementations (over 20 facilities) are already present in forms such as ponds, wetlands, swales, canals, detention lakes, green roofs, etc. while there is only one large-scale project realized in Copenhagen (Ørestad). The current inter-

Figure 6. *Open storm water handling solution suggested for Sønder Boulevard in Copenhagen (illustration by Copenhagen municipality). Pictures are adopted from Jørgenssen (2013) with permisson.*

organizational cooperation framework in Malmö owes a lot to Peter Stahre. In other words the existing full-scale implementations of open systems in Malmö can more or less be accredited as Peter Stahre's heritage. The City of Malmö has generated a storm-water policy (Dagvattenstrategi för Malmö, 2008) in which responsibilities of different departments, classification of different recipients according to their sensitivity to high flow/pollution, as well as different sources of pollution in storm water are addressed. This means that the administrative framework for alleviation of storm water in Malmö already exists while an in-depth evaluation of the existing system and its behavior in case of different scenarios for extreme storm events in Malmö as well as its probable consequences needs to be studied.

Improvement of harbor water quality to make it suitable for bathing and recreation has been the main ambition and driving force for wastewater management (including storm water) in the city of Copenhagen for over two decades until the extreme rain event on the 2nd of July 2011 which influenced the concept of management fundamentally. Comparing the evolution of the two cities regarding storm-water plans it can be observed that most of the large-scale projects in Malmö are fulfilled in the suburbs of the city while a substantial adaptation plan has neither been implemented nor planned for the inner city areas. Copenhagen, on the other hand, has studied the most vulnerable areas of the city and concentrated on rehabilitating the system by implementation of a holistic approach including all different actors such as utilities, municipalities and public. Quick transport of storm water to the sea by a network of roads, canals and subterranean tunnels, storage of storm water on open areas, sport fields, parks as well as multipurpose streets has all been mentioned as possible solutions in the Cloudburst Management Plan in Copenhagen. Adoption of such an approach requires active engagement of different city actors, as well as legal adaptations. However, inter-organizational cooperation has not been practiced in reality in Copenhagen yet as lack of mutual understanding as well as a framework of responsibilities and contributions were found to be major hurdles on the way of implementation of new techniques, as told in Malmö's experience.

Conclusions

The two cities, despite similar climates, have chosen two different approaches towards management of storm water. Copenhagen has remained loyal to the pipe-bound system while Malmö has gradually shifted towards open solutions and further implementation of Best Management Practices. The history of the concerns and problems plays an important role in adoption of the storm-water handling systems. The extreme flood that took place on the 2nd of July 2011 has obviously changed the Danish angle of view so that they are determined to take serious steps in adaptation of the densely constructed parts of Copenhagen for an effective storm-water management. In Malmö, various implementations of Best Management Practices can be observed mostly in the suburbs tackling the handling of the storm water according to the current design criteria. Considering the Three Points Approach (3PA) it might be concluded that the city actors in Copenhagen during the last years have concentrated on solving the problems associated with extreme rain (Point 2); while design rain (Point 1) and maintenance of the system for little rain (Point 3) have been more underlined in Malmö.

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