# Pluvial urban flooding in a densified Sweden

## Do sustainable flood management and densification fit together?

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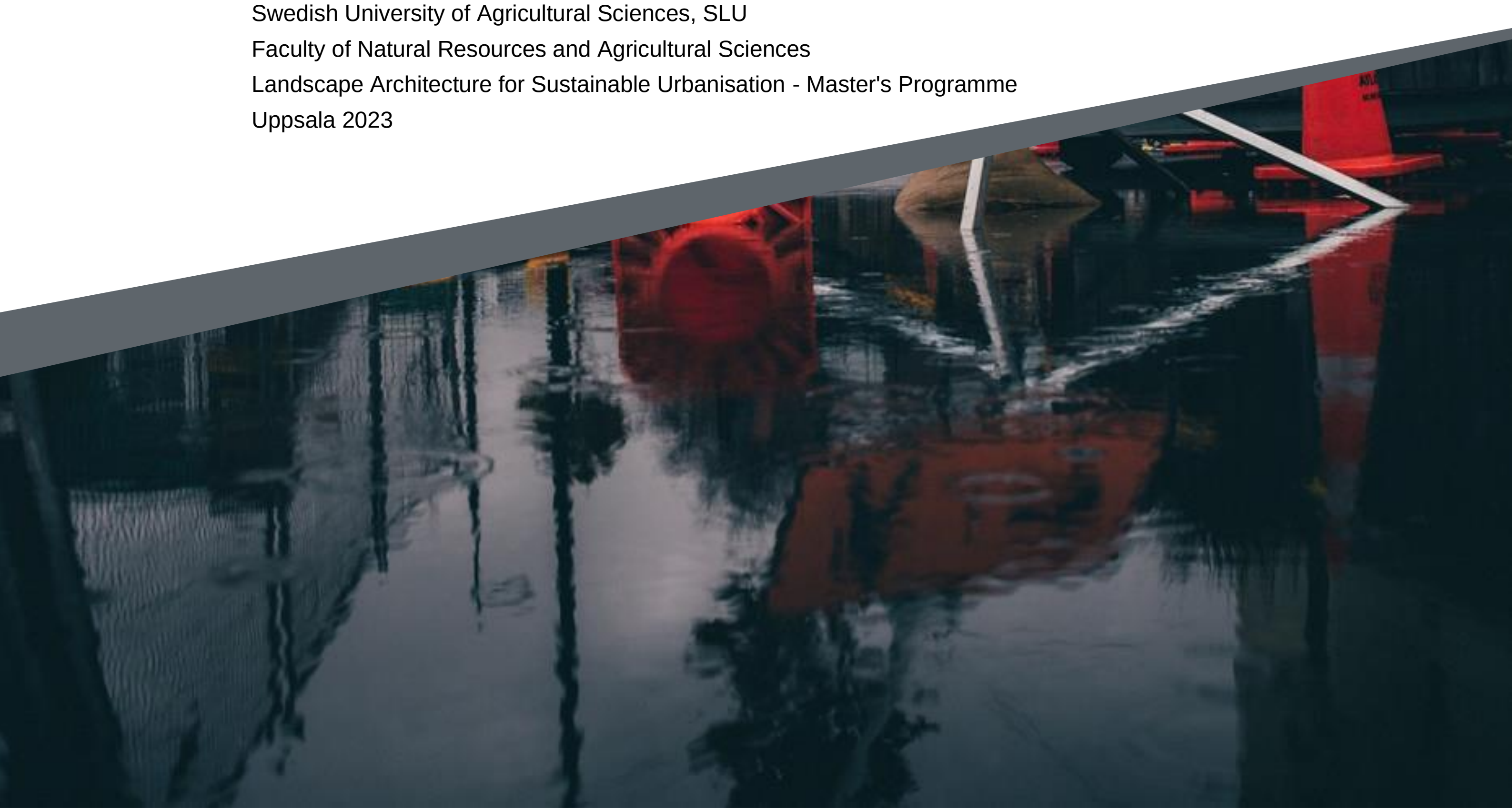
Independent project • 30 credits
Swedish University of Agricultural Sciences, SLU
Faculty of Natural Resources and Agricultural Sciences
Landscape Architecture for Sustainable Urbanisation - Master's Programme
Uppsala 2023



# Pluvial urban flooding in a densified Sweden. Do sustainable flood management and densification fit together?

*Pluviala urbana översvämningar i ett förtätat Sverige. Går hållbar översvämningshantering ihop med förtätning?*

Helena Arro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|---|---|
| **Credits:** | 30 credits |
| **Level:** | Second cycle, A2E |
| **Course title:** | Independent Project in Landscape Architecture, A2E – Landscape Architecture for Sustainable Urbanisation – Master’s Programme |
| **Course code:** | EX0945 |
| **Programme/education:** | Landscape Architecture for Sustainable Urbanisation - Master's Programme |
| **Course coordinating dept:** | Department of Urban and Rural Development |
| **Place of publication:** | Uppsala |
| **Year of publication:** | 2023 |
| **Cover picture:** | Casey Horner (2018). Flooding in Christchurch, New Zealand. [photograph]. https://unsplash.com/photos/xcd6DseGyZo (Unsplash Licence, Free to Use). [2023-05-08] |
| **Copyright:** | All featured images are used with permission from the copyright owner. Images for which nothing else is stated belong to the author. |
| **Online publication:** | https://stud.epsilon.slu.se |
| **Keywords:** | urban flooding, pluvial urban flooding, sustainable urban flood management, technological fix, densification |


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## Abstract

Pluvial urban flooding occurs in many parts of the world, including Sweden, often with severe consequences. Climate change and increased urbanization exacerbate the risk of urban flooding, and traditional urban drainage systems are unable to keep up. Alternate solutions utilizing green infrastructure have thus emerged to manage flooding in more sustainable ways. At the same time, a popular planning strategy for urban growth is densification, which can potentially put these sustainable systems at risk. Despite this apparent contradiction between sustainability in urban flood management strategies and densification, the aim is evidently to include both in the same urban landscape. This contradiction is explored in this thesis, through an investigation into Sweden's national and municipal strategies for urban flood management. An analysis of these strategies is then made with the concept of the technological fix, to discuss whether or not technical solutions are used to bypass other necessary solutions for urban flood management. It was found that Sweden has a number of national laws and guidelines pertaining to flooding, as well as a national strategy for climate adaptation. Investigating the municipalities of Malmö and Uppsala yielded rain gardens, limiting hard surfaces, and multifunctional areas designed to handle flooding and retain water as strategies used on a municipal level in Sweden. Furthermore, it was shown that both municipalities also aim for further urban growth through densification, since housing needs to be provided for their growing populations. While sustainable solutions have the potential to effectively manage flooding, they could still be considered technological fixes in that they are seemingly used to ensure the possibility of continued urbanization, without requiring society to really change. On the other hand, the increased implementation of nature-based solutions could be considered as steps towards a societal change regarding how cities are planned and how resilient or adaptable they are. Though densification has its downsides, other forms of urban planning strategies do as well, and until a better alternative has potentially been devised, the desire for densification is unlikely to abate. Thus, even if sustainable solutions for flood management are used as technological fixes, it is still vital to include them in densification projects since they are necessary to meet current and future demands for protection against pluvial urban flooding.



*Keywords:* urban flooding, pluvial urban flooding, sustainable urban flood management, technological fix, densification

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# 1. Introduction

Pluvial urban flooding is experienced in many parts of the world (O'Donnel & Thorne 2020), and reports have shown that the number of locations where it occurs has increased (Schmitt & Scheid 2019). This increase is, in large part, caused by climate change, as higher temperatures bring about more frequent occurrences of extreme precipitation (O'Donnel & Thorne 2020; Caretta et al. 2022). Increased urbanization is another factor that exacerbates urban flooding, as is aging and deteriorating infrastructure related to urban water management (Doeffinger & Rubinyi 2022).

Sweden, a country otherwise relatively spared from extreme weather events, has seen several urban floods caused by heavy rainfall or rapidly melting snow in recent years (SMHI 2022a). These events can have dire consequences, such as mental trauma, injuries, and deaths (Jha et al. 2012), along with damages to infrastructure such as roads and buildings (Schmitt & Scheid 2019). Moreover, floods typically turn out incredibly costly for society. A pluvial flooding that occurred in Malmö 2014 due to extreme rain cost the municipality around 600 million Swedish crowns (Malmö stad 2017). Another cloudburst and subsequent pluvial flooding in Gävle 2021 caused damages for circa 300 million Swedish crowns for the municipality, while the cost for the insurance companies amounted to 1.1 billion Swedish crowns (Bederoff 2023).

These events are examples of major floods with significant impacts, but minor flooding events in urban areas can cause disturbances as well, such as flooded basements (Svenskt Vatten 2007) or fully or semi-blocked transportation networks that may impede emergency services (Yu et al. 2020). Evidently, pluvial urban flooding is a highly relevant issue on several levels regardless of the scale of the event, and it needs to be considered in urban planning and landscape architecture in Sweden. Since gray infrastructure is inflexible and therefore unable to adapt to changing parameters (Jha et al. 2012; Wagner & Breil 2013), other ways to manage flooding are needed. As a result, sustainable systems utilizing natural processes are increasingly considered beneficial alternatives to traditional urban drainage systems (Huang et al. 2020). However, these solutions often rely on green infrastructure and the permeability of the urban ground cover (Stahre 2008; Rosenberger et al. 2021), both of which are potentially at risk when cities and municipalities wish to grow. This wish to grow is accommodated in the strategy of urban densification, which is an increasingly popular urban planning strategy for a growing population (Erlwein et al. 2023). Although densification is typically considered a sustainable strategy (Lin et al. 2015; Kaur et al. 2022), it has also been shown that it can result in the removal of green spaces and an increase in impermeable surfaces (Haaland & van den Bosch 2015; Rosenberger et al. 2021).

Following this, the densification of urban areas appears to stand in direct opposition to sustainable flood management strategies, and yet they are expected to coexist within the same urban landscape. It is possible that sustainable solutions are used as 'technological fixes' to facilitate this coexistence, in an attempt to reduce the complex problem of urban flooding to a more manageable one which only needs technology to be solved (Oelschlaeger 1979). This thesis aims to explore and discuss this apparent contradiction between densification and sustainability solutions, to see if there actually is room for sustainable strategies against urban flooding in Sweden's densification strategies.

## 1.1 Purpose

The purpose of this thesis is to identify and discuss problematic aspects of Sweden's strategies for the management of pluvial urban flooding, specifically in the context of sustainability and Sweden's densification strategies.

## 1.2 Research questions

The following research questions were formulated to guide the work, and to fulfill the purpose for this thesis:

1. What are Sweden's strategies – on a national and municipal level – for the prevention and mitigation of pluvial urban flooding?
2. How can the relationship between sustainability and densification in these strategies be understood with the help of the concept of the technological fix?

In order to answer the first research question, an investigation into empirical material for Swedish pluvial urban flood management is necessary. The second research question forms the basis for the analytical frame used when analyzing the found material. A further explanation on the methodology, and on the concepts of densification and the technological fix, is presented in chapter 2.

## 1.3 Delimitations

Since the focus of this thesis is urban flooding and ways to manage it in Sweden, the general geographical area of study is limited to this country. On a more detailed level, the geographical area of study is limited to the two municipalities of Malmö and Uppsala. These municipalities were chosen because they have experienced more or less severe urban flooding because of cloudbursts within the last 10 years, which is also a time frame that most documents regarding municipal strategies have been found to fit within. This therefore sets the basis for the temporal limitation for this thesis. However, this particular limitation is flexible. Since some concepts, regulations, and documents are older than 10 years, even if they may have later been revised, setting a strict temporal limitation becomes somewhat contrived and does not provide any particular benefits to the investigation.

Furthermore, the type of flooding investigated in this thesis is limited to pluvial flooding, which is flooding that occurs when urban drainage systems are unable to fully evacuate the water after intense precipitation (Jha et al. 2012). Other types of flooding such as fluvial, i.e. flooding as a result of rivers overflowing after heavy rain (Houston et al. 2011), are not investigated in this thesis.

# 2. Methodology, material, and theoretical perspectives

## 2.1 Document analysis

The main form of research was the study of documents, scientific articles, reports, books, and other existing material. Listed below (figure 1) is the empirical material specific for Sweden, which was analyzed in order to fulfill the purpose and answer the research questions for this thesis.

**Articles, books, other documents**

- Ahlman (2011)
- Bengtsson (2008)
- Fridell et al. (2020)
- Haghighatafshar (2014)
- Haghighatafshar et al. (2018)
- Hernebring (2006)
- Hernebring et al. (2017)
- Qiao et al. (2019)
- Stahre (2008)

**Laws & national guidelines**

- MSB et al. (2017)
- SFS 2003:778
- SFS 2006:412
- SFS 2009:956
- SFS 2010:900
- Westlin et al. (2012)

**Municipal & county documents**

- Karlsson & Larsson (2022), water plan for Uppsala County
- Länsstyrelsen Uppsala (2021), risk management plan
- Malmö stad (2017), cloudburst plan
- Malmö stad (2018), comprehensive plan
- Uppsala municipality (2016), comprehensive plan
- Uppsala municipality (2022b), environment & climate program
- Öman & Gustavsson (2022), climate analysis for Uppsala

**Newspapers & websites**

- Boverket
- Dagens Industri
- Länsstyrelsen Uppsala
- Malmö stad
- Miljöbarometern
- Uppsala municipality
- Uppsala Nya Tidning
- VISS

*Figure 1. Empirical material specific for Sweden. See the reference list for more details.*

On a national level, the investigation was done in order to find out whether there is any national framework that cites specific procedures or measures that must be followed or executed to prevent or mitigate pluvial urban flooding. This was also tied to the existence of any national law that regulates which actors should be responsible – and in what way – during and after a cloudburst event. Some Swedish laws reference and are based on EU regulations, but due to the time limit and for the sake of keeping the focus on Sweden, these regulations have not been studied for this thesis.

As for Sweden's strategies on a municipal level, they were investigated both in order to find out how municipalities might handle any potential responsibilities given to them by Swedish law, and to study concrete strategies on a more detailed level. Pluvial urban flooding due to cloudburst events, even if it happens over a large area, still happens on a local scale rather than on a national, and it is plausible to assume that municipalities have developed their own plans and systems for how to deal with it.

### 2.1.1 Municipal study areas

As part of the document analysis, studies of two Swedish municipalities were conducted. Although not termed 'cases', these studies do follow Lund's (2014) definition of 'case study' as a part of empirical reality that has been edited to privilege certain aspects in order to organize knowledge so it becomes manageable. As such, these studies are not exhaustive and do not cover all available information about the municipalities, but focus specifically on urban flood management strategies and densification strategies. Since this thesis focuses specifically on pluvial flooding and not fluvial flooding, as described previously, the investigation into the flood management strategies of the chosen municipalities will mainly concern information relevant to pluvial flooding.

*Malmö*

Malmö municipality – called Malmö stad (i.e. Malmö city) in Swedish – was chosen as a study area for municipal strategies because the city has a long tradition of working with sustainable urban trainage systems (Stahre 2008). The concept of sustainable urban drainage was introduced early in Malmö through various projects such as 'Toftanäs Wetland Park' from 1989–1990 (Stahre 2008) and the Augustenborg district from 1997 (Haghighatafshar et al. 2018; Qiao et al. 2021), and continues to be implemented in newer projects, such as the Hyllie stormwater park, which was inaugurated in 2020 (Malmö stad 2021). Malmö has therefore become one of the leading cities in Sweden when it comes to the use of sustainable urban drainage (Haghighatafshar 2014), making it a highly relevant area to study for this thesis.

*Uppsala*

Uppsala municipality was chosen as a study area for municipal strategies because there are innovative technological and green-blue solutions for urban drainage and flood management currently being tried in new development projects there (Uppsala municipality 2022b). One such project is Rosendal (Uppsala municipality 2022b), which was why this area was investigated in more detail. Studying Rosendal also provided an opportunity to look into how Uppsala's flood management strategies are currently applied in practice. Furthermore, from my own experience as a born resident of Uppsala, sustainable urban drainage does not seem to have been given as much focus in historic city planning in Uppsala as it has been in Malmö, despite the fact that the Fyrisån river and Uppsala itself have been shown to be at risk of flooding (Länsstyrelsen Uppsala 2021). This made it an interesting municipality to study in comparison to Malmö.

### 2.1.2 Interview

An interview with an employee at Uppsala municipality, who works as a project manager for the Rosendal project, was conducted on 2023-04-05, in order to better understand how municipal strategies may be applied in practice. The interview was held via Zoom and lasted approximately one hour. Questions were prepared in advance, with follow-up questions being asked as the interview proceeded. See Appendix 1 for a guide to all interview questions.

## 2.2 Analytical frame

Documents and other empirical material were analyzed through the lens of two concepts: the technological fix and urban densification. As described previously, the purpose of this thesis is to identify and discuss problematic aspects of Sweden's strategies against pluvial urban flooding. For the sake of keeping the investigation and analysis within reasonable limits, these 'problematic aspects' were decided to be issues relating to sustainability. In particular, the relationship between sustainability and densification was to be considered, since densification is a common strategy within urban planning that, while considered positive for the environment in some ways (Lin et al. 2015; Kaur et al. 2022; Erlwein et al. 2023), has been proven to often result in certain negative environmental impacts as well (Haaland & van den Bosch 2015; Rosenberger et al. 2021). The concept of the technological fix was used as a conceptual tool to explore this relationship between sustainability and densification.

Also considered in the analysis of Sweden's strategies was the concept of resilience, which is a system's capacity to adapt to disturbances or change (Ahern 2011).

Urban adaptability – the capacity of an urban area to adapt its physical spaces to various changes (Tsahor et al. 2023) – is another concept that can be used when discussing the potential benefits of flood management systems, but it was not considered in-depth for this thesis.

From this, the analytical frame was formed, with the aim of facilitating a discussion on the potential difficulties for sustainable pluvial flood management strategies to coexist with strategies and plans for densification.

### 2.2.1 The technological fix

> In short, technology networks are the carriers of goods and services that promise to deliver the modernist dream for a happier, better society . . . This is exactly where the fetishization of urban technology networks dwells: in being carriers of the modernist promise of participating in the phantasmagoric new world of technological advancement and progress; a world in which human freedom and emancipation resides in connecting to technology. (Kaika 2005:33)

The term 'technological fix' was first coined in 1965 by Alvin Weinberg – a technologist, essayist, and government consultant – and is a label for the idea that engineering or technology can be used to circumvent problems that would typically be considered to be cultural, political, or social, and for which the solutions would also lie in those realms (Johnston 2018). Weinberg argued that "cheap technological fixes" could be superior to social solutions, and that they are easier to put into use than social inventions (Johnston 2018). One idea Weinberg had of a technological fix early on concerned violent riots – specifically the Watts riots in 1965 – for which Weinberg suggested an engineering solution of using "anti-poverty funds" to install air-condition in poor areas, which would lessen the discomfort of the residents and thereby making them less inclined to go outside and participate in the riots (Johnston 2018:163). This is a clear example of using technology in an attempt to circumvent a problem; the underlying reasons for the problem are not solved, but the aim is that the technology can, at least partly, soothe the situation nonetheless.

Johnston (2018) writes that even though the technological fix as a concept garnered support from Weinberg's contemporaries, it was also critiqued. Since Weinberg dismissed social and humanistic solutions in favor of technical ones, many who advocated solutions from these fields opposed his ideas, with some arguing that technological fixes need to be complemented with social interventions for them to be fully successful (Johnston 2018).

Oelschlaeger (1979) concedes that technology is often an important, or even necessary part of the work with solving social problems, but asserts that technology on its own is not enough as a solution. He claims that part of the "appeal" of the technological fix "lies in an assumption that complex social problems can be reduced to simpler and more manageable technical ones" (Oelschlaeger 1979:46). This assumption becomes problematic when technology itself is part of a problem, which Oelschlaeger (1979) claims is often the case, even if that problem is of a social nature. He also criticizes the idea that the existence of a technological fix means that non-technical aspects of a problem, such as ethical, economic, or political, can be ignored (Oelschlaeger 1979).

According to Swyngedouw et al. (2002), various technological fixes are part of the management of water within urban spaces, particularly with the aim of reducing water consumption for the sake of environmental sustainability. It thus stands to reason that the concept of the technological fix can be applied specifically to urban flood management as well – particularly since urban water has been largely commodified (Swyngedouw et al. 2002) yet also remains a threat which needs to be removed from our cities (Kaika 2005). Technologies aiming to be environmentally friendly in one area might still negatively impact the environment in other areas, for example when it comes to the process in which they are produced (Swyngedouw et al. 2002; Swyngedouw 2010). Evidently, it is not so easy to deem a technological fix entirely beneficial for the environment, even if that is its goal.

### 2.2.2 Urban densification

> Environmental problems . . . are directly linked to urbanization and to the function of cities. Whether we consider water, energy, food or clean air, socio-environmental issues are city-centric, and their unpredictability exemplifies the fallacy of the myth of the perfectly managed city. (Kaika 2005:49).

Within the context of urban planning, densification is a strategy that aims to limit urban sprawl – that is, the outwards expansion of an urban area – by furthering exploitation within already built-up areas (Rosenberger et al. 2021). It is an approach that is now commonly used in order to avoid the loss of agricultural land and other natural resources that urban sprawl might entail (Erlwein et al. 2023), as well as to make sure that a city's population is able to easily reach urban amenities such as public transport and employment opportunities (Lin et al. 2015).

As summarized by Haaland & van den Bosch (2015), densifying a city, either in the suburbs or in more central parts, can involve building on previously undeveloped areas existing between built-up areas , i.e. infill, or repurposing areas that are no longer used for their original purpose, such as old industrial sites. Existing buildings can also be expanded or replaced with taller buildings (Haaland & van den Bosch 2015).

Densification is commonly considered a sustainable strategy for urban development (Kaur et al. 2022); however, it does not come without certain negative consequences, both environmental and societal (Haaland & van den Bosch 2015). The removal of green spaces during densification processes and the ensuing lack of green infrastructure are two such consequences that have become increasingly evident (Haaland & van den Bosch 2015; Rosenberger et al. 2021; Erlwein et al. 2023). Reducing green spaces and replacing them with impervious surfaces puts further strain on existing underground water infrastructure (Kaur et al. 2022) due to the lessened possibilities for rain to infiltrate into the ground and the increased surface runoff that reaches the drainage systems (Rosenberger et al. 2021).

Since green infrastructure is an effective way to manage the urban climate, reducing green spaces also causes a rise in urban temperatures (Lin et al. 2015; Erlwein et al. 2023), but this particular issue is outside the scope of this thesis and has not been further studied. It is, however, worth noting that this does have a certain relevancy to the issue of urban flooding, since rising temperatures increase the frequency of storms and cloudbursts (United Nations n.d.), and efforts to prevent temperatures from rising further can be considered as part of preventative measures against pluvial flooding in general.

# 3. Urban flooding and ways to manage it

Flooding can occur when rivers overflow after heavy or prolonged rainfall, i.e. fluvial flooding, or due to rising water levels or storms at the coast (Houston et al. 2011). Another type of flooding is pluvial flooding, which can occur in urban areas when precipitation is so intense that the drainage system is incapable of fully leading away the water, thereby causing water to remain on impermeable surfaces (Houston et al. 2011; Jha et al. 2012). This thesis focuses specifically on pluvial urban flooding, and the other types of flooding mentioned above – or strategies specifically meant to manage those types of flooding – are not studied.

## 3.1 Causes and consequences

Extreme precipitation is one consequence of climate change: rising temperatures cause more frequent occurrences of heavy rainfall alongside intense storms (United Nations n.d.; Caretta et al. 2022). In Europe, there were several instances of extreme precipitation and subsequent flooding events during 2021 (WMO 2022). Belgium and Germany experienced particularly severe floods, but other countries such as Switzerland, France, and the Netherlands were also affected (WMO 2022). Evidently, it has been shown that there is a clear correlation between climate change and an increased risk of pluvial urban flooding (O'Donnel & Thorne 2020).

Urbanization is another factor, apart from increased precipitation, that increases the risk of pluvial urban flooding (Bertilsson et al. 2018; O'Donnel & Thorne 2020; Doeffinger & Rubinyi 2022). In natural areas, much of the surface is permeable and water can infiltrate into the ground. Urbanization as well as the densification of cities typically involve green areas being replaced with hard surfaces, which leads to fewer possibilities for water to infiltrate into the ground, and fewer areas where excessive runoff can be managed (Jha et al. 2012; MSB et al. 2017; Rosenberger et al. 2021). The large amount of hard surfaces in urban areas also brings about a more rapid runoff process than in natural ones (Hernebring & Mårtensson 2013), thereby creating a faster buildup of peaks and flows and increasing the risk of pluvial flooding (Jha et al. 2012). To lead runoff away, there is infrastructure such as pipes and open dikes in place in urban areas, but these stormwater systems have a limited capacity (MSB et al. 2017). If this capacity is exceeded there will be nowhere for the runoff to go, and the area will flood.

In addition to climate change and increased urbanization and densification, the problem of pluvial urban flooding is exacerbated by aging and deteriorating infrastructure (Doeffinger & Rubinyi 2022). Some types of older water management systems have a combined system for stormwater and wastewater; in Sweden, this was the dominant system up until the 1950s (Svenskt Vatten 2007). Stormwater is water from precipitation, including meltwater from snow; wastewater is polluted water from various processes such as domestic and industrial, and needs to be cleaned before reaching a recipient water body (Klimatanpassning.se 2022). Basements in areas with a combined system are particularly vulnerable to being flooded (Svenskt Vatten 2007). Furthermore, if a combined drainage system is overwhelmed because of extreme rain, untreated wastewater might reach the surface and result in an urban flood that is hazardous to human health, not just because of the water itself but also because of the pollutants within the water (Houston et al. 2011).

Apart from the health hazards of flooded combined drainage systems, pluvial urban flooding has a number of negative consequences that can range from mild to severe, depending on the situation. Flooding can cause physical injuries or deaths, as well as mental trauma with subsequent psychological issues, such as anxiety or depression (Jha et al. 2012). Damages to buildings, roads, and other types of infrastructure are other possible consequences (Schmitt & Scheid 2019), which in turn can lead to people losing their homes or other material belongings (Jha et al. 2012). Other, less severe consequences include basements being flooded (Svenskt Vatten 2007) or transportation networks being partly or fully blocked by water, which may disrupt emergency services (Yu et al. 2020) or otherwise inconvenience the inhabitants in a city, for example if they need to cross a flooded road.

## 3.2 Structural and non-structural flood management

Jha et al. (2012) write that measures for managing flooding are customarily divided into so-called ‘structural’ and ‘non-structural’ measures. These are meant to complement each other, with structural measures seeking to control how the water flows, whereas non-structural measures aim to spread awareness and protect people from flooding through the use of urban planning and management (Jha et al. 2012). Both artificial solutions – referred to by the authors as “hard-engineered structures” such as drainage channels, and more natural ones such as wetlands, are included in the definition of structural measures (Jha et al. 2012). Included in non-structural measures are: avoiding flooding through land use planning; planning and managing emergencies, for example via flood warning systems; increasing awareness and the level of preparation; and improving the design and construction of buildings to speed up recovery after floods and increase resilience (Jha et al. 2012).

From this, it can be argued that all structural measures, regardless of whether they are 'hard-engineered' or more natural, have the potential to be characterized as technological fixes. That is, if natural measures relying on green infrastructure can be considered as technical, which could potentially be a question that inspires contention. Within urban areas, green-blue infrastructure for managing flooding is often engineered or regulated in some way, with rain gardens, green roofs, or artificial ponds as examples, which is clearly shown by the technical drawings and descriptions for how to construct these types of systems presented by Fridell et al. (2020). This supports the argument that natural measures can be considered technical and therefore possible to characterize as technical fixes, and it is the viewpoint used in this thesis.

Conversely, measures categorized as non-structural evidently focus more on social solutions and the idea of raising resilience against flooding through urban planning, which arguably puts them outside the realm of technological fixes. Jha et al. (2012) also touch upon the potential difficulties involved with non-structural measures compared to the apparent simplicity of structural ones:

> The challenge with many non-structural measures lies in the need to engage the involvement and agreement of stakeholders and their institutions. This includes sometimes maintaining resources, awareness and preparedness over decades without a flood event, bearing in mind that the memory of disaster tends to weaken over time. This challenge is also made greater by the fact that most non-structural measures are designed to minimize but not prevent damage, and therefore most people would instinctively prefer a structural measure. (Jha et al. 2012:33)

This mirrors Weinberg's claims about social solutions being more difficult to implement than purely technical ones (Jonhston 2018), and shows why people in general might be more perceptive towards measures that have clear technical characteristics. Even so, Jha et al. (2012) argue that non-structural measures are necessary since structural ones can never reduce the risk of flooding completely: they will always be limited by their design capacity and can be overwhelmed by events that exceed it. Furthermore, it is noted that some structural measures may reduce the risk of flooding in one area while increasing it somewhere else, and since they aim to control and redirect water they often have an impact on the environment as well (Jha et al. 2012). Since technological fixes aiming to be environmentally sustainable in one field might negatively affect the environment in other fields (Swyngedouw et al. (2002; Swyngedouw 2010), it would be appropriate to apply the term to these types of measures that solve one problem in exchange for creating another.

Unlike the similarities described above regarding the difficulties associated with non-structural measures, there is a clear difference between Weinberg's views, as described by Jonhston (2018), and the views of Jha et al. (2012) when it comes to the economical aspect of technical versus non-technical solutions. Weinberg claimed that social solutions are often expensive whereas technological fixes are cheap, and he maintained that this was yet another factor that supported his idea that technological fixes were superior (Jonhston 2018). Jha et al. (2012) assert the opposite, writing that non-structural measures typically do not have a very high upfront cost, while structural measures often do. Weinberg's view in this matter could be attributed to his strong faith in the possibilities of technology, whereas Jha et al. (2012) represent a more skeptical – and possibly realistic – view of what technology can actually accomplish on its own. Small-scale technical solutions might be quite cheap, but if a solution is to be implemented on a larger scale it might become considerably more expensive – although the exact cost would, of course, vary depending on the situation.

Regardless of whether a structural measure is meant to be sustainable or not, its base function is still to control the flow of water (Jha et al. 2012). In Western countries, efforts to create an ordered city often include attempts to control or subjugate nature (Kaika 2005), and structural measures can clearly be connected to this. Mathur and da Cunha (2015) criticize this view of nature as something expected to adhere to the arbitrary rules and limits set for it by human society. Nature becomes a "visitor" rather than a "resident" in spaces where it is not wanted (Mathur & da Cunha 2015). Non-structural measures for flood management could potentially be used to move away from this mindset, since they involve society adapting to the water, rather than the water being forced to adapt to society.

## 3.3 Sustainable flood management

As described, structural measures aim to control the flow of water, and can be both artificial and natural (Jha et al. 2012). It is becoming increasingly clear that traditional, human-engineered systems only utilizing gray infrastructure are not capable of managing an elevated risk of pluvial urban flooding caused by climate change and continued urbanization. Gray infrastructure has precisely defined parameters and is inflexible; it is unable to adapt to change and can therefore be overwhelmed by events exceeding the limits of its design (Jha et al. 2012; Wagner & Breil 2013). Additionally, the traditional urban drainage systems are often not able to keep up with the rapid urbanization happening in many areas (Huang et al. 2020), and further expansion of these systems can often be very expensive (MSB et al. 2017). Thus, it becomes necessary to consider other ways to prevent and mitigate pluvial urban flooding.

Various sustainable solutions aiming to create and restore ecosystem services in urban areas have emerged as alternatives to traditional, hard-engineered drainage systems (Huang et al. 2020). These solutions can be described using several different terms, such as water sensitive urban design (WSUD) and sustainable urban drainage systems (SUDS) (Liu & Bergen 2018). As summarized by Haase et al. (2014), a common way to classify ecosystem services within an urban context is to divide them into four categories: regulation, provisioning, cultural, and supporting or habitat services. When it comes to pluvial urban flood management specifically, the category providing regulation services is particularly interesting; these services maintain functions relating to the control of stormwater and flooding, among other things (Haase et al. 2014).

### 3.3.1 Green infrastructure and nature-based solutions

*Figure 2. Permeable pavement at Greenfield City Hall, Greenfield, Wisconsin, USA (Aaron Volkening 2014). (CC BY 2.0)*

*Figure 3. Rain garden in Rosendal, Uppsala, Sweden.*

*Figure 4. Green roof at USIF Arena in Rosendal, Uppsala, Sweden.*

Green infrastructure (GI), which is another way to refer to the natural processes providing ecosystem services in the urban landscape (Liu & Bergen 2018), can be utilized in so-called 'nature-based solutions' (NBS) to manage urban flooding (Maragno et al. 2018; Huang et al. 2020; Green et al. 2021). Permeable pavement, (figure 2), rain gardens (figure 3), and green roofs (figure 4) or walls are examples of systems utilizing green infrastructure and aiming to clean polluted water, reduce surface runoff, and improve water infiltration and retention (Huang et al. 2020; Rosenberger et al. 2021). These types of systems can also enhance an area visually and thereby promote local tourism, and are typically very cost-efficient (Huang et al. 2020). Furthermore, they strengthen urban resilience against flooding by decentralizing water management functions and improving biodiversity (Ahern 2011).

It has been shown that nature-based solutions have the potential to effectively lessen the strain on the traditional drainage system and mitigate flooding in urban areas (Green et al. 2021; Rosenberger et al. 2021). However, similarly to gray infrastructure, nature-based systems can also be overwhelmed by extreme precipitation (Maragno et al. 2018), and they cannot handle flood management completely on their own (Huang et al. 2020). Hence, a holistic approach involving a combination of gray infrastructure and nature-based solutions is necessary (Green et al. 2021).

### 3.3.2 Sustainable urban drainage in Sweden

In Sweden, Peter Stahre has had great influence when it comes to how sustainability in urban drainage systems is defined and approached, and his studies and writings on the subject are often cited (Haghighatafshar 2014). According to Stahre (2008), the main goal of urban drainage systems in Sweden before the 1970s was simply to quickly dispose of stormwater. During the 1970s, the focus shifted to the quality of the runoff instead due to growing concerns regarding the pollution in stormwater and how that might impact the receiving water (Stahre 2008). Then, in the 1900s, the idea of developing sustainable drainage systems came about (Stahre 2008).

Stahre (2008) writes that sustainable drainage in urban areas is commonly achieved by using what he refers to as 'partly open' or 'open' drainage systems, which are systems that utilize natural ways to manage rainwater. Some examples mentioned by Stahre (2008) are infiltration, slow drainage, and detention of water in wetlands or ponds. He divides the facilities of sustainable urban drainage into four categories (figure 5), which he calls "source control", "onsite control", "slow transport", and "downstream control" (Stahre 2008:8).

| Source control | Onsite control | Slow transport | Downstream control |
| --- | --- | --- | --- |
| Green roofs | Green filter strips | Canals | Lakes |
| Lawns | Permeable pavings | Creeks | Large ponds |
| Local ponds | Ponds | Ditches | Wetlands |
| Rain gardens | Rain gardens | Swales | |
| | Temporary flooding areas | | |

*Figure 5. Examples of systems in Stahre's (2008) four categories of sustainable urban drainage.*

*Stahre's categories and the analytical frame*

An analysis on whether the systems in Stahre's (2008) categories can be considered technological fixes, or on their connection with Sweden's densification strategies, would lack complexity without a specific urban context to put them in. That context comes with the investigation into the strategies of the chosen municipalities in chapter 4, and is therefore missing here. For this reason, an in-depth analysis using the analytical frame will not be attempted in this chapter. Instead, what follows is a brief overview of the systems, along with a reflection on how they might be affected by urban densification. Additionally, it is worth noting that the systems in these four categories all aim to control or manage the flow of water in some way; thus, according to the definition by Jha et al. (2012), they would all fall under the categorization of structural measures. This means that they at least have the potential to be characterized as technological fixes.

*Source control*

*Figure 6. Green roof at WIPO headquarters in Geneva, Switzerland (Emmanuel Berrod 2021) (CC BY-NC-ND 2.0)*

Systems in this category are described by Stahre (2008) as small-scale systems on private properties, such as green roofs (figure 6), rain gardens, or lawns, where water can infiltrate.

Since this category concerns private properties, it largely depends on the property owner’s wants and needs whether or not these types of green systems are at risk due to densification. It might be that a property owner will choose to build on a previously open green area for economic reasons, or choose not to have green roofs on their property for administrative reasons. Conversely, nature-based systems have a number of benefits (Huang et al. 2020) which might increase property value, and a property owner might choose to implement them for this reason.

*Onsite control*

*Figure 7. Water retention and seating at Tåsinge Plads in Copenhagen, Denmark (Gudrun Rabenius 2016).*

This category refers to small-scale systems on public properties which are thereby the responsibility of the municipality (Stahre 2008). These systems, like the ones defined as source control, include rain gardens and permeable pavement, with some additions such as areas designed to handle temporary flooding (Stahre 2008). An example of a multifunctional area for temporary flooding is Tåsinge Plads in Copenhagen, Denmark (figure 7), which provides both rainwater control and retention, as well as possibilities for recreation (Klimakvarter n.d.).

For this category, densification efforts might result in an increase in these types of systems. As the limitations of traditional gray drainage become progressively clearer (Wagner & Breil 2013), new development projects provide great opportunities for municipalities to try out new and more sustainable strategies for urban drainage and flood management.

*Slow transport*

*Figure 8. Bioswale and bioretention area in Greendale, Wisconsin, USA (Aaron Volkening 2009). (CC BY 2.0)*

These types of systems, as the name implies, transport stormwater within open drainage systems, such as swales (figure 8), canals, or ditches (Stahre 2008).

Within urban areas, these types of systems may already be heavily regulated due to previous urban expansion. Nevertheless, there is a possibility that further densification efforts would cause them to be constricted, or exchanged with gray infrastructure such as underground drainage pipes, to make more room for buildings.

*Downstream control*

*Figure 9. Clumber wetlands by the river Poulter near Nottinghamshire, England (David Dixon 2013). (CC BY 2.0)*

Downstream control refers to large-scale systems which detain water temporarily in the downstream parts of the sewage system, such as wetlands (figure 9) or lakes (Stahre 2008).

There is a high probability that these types of large-scale systems typically lie at the outskirts of an urban area, or even further outside of it, in which case they would be more threatened by urban sprawl, since densification involves growing a city inwards rather than outwards (Rosenberger et al. 2021).

## 3.4 Cloudbursts and pluvial urban flooding in Sweden

The Swedish Meteorological and Hydrological Institute (i.e. Sveriges meteorologiska och hydrologiska institute, SMHI) defines cloudbursts, or extreme short-time precipitation, as events when more than 50 millimeters of rain fall in an hour, or alternatively, more than one millimeter in one minute (SMHI 2021c). Worth pointing out is that there have been discussions among experts regarding how to best quantify cloudbursts, and whether or not SMHI’s definition should be revised (Olsson et al. 2017). Regardless, this is the current definition used in Sweden, and any discussion of potential revisions, needed or not, will not be attempted in this thesis.

Another important term used by SMHI in relation to precipitation is the so-called 'reapperance time' (SMHI 2021d). SMHI (2021d) describes this as a measurement of how often extreme nature events can be expected to appear; as an example, a rain event with a reappearance time of 100 years is so extreme that it is expected to only occur once every 100 years. This is necessary to consider when it comes to prevention measures against pluvial flooding in urban planning, since the dimensioning of the urban drainage systems plays a large part in how much water can reliably be evacuated from a city. If the infrastructure has been designed to withstand the amount of water from a 100 year rain without flooding, it should, at least in theory, be able to handle less heavy precipitation without much issue. However, the risk in this context is accumulative. Since the probability that an event described by a reappearance time occurs is 1 % each year, the risk will accumulate year by year until the expected appearance time is reached (Öman & Gustavsson 2022). This means that, for infrastructure designed for an event with the appearance time of 100 years, it is more likely that the construction will be exposed to values above the estimated 100 year value, than that such circumstances never happen during the construction's lifetime (Öman & Gustavsson 2022).

### 3.4.1 Towards a rainier Sweden?

As was established previously, it has been shown that many places, including most of Europe, experience increasingly intense precipitation as a result of climate change, and it is expected that this increase will continue (Caretta et al. 2022). This expectation is shared by an SMHI report written by Olsson and Foster (2013), in which climate model simulations were used to analyze short-term precipitation in Sweden. According to Olsson and Foster (2013), rains that last at least 30 minutes with a reappearance time of 10 years are expected to increase by "6 % from the years 1981-2010 to 2011-2049, 15 % to 2041-2070, and 23 % to 2071-2100". More recently published and updated Swedish references also align with this viewpoint: in a study by Olsson et al. (2017), the expectation is that the occurrence of cloudbursts will increase by 10-40 % depending on the situation and time horizon.

At the same time, the actual rainfall data in Sweden does not seem to indicate an increase in precipitation. Two studies by Hernebring (2006; 2008) that look at data from 15 municipalities as well as specifically Gothenburg, Malmö and Halmstad respectively, show that there is no trend towards increased occurrences of extreme precipitation in the observed areas. The study by Olsson et al. (2017) corroborates this despite the fact that the authors conclude that cloudbursts are expected to become more frequent in the future. During the years 1996-2017, there are no trends suggesting that cloudburst events have become more frequent (Olsson et al. 2017). Generally, there are higher values for precipitation in the southwest region of the country, but that is due to the fact that the warmer temperatures in the south naturally result in more frequent cloudbursts, and not because cloudbursts are more severe there (Olsson et al. 2017).

Nevertheless, the study by Olsson et al. (2017) also emphasizes that the period during which observations of short-term precipitation on a national level exist and were studied, i.e. 1996-2017, is too short for any final conclusions to be drawn. Thus, the fact that no discernible trends could be seen may, in part, be because of the short time period. Olsson et al. (2017) also assert that it is unclear whether or not the rise in temperatures before and during the study period was enough to actually have a clear effect on cloudbursts, and that any eventual distinct trends regarding extreme precipitation may not be possible to observe until the middle of the 21st century.

When considering these facts together with the described conclusions regarding increased precipitation, it seems plausible that, as is the case globally, there is indeed a trend towards more frequent and severe cloudburst events in Sweden as well. It would simply require a longer period of observation data than is currently available to be visible.

### 3.4.2 Implications

Clearly, the expectations are that Sweden's future will become rainier than before – and with increased precipitation comes an increased risk of pluvial flooding. Sweden has had several flood events in the past, both fluvial and pluvial (SMHI 2022a), and each year there are occurrences of extreme rainfall in various parts of the country (Ahlman 2011; Olsson et al. 2017; SMHI 2018). SMHI (2022a) has compiled a list of historical flood events that starts with the year 1596, in which most of the recorded floods are fluvial ones; however, urban pluvial floods have also been included, mainly when the consequences have been particularly dire. To manage the expectation that cloudbursts and pluvial urban flood events will become more frequent – and more severe – than before, Sweden has a number of both national and municipal strategies that involve the cooperation of Sweden's counties, municipalities, and national authorities. These strategies will be presented and analyzed in the coming chapters.

# 4. Sweden’s strategies for pluvial urban flood management

## 4.1 National strategies

From the investigations done for this thesis, it seems that Sweden has no national framework that describes specific measures that must be taken in the case of pluvial urban flooding events. There is, however, a national strategy for so-called ‘climate adaptation’, presented by the Swedish government in 2018, which aims to strengthen Sweden’s work with adapting the physical environment to the climate (Boverket 2022b). Extreme precipitation is cited by Boverket (2022b) as one of the risks of climate change that must be considered and adapted to in urban planning. To support and guide relevant actors when it comes to climate adaptation, a number of national agencies and authorities such as Boverket, the Swedish Civil Contingencies Agency (Myndigheten för samhällsskydd och beredskap, i.e. MSB), SMHI, and the County Administrative Boards were tasked by the Swedish government to coordinate the necessary knowledge and efforts (Boverket 2022b).

### 4.1.1 Legislation

In addition to the national strategy for climate adaptation, Sweden has a number of laws that regulate the responsibilities of both the counties and the municipalities regarding the management and protection of water. As a member country of the European Union, Sweden also has a responsibility to follow the European regulations for water management. Particularly interesting for this subject matter is the Directive (EG) 2007/60 of the European Parliament and of the Council on the assessment and management of flood risks; this directive describes regulations for how to manage the risks of flooding which the member states must have in common. However, as described in chapter 2, an in-depth investigation of EU regulations was not done for this thesis due to the time limit.

*Flood risk regulation (SFS 2009:956)*

This regulation (SFS 2009:956 1 §) aims to lessen the negative consequences of flooding, for the sake of the environment, human health, and cultural heritage, as well as for economic reasons. Among other things, stated in this law (SFS 2009:956 4-5 §) is that an assessment of the flood risks in each water district in Sweden should be done by MSB every sixth year. Based on MSB's assessment, all Swedish counties must produce a plan for how flood risks should be managed (SFS 2009:956 12 §).

*Law of protection against accidents (SFS 2003:778)*

This law (SFS 2003:778 1 c. 1 §) aims to grant protection against accidents suitable for the local conditions, for human health and lives, as well as properties and the environment. It is the municipality's responsibility to take preventative measures against accidents (SFS 2003:778 3 c. 1 §). It would be reasonable to consider the management of urban flooding as part of these preventative measures, even though this is not explicitly stated.

*Law of public water services (SFS 2006:412)*

This law (SFS 2006:412 1 §) aims to ensure that drainage and other types of water services are managed, if necessary to protect the environment or human health. A revision by the government in 2022 introduced 6 a-d §, which were implemented on 2023-01-01. Summarized, the revised law (SFS 2006:412 6 §) states that the municipality must have an up-to-date plan for water services which, among other things, should contain the municipality's assessment for what measures should be taken in order to ensure that the public water and sewage facilities remain functional during cloudbursts. Moreover, the municipality is responsible for providing water and drainage services (SFS 2006:412 6 §), which, of course, connects to the issue of draining enough water to prevent flooding during heavy precipitation.

*Planning and Building Act (SFS 2010:900)*

This law (SFS 2010:900 1 c.) regulates the planning of physical environments, including land and water, on a municipal level. Consideration should be taken during planning in regards to the risk of flooding, as well as other matters such as human health and safety (SFS 2010:900 2 c. 5 §). Also stated is that the comprehensive plan must show the municipality's views on damages caused by flooding and other climate-related disasters, as well as how such risks can be avoided or mitigated (SFS 2010:900 4 c. 5 §).

### 4.1.2 Guidelines

In 2012, the County Administrative Boards of Sweden collectively released a document on implementing climate adaptation in the planning of physical environments (Westlin et al. 2012). The report itself is not legally binding, but it is meant to provide guidance and support to Sweden's municipalities in how climate change should be taken into consideration during the urban planning process, and this is to be done in accordance with current legislation (Westlin et al. 2012).

Another document meant to guide municipalities in their work with preparing for and managing the consequences of cloudbursts was made by MSB et al. (2017). MSB et al. (2017) argue that, while climate change and densification increase the risk of pluvial urban flooding, Sweden's cities can be adapted to both current and future cloudbursts through long-term preventative efforts. According to this report, it is near impossible to fully prevent urban flooding merely by expanding the capacity of urban drainage systems, and if it were to be attempted, it would end up being unreasonably expensive (MSB et al. 2017). For that reason, the 'best' strategy against urban flooding is described as creating areas that can withstand flooding without suffering too severe consequences, and then leading the water there (MSB et al. 2017).

## 4.2 Acceptance as a management strategy?

Evidently, while there are clear efforts on a national scale to make sure that Sweden is prepared for pluvial urban flooding, it is considered difficult to completely prevent such events from occurring, at least through technical means. Hence the recommendation by MSB et al. (2017) to include specific areas which are allowed to flood in the planning of a city. However, if the presumably most successful flood management strategy is to lead the water to areas where the consequences of a pluvial flood event are not so severe, it becomes prudent to consider what consequences should be deemed acceptable. Even if an area is specifically designed to handle flooding, it seems reasonable to imagine that a pluvial flood event might still cause some damage. Such damage would then need to be repaired, which has more or less severe economic implications depending on the type and amount of damage. Still, the cost of damages to surrounding, more vulnerable areas would probably be significantly lowered.

Moreover, if an area is to be allowed to flood, the planning preparations for this likely include estimations and calculations on how much water that specific area can handle, depending on various factors such as the size of the area and the types of surfaces within. If the area's limit is exceeded the water might eventually flow back into the surroundings, and if that limit is too low it rather defeats the purpose of having specifically prepared areas for flooding in the first place. This aligns with what Jha et al. (2012:32) write about structural measures and how they can "be overtopped by events outside their design capacity". Thus, in this case, the acceptable level of pluvial flooding could be considered any amount of flooding that remains within the limits of what an area has been estimated to handle.

Something else to consider is that the areas used for ‘planned flooding’ are often parks or other green or open recreational spaces (Malmö stad 2017). This means that if they flood or are damaged it would negatively impact the space’s availability to the public. Of course, in the case of a pluvial urban flood event, not having access to a park or a sports field would presumably be rather low on most people’s list of priorities. A more pressing issue would certainly be damage to buildings or public roads.

However, allowing an area to flood on purpose might still not be viewed very favorably, and some people might wonder why the municipality doesn’t simply ‘try harder’ to prevent pluvial flooding completely. As pointed out by Sörensen and Mobini (2017), flooding is becoming a less accepted part of living in urban areas, and there is an increased awareness that cities can use various means to manage flooding. Due to this, while the municipality or local water authorities may have decided that a certain amount of pluvial flooding in a certain area is acceptable and should be allowed, the public might not agree. At the same time, both societies and individuals have the potential to learn and adapt to new ways of thinking when it comes to the management of cities and natural resources. Using non-structural measures to increase awareness and readiness, as described by Jha et al. (2012), might also increase social acceptance of the fact that viable management strategies often do not actually fully prevent flooding.

## 4.3 Municipal study area: Malmö

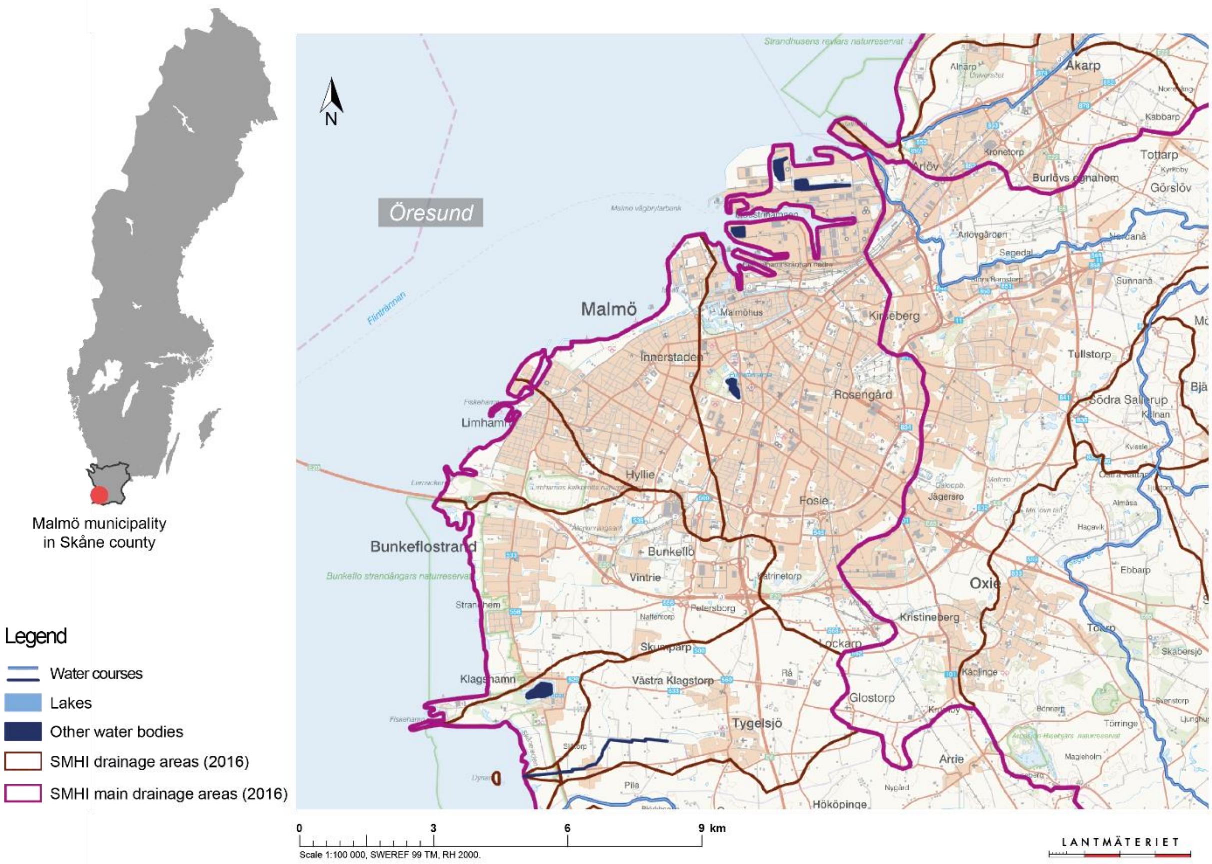


*Figure 10: Location of Malmö in Sweden, and water courses, water bodies, and drainage areas in/around Malmö. Map, raster © Lantmäteriet, edited by the author. Water data from VISS (CC0).*

Malmö municipality is located in Skåne county (SCB 2023) in the southwest parts of Sweden, with the strait Öresund directly to the west (figure 10). As shown in figure 10, Malmö is divided into several drainage areas by SMHI. SMHI describes a drainage area as “the area from which water is drained to a water body upstreams of a certain point” (SMHI 2021a). The border for a drainage area is set by a so called ‘water divider’, i.e. typically a high point in the landscape where water from rain and melted snow flows downwards on different sides of the height, and thus into different drainage areas (SMHI 2021a). Apart from these drainage areas, Sweden is also divided into a set of main drainage areas (figure 10), defined by the predecessor of SMHI in 1908 as drainage areas where the size of the water bodies where they meet the sea are at least 200 km$^2$ (SMHI 2022b).

On August 31st 2014, Skåne was set upon by the most extreme cloudburst event seen so far (SMHI 2021; Malmö stad 2022). Malmö was hit especially hard, with parts of the urban center getting 100 millimeters of rain in only 24 hours, which overwhelmed the urban drainage systems and resulted in several areas being flooded (Malmö stad 2022). This can be compared with the standard value for yearly precipitation for Malmö: 658 millimeters for the years 1991-2020, with many years having a standard value between 500 and 600 millimeters (Miljöbarometern 2023). The reappearance time for this cloudburst event is difficult to determine according to SMHI (2021c), but 35 millimeters of rain fell during one hour, and 85 millimeters fell during six hours, which match and even exceed the amount estimated for rainfall events with a reappearance time of 50 years. Based on local measuring equipment, Malmö municipality has made the assessment that the reappearance time is over 200 years (SMHI 2021d).

According to studies done by Sörensen and Mobini (2017), the main type of flooding in Malmö is pluvial, and it is expected that climate change and urban densification will worsen the risk of flooding. The areas in the city with combined drainage systems generally suffer more from flooding when compared with areas with newer types of systems (Sörensen & Mobini 2017).

### 4.3.1 Strategies for urban growth and densification

Malmö municipality's plans regarding urban growth and densification are presented in the comprehensive plan (Malmö stad 2018). There are clear expectations that Malmö's population will grow, and that expansions in several urban sectors, such as housing, various types of workplaces, and public services, are needed as a result (Malmö stad 2018). More schools and preschools are especially required (Malmö stad 2018).

These expectations are based on the latest population projection for Malmö, which indicates that the population will increase by around 5000 inhabitants on average each year, culminating in a population of around 378 000 inhabitants in the year 2027 (Malmö stad 2018). Malmö stad (2018) notes that approximately 1900 new residences per year will be needed as a result. As can be seen, urban growth is needed in Malmö to provide for a growing population. Moreover, Malmö stad (2018:12-13) writes that measures to promote growth are of "utmost importance for the development of the city", and that Malmö will be further developed to both be an attractive city to live in and visit, as well as a regional center for growth for companies. This, along with how the idea of Malmö becoming a bigger city is also included in the vision for Malmö's future presented in the comprehension plan (Malmö stad 2018), shows that urban growth is not only considered needed due to the population growth, but is also a goal.

Also mentioned in the vision for Malmö's future is the built environment of the city becoming denser (Malmö stad 2018). Described in the comprehensive plan are several prioritized focus points for Malmö's development, and densification is specifically noted as being part of one such focus point (Malmö stad 2018). The strategy is that Malmö mainly should grow inwards, and existing built-up areas should be made denser (Malmö stad (2018). Malmö stad (2018) writes that a dense city is more effective when it comes to resources and energy consumption, and densifying the urban environment is desirable both in newly built areas and in revamped existing ones. Evidently, densification is the prioritized and most desired way for Malmö municipality to achieve urban growth.

### 4.3.2 Flood management strategies

Malmö municipality – called Malmö stad, i.e. Malmö city – has developed a cloudburst plan in order to make sure that the city is prepared, long-term, for cloudburst events (Malmö stad 2017). This was done in conjunction with VA SYD (Malmö stad 2022), which is the regional organization that Malmö Water, the organization managing the urban drainage systems in Malmö, belongs to (Stahre 2008). According to the cloudburst plan, there are signs of an increase both in the number of days with heavy rain, and in the amount of rain itself; as such, the plan concerns rain the stormwater system is unable to handle (Malmö stad 2017).

In the cloudburst plan, multifunctional solutions are described as an important strategy, particularly when it comes to finding a balance between flood prevention and renewal measures for the city (Malmö stad 2017). Green areas and areas for activities, recreation, or transportation are named as examples of multifunctional solutions that can be allowed to temporarily flood during cloudbursts, in order to protect surrounding buildings and infrastructure from harm (Malmö stad 2017). Since the cloudburst plan was produced in 2017, it does not reference the national strategy for climate adaptation from 2018, but it does make note of the inquiry from 2015, which the government appointed to look into potential revisions of legislation necessary for the sake of climate adaptation (Malmö stad 2017).

In addition to multifunctionality, Malmö stad (2022) presents two other strategies for managing cloudbursts and pluvial urban flooding on the municipality's website: 'planned flooding', and limiting the amount of hard surfaces. 'Planned flooding', is described as deliberately allowing certain areas that will not take much damage from the water to be flooded by leading the water there (Malmö stad 2022). This is in line with the guidelines presented by MSB et al. (2017), and fits with Stahre's (2008) inclusion of surfaces for temporary flooding in the 'onsite' category for sustainable urban drainage. Malmö stad (2022) writes that the urban water system does not have the capacity to deal with large quantities of water, and some areas, such as parks or sports fields, have therefore been adapted to handle being flooded. Malmö stad (2022) also considers such areas multifunctional solutions, similarly to what is written in the cloudburst plan. Cloudbursts are taken into consideration when new neighborhoods are built, and detention basins are mentioned as an example of how to make sure that an area can handle large amounts of water (Malmö stad 2022).

Apart from the aforementioned structural solutions, Malmö stad (2017) also presents social solutions involving communication and cooperation with different actors and stakeholders. For example, the municipality should ensure communication with inhabitants and businesses both regarding the development of the cloudburst plan, and how they can protect themselves in the event of a flooding (Malmö stad 2017).

The solutions presented by Malmö municipality share some clear similarities with the solutions included in Stahre's (2008) four categories of sustainable urban drainage, which could imply that Stahre was a source of inspiration when they were formulated. Even if that is not the case, the similarities do show that sustainability was considered and aimed for. Permeable surfaces, multifunctional areas, and surfaces for temporary flooding – all mentioned in the cloudburst plan (Malmö stad 2017) and on the municipality's website (Malmö stad 2022) – are described as sustainable solutions by Stahre (2008).

Like what Stahre (2008) writes about different scales for different solutions, Malmö stad (2017) notes that a combination of both local, small-scale, and large-scale measures is necessary in order to manage extreme precipitation in Malmö (Malmö stad 2017). These solutions make use of both public and private land for handling water, and include measures such as local water pathways, retention areas close to the source, and areas for planned flooding (Malmö stad 2017). For example, limiting the amount of hard surfaces is described as a strategy which is possible to use, not only for the municipality but also for private property owners, to contribute to a sustainable drainage system, since more areas where the water can infiltrate will result in less water that remains above ground, which reduces the risk of buildings being damaged (Malmö stad 2022).

When stormwater is handled on private land by the property owner it is called local handling of stormwater (Swedish: lokalt omhändertagande av dagvatten, i.e. LOD) (Persson et al. 2009). During the process of adopting a detailed development plan for an area, the municipality is required to specify how stormwater is to be handled, and whether or not the area is part of a public water and drainage facility's area of operations (Svenskt Vatten 2016; Boverket 2020). If a private property does lie within such an area of operations, the property owner is responsible for ensuring that all water that cannot infiltrate into the ground on the property itself is evacuated from the property and led to the so called 'connection point' established by the public water and drainage facility (Boverket 2015). This connection point can, for example, be an open ditch or a storm drain (Boverket 2015). Furthermore, according to the law of public water services (SFS 2006:412), private property owners are required to follow the regulations set by the municipality in the detailed development plan during construction or other land measures on the property. This means that the property owner has to follow any specific regulations for how stormwater is to be managed within the area which may exist, or certain necessary measures to protect both the surroundings and the buildings on the property (Boverket 2015).

### 4.3.3 Applying the analytical frame

As can be seen, many of Malmö's flood management strategies involve more or less straightforward natural or engineered solutions, utilizing both gray and green-blue infrastructure to control the flow of the water. According to the definitions described by Jha et al. (2012), these measures for urban flood management in Malmö can be characterized as structural. Whether or not they can be considered technical fixes is another question, however. Following the original definition of the technological fix in that it is meant to allow for the complete disregard of other solutions to a problem, as well as the circumvention of the problem itself (Johnston 2018), it can be argued that any technological solution designed to complement or to be complemented by other types of solutions, for example social, can not be characterized as a technological fix.

This is clearly the case for Malmö municipality. While many of the municipality's concretely outlined strategies do rely heavily on structural measures involving engineering and natural green-blue infrastructure to manage flooding, Malmö stad (2017) also clearly states that long-term cooperation between various stakeholders is needed. Evidently, non-structural measures are also considered. Another important measure mentioned in the cloudburst plan is communication with the inhabitants, both regarding how they can protect themselves from flooding and how Malmö in general can be made more resilient. Such measures fit into the description of non-structural ways to manage flooding (Jha et al. 2012), and show that Malmö municipality does not rely solely on technological solutions to the exclusion of all else.

However, when put in the context of Malmö's densification strategies, the question of whether Malmö's flood management strategies are technological fixes or not becomes more complex. When examining the strategies for densification outlined in Malmö's comprehensive plan and comparing them to the stategies for flood management – and to each other, some contradictions seem to emerge. Similarly to the cloudburst plan, the comprehensive plan specifies that it is necessary to minimize hard surfaces and work actively with solutions that include retention measures, green roofs, and permeable surfaces (Malmö stad 2018). Existing blue and green infrastructure is to be protected and expanded for the sake of human health as well as increasing biological diversity and lessening the effects of climate change (Malmö stad 2018). At the same time, two strategies often mentioned and noted as highly prioritized are for Malmö to grow inwards rather than outwards, and for the city to become denser (Malmö stad 2018). This is described as lessening the city's general strain on the environment, and the need to build on farmland, which is considered one of the municipality's most important natural resources (Malmö stad 2018).

Clearly, Malmö's urbanization strategies align with the well-established viewpoint of densification as a sustainable strategy for urban planning. However, it was previously noted in this thesis that while urban densification does limit certain types of negative impacts on the environment, it may contribute to others (Haaland & van den Bosch 2015). The clearly expressed strategies of preserving and expanding existing green spaces within the urban landscape (Malmö stad 2018) suggests that Malmö is aiming to densify using means other than urban infill, such as by expanding existing buildings or repurposing already built-up areas that are no longer used. Nevertheless, some infill might still be done, since there is likely a limited amount of built-up areas which are available and possible to repurpose. To add to that, expanding or replacing existing buildings might not always be possible either, and careful considerations should be made when deciding the height of new buildings to ensure that they fit into existing environments.

Malmö stad (2018) does acknowledge that densifying the city will put more pressure on the water and drainage systems, and it is for these exact reasons that measures such as green roofs and limiting the amount of hard surfaces should be used. Evidently, mitigating the problem of pluvial urban flooding is, indeed, part of the point with the sustainable strategies for flood management that Malmö stad (2018) presents. These strategies do have the potential to manage pluvial urban flooding effectively (Green et al. 2021; Rosenberger et al. 2021) and provide ecological, social, and other benefits (Huang et al. 2020). Thus, there is a clear belief in the capacity of these technical solutions to mitigate the negative effects caused by continued urban growth.

## 4.4 Municipal study area: Uppsala

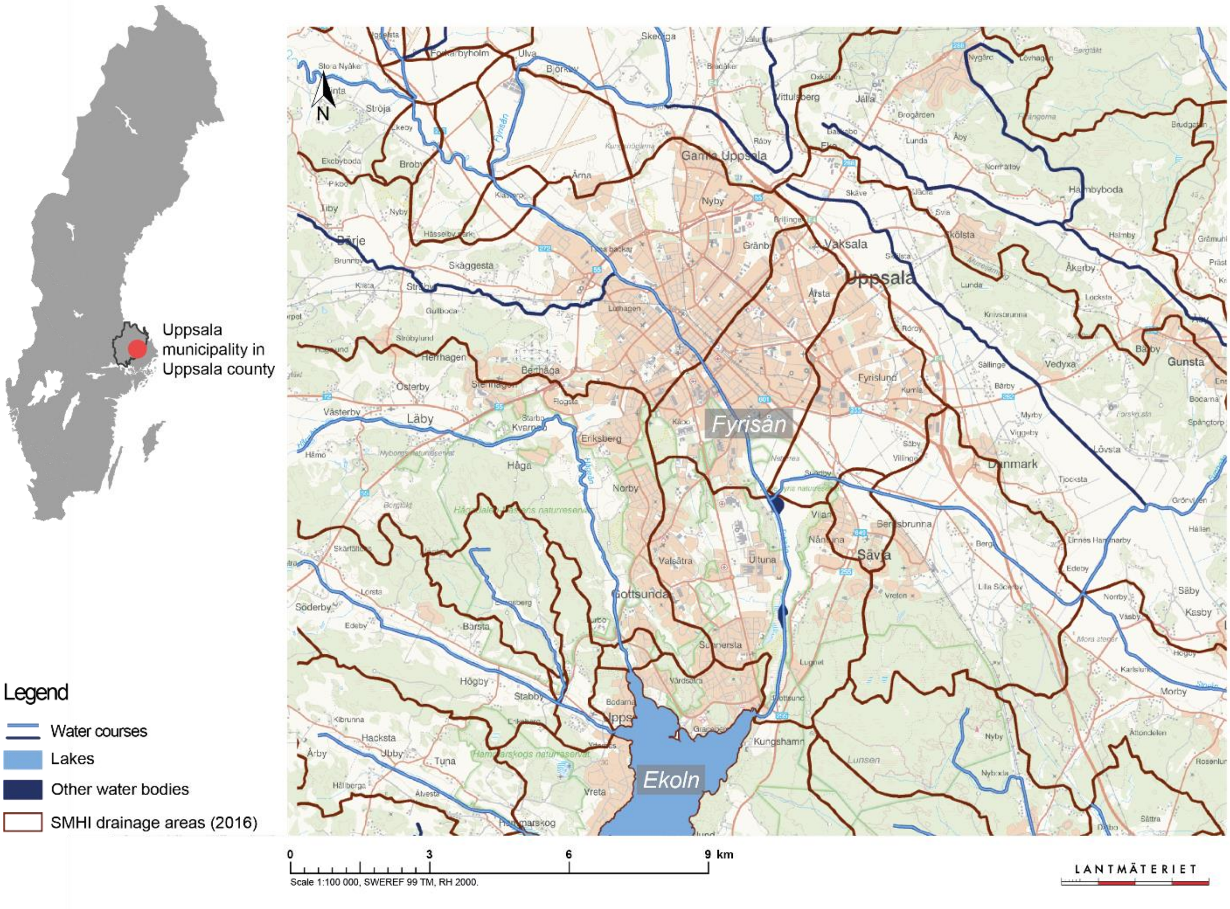


*Figure 11: Location of Uppsala in Sweden, and water courses, water bodies, and drainage areas in/around Uppsala. Map, raster © Lantmäteriet, edited by the author. Water data from VISS (CC0).*

Uppsala municipality lies in Uppsala county (SCB 2023) in the east of Sweden, north of Ekoln (figure 11). Ekoln is the northernmost part of the lake Mälaren (VISS n.d.), and the river Fyrisån, which flows from north to south through Uppsala city, has its mouth in Ekoln (Fyrisåns Vattenförbund 2023). Like Malmö, Uppsala municipality is divided into several drainage areas by SMHI, as can be seen on figure 11.

On 29th of July 2018, Uppsala experienced pluvial urban flooding in several parts of the city (Hallqvist & Idemark 2019). Over 80 millimeters of rain fell during the day, which set a record for the most amount of rain during a day in July since 1857 (Forsell 2018). While this event is not part of the historical floods listed by SMHI (2022a), it was nevertheless the cause of significant disturbances, with the train station and hospital as notable parts of the city being flooded (Hallqvist & Idemark 2019). It is expected that Uppsala will experience pluvial urban flooding more frequently in the future, due to increased precipitation as a result of climate change (Karlsson & Larsson 2022; Öman & Gustavsson 2022). Uppsala municipality

(2016) therefore states that flooding, along with other consequences of climate change, must be taken into consideration during reconstruction or new development projects.

### 4.4.1 Strategies for urban growth and densification

In the comprehensive plan for Uppsala, Uppsala municipality (2016) writes that the population in Uppsala is growing fast since it is an attractive municipality to live in, and rapid urban development is needed as a result. The expectation is that Uppsala will grow with up to 130 000 inhabitants until the 2050s, and expansions are therefore needed when it comes to housing, job opportunities, and the business sector (Uppsala municipality (2016). According to Uppsala municipality (2016), up to 70 000 new residences are needed by the year 2050, along with the same amount of new job opportunities.

Clearly, Uppsala's need for urban growth due to an increased population is similar to the situation described by Malmö stad (2018). Furthermore, like the comprehensive plan for Malmö, Uppsala's comprehensive plan also contains prioritized focus points, of which one priority is for Uppsala to become an attractive enough place that companies, investments, and people with various kinds of expertise from all across the world are drawn there (Uppsala municipality 2016). Uppsala municipality (2016:168) states that Uppsala needs to become a "strong alternative" to Stockholm for where organizations and companies wish to establish themselves, particularly when it comes to what the municipality refers to as "knowledge or contact intensive" enterprises. This strongly indicates that, like for Malmö, further urban growth in Uppsala is not merely a reactionary measure in response to an increased need for housing and other services, but also in itself a goal.

When it comes to how that urban growth is achieved, Uppsala municipality (2016) mainly mentions densification. There are several strategies in the comprehensive plan involving new and expanded urban developments, both in the central city of Uppsala and around it (Uppsala municipality 2016). Most of the new residences built until year 2050 will be located in Uppsala city, meaning that the city itself will grow with about 60 000 new residences and workplaces until then (Uppsala municipality 2016). 3000 new residences per year are to be built, and it is specifically noted in the comprehensive plan that the urban environments for these new residences will be dense and have a variety of functions (Uppsala municipality 2016).

The strategy for the inner city in particular means for the built-up environment to have a significant level of density and the potential to be densified even further, with public environments that have "high qualities of use" as well as different types of functions, both local and regional (Uppsala municipality 2016). There will be designated places and passages for urban life, where prerequisites for a high concentration of both “urban life qualities” and premises for enterprises will be created (Uppsala municipality 2016).

*Urban nodes*

Uppsala municipality (2016) describes a strategy involving four new dense urban nodes, located in Gottsunda-Ultuna, Gränby, Bergsbrunna, and Börjetull (figure 12).

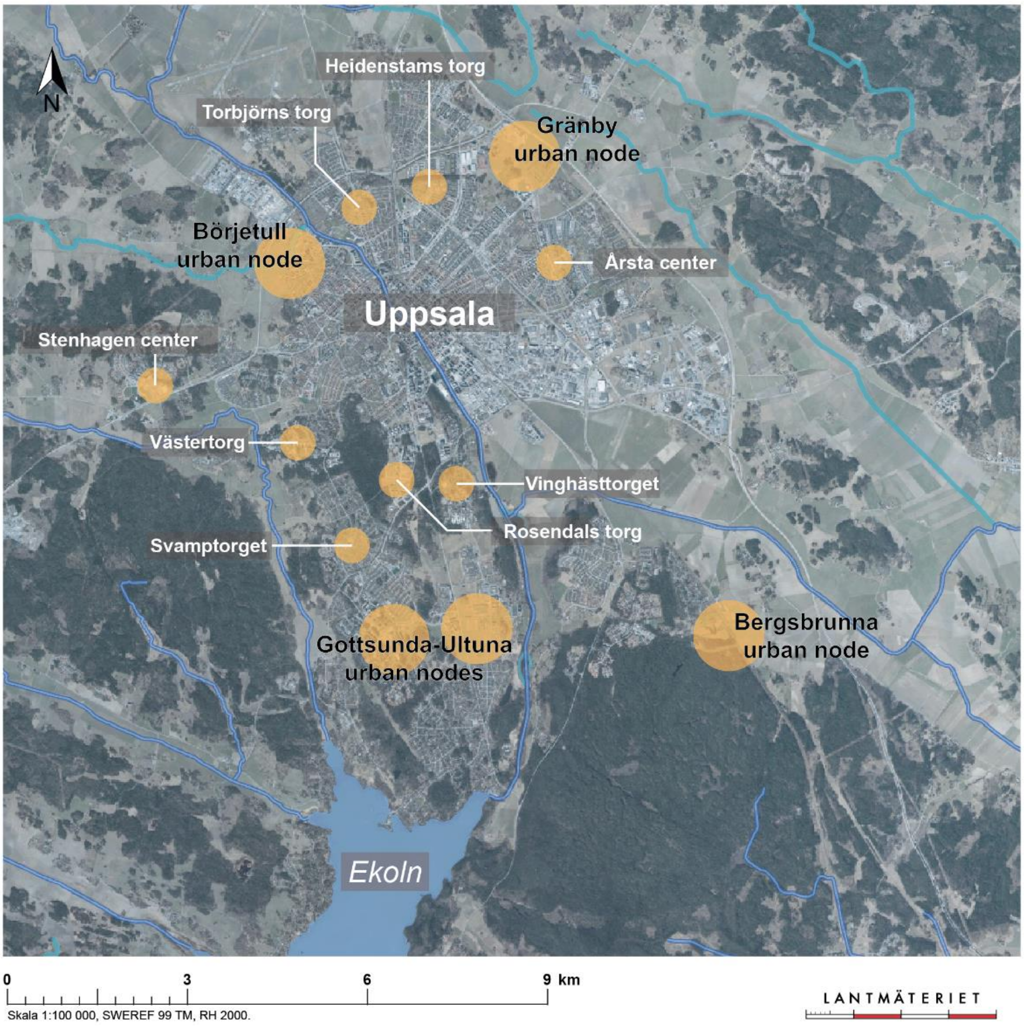


*Figure 12: Map showing the location of planned urban nodes and neighborhood nodes in Uppsala. Aerial photograph, raster © Lantmäteriet, edited by the author.*

These urban nodes consist of both new and existing sub-centers with the potential to develop into regional and local centers that complement the inner city of Uppsala, providing housing, businesses, and other services (Uppsala municipality 2016). Furthermore, Uppsala municipality (2016) notes that the nodes are located around connectivity points in Uppsala’s public transportation network, further strengthening the possibility of moving between different areas in the city.

Like the inner city, the urban nodes are to have “a very high concentration of buildings” and supply a wide variety of functions (Uppsala municipality 2016:55). According to Uppsala municipality (2016) there is also a relatively large amount of unexploited land, and the planning and construction efforts in the urban nodes should therefore contribute to the development of innovative and sustainable technical maintenance systems. Moreover, the urban nodes should be planned in a way that allows for the usage of areas to easily change, as well as for further densification if necessary (Uppsala municipality 2016).

*Neighborhood nodes*

In addition to the urban nodes, eight densely built neighborhood nodes – ‘stadsdelsnoder’ in Swedish – providing local services will continually be developed (Uppsala municipality 2016). As shown on figure 12, the neighborhood nodes are Heidenstams torg, Torbjörns torg, Stenhagen center, Västertorg, Svamptorget, Rosendals torg, Vinghästtorget, and Årsta center (Uppsala municipality 2016). Neighborhood nodes are similar to urban nodes, but on a smaller scale: they are existing and new places functioning as a local center for adjacent neighborhoods (Uppsala municipality 2016).

### 4.4.2 Flood management strategies

The river Fyrisån, along with Uppsala city in general, have twice been pointed out by MSB as areas at risk of flooding (Länsstyrelsen Uppsala 2021). Therefore, the County Administrative Board of Uppsala produced a risk management plan in 2009, meant to guide the work with preparing for and preventing flooding (Länsstyrelsen Uppsala 2021). A revised plan was produced in 2021, and is described as including clearer goals as well as information about climate adaptation and water management plans (Länsstyrelsen Uppsala 2021). Flooding related to urban rivers is, of course, important to consider in landscape and urban planning for relevant areas, but since this thesis focuses on pluvial flooding rather than fluvial flooding, as described in chapter 2, the flood risk specifically connected to the river Fyrisån is not investigated in detail.

Uppsala municipality is also working on producing a cloudburst plan, in accordance with MSB’s guidelines (Länsstyrelsen Uppsala 2021). According to the information in the risk management plan from 2021, the aim was that the cloudburst plan would be finished in 2022 (Länsstyrelsen Uppsala 2021), but no such plan seems to be available for the public to view at the time of writing this thesis.

Apart from the risk management plan and in-progress cloudburst plan, there are a number of documents concerning water and drainage management, climate adaptation, and emergency planning in Uppsala. The County Administrative Board of Uppsala has produced a climate and vulnerability analysis for Uppsala County (Öman & Gustavsson 2022), as well as a 'roadmap' for a sustainable county, specifically focused on water (Karlsson & Larsson 2022). Other relevant documents have been produced by the municipality, such as the comprehensive plan and the environment and climate program (Uppsala municipality 2016; 2022b).

Several strategies for mitigating and preventing flooding are presented in the comprehensive plan for the municipality (Uppsala municipality 2016). The risk of flooding, regardless of reappearance time, is to be considered during new construction projects, and important societal functions as well as new development areas for residences should be placed above the level for the highest estimated flow of water (Uppsala municipality 2016). These measures are also presented in the risk management plan, specifying that new development areas should be planned so that they can withstand a 100 year rain (Länsstyrelsen Uppsala 2021).

Another strategy is the planning and creation of areas able to handle being purposefully flooded (Uppsala municipality 2016), which, like Malmö stad's (2017; 2022) strategy for areas for planned flooding, aligns with the guidelines created by MSB et al. (2017). In conjunction with this, naturally low parts of the landscape in Uppsala should be utilized to lead stormwater and surface water away from urban areas (Uppsala municipality 2016). These so-called 'stormwater passages' (figure 13) are to be combined with' green passages' – i.e. green wedges consisting of parks and other natural areas – to form buffers against flooding (Uppsala municipality 2016). The stormwater will be handled in ponds and open dikes, and the stormwater passages will thereby not only protect against flooding but also slow down the flow of the water and clean it before it reaches a recipient water body (Uppsala municipality 2016).

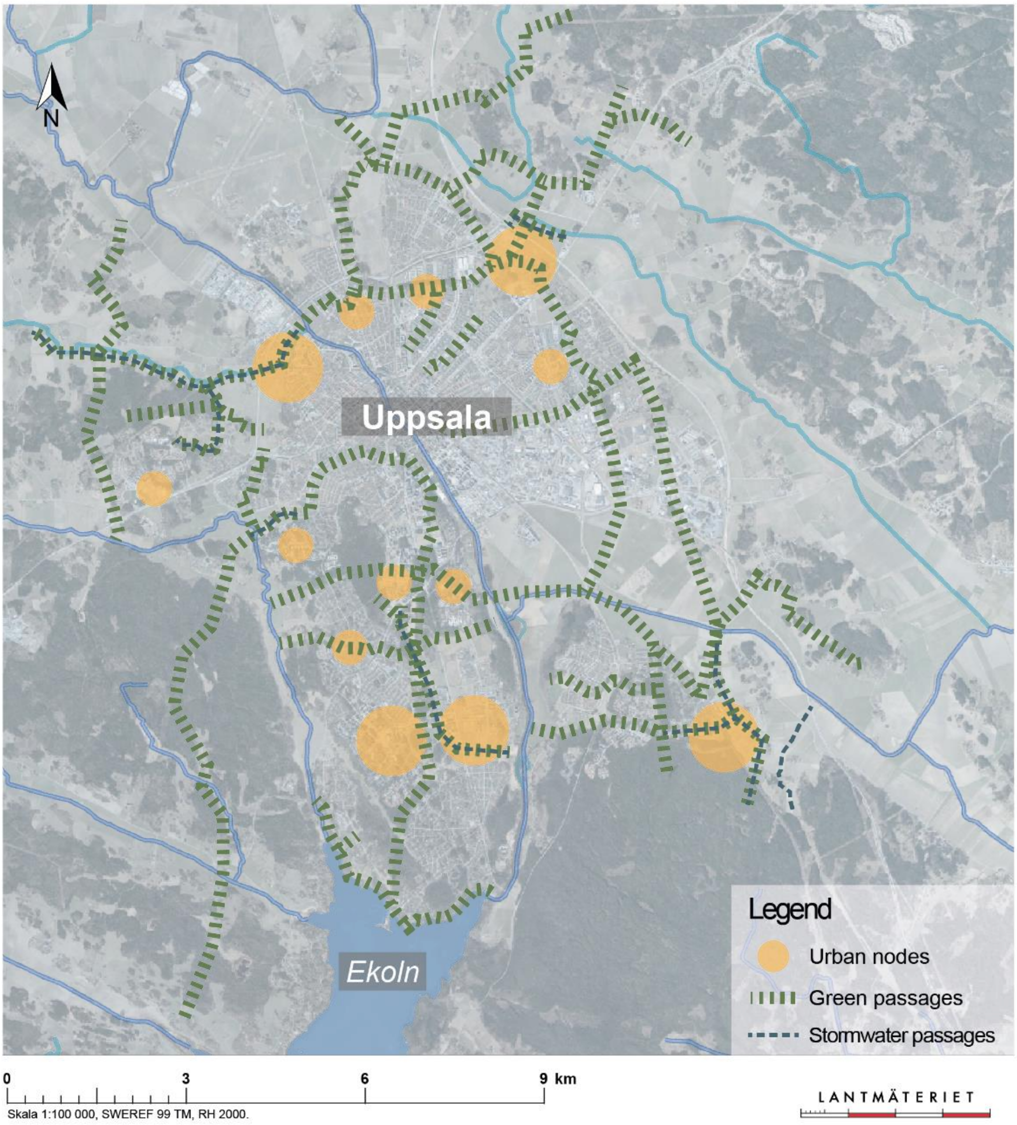


*Figure 13: Map showing the location of stormwater/green passages in Uppsala. Aerial photograph, raster © Lantmäteriet, edited by the author.*

As can be seen on figure 13, certain green passages cross through some of the urban nodes and neighborhood nodes previously described. In these cases, Uppsala municipality (2016) notes that the continuity of the green passages should, as much as possible, be secured without negatively affecting the quality of the node's built environment or possibility for movement.

When it comes to the usage of plants in areas for planned flooding, they should naturally be able to handle being flooded. Although this might necessitate specific types of plants, particularly if they are also meant to clean water, it does not necessarily mean the aesthetic attractiveness of the area is lowered. This is evident in the Buire park – also called the Jacob-Kaplan park – in Lyon, France, where many elements aimed to increase aesthetic and recreational values are also designed to manage water in various ways (L'Observatoire CAUE 2022). Two examples of such elements in the park are the water retention basin and the plantations with plants for filtering water (L'Observatoire CAUE 2022).

### 4.4.3 The Rosendal project

Rosendal is a neighborhood located south of central Uppsala, west of the river Fyrisån and between two nature reserves called Stadsskogen and Kronparken (figure 14). It is also a currently on-going development project in Uppsala where many of the municipality's strategies for flood management, such as multifunctionality, stormwater passages, and areas for planned flooding, are being implemented (Uppsala municipality 2022b), and there is a particular focus on innovation and sustainability (Uppsala municipality 2021).

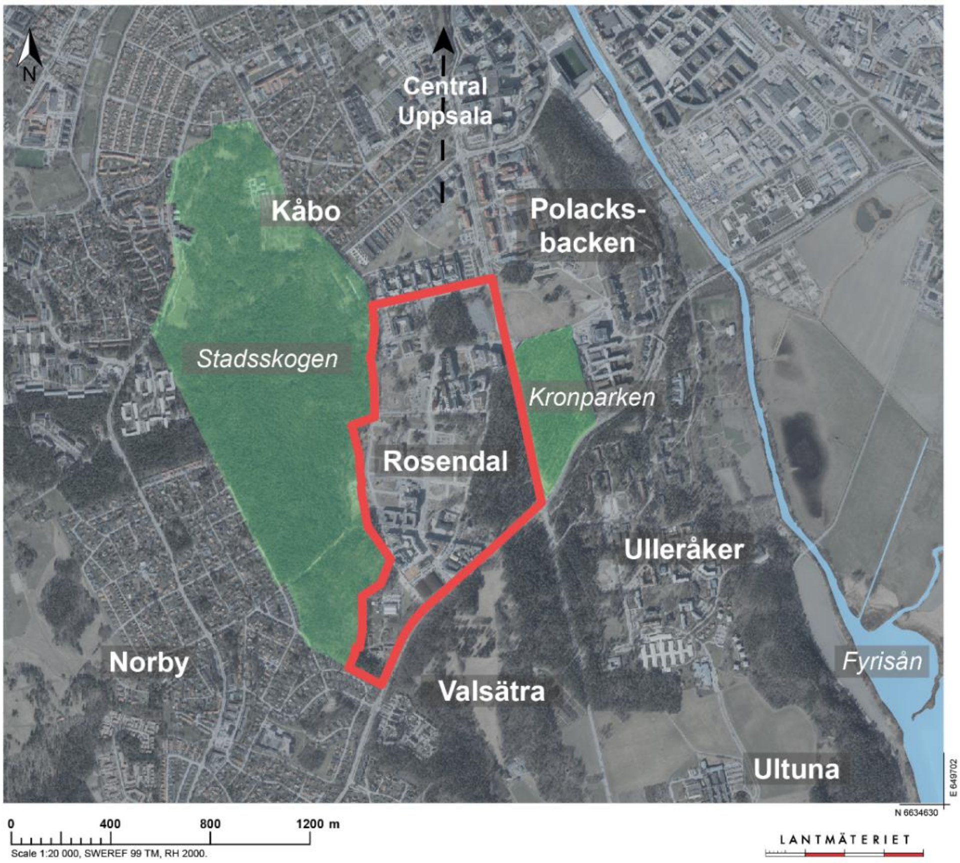


*Figure 14: Map showing the location of Rosendal and nearby neighborhoods. Aerial photograph, raster © Lantmäteriet, edited by the author.*

Investigating Rosendal thus provides insight into how Uppsala's strategies against pluvial flooding are implemented in reality, which is why Rosendal specifically was studied in this thesis. Furthermore, it is a particularly interesting area to study within the context of Uppsala city, since its proximity to the Uppsala esker means that solutions for handling water need to be carefully planned so polluted water from roads does not leak into the esker (Uppsala municipality 2022c).

The Rosendal neighborhood lies between the urban node of Gottsunda-Ultuna and central Uppsala, and includes the neighborhood node of Rosendal torg, i.e. Rosendal square (figure 14), as described by Uppsala municipality (2016). As noted previously, Uppsala municipality (2016) wants the urban nodes to support the development of technical management solutions that are sustainable and innovative, and Rosendal is a clear example of this effort. The intent with Rosendal was to create a neighborhood where ecosystem services – natural systems that benefit human health – are utilized in various ways for the sake of sustainability (Uppsala municipality 2021). A so-called green-blue system, combining vegetation and water management, is used to both clean rainwater and lessen the risk of flooding (Uppsala municipality 2022c). This system works in conjunction with traditional gray infrastructure (Uppsala municipality 2021). Water is cleaned in rain beds, and then collected and delayed underneath the car roads and later in dams (Uppsala municipality 2022c), before finally reaching recipient water bodies (Uppsala municipality 2021). Cleaning and delaying water locally is described as both lessening the burden on the stormwater system in the city, and making it so that, if flooding occurs, it does so in places where not much harm is done (Uppsala municipality 2022c).

An interview was conducted with one of the project managers of the Rosendal project at Uppsala municipality, henceforth referred to as the 'informant'. The informant (2023) explains that the core of the Rosendal project is the municipality's ability to set certain demands regarding, for example, the number of green spaces and the quality of the stormwater management. The detailed development plan leaves many parts of the plan unspecified, such as the exact placement of buildings, and these parts are then decided upon in an agreement between the municipality and whichever housing developer who buys land within the area (Informant 2023). Such an agreement between the municipality and a developer is called land allocation agreement (Boverket 2022a). All municipalities in Sweden are required by law to formulate guidelines for land allocation, which should include, among other things, basic conditions for the allocation of land and the municipality's standpoint and goals for ceding or allowing the use of land areas for construction (Boverket 2022a). Thus, any developer who wants to buy land in Rosendal has to agree to the conditions set by the municipality (Informant 2023). According to the informant (2023), it is also the municipality's responsibility to set these types of demands in order to develop knowledge regarding sustainability and measures for climate adaptation within the field of landscape and urban planning.

The informant (2023) mentions the Carlshage park and Elsa Eschelsson's park as examples of multifunctional solutions. Both of these parks are created to be able to handle large amounts of rainwater so as to protect surrounding areas from flooding (Uppsala municipality 2022a; Uppsala municipality 2023a). A stormwater pond for water retention (figure 15), designed to be able to handle 1 154 cubic meters of rain before the rest of the park is flooded, makes up the central part of Elsa Eschelsson's park (Uppsala municipality 2022a).

*Figure 15. Stormwater pond for planned flooding at Elsa Eschelsson's park in Rosendal, Uppsala, Sweden.*


*Figure 16. Activity area designed to handle planned flooding in Elsa Eschelsson's park in Rosendal, Uppsala, Sweden. The text reads "regnpark", i.e. rain park.*

In another part of the park lies an 'activity area' (figure 16) for skating or biking, which is also designed to handle temporary flooding in case the pond overflows (Uppsala municipality 2022a). While the original main purpose of the park was to handle flooding, design elements such as seating and a basketball hoop have been added to provide better opportunities for recreation, thereby creating a multifunctional area (Informant 2023).

Similarly to Elsa Eschelsson's park, the Carlshage park (figure 17) contains a pond for water retention (Informant 2023). The pond's edges have been made relatively flat to allow for the addition of recreational design elements, such as plantings, benches, and pedestrian pathways, to make the area multifunctional (Informant 2023).

*Figure 17. Construction at Carlshage park in Rosendal, Uppsala, Sweden.*


*Figure 18. Fence around Carlshage park in Rosendal, Uppsala, Sweden.*

When it comes to the economical aspect, there is generally a risk that multifunctional areas, such as the two mentioned parks, become rather expensive to finance (Informant 2023). Yet the informant (2023) explains that they are profitable long-term, since they provide multiple functions in a spatially effective way. Uppsala municipality also receives financial aid from the Swedish government for the technical solutions in Rosendal, due to their innovativeness (Uppsala municipality 2022c). Even so, the municipality has a responsibility to manage public land in a sustainable way, and has to ensure the Rosendal project is economically justifiable (Informant 2023). The cost of the green-blue systems themselves is not much higher than the cost of traditional drainage solutions, but the location of Rosendal within Uppsala does mean that some more costly measures to protect the groundwater need to be taken (Uppsala municipality 2022c). Rosendal is located within the protected area for the Uppsala esker, and particular consideration is therefore needed to ensure that polluted water from roads does not infiltrate into the esker and, in turn, the groundwater (Informant 2023). For this reason, further construction work is currently being done in Carlshage park to prevent leakage from the pond (figure 17-18).

The informant (2023) explains that the proximity of Rosendal to the Uppsala esker was what spurred on the technical development to reach as far as it has, since there would otherwise not be as important to make sure that the technical solutions do not leak. After an investigation it was found that different soil compositions matter when it comes to how sensitive the areas around the esker are when it comes to the risk of polluted water infiltrating into the ground (Informant 2023). As described by the informant (2023), if it rains on clay – the main type of soil in the outer water protection area, which is where Rosendal is located – it takes longer for the water to infiltrate than it would if it rains on the area directly above the esker, where the soil consists of coarse-grained gravel and sand. Thus, while Rosendal is a sensitive area to build on, it is less sensitive than for example Ulleråker (Informant 2023). Since Uppsala municipality has plans to further develop Ulleråker as well (Uppsala municipality 2016) Rosendal could be used to test the new technical solutions for water management to ensure that they work as intended before proceeding to use them during the development in Ulleråker (Informant 2023).

Another multifunctional solution mentioned by the informant (2023) is the combination of car roads and systems for retaining water. Since roads are normally only meant to be used by vehicles and pedestrians, adding rain gardens beside them and retention systems beneath them provides more functions and therefore makes them multifunctional (Informant 2023). In turn, this allows for smaller ponds in the parks, and thereby more available space for play or seating areas (Informant 2023).

### 4.4.4 Applying the analytical frame

Uppsala municipality's strategies for urban flood management are, as can be seen, a combination of planning for future development projects, and technical solutions for managing the water itself. Hence, if one follows the definitions of Jha et al. (2012), they are a combination of structural and non-structural measures. The structural measures consist of sustainable, nature-based solutions (Stahre 2008; Huang et al. 2020; Green et al. (2021), such as rain gardens and areas for planned flooding, clearly showing that the aim is not only to manage flooding, but to do so in sustainable ways.

Similarly to Malmö, it seems unlikely that a municipality would deliberately ignore non-technical aspects of a problem and attempt to only use technological means to solve it. If one strictly follows the original definition of the technological fix, as presented by Johnston (2018), this would disqualify Uppsala's strategies from being characterized as technological fixes. However, the strategies must be viewed within the urban context they are being implemented in, which brings about a more complex discussion.

As described previously, the plan is for Uppsala to grow with 3000 new recidences per year until the year 2050, with a focus on creating dense and multifunctional urban environments, as written in the comprehensive plan (Uppsala municipality 2016). Existing built-up areas are to become even denser, and new urban nodes – also with very densely built environments – are planned (Uppsala municipality 2016). Other strategies presented in the comprehensive plan are the preservation and expansion of natural areas (Uppsala municipality 2016), but it is known that urban green areas are put at risk due to infill (Lin et al. 2015), and a seemingly undeniable conflict between strategies thus becomes visible.

Uppsala municipality (2022b) also acknowledges that the large amount of hard surfaces and densely built areas in the city aggravate the issue of urban flooding, yet there seems to be no explicitly stated plan for how to limit hard surfaces during new development projects. The informant (2023) describes Rosendal as a project where urban infill is utilized in a green area that was previously “relatively unused”. Small-scale nature-based systems, such as rain gardens and ponds, are used as a way to mitigate the negative effects on flood risk brought about by the loss of green space on a larger scale. A plausible interpretation is thus that Uppsala municipality is reducing a very complex problem to something that can be solved using largely technological solutions, similarly to Oelschlaeger’s (1979) critique of the technological fix. Although the sustainable measures implemented in Rosendal are effective for managing pluvial flooding and lessening the pressure on traditional drainage systems (Rosenberger et al. 2021), they do not actually solve the problem of densification exacerbating flood risk.

At the same time, this is a very complex matter. Uppsala does need to provide housing for a growing population (Uppsala municipality 2016), and strategies involving urban sprawl or expanding existing buildings upwards come with their own problems which are not necessarily more advantageous than those caused by densification. Furthermore, Uppsala’s sustainable strategies for flood management are likely not meant to solve the negative effects of densification, but mitigate the general problem of flooding that, as noted by MSB, currently exists even without further densification (Länsstyrelsen Uppsala 2021), and is evidently expected to become even worse due to climate change (Karlsson & Larsson 2022; Öman & Gustavsson 2022).

*Rosendal and its significance for Uppsala’s development*

From the comprehensive plan, it can be seen that Rosendal as a development project is a part of a larger city-scale urbanization effort with the aim of providing housing and other services for the municipality’s growing population (Uppsala municipality 2016). The implementation of sustainable, nature-based solutions for pluvial flood management (Uppsala municipality 2022c; Informant 2023) also makes Rosendal a clear example of Uppsala municipality’s (2016) stated intent to consider future environmental circumstances during new developments.

In the case of Rosendal specifically, technical innovation for managing water is not merely desired but also necessary to ensure the protection of the Uppsala esker and the groundwater in the area (Uppsala municipality 2022c; Informant 2023). As mentioned, due to the location of Rosendal, considerable care needs to be taken during the construction of the water management systems lest they leak and cause polluted water to infiltrate into the groundwater (Uppsala municipality 2022c; Informant 2023). Clearly, Uppsala municipality has a lot of faith in technological solutions and how they can be used to allow for construction in sensitive areas. Since the municipality has plans to continue building close to and on the esker (Uppsala municipality 2016), being able to trust that the systems for managing water are able to fully prevent the aforementioned risk of polluting the groundwater becomes imperative.

Accordingly, the Rosendal project is a highly important part of the municipality’s strategies for continued urbanization, since it is used to test new solutions for managing water and ensure they work as intended before they are implemented in even more sensitive areas, as explained by the informant (2023). Without these tests, it would be much more difficult to trust in the technological systems, making it significantly less defensible to build in sensitive areas near the esker, which would in turn necessitate several changes to Uppsala municipality’s urbanization plans.

Since new technology is necessary in Rosendal to allow for construction so close to the esker, it might be appropriate to not label the flood management strategies implemented in Rosendal as technological fixes. At the same time, from the information given by the informant (2023), it is clear that Rosendal is being used as a location for new construction because it was an ‘underutilized’ area inbetween urban spaces, and the municipality wished to create better connections between these urban areas. Evidently, this is being done through urbanization of the previously ‘unused’ green space of Rosendal. Thus, if the sustainable solutions for managing pluvial flooding in Rosendal are what allows for developments in the area, they are also a way for the municipality to realize their plans for urban growth and densification. Hence, the sustainable solutions could potentially be seen as a way for the municipality to simply continue building, without really needing to consider alternate ways for society to move forward; this concept is brought up by Swyngedouw (2010) in regards to technologies aiming to “fix” environmental problems without addressing underlying reasons for why these problems may exist.

# 5. Discussion

## 5.1 Managing pluvial flooding in a densified city

This thesis has sought to identify and discuss problematic aspects of Sweden's strategies for pluvial urban flood management, in the context of Sweden's strategies for densification and with a specific focus on sustainability. This was done by investigating empirical material describing the strategies for urban flood management existing in Sweden, specifically relevant for pluvial flooding, and analyzing it in accordance with the analytical frame described in chapter 2. This is a complex matter, and since the purpose was to identify problematic aspects and not to solve them, no attempt to create other solutions was made in this thesis.

Along with the need to investigate Sweden's flood management strategies came a necessity for an investigation into how pressing an issue pluvial urban flooding actually is in Sweden, and into what research has been done regarding the risk of increased precipitation and pluvial flooding in the country. From the floods that have occurred in recent years in Sweden, pluvial urban flooding has increasingly been revealed to be a problem which doesn't only happen 'elsewhere', but here in Sweden as well, and thus needs to be considered in Swedish landscape architecture and urban planning. This need is strengthened by the results from simulations showing that climate change and increased urbanization will cause extreme cloudbursts to become more common in Sweden in the future (Olsson & Foster 2013).

As can be seen from the investigation and analysis done in previous chapters, there is clearly work being done in Sweden, both on a national and municipal level, to manage pluvial urban flooding in sustainable ways. The strategy for climate adaptation from 2018 and the revisions of laws regarding urban flooding make it clear that the Swedish government is taking climate change, increased precipitation, and urban flooding into consideration, and is continually working to ensure relevant actors take responsibility for raising Sweden's ability to handle this issue. The municipalities of Malmö and Uppsala, which were investigated in this thesis, have evidently formulated strategies against urban flooding largely according to the guidelines by MSB et al. (2017), and to contemporary ideas of sustainable flood management and urban drainage utilizing green infrastructure (Stahre 2008; Huang et al. 2020; Green et al. 2021).

Both Uppsala and Malmö municipality's strategies for managing pluvial urban flooding in sustainable ways include structural as well as non-structural measures, as shown in chapters 4.3 and 4.4. There is, however, a clear difference between Malmö and Uppsala concerning what the non-structural measures entail. Although the focus of Malmö's flood management strategies largely lies on structural measures, the cloudburst plan does include non-structural measures for managing pluvial flooding, mainly involving cooperating and communicating with inhabitants and other actors, such as collecting opinions and experiences from inhabitants regarding how Malmö can be made more resilient against flooding (Malmö stad 2017). Uppsala municipality (2016) also presents certain strategies that can be considered non-structural, but they are more focused on urban management and planning, such as investigating and analyzing potential risks of flooding in an area before planning new development projects there.

### 5.1.1 Technology to pave the way for continued urban growth

To discuss whether the flood management strategies found during the research for this thesis are technical fixes or not, the strategies must of course be put into an urban context – or, more specifically, the context of their respective municipality's urban landscapes and urban planning strategies. Investigating the municipalities of Malmö and Uppsala revealed how both municipalities aim to densify already built-up areas, in order to meet existing and future demands for more housing. One would expect this densification, at least in part, to be achieved through urban infill, as there is likely to be a limit to already built-up areas that can be reused or repurposed, and expanding buildings upwards may be met with resistance in certain areas or situations. Even if there is an effort to build sustainably, new development areas in previously unexploited areas will, at the very least, add more car roads and pedestrian walkways, which will increase the amount of hard surfaces in these areas. An increase in car traffic will also increase the amount of polluted water needing to be cleaned before reaching a recipient water body, which in turn necessitates solutions, nature-based or not, to do so. Preserving urban parks or including rain gardens in the plans for a new urban area do, of course, help compensate for densification through urban infill, but they are still measures that often exist on a much smaller scale than the amount of green area that is lost. The Rosendal project in Uppsala, which was described previously, is an example of this.

Both Uppsala and Malmö municipality seem to put a lot of faith in new technological nature-based solutions being able to effectively manage urban flooding, while simultaneously acknowledging the shortcomings of technology in the form of traditional urban drainage systems. As noted in chapter 3.5, this thesis uses the viewpoint that nature-based solutions for flood management can be considered technical, which is supported by how Jha et al. (2012) include natural systems in structural measures for managing flooding. Although they utilize natural processes and green infrastructure, nature-based solutions such as green roofs or rain gardens are still planned and regulated, as can be seen in the technical construction manual for green-blue stormwater systems written by Fridell et al. (2020), which is used by Uppsala municipality as basis for the nature-based solutions implemented in Rosendal (Informant 2023).

Existing theory, as already mentioned, does show that nature-based solutions can effectively manage flooding (Lin et al. 2015; Huang et al. 2020; Green et al. 2021), whereas traditional gray infrastructure is unable to keep up (MSB et al. 2017; Huang et al. 2020). Still, it is interesting to consider this contrast in which technological solutions are trusted and which are not, particularly when it comes to Rosendal and the sensitive areas around the Uppsala esker. Since the esker constitutes the source from which Uppsala gets its drinking water (Uppsala municipality 2016), any malfunction or damage to the management systems preventing leakage of polluted water into the esker could have catastrophic consequences for the entire municipality. Evidently, the trust in the technological systems utilized in Rosendal, and in other sensitive areas in the future, is strong enough that this risk is deemed to be on an acceptable level.

However, it is also clear that the Uppsala esker is considered in how Uppsala municipality formulates its strategies on continued urban growth. The location of the esker dictates where it is appropriate to further urbanize in Uppsala, and the strategies presented in the comprehensive plan reflect this. In sensitive areas on the esker, new development projects should be limited (Uppsala municipality 2016), and innovative technological solutions should be developed to minimize the risk of urbanization and densification efforts polluting the groundwater. Contrary to this, Malmö municipality has no esker, and the strategies in the comprehensive plan thus do not need to take the sensitivity of areas in close proximity to an esker into consideration (Malmö stad 2018). For this reason, there is potentially more freedom in where new development project can be located in Malmö, compared to in Uppsala. Nevertheless, the same trust in sustainable new technologies can be seen in Malmö’s flood management strategies as in Uppsala’s.

Swyngedouw (2010) describes how “eco-technologies” are used with the aim of procuring a fix for environmental problems and climate change, which would ensure nothing in the way society functions actually has to change. Although not on the same scale as climate change itself, the strategies presented by both Malmö and Uppsala municipalities could be connected to this mindset described by Swyngedouw (2010). Both municipalities recognize that the risk of flooding is heightened because of urbanization, yet further urban growth is still a goal; thus, technology in the form of nature-based solutions is utilized to allow these municipalities to continue building 'as they always have'. Sustainable management measures become the bedrock on which dreams of continued densification rest, and little thought seems to be devoted to the question of whether that very densification could erode the protection such measures are meant to create. Swyngedouw (2010) touches upon this factor as well; how environmental problems are often externalized, even if they originate from internal processes – in this case, the internal process would be the municipalities' seemingly prioritized efforts to grow. Consequently, society has to continually play catch-up with problems it largely creates itself.

On the other hand, it has been shown that new technology involving nature-based solutions are needed, since traditional gray infrastructure is unable to adapt to changes in the climate and therefore cannot meet the current and future demands on the mitigation of pluvial urban flood risk (Wagner & Breil 2013; Huang et al. 2020). Considering the fact that growing Swedish municipalities have to make sure they provide housing, schools, jobs, and other services for their inhabitants, further urban growth is both necessary and desired. In that case, nature-based solutions are an efficient, sustainable way to provide new developments with the water management systems necessitated by both climate change and continued urbanization (Lin et al. 2015; Huang et al. 2020), and a combination of these and traditional drainage systems are certainly better than continuing to rely on gray infrastructure alone. From this point of view, it may not be applicable to label the nature-based solutions used in Uppsala and Malmö municipality as technological fixes after all.

### 5.1.2 Risk analyses and planning sustainable developments

Sustainable, nature-based flood management strategies do work, as noted before. Rain gardens, green roofs, and permeable pavement have been proven to effectively contribute to reducing runoff, retaining water, and lessening the pressure on traditional urban drainage systems (Lin et al. 2015; Huang et al. 2020). There is a clear potential for these types of systems to reduce the risk of flooding in urban areas (Green et al. 2021), but to do so, they need to actually be installed within the urban landscape. Since it is difficult to retroactively add green infrastructure to already densified areas (Lin et al. 2015), sustainable measures need to be actively integrated into the planning and implementation of densification projects, if both densification and sustainable management of pluvial urban flooding are desired. Moreover, since nature-based strategies need to be complemented with traditional gray infrastructure for a truly effective pluvial flood management, a holistic approach with integrated green-blue-gray infrastructure is necessary (Green et al. 2021).

A risk and sensitivity analysis is also needed when working with sustainable flood management and densification; this can be seen particularly in the non-structural strategies described by Uppsala municipality (2016). Not only can this type of analysis be a tool for municipalities to know which areas might have too high a flood risk to be economically and socially viable for new developments, but also as which areas are sensitive and need additional protective measures if new construction is to be done there. This is evident from the Rosendal project in Uppsala, and how a sensitivity analysis was done for the area (Informant 2023). Since floods can have severe economic consequences (Malmö stad 2017; Bederoff 2023), companies and private property owners could also benefit from doing such an analysis for their properties. Knowing which properties are more at risk during pluvial flood events could, for example, allow housing developers to know from the beginning to implement additional protective measures on their property, and could help them save a lot of money on damage mitigation later.

## 5.2 Sustainability, resilience, adaptability

There are several aspects of sustainability that should be considered in the fields of landscape and urban planning. Nature-based solutions, such as the ones mentioned by Stahre (2008), provide both ecological, social, and economic benefits (Huang et al. 2020), which shows that there is some overlap between different aspects of sustainability. An example of this overlap is how the green infrastructure used in natural solutions not only positively affects ecological values, but also provides social benefits by enhancing an area's aesthetic qualities and making it more pleasant to visit (Huang et al. 2020). It thereby becomes more likely for social and recreational activities to happen there. Pluvial urban flooding can also cause incredibly costly damages, so finding ways to prevent or mitigate it could be considered to increase the economic sustainability of an area as well.

However, as written by Lin et al. (2015), the direct benefits of green infrastructure and ecosystem services in urban areas will only be experienced if such systems are available where the inhabitants live out their lives. From the interview with the informant (2023), it is clear that retroactively adding nature-based solutions to existing public urban landscapes can be considered an economic loss for the municipality if it is done before renovations are absolutely necessary. On the other hand, new development projects in previously unexploited areas allow for the inclusion of measures for sustainable flood management from the beginning, while also providing an opportunity for the municipality to earn money through selling land (Informant 2023). As a result, there is a potential risk for inequity when it comes to where sustainable flood management strategies are implemented. This is necessary to consider during urban planning projects; however, it is outside the scope of this thesis and further discussion on the subject will therefore not be done.

Another important aspect to consider in the context of pluvial urban flood management is resilience. Ahern (2011) writes that sustainability in urban and landscape planning was, at first, thought of as a static or even formulaic state which could remain for many years to come once it had been achieved. However, this view of sustainability was incompatible with the non-equilibrium perspective of cultural and natural systems being “inherently variable, uncertain, and prone to unexpected change”, which emerged during the later half of the 20th century (Ahern 2011:341). A landscape can therefore not be sustainable if it is static and unable to respond to the changes in these systems (Ahern 2011). In contrast to this, a resilient system can react and adapt to change without losing its base characteristics (Ahern 2011). When it comes to urban drainage specifically, gray infrastructure is essentially inflexible (Wagner & Breil 2013) due to being limited by its set dimensions, as previously established. Such infrastructure is not able to adapt to a higher amount of water than it was originally designed for (Wagner & Breil 2013), which is why it needs to be complemented with other forms of sustainable drainage and water management systems to increase resilience against pluvial urban flooding.

The strategies presented by both Malmö and Uppsala municipalities have clear connections to resilience theory, since natural systems utilizing green infrastructure are more resilient to future changes than inflexible, hard-engineered solutions (Green et al. 2021). Multifunctionality, which is used by both municipalities and recommended by MSB, is a spatially effective way to increase resilience through the incorporation of ecosystem services in dense urban areas (Ahern 2011). An additional way to increase urban resilience against disturbances is the decentralization of major functions (Ahern 2011; Green et al. 2021). This is also achieved with the sustainable small-scale solutions for flood management presented by both Uppsala and Malmö municipalities.

Furthermore, it could be argued that multifunctional solutions for managing water can contribute to strengthening the idea of nature being allowed in urban areas without needing to be so strictly controlled; this topic was also touched upon in chapter 3.2, although for non-structural measures for flood management instead. Multifunctional solutions have the potential to allow nature to be more visible in the urban landscape than traditional urban drainage systems, which are often hidden away underground (Kaika 2005). While perhaps not entirely to the point of viewing natural events with negative consequences as “residents” rather than natural disasters, Mathur and da Cunha (2015) talk about, solutions such as areas for planned flooding do allow the water to take up more space in the urban landscape.

In conjunction with both sustainability and resilience, another concept prudent to consider within landscape architecture and urban planning is urban adaptability. As mentioned in chapter 2, urban adaptability is the capacity of an urban area to adapt its public and private spaces to changes that can be caused by a variety of reasons, such as environmental or technological (Tsahor et al. 2023). Although not contemplated in detail in this thesis, this concept can be connected with Sweden’s national strategy for climate adaptation, since it concerns ways to adapt the physical environment to changes brought on by climate change.

## 5.3 Reflections on the method

### 5.3.1 Document analysis and interview

A consequence of the main form of research for this thesis being the analysis of existing documents and other types of material, is that the knowledge garnered is limited by the types of documents found and thereby studied. Some difficulties were encountered during the process of finding documents with relevant information for different municipalities, as the documents from one municipality may differ from the documents from another municipality, in name or contents. For example, much of the relevant information for Malmö municipality could be found in the municipality’s cloudburst plan, but no such plan was found for Uppsala municipality, and hence there was a need to study a number of other documents to find the relevant information for Uppsala. Finding the relevant material was part of the investigative process, but the difficulties involved with actually doing this were perhaps underestimated at the beginning of the process.

The interview provided insight into the practical application of the strategies currently used in Uppsala municipality, and was therefore a valuable addition to the document analysis. Further interviews with other employees at Uppsala municipality would have enhanced this insight even more, but although attempts were made to arrange this, it was not possible during the time limit for this thesis. Interviews with employees at Malmö municipality, or other people with relevant knowledge of pluvial urban flooding and preventative measures in Sweden, would have also been beneficial for the overall understanding of how Sweden works with pluvial urban flood management.

Worth noting is that the material collected from the interview did not, in itself, provide a critical reflection on municipal strategies, and merely added to the information used for the analysis done in this thesis. Interviews with organizations other than municipalities might have provided a more critical perspective on municipal strategies, which could have been beneficial for the analysis.

### 5.3.2 The analytical frame

The effectiveness of the analytical frame used when analyzing documents naturally depends on how the concepts that form the frame are understood. When it comes to the technological fix, only using Weinberg's original definition of the term causes it to become a very narrow analytical lens, and a broader perspective was needed and thus developed to allow for a more nuanced discussion regarding the sustainability of new, technological systems implemented in densified areas.

Due to the nature of Sweden's national strategies, and how they involve laws, regulations, and stakeholder cooperation rather than specific structural solutions, it was rather difficult to apply the analytical frame on this level. As it turned out, the analytical frame fit the analysis for the municipal level more, and perhaps the analysis of the strategies on the national level might have benefited from a modified, or different analytical frame.

## 5.4 Further investigations

The depth of the research and analysis for this thesis was, of course, limited by the length of the time period during which the work was set to be completed. For a more in-depth investigation, further studies would need to include a larger number of Swedish municipalities and their strategies and urban planning goals. This would help give a broader understanding of Sweden's flood management strategies within the context of the country's strategies for densification, compared to the limited information gleaned from only two sample municipalities.

The idea of studying the management strategies for pluvial flooding from countries other than Sweden was considered during the process of this thesis, but due to the time limit it was decided early on that the investigations would be limited to Sweden only. Further studies on this subject could therefore include detailed research into other countries to see if their strategies are similar to Sweden's or not. If they are not similar, an analysis could perhaps be made of foreign 'sucessful' strategies for managing pluvial flooding in urban areas, to see if any of them could be implemented in Sweden. Since many of the references for this thesis are European or American, conducting further studies on non-Western countries in particular could provide a more nuanced perspective.

Studies on management strategies specifically meant for flooding due to rising sea levels or fluvial flooding, i.e. the flooding of rivers, could also be an interesting topic for further studies, which would complement the focus on pluvial flooding in this thesis.

# 6. Concluding remarks

Making room for both sustainable management of pluvial urban flooding and a growing population in cities with increasingly limited available space is a highly complex matter and not easily solved. Urban growth is evidently highly desired by the municipalities of Malmö and Uppsala, and the situation is presumably the same for many other Swedish municipalities. For this reason, sustainable flood management strategies become necessary to mitigate the increased risk of pluvial flooding caused by urbanization and densification, but they do not actually solve the problems caused by these processes. Instead, since the strategy used for urban growth is further densification, sustainable flood management measures are seemingly used to make that strategy possible, allowing municipalities to use technology as a shortcut that removes the need for any substantial societal change. On the other hand, a holistic approach with both nature-based solutions and traditional urban drainage is surely preferable to only relying on gray infrastructure, and both Uppsala and Malmö are clearly taking steps to take such an approach. This could perhaps be considered as moving towards a societal change, at least when it comes to how water is managed in urban areas, and how cities can become more resilient and adaptable.

Due to the increasing need to provide housing for Sweden's population, the desire for continuous urban growth is not likely to diminish, and until any other urban planning strategy is determined to be more beneficial, the desire for densification is likely to continue as well. Of course, if densification were to actually be replaced with a different planning strategy, careful consideration would have to be done to ensure this new strategy does not result in similar – or worse – problems. Until such a strategy is potentially devised, sustainable, nature-based solutions for managing urban pluvial flooding have to be actively integrated into new development projects throughout the entire process. Even if these solutions are used as technological fixes, they are still required to meet the current and future need for increased protection against flooding.

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# Popular science summary

Flooding in cities and other urban areas is increasingly recognized as an issue that needs to be considered in landscape architecture and urban planning. This thesis deals specifically with *pluvial urban flooding*, which is when it rains intensely in an urban area and the sewage system is not able to fully handle the water, which results in a flood. Climate change is causing extreme rainfall to become more common, and the large amount of hard pavement in urban areas means that water remains on the surface instead of being able to flow directly into the ground. Traditional sewage systems are made to transport this water away from cities, but they are unable to keep up with the increased amount of rain caused by climate change. Because of this, more sustainable alternatives have cropped up in both Sweden and other countries.

*Nature-based solutions* use nature and natural processes to clean, store, and lead water away from urban areas. In this thesis, Sweden's national and municipal strategies for managing flooding are investigated, with the two municipalities of Malmö and Uppsala chosen as focus areas. The following nature-based solutions are included in the strategies presented by Malmö and Uppsala:

- Adding permeable pavement and limiting hard pavement.
- Areas specifically designed to handle flooding and detain water.
- Rain gardens that clean water before it is transported away from urban areas.

However, both Malmö and Uppsala also want to densify. *Densification* is a popular urban planning strategy meant to prevent urban areas from growing outwards by building within already built-up areas. This puts the green spaces needed for nature-based solutions at risk of being reduced or replaced by roads and buildings, and could increase the risk of flooding. Despite this apparent contradiction between densification and sustainable flood management, both of these things are evidently wanted at the same time. It seems that nature-based solutions are used to pave the way for continued urbanization, and to allow municipalities to continue to build more or less as they always have without society really needing to change. At the same time, nature-based solutions do work, and are necessary to meet the increased need for protection against pluvial urban flooding, so if densification is to be used, it is important that sustainable flood management solutions are actively considered and implemented during new development projects.

# Acknowledgements

I would like to sincerely thank everyone who has supported me during my work with this thesis, without whom this would not have been possible.

My supervisor Vera Vicenzotti, for your guidance and help throughout the entire process.

Gudrun Rabenius, for your helpful suggestions and provision of photos.

The informant at Uppsala municipality, for your valuable contribution to my research into municipal strategies.

My classmates, and friends and family outside SLU, for your feedback and kind encouragement.

# Appendix 1

Questions asked during the interview 2023-04-05 with the project leader for the Rosendal project at Uppsala municipality. As the interview was held in Swedish, this appendix shows an approximate English translation of the questions.

- Could you present the Rosendal project in your own words?
- Have you gone back and redone certain things during the development process? *(On the subject of continuous evaluation and fixing mistakes from early stages of the project.)*
- Regarding the Uppsala esker – is the closeness [of Rosendal] to the esker the reason for the implementation of new systems? Or is the reason more a general aim to be environmentally sustainable?
- Is the plan that these types of new [sustainable] systems will be implemented in other new development areas as well?
- Are there any plans to implement these systems in existing areas that do not already have them?
- The systems are meant to be self-sustainable. Could you talk a little about what this means?
- Regarding multifunctional areas – is this something that was specifically considered in Rosendal?

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