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Climate Adaptive Stormwater Management:

A comperativ study of Oslo and Helsinki

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Landscape Architecture for Global Sustainability

Preface

This master thesis marks the end of my masters in Landscape Architecture for Global Sustainability at the Norwegian University of Life Sciences (NMBU).

The interest of water management has been a central topic throughout my master. Combining this with the core of the master: sustainability and global perspective, I was inspired to dive deeper into the topic of sustainable stormwater management.

I express my sincere gratitude to my supervisor, Ingrid Merete Ødegård, for her invaluable advice, support and exceptional guidance. I would also like to extend a thank you to my parents for their multiple reviews of my paper and the general support throughout the semester.

In addition I would like to express my gratitude to Oslo and Helsinki municipality. I am especially thankful to the employers in Helsinki who have promptly responded to every email I sent inquiring about laws, plans, documents and the availability in language besides finnish. Without the assistance of several helpful individuals in Finland, I would not have had the necessary foundation for a comparison.

Lastly, I would like to acknowledge my friends and my fellow students at KA for making this semester a memorable one. In particular I want to express my appreciation to Helene, Emilie og Say, whom I shared a room with and who made this journey even more rewarding.

Bibliography

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Table of content

Abstract

The world is facing the consequences of climate change and needs to adapt. The increasing temperature is a central change and with it comes several consequences. One of these is an increase in precipitation, and therefore an increase in stormwater. In cities where the natural water cycle is disrupted, stormwater management is becoming a challenge. The main increase in precipitation will be during the winter. This will increase the amount of snow, meltwater and ice formation.

Helsinki and Oslo are both cities that are having to adapt to the increase in rain, snow, ice and meltwater. The thesis will be focused on comparing these two cities' stormwater management. To understand in which degree the cities are adapting to this challenge, documents in three different levels were analyzed. The documents covered the overall municipalities plan, the climate adaptive plan and the concrete stormwater plan.

By analyzing these documents, an opportunity to see the overview from overall to specific measure was achieved. It is important that the consistency from climate adaptation to local measures hold up, and that it is emphasized that this is a global situation which needs local action.

The discussion proved that the main research question:

To which extent is climate adaptation part of planning for the increasing challenge of stormwater management in Oslo and Helsinki?

Should be answered in three distinct aspects:

Managing and adapting to the general increase of precipitation during spring, summer, and fall.
Both cities have adapted quite well to the general increase, with blue- green infrastructure and a goal of purifying the stormwater before it meets the sea or larger rivers.

Handle the heavy rain expected during the summer months.
A bit more complex, both cities have this as a priority, but Oslo has included it in its strategy while Helsinki is working on it through pilot projects. The change here is due to differences in ownership in the respective municipalities.

Managing the increase in precipitation during the winter together with the changing climate conditions.
Helsinki is one step ahead of Oslo here due to its very thorough weather and climate change risk report, and the Nasta strategy which brings up the issue of weather effects on traffic. Other than this strategy, Helsinki has, same as Oslo, no specific measures in place to handle stormwater management during the winter months.

Both Helsinki and Oslo have included climate adaptation measures in their planning to address the challenges of stormwater management. The two cities differ in the level of detail in stormwater management, and where the focus lies. The largest weakness they both have is the lack of specific measures in the winter. This is a crucial and significant part of stormwater management where there is little to no climate adaptive measures taken.

Sammendrag

Verden står ovenfor konsekvensene av klimaendringer og trenger å tilpasse seg. Økende temperatur er en sentral endring, og med det følger flere konsekvenser. En av disse er økt nedbør og dermed økt overvann. I byer der den naturlige vannsyklusen er forstyrret, blir overvannshåndtering en stadig større utfordring. Den viktigste økningen i nedbør vil være om vinteren. Det betyr at mengden snø, isdannelse og smeltevann vil øke totalt sett.

Helsingfors og Oslo er begge byer som må tilpasse seg økende, regn, snø, is og smeltevann. Denne oppgaven vil fokusere på hvordan disse to byene tilpasser overvannshåndt eringen sin. For å forstå i hvilken grad byen tilpasser seg denne utfordringen, ble dokumenter på tre forskjellige nivåer analysert. Dokumentene dekket kommunenes overordnede plan, klimatilpasningsplanen og den konkrete plan for overvannshåndtering.

Ved å analysere disse dokumentene, ble det oppnådd mulighet for å se oversikten fra overordnet til konkrete tiltak. Det er viktig at den røde tråden fra klimatilpasning til lokale tiltak opprettholdes, og at det understrekes at dette er en global situasjon som trenger lokal handling.

Diskusjonen viste at hovedspørsmålet:

I hvilken grad er klimatilpasning en del av planleggingen for økende utfordringer med overvannshåndteringer i Oslo og Helsingfors?

Bør besvares i tre forskjellige aspekter.

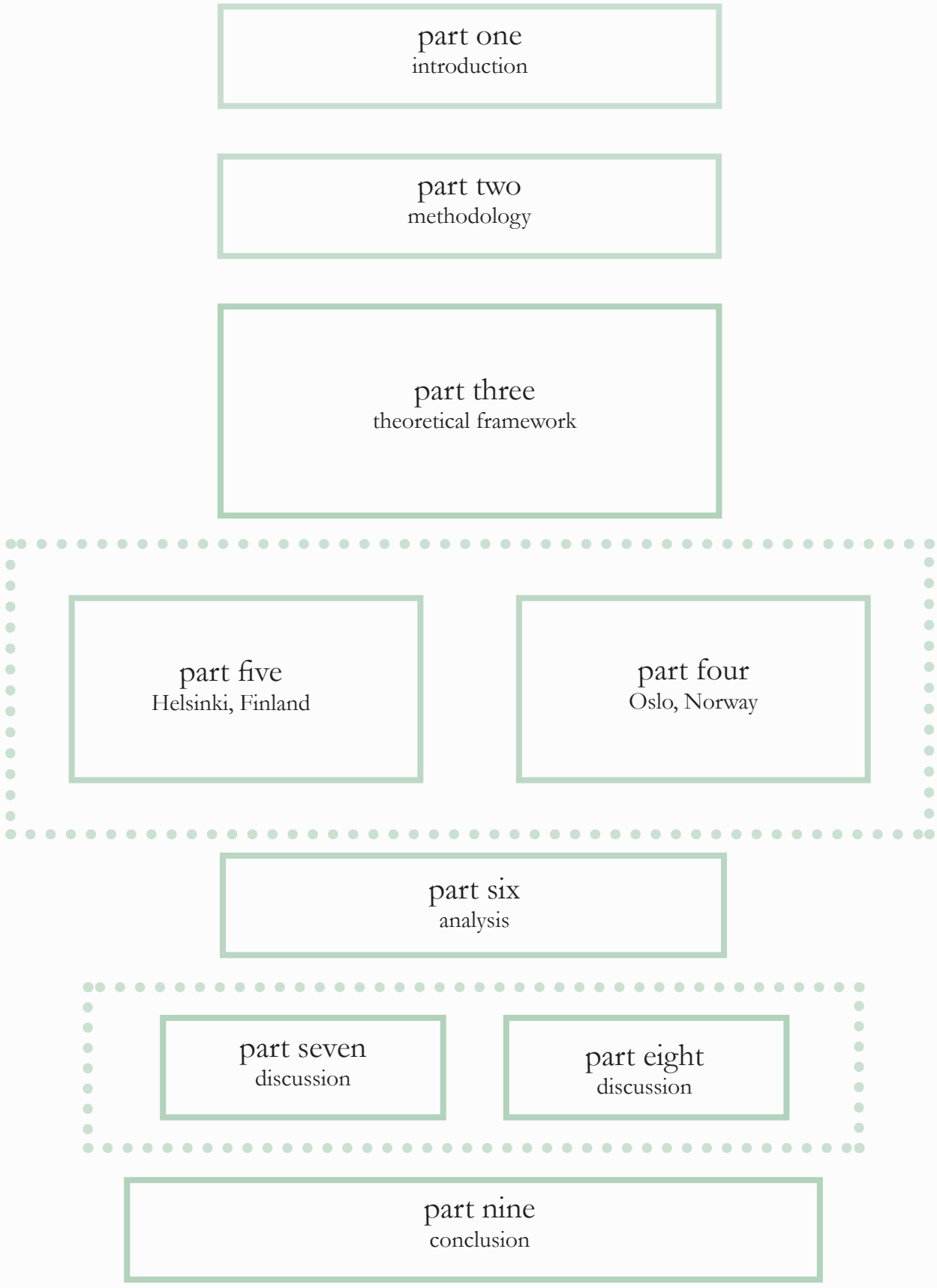
Håndteringen og tilpasning til den generelle økningen i nedbør i løpet av våren, sommeren og høst.
Begge byene har tilpasset seg ganske bra til den generelle økningen, men blågrønne infrastruktur og et mål om å rense overvannet før det når sjøen eller større elver.

Håndtering av tung nedbør som forventes i løpet av sommermånedene.
Litt mer komplekst, begge byene har dette som prioritet, men Oslo har inkludert det i sin strategi mens Helsingfors jobber med det gjennom pilotprosjekter. Endringen skyldes forskjeller i eierskap i de respektive kommunene.

Håndteringen av økningen i nedbør i løpet av vinteren sammen med endrede klimatiske forhold.
Helsingfors er et sted foran Oslo på grunn av sin meget grundige rapport om vær- og klima risiko og Nasta strategien som tar opp spørsmålet om vær på trafikken. Bortsett fra denne strategien har ikke Helsingfors, som Oslo, ingen konkrete tiltak på plass for å håndtere overvann utfordringene i vintermånedene.

Både Helsingfors og Oslo har inkludert klimatilpasning i planleggingen sin for å håndtere utfordringene med overvannsproblemet. De to byene skiller seg fra hverandre i detaljnivåene for overvann og hvor fokuset ligger. Den største svakheten de begge har er mangelen på konkrete tiltak om vinteren. Dette er en viktig og betydelig del av overvannshåndteringen der det er tatt lite eller ingen klimatipanseringstiltak.

Overview over thesis structure



Terminology clarification

Stormwater / Overvann
Stormwater is water that runs off surfaces as a consequence of rain or meltwater.

Retention spaces / Fordrøyningsbassenger
Is a process where rain, flood, or wastewater is held back in order to dampen or slow down the flow of water downstream.

Precipitation / Nedbør
Precipitation is water in a liquid or solid form that falls to the earth's surface. It is a collective term that includes rain, snow, hail, or drizzle..

Impervious surfaces / ugjennomtrengelige overflater
These are surfaces that do not allow the passage of liquids. Examples of such a surface are concrete, asphalt, and clay coatings.

Permeable surfaces / Peramble dekker
These are surfaces that allow liquids to pass through. Examples of such a surface are gravel, soil and sand.

Saturated soil / Mettet jord
This happens when all cracks, spaces, and pores in the soil are filled with water, making the soil "full". Can happen when there is heavy rainfall and too much water gets directed to the same soil.

SuDS / LID / LOD
This thesis will be using SuDS as the term for infiltration or retaining stormwater. Norway, the term is LOD (lokal overvannsdiponering) and in the US, it is LID (Low impact development).

Multifunctional spaces / multifunskjonelle rom
Refers to areas that are designed and used for multiple purposes or functions, instead of being for one single specific use.

Resilient / Motstandsdyktig
In this thesis resilient will be used in the context of resilient cities in the case of stormwater management.

Mitigation / Reduksjon / Avbøting
Mitigation in this thesis will refer to actions or measures taken to reduce or minimize the impact of climate change and the consequences.

Dictionary

Gutter / Takrenne

Daylighting rivers and streams /
Åpning av elver og bekker

Ducted rivers / Elver i rør

Slippage / Å skli på isen

Drainage network / Avløpsnett

Flood routes / Flomvei

Catchment area / Nedbørfelt

Patchwork / Lappeteppe

Conveyed / Dirigert/Veiledet

Specific Measure / Konkrete tiltak

Meltwater / Smeltevann

part one
introduction

Climate change is not just a possibility, it is happening and affecting everything around us. The impact of climate change is triggering transformative changes, albeit with variations across regions.

At the core of these changes lies the shift in temperature. The increase has already surpassed 1 degree since pre-industrial times and nine of the last ten years have been the warmest ever recorded globally (Miljøstatus, 2023). One of the many consequences of the rising temperature is the increase in precipitation.

It is predicted based on the last climate period (1995-2015) that globally there will be an increase of precipitation of 0- 5% in the lowest scenario, 1,5 – 8% in the middle scenario, and 1-13% in the highest scenario by the end of the century (Miljødirektoratet, 2021).

With rising precipitation stormwater is increasing, and this is not in a stable and predictable way. The wetter, wilder, and warmer climate is predicted for the Nordic countries, and this can cause chaos and damage in cities.

1.1 Research questions

This paper aims to conduct an in-depth comparison of the challenges of stormwater in Oslo and Helsinki.

The urban built environment involves conflicting interests in land use. This causes making changes in this space a challenge and pressurized discussion involves multiple functions and land use. In addition to the complexity of land use, the changing climate necessitates climate adaptation through strategic planning and effective stormwater management.

Therefore the research questions are as followed:

Primary research question:

To which extent is climate adaptation part of planning for the increasing challenge of stormwater management in Oslo and Helsinki?

I hvilken grad er klimatilpasning en del av planleggingen for økende utfordringer med overvannshåndteringer i Oslo og Helsinki?

Secondary research questions

What are the similarities and differences in the current stormwater management in Oslo and Helsinki?
Hvordan er den nåverende overvannshåndteringen i Oslo og Helsinki like og ulike?

How is stormwater management in Oslo and Helsinki addressing seasonal variation in the future, specifically winter?
På hvilken måte adresserer overvannshåndteringen variasjon i fremtiden, spesielt på vinterstid?

1.2 Goal

The primary objective of this thesis is to conduct a comparative analysis of the stormwater management strategies implemented in Oslo and Helsinki. This study aims to identify commonalities and differences between the two cities´ approaches and solutions. Potentially there is something the cities can learn from each other in strategic planning, specific implementation or climate adaptation.

In short; **Can the cities learn something from each other?**

Oslo, Norway

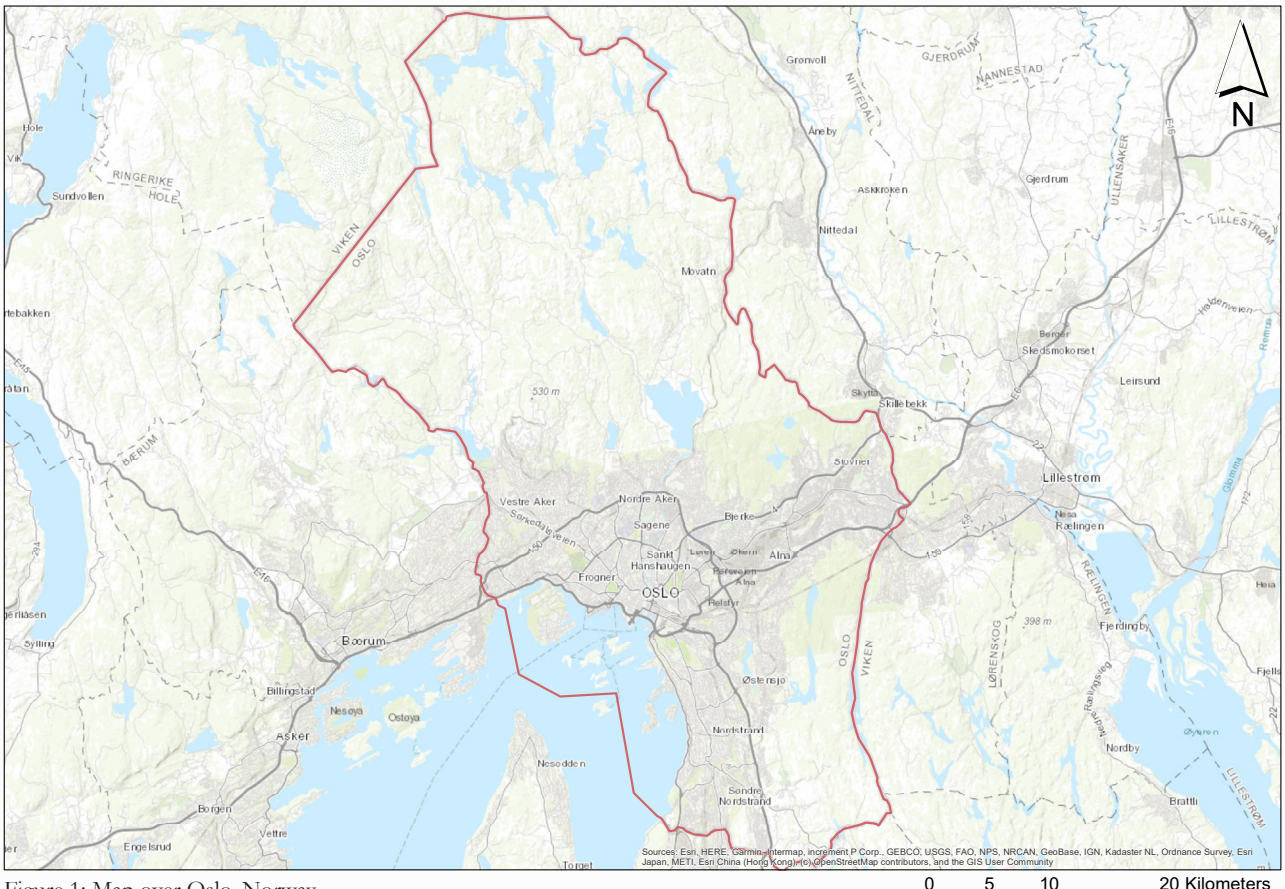


Figure 1: Map over Oslo, Norway

1.3 Scope, why Oslo and Helsinki?

Narrowing down the scope is a critical aspect of refining the paper to focus on topics that are pertinent to the research questions.

Earlier several studies have been done on the Nordic cities, Copenhagen and Malmö. However, I do have concerns about looking to cities that don't have the same winter climate. There are specific challenges that cities that have winter need to tackle.

I have chosen to compare Oslo to Helsinki, because of three factors. They have similar climatic conditions, are waterfront cities, and have rivers that run through the urban space. In addition, both cities are located at around 60 degrees north.

Climate conditions:
Winter temperatures can reach as low as -20 degrees Celsius and summer temperatures hover around 20- 25 degrees Celsius.

Waterfront cities
The two cities are situated along the coastline, thereby elevating the risk of urban pollution due to stormwater runoff. Consequently, stormwater management assumes a critical role in mitigating the pollution.

Urban rivers
The presence of rivers that run through both cities and flow towards the ocean implies that river and pluvial flooding are plausible occurrences in both locations.

This paper will concentrate on Oslo´s stormwater management strategies and compare them with Helsinki's similar strategies to enhance understanding of the topic.

Helsinki, Finland

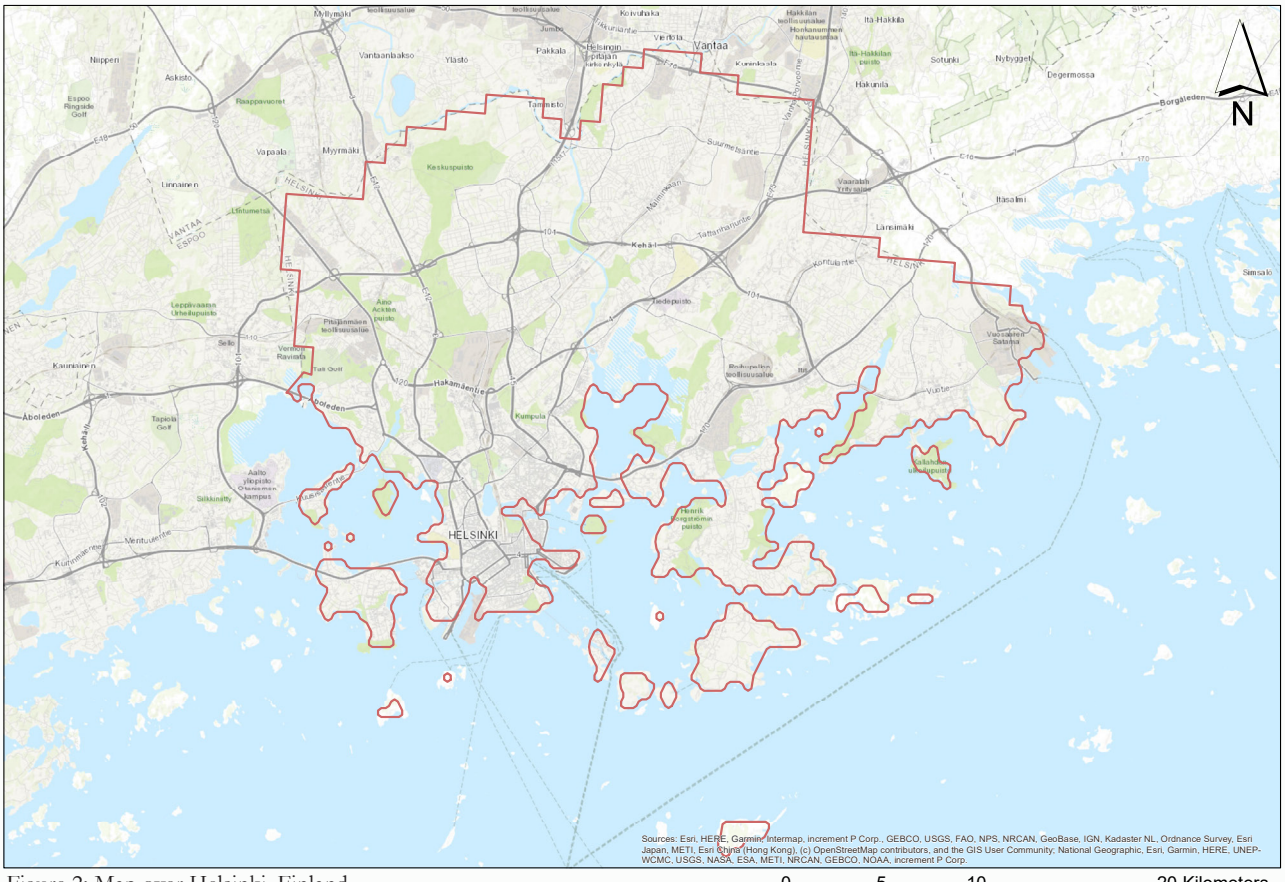
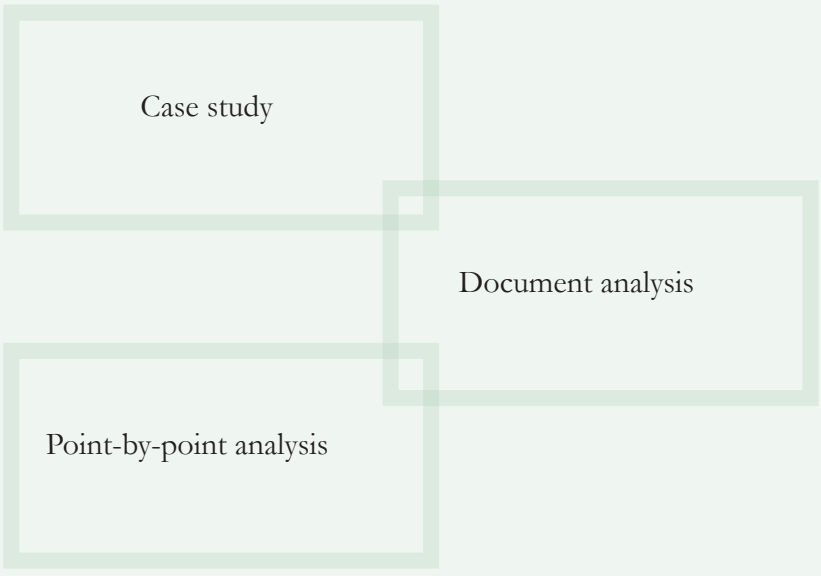


Figure 2: Map over Helsinki, Finland

part two
methodology

There are three main methods used in this thesis. These three are; a case study, a document analysis, and a point-by-point analysis comparison. An important element is to understand how they are all connected. The finished findings are a result of all three methods.



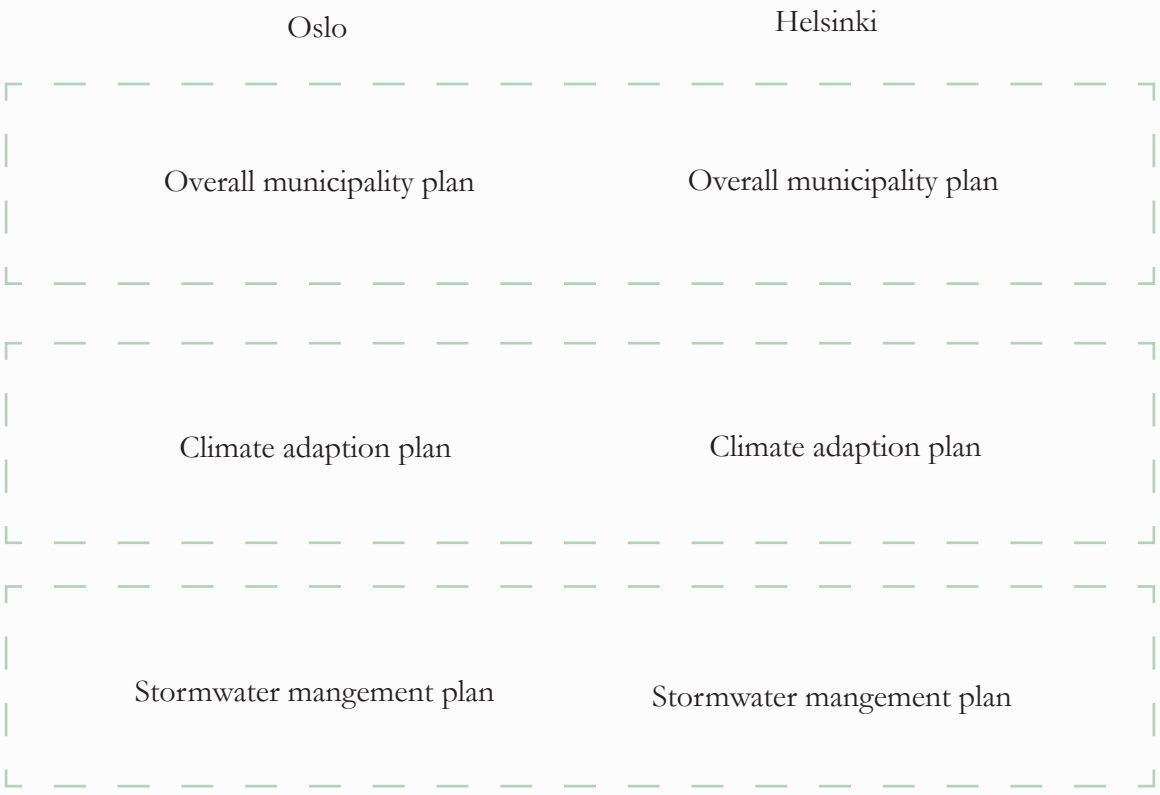
2.1 Case study

Firstly a case study was conducted. The study involved a thorough review of the respective municipal web pages to identify relevant documents on stormwater management.

The document selection process was guided by three primary perspectives; City development, climate adaptation, and stormwater management. The aim here was to select key documents in each category.

To ensure comparability, the selected document from each city needed to be reflective of one another. This allowed for a standardized and systematic analysis and facilitated a point-by-point comparison.

Note; the key document needed to be readily accessible to the general public.



2.2 Document analysis

To further establish a basis for the comparison, a dataset foundation was constructed through a structured document analysis of municipal documents from Oslo and Helsinki. The documents were analyzed according to three predetermined criteria, which enables a breakdown of the document into comparable elements. The purpose of this document study was to gather the information that would enable a comprehensive evaluation of the stormwater strategies of both cities on the same basis (Oliver, 2012).

The three criteria to which the document will be analyzed are **Climate adaptation, Concrete measures, and Winter conditions**. These three criteria were selected according to the research questions.

Breaking down the content of the document according to the predetermined criteria facilitates **the point-by-point comparison,** which enables a more comprehensive evaluation. This approach allows for an examination of how the document can be compared, as emphasized by Oliver (2012).

Criteria	Explanation
Climate Adaptation	How does the document facilitate climate adaptation?
Specific Measures	Which specific measures do the document suggest?
Winter Conditions	Are the cities taking into account the changing winter conditions in stormwater manegement?

2.3 Point- by- point analysis

This study utilizes a comparative analysis approach to evaluate the stormwater management strategies of two cities, Oslo and Helsinki.

To conduct a comprehensive and detailed evaluation, a point-by-point comparison methodology was employed as opposed to a block-by-block approach.

This method allows for an analysis of individual elements of the management initiative, providing a more focused and detailed evaluation (Barnet, 2015, p. 148-149)

When choosing to do a point-by-point analysis instead of a block-by-block analysis the reason is that point-by-point is viewing elements as singular instead of a whole. This makes the comparison of the cities in question easier to break down.

The challenge of a point-by-point is that it is easy to leave loose ends or go too much back and forth between the elements. Therefore it is essential to bring it all together, in the end, (Barnet, 2015, p. 150-153).

For example;

If we consider the analysis of a subway station, this is an example of how the two different methods could differ in their approach.

Block-by-block analysis

Subway station A
Subway station B

Versus

Point-by-point analysis

Subway station A (walkway)
Subway station B (walkway)

Subway station A (benches)
Subway station B (benches)

Subway station A (availability)
Subway station B (availability)

part three
theoretical framawork

To gain a comprehensive understanding of the subsequent discussion, it is imperative to gain a broad knowledge base for a range of background topics, spanning from a global perspective to stormwater in the local context.

Figure 3: Bjølsen student city, an open stormwater canal between the residental blocks (Miljødirektoratet, 2022)

3.1 Global perspective

It is important to keep a global perspective when investigating stormwater management.

Stormwater cannot be understood and addressed in isolation but needs to be tackled locally with specific solutions. The increase in stormwater is a global phenomenon, linked to the increase in precipitation, including both regular and heavy rain, due to climate change.

The intensity and frequency of precipitation are expected to increase and extreme precipitation is expected to become more common worldwide, even in areas where seasonal precipitation is decreasing. As a result, pluvial flooding (rain-related flood) is projected to increase in most regions (IPCC, 2021b).

As seen in Figure 4, Oslo and Helsinki is in Northen Europe and are therefore a part of the same region, but at the same time a part of a global perspective.

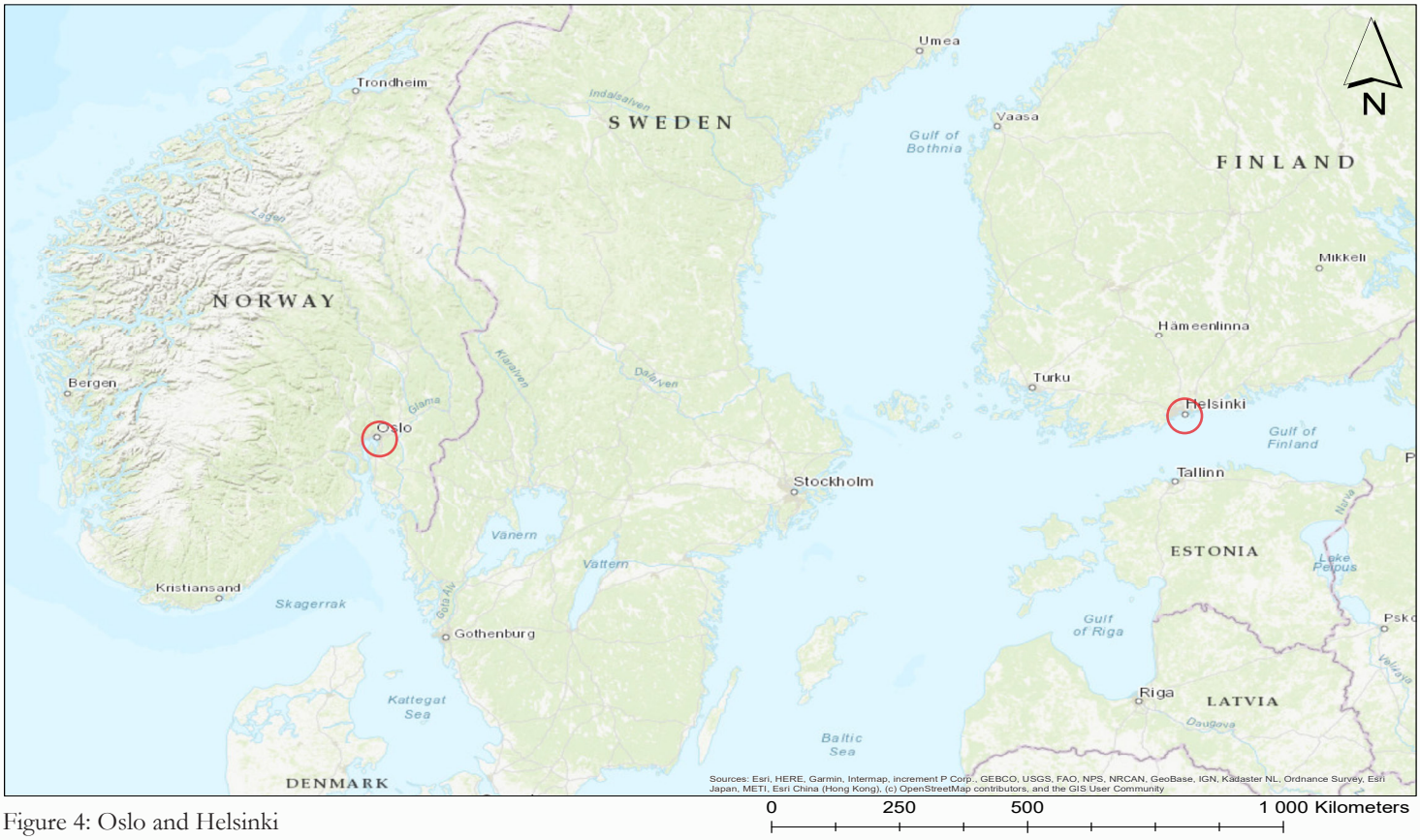


Figure 4: Oslo and Helsinki

UN Sustainable Devlopment Goals

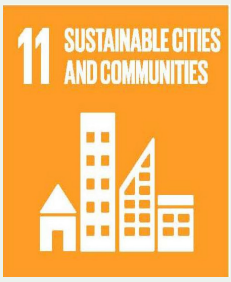
In 2017, the United Nations established 17 goals aimed at achieving a sustainable and secure future. Each of these goals addresses a unique aspect of development, and they all must work together in harmony, see Figure 5. While it is possible to examine each goal independently, it is essential to consider their interconnections. If action is being taken toward one goal, it is important to consider how it will affect the other goals.

In other words, the implementation of each goal should be done with a holistic view that takes into account the broader context of sustainable development (United Nations, s.a).

The following four goals are directly linked to stormwater mangement.

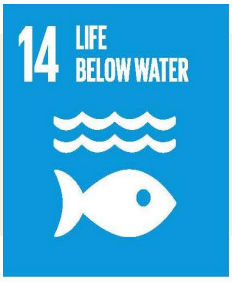
Figure 5: Sustainable Development Goals (UN, 2023)

6.3 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.
6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.



11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities
11 B By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters

13.1 strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
13.2 Integrate climate change measures into national policies, strategies and planning
13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning



14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

The Paris agreement

The Paris Agreement is an international legally binding agreement that 194 countries, plus the European Union have agreed to. The international treaty adopted in 2015 covers climate change, change mitigation, adaptation, and finance. The agreement is meant to encourage international cooperation to combat the ongoing climate crisis.

The agreement has three key elements.

Limit the temperature increase to 1.5 degrees

Review countries' commitment to cutting emissions every five years

Provide climate finance to developing countries

Both Finland and Norway have agreed to the terms, and are obliged to follow the agreement.

The Paris Agreement provides a framework and implementation that are essential to achieve sustainable development goals from 2017 (United Nations, 2023).

Figure 7: European union (EU 2023b)

Figure 6: Paris Agreement (2015)

The Water Framework Directive from the EU

This directive's principle is to ensure the protection and sustainable use of water, through integrated and coordinated management across sectors. The directive provides a framework for several underlying EU directives, such as the urban water treatment directive and the drinking water directive (NVE, 2021).

The directive covers healthy rivers, lakes, groundwater, and bathing water. It ensures an integrated approach to water management, including whole ecosystems, regulating pollution, and setting regulations standers (EU, s.a-b).

Both Finland and Norway are obliged to implement the directive in their national legislation and planning.

3.2 Nordic perspective

In the Nordic region, Norway, Sweden, Denmark, Faroe Island, Finland, and Island (see Figure 8), there have been a few extreme events that have had an impact on the region. The most devastating extreme rain event extreme event in 2011 in Copenhagen Denmark, and 2014 in Malmö, Sweden (Langeland, 2017).

These two extreme events have been a wake-up call for all the Nordic cities, showing what could and will happen and the need for mitigation and adaptation. These events are showcasing that why managing stormwater is important in dense cities.

Figure 8: Nordic region

Extreme rain events

An extreme weather event is identified when weather, climate, or environmental conditions including, precipitation, temperature, flooding, or drought, exceed the threshold value located near the upper or lower end of the range of historical measurement (Herring, 2020).

Extreme precipitation events are when the amount of water that falls in a specific time and place creates dangerous conditions for important societal needs, like critical infrastructures or living conditions (Klimaservicesenter, s.a).

There is no single definition for what makes a certain precipitation amount an extreme event. Countries and regions have a different amount of precipitation that is normal and therefore have different limits to which amount is dangerous.

Knowing that the winters will become increasingly wild, one could in the new climate be expecting the first "extreme winter storm". The consequences of an event like that would paralyze any city. Emergency vehicles would be unable to get safely to their intended destinations, workers that are crucial to keeping society going would not be able to get to work, and traffic chaos could create extremely dangerous situations.

Copenhagen, Denmark

On July 2, 2011, Copenhagen was struck by one of the most significant natural disasters in its history. In just a few hours, the city experienced two months' worth of precipitation, with more than 5,000 lightning strikes recorded, resulting in widespread chaos, an example is seen in figure 10.

The amount of rain, measuring 150 mm, caused significant damage to urban areas with estimated costs of up to 10 billion Danish kroner in insurance money (Langeland, 2017).

Such a large volume of water posed a severe threat to critical infrastructure, including the main hospital, which was forced into crisis mode. The hospital´s generators in the basements were at risk of being destroyed by the floodwater, which would have resulted in the evacuation of 1,400 patients (Christiense & Bjørgn-Hansen, 2022).

While climate change may not be directly attributed to the cloudburst, its impact was intensified by the effects of global warming. The University of Copenhagen and the meteorological institute have developed a model that links cloudbursts to the increase in global temperatures (Christiense & Bjørgn-Hansen, 2022).

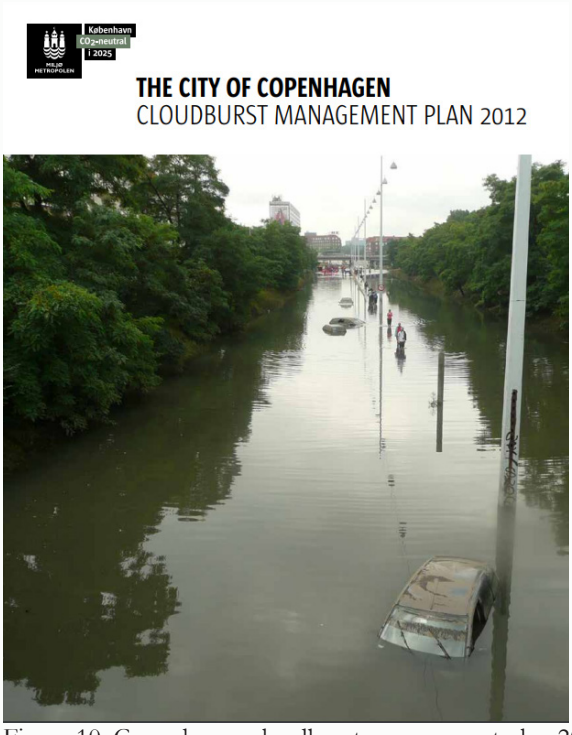


Figure 10: Copenhagen cloudburst management plan 2012 (Baykal, 2012).

Figure 9: Flooded street in Copenhagen (Baykal, 2012)

As a consequence of the cloudburst, 11 billion kroner were allocated to the municipality for implementation purposes over the next two decades. The funds were utilized to plan 300 projects aimed at improving the management of stormwater from roads and buildings. Additionally, several larger areas were defined to be adaptable to temporary standing water, thereby creating versatile spaces (Langeland, 2017).

A cloudburst plan was published in 2012 to plan for the next extreme rain, the plan showcased in figure 9. The plan outlines the priorities and measures recommended for climate adaptation for heavy to extreme precipitation. An Assessment that worked as a foundation for the plan showcased that focusing on the traditional sewage system would have a negative impact, but rather a combination of open stormwater management and drainage system was the new strategy (Miljø-Metropolen, 2012)

Malmö, Sweden

In 2014 Malmö experienced what damage extreme rain could cause. With only a bridge separating Copenhagen and Malmö, the cloudburst in 2011 was still very relevant. The event in 2014 was the most intense precipitation event ever experienced in Sweden and resulted in over 300 million Swedish kroner in an insurance claim. Street flooded and the city was left in chaos, as seen in figure 11.

The traditional drainage system that Malmö was relying on was not designed for the volume of water that rained that day. (Hernebring et al., 2015). The amount of precipitation didn't reach the same level as in Copenhagen, but the amount was still historic in Sweden with 122 mm in six hours (Langeland, 2017).

In the aftermath of this, the muncipality published the "skyfallsplan for Malmö" (Figure 12) to transform the city to a city prepared for the new weather.

Figure 12: Skyfallsplan för Malmö (Nilsson, 2017)

Figure 11: Flooded street in Malmö (Nilsson, 2017)

The neighborhood of Augustenborg in Malmö was relatively less impacted by the extreme rain event. Historically prone to flooding due to an inadequate drainage system resulting in economic and social decline. However, from 1998- 2002, the area underwent a regeneration project that focused on the implementation of sustainable urban drainage systems (SuDS).

Figure 13: Stormwater pond in Augustenborg (Folkesson, 2021).

The projects included the creation of ten retention ponds and six kilometers of water channels, which redirected the water from roofs, roads, and car parks through ditches, ponds, trenches, and wetlands, allowing only the surplus water to be directed into the conventional sewage system. An example of one of these ponds can be seen in figure 13. As a result, the neighborhood was better equipped to handle extreme rain events, and its overall image was significantly improved (Johansson, 2022).

3.3 Stormwater

n the natural environment, the water cycle operates smoothly with water passing through various stages. This includes precipitation, evaporation, absorption by plants and wetlands, and infiltration into groundwater or flows into rivers or lakes.

However, in urban areas, the natural cycle has been disrupted due to the limitations of the urban environment. The impervious surfaces such as roads, pathways, sidewalks, building rooftops, and walls in urban areas obstruct the water cycle, resulting in challenges in managing this stormwater.

In urban areas, where there the surfaces are dominated by impermeable materials, stormwater can sometimes account for 30-95% of the total precipitation. Historically because of pollution in urban spaces, stormwater has traditionally been viewed as a waste product, this perception is changing (Liptan, 2017).

As cities continue to grow and urbanize, there is less space available for open areas, green spaces, and bodies of water. In addition, the city becomes increasingly densely populated, emphasizing housing, offices, and industry, leading to the neglect of green and blue structures.

This leads to a pressurized land use debate in the urban structure. Urbanization also affects the water cycle, increasing both the intensity of precipitation and runoff (IPCC, 2021b).

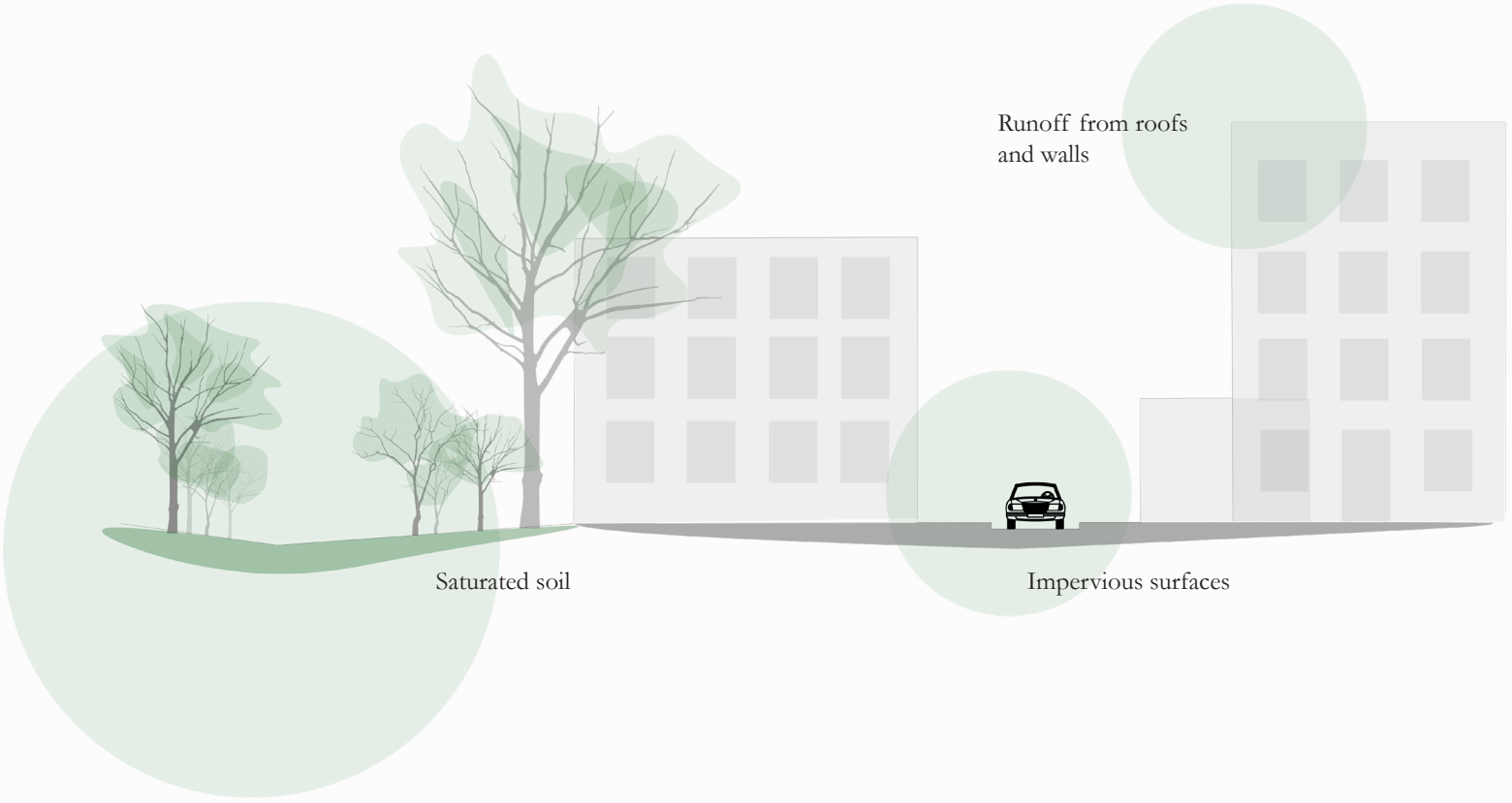


Figure 14: Stormwater challanges during the summer

Stormwater management is a challenge throughout the year, the challenges only change. With the increase in precipitation in the winter together with frozen grounds, pipes, and SuDS, the snow and meltwater will be challenging to hold back and intrude into the urban space and possibly buildings.

The predicted temperature change during winter means that when temperature fluctuates around zero degrees, the stormwater becomes unpredictable and therefore difficult to manage. A general rule is that 1 mm with rain equals 1 cm with snow (YR, 2023). So even with warmer temperatures in the winter, and in general less snow. If the temperature is under 0 degrees and heavy precipitation is coming, it can cause great challenges.

Two primary methods for implementing stormwater management are conventional drainage systems and sustainable drainage systems (SuDS).

Figures 14 and 15, exemplifies stormwater challenges and sources during the summer (14) and winter (15).

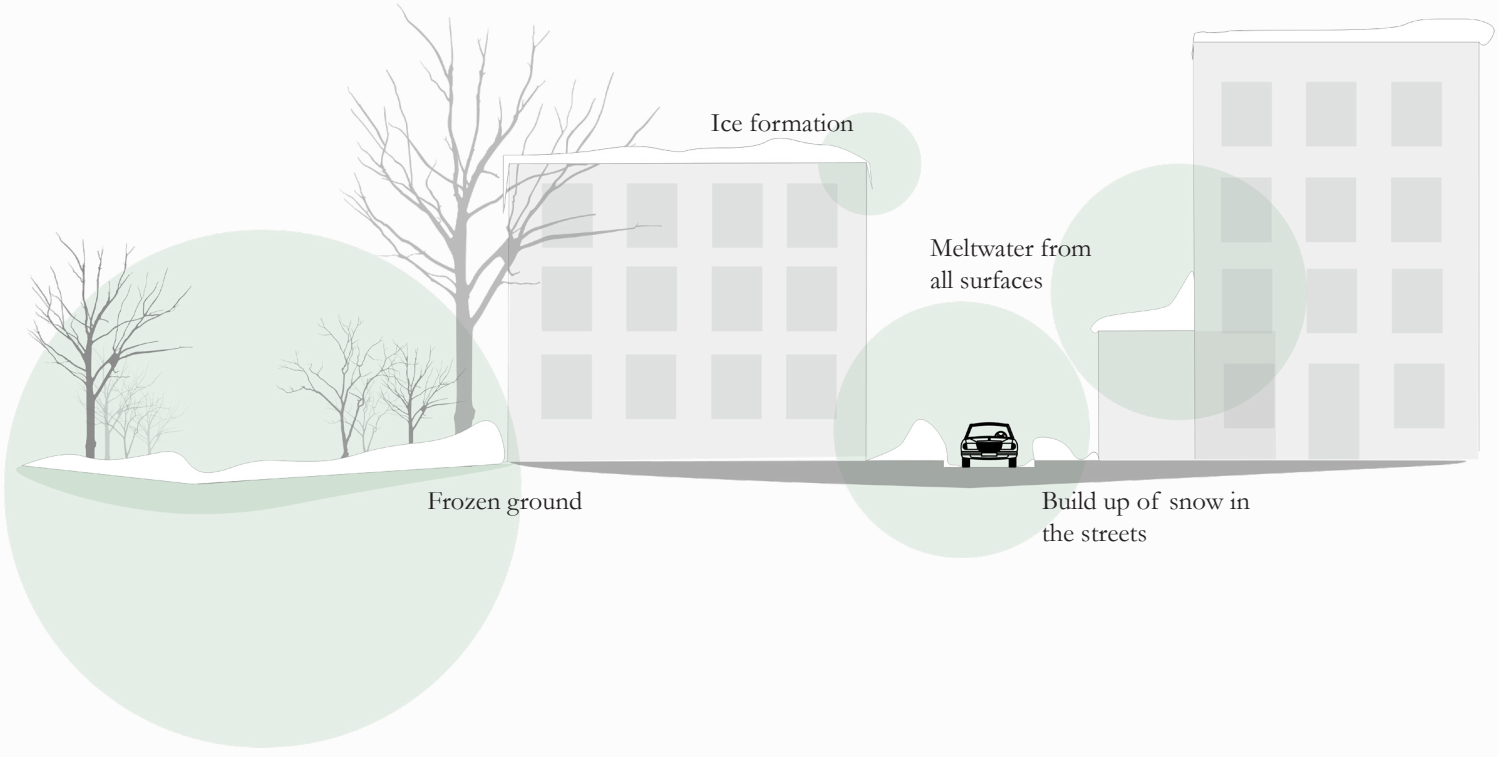


Figure 15: Stormwater challanges during the winter

Drinage systemes

Traditionally drainage systems have been the technique to handle stormwater, in the spring, summer, and fall. Creating a network of pipes, channels, and structures underground that carry the stormwater to water bodies, rivers, or the sea. In the winter it is about removing ice, moving snow, and storing it.

A century ago stormwater was labeled as wastewater, at the time it was a valid way to view it since the water could be infected with various diseases coming from trash, sewage, animal waste, or pollution (Liptan, 2017).

In densely urban spaces pipe systems still have an important role as a stormwater management system. In some urban spaces, this may also be the only choice for diverting water, an example of this is drainage along roads as seen in figure 16.

Lipton suggests in the book sustainable stormwater management (2017) to change the way we view stormwater, from a waste product to a limited resource.

This would mean that the conventional drainage system, where stormwater is paired with sewage would need to change.

The main challenge of utilizing the drainage systems method is that you remove the water from its natural cycle (Haug, 2016). In densely built cities extreme precipitation causes the most damage. Heavy rain in a short amount of time causes the pipe network that handles stormwater to overflow quickly forcing the water to other places. It is the combination of the extreme amount of water, the loose sediments, leaves, and masses the water brings with it which clogs pipes and drains (Hanssen-Bauer, 2015).

In addition, problems with the pipes overflowing and mixing with sewage are causing pollution of the sea.

During the winter the pipes can freeze, lids made out of ice and snow can form over the inlets, and the ice, snow, and water get trapped on the surface. The snow and ice need to be removed and it is then essential that the cities have areas that can store it.

 Figure 16: Conventional stormwater drain (Vodaland, 2023)

Sustainable urban drainage system (SuDS)

Sustainable urban drainage systems (SuDS) are stormwater management systems that aim to contribute to sustainable development and improve urban spaces. SuDS employ various techniques such as retention areas, daylighting rivers, and rain gardens, which are designed according to the principles of management of stormwater itself (Haug, 2016). Open stormwater management is a key focus of SuDS.

In planning SuDS, there are five guiding's principles: (1) Put the water in the landscape, (2) Let the water move across the landscape, (3) Make sure the design looks good and works well, (4) Design to maintain, (5) Be aware (Liptan, 2017).

SuDS offer several benefits, including natural flood mitigation, increased biodiversity, improved water balance, enhanced experience values, strengthen economic relationships, and water purification (Haug, 2016). Consequently, SuDS has become increasingly popular as a sustainable solution for urban stormwater management.

SuDS aims to mimic the natural water cycle in the urban space. The mimic effect can be reached with natural landscape features as well as man-made engineered structures (Lambley, 2019).

By combining the two, a resilient urban space can be reached. The natural landscape SuDS can be used to manage rain as it falls and at its source, while the engineered SuDS could provide, a more robust and resilient structure in case of extreme weather (Lambley, 2019). Lambley highlights an example of a soft, natural SuDS in Figure 17.

Figure 17 Open stormwater mangement, (Susdrain, 2019)

3.4 Climate adaptation

Climate adaptation in cities refers to the measures taken to cope with the impacts of climate change on urban areas. With the increasing frequency of extreme weather events such as floods, storms, and heavy rain, cities are facing significant challenges in ensuring the safety and well-being of their citizens (UN, s.a)

Adaptation strategies may include measures such as flood barriers, improving drainage systems, and using green infrastructure to absorb excess rainfall. Cities can also implement policies to reduce the effects of the changes in implementing strategies and assigning responsibility to the inhabitants (UNFCCC, 2014).

Overall, climate adaptation in cities is a complex and ongoing process that requires a combination of physical, social, and economic measures. It is crucial to act quickly and proactively to ensure the resilience of urban areas and the well-being of their inhabitants in the face of climate change.

Municipalities in Norway have a broad range of elements that in under their responsibility in climate adaptation. In Figure 18 the different elements of climate adaption are displayed. Since climate adaptation is interdisciplinary, it is important to understand that the branch that stormwater is under needs to work together with the other branches.

The UN is warning against not implementing climate adaptions in our everyday life. There are multiple layers of climate adaptation implementations, personal, business, local, regional, national, international, and global levels. Climate adaptation included more than making our cities resilient, it covers social, societal, national international, and local.

Finland and Norway agreed to the Paris Agreement in 2015, meaning they are legally bound to strengthen the global response to climate change by increasing the ability to adapt, build resilience, and reduce vulnerability (UN, 2023).

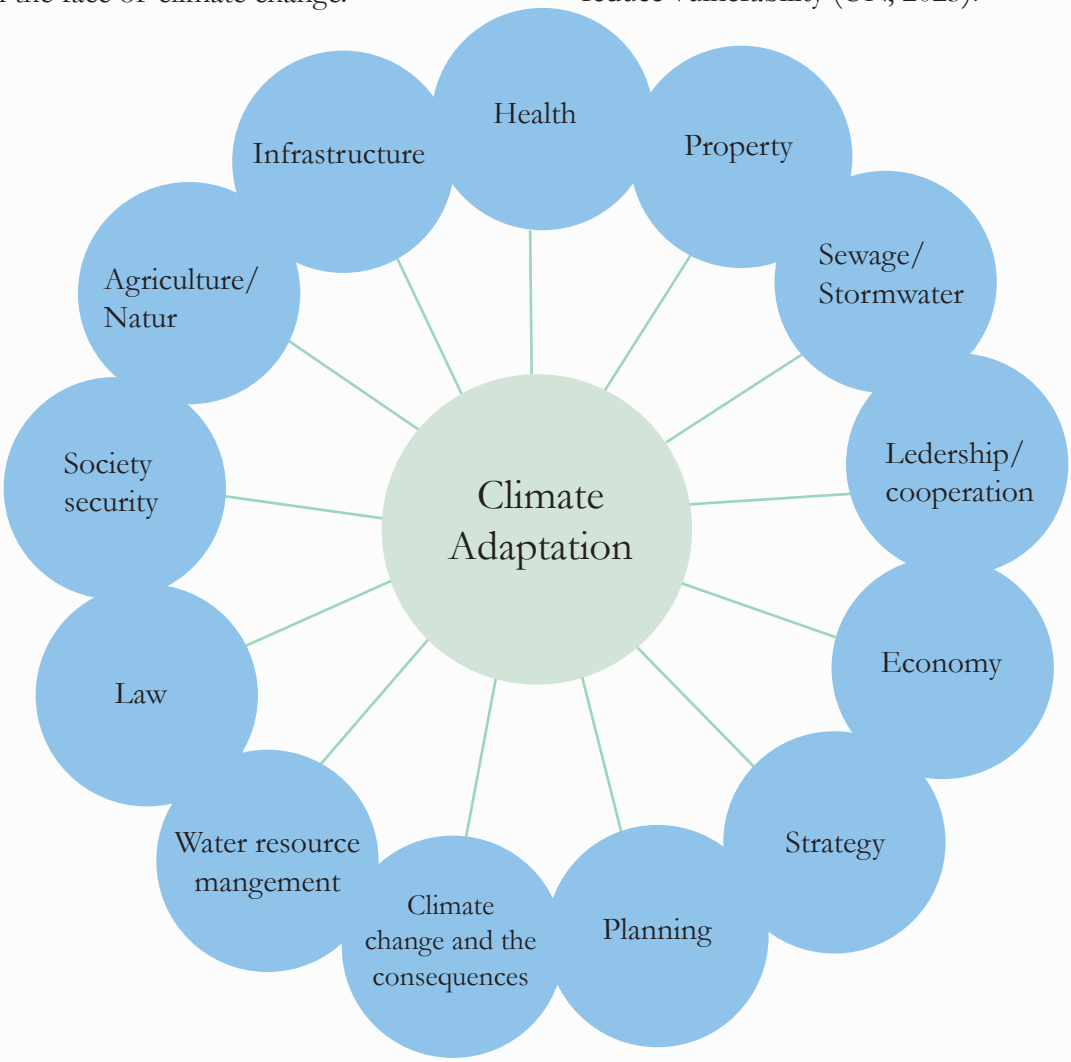


Figure 18: Norwegian municipalities responsibility in Climate adaptation (KS, 2023)

part four
Oslo, Norway

The present chapter serves to present an overview of the pertinent regulation and historical management of stormwater in Oslo. To grasp the current situation, it is crucial to gain an understanding of the various factors that have contributed to its evolution.

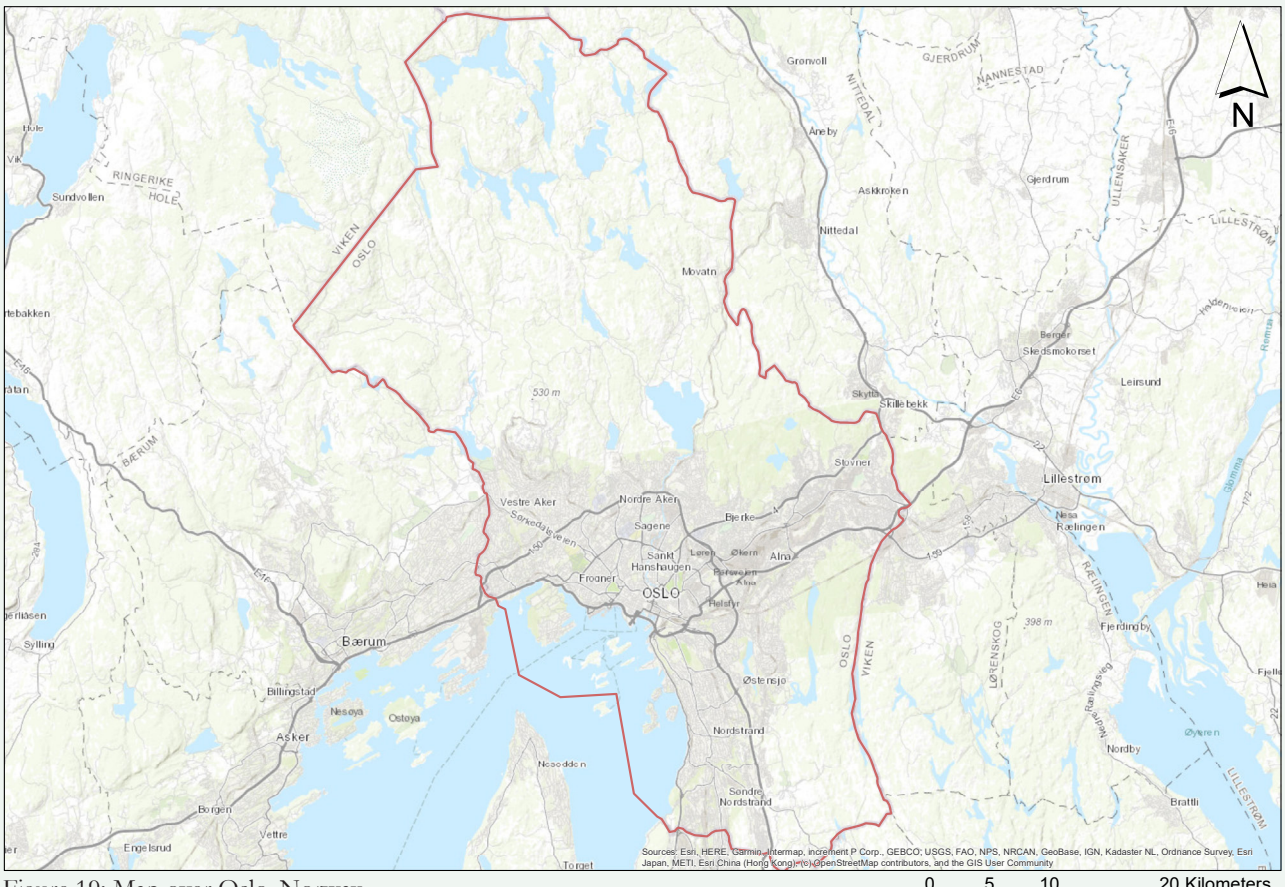


Figure 19: Map over Oslo, Norway

4.1 National context

To understand the strategies implemented in the local context, it is essential to understand the national guidelines, requirements, laws, and regulations the municipality needs to take into account.

The EU water framework directive

The European Union Water framework directive holds significant influence as one of the most substantial frameworks for water management. Following Norway´s partial membership to the EU through the EØS agreement in 2007, the country became legally obligated to comply with the Water framework directive since its adaption in 2000 (Haug, 2016).

Norway has various legislations in place to uphold the water directive, including the Planning and Building Act, the Pollutions Act, the water resource act, and the biodiversity act. The Climate and environmental department is responsible for overseeing these regulations, while the Norwegian Water and Energy Directorate (NVE) is responsible for the national administration of the directive (NVE, 2022).

Norwegian laws

Multiple laws are part of water management, and thereby stormwater management here it an outtake of the most important.

Planning and Building Act

§ 28- 3 requires that all new construction projects including buildings and infrastructure consider stormwater management in their designs and contribution plans. Stormwater management plans must include measures to reduce stormwater runoff and treat and store stormwater (Plan- og bygningsloven – pbl, 2008).

The Pollution Control Act

§ 22 and § 26 focuses on how to prevent water pollution of larger water bodies. It requires that measures be taken to reduce stormwater runoff and ensure that any discharged stormwater meets established water quality standards (Forurensningsloven – forurl, 1981).

Biodiversity Act

§ 13 and § 26a emphasizes the importance of stormwater management in protecting and preserving biodiversity. It requires that measures be taken to minimize the impact of stormwater management runoff on ecosystems and biodiversity (Naturmangfoldloven – nml, 2009).

Norway official reports (NOU)

In addition to the EU directive and the laws, there is the official report from Norway (NOU). These reports are prepared by appointed committees and commissions and are used to investigate and provide recommendations on specific policy issues or topics of public interest. The report may be commissioned by the Norwegian government or other public bodies and is intended to inform and guide policymaking and decision-making processes.

There is one NOU that is especially interesting regarding stormwater, “Stormwater in cities and urban areas- as a problem and resource” (NOU 2015:16).

4.2 Local context

The changes resulting from climate change are happening simultaneously with rapid population growth in Oslo. In Oslo municipality, the population has increased by 5.9% in the last five years, and there is still a steady increase in population (Statistisk sentralbyrå, s.a). The pressure resulting from population growth is changing the city structure from a historic open city to a denser and greyer city.

The open, green, and blue spaces within the city have been de-prioritized, making the city dominated by non-permeable surfaces (Langeland, 2017).

Majorstuen is an example of a highly pressurized area that is dominated by impervious surfaces. The space is dominated by traffic and builings as seen in Figure 20. Combining the historic decline in blue-green surfaces and the increase in precipitation, society is facing a future with increasingly challenging stormwater management issues.

The largest municipalities in Norway (Oslo, Bergen, and Trondheim) all include the topic of stormwater management in the guidelines of the municipal land use plans. Oslo municipality describes the goal for stormwater to in the best extent it should be managed in open solution or infiltrate into the ground (Haug, 2016).

The municipalities do have planning authority and are required to consider stormwater in all development (Miljødirektoratet, 2023). To have planning authority means to be responsible for the planning and building Act being followed and facilitate sustainable development (Plan- og bygningsloven – pbl, 2008).

The definition of stormwater is " water which runs off surfaces because of rain and melting snow" (NVE, s.a).

Figure 20: Majorstuen in Oslo (Tolgensbakk, 2010)

4.3 Climate profile

According to the Norwegian Climate Service Centre, the anticipated temperature increase towards the year 2100 in Norway is 4.5°C, with an expected increase of 4.0 in Oslo and Akershus. This increase varies depending on the season, with a 3.5°C increase in the summer and a 4.5°C increase in the winter (Norsk Klimaservicesenter, 2021).

The report´s climate profile emphasizes the expected increase in precipitation, with an estimated annual increase of 15% in the region and 18% nationally. The increase is primarily anticipated during the winter, spring, and autumn seasons, with the lowest increase in summer. This will result in more rain and snow/ ice then it is now.

Increase in precipitation	
Winter	30%
Spring	25%
Summer	5%
Atumm	10%

The report also highlights an anticipated increase in the frequency of heavy rainfall events. Especially, periods with intense rainfall are projected to increase by 20% with an even higher increase expected for a duration of fewer than 24 hours (Norsk Klimaservicesenter, 2021). This means that events like the example in figure 21, will increase both by intensity and frequency.

Figure 21: Heavy summer rain in Oslo (Kleiven, 2020).

4.4 Historic mangement

Oslo municipality has historically been focused more on the traditional drainage systems for managing stormwater. For the last 150 years, the municipality has been ducking rivers and streams in the city to make space for industry, housing, and infrastructure (Johansen, T., 2001).

Before 1920, stormwater was typically conveyed alongside sewage systems of pipes. However, by 1920, a shift towards separate systems for sewage and stormwater had begun. Despite this, it wasn't until the 1950s that this approach became commonplace.

Due to the fact that the separation of systems was primarily implemented in new housing construction, a fragmented network of pipes existed though the city. In 1970, a calculation was conducted that projected that if the current approach was to persist, it would take then two centuries to complete the necessary infrastructure upgrades (Johansen, T., 2001). Towards the end of 1970, the municipality stepped away from this practice and was looking into a new way of managing water- SUDS (Johansen, T., 2001).

When it comes to winter, the perspective has not been addressed historically. Snow has earlier been dumped directly into the fjord causing increasing pollution of the fjord (Oslo havn, 2021).

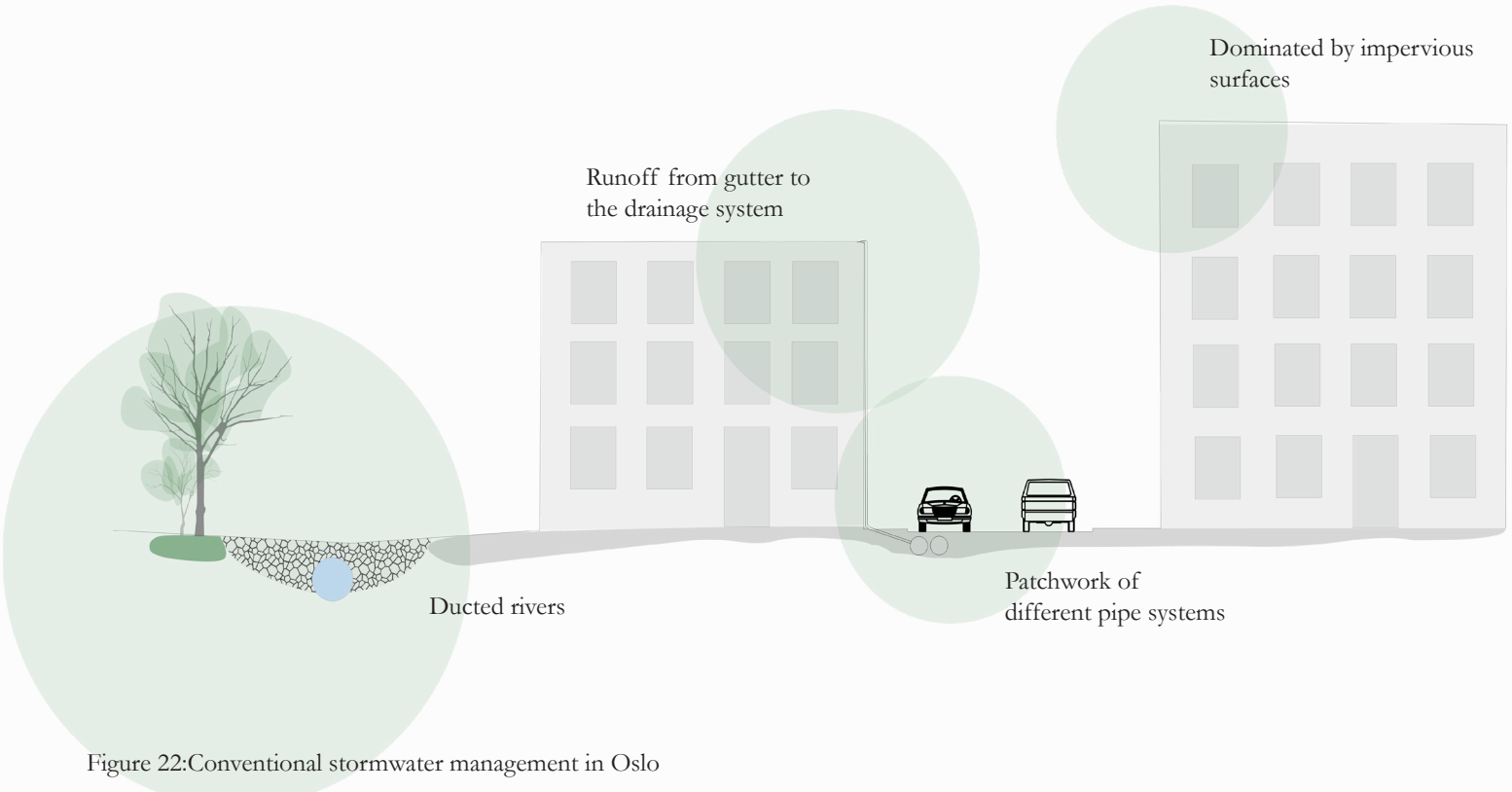


Figure 22:Conventional stormwater management in Oslo

4.5 Current mangement

Oslo municipality's main goal is that as far as it is possible stormwater is to be managed on private property and in open solutions (Oslo Kommune, s.a). Oslo has for several years now been focusing on SuDS solutions (Oslo Kommune, 2014). Central in this strategy is nature-based solutions, which are daylighting rivers, bioswales, rain gardens, or other solutions which are focusing on introducing green structures to stormwater management (Oslo Kommune, 2019).

The municipality does require stormwater to be managed on private property, emphasizing that the responsibility is overall the municipality, but the private property owner is responsible for their own land (Oslo Kommune, 2023). This means that stormwater needs to be infiltrated into the ground or handled in an open solution on every individual property.

The challenges in the current management are tied to different aspects. The first aspect of challenges is the fact that since the municipality is not the majority owner of land in the city, there is not that much the municipality can do in the dense city.

It is only in transformative or new development areas that the municipal can require a certain amount of green and blue structure by using the blue-green factor. This is a tool that the Oslo municipality use which gives developers a minimal requirement of blue-green structures in new zoning plans. The requirement changes, depending on where in the city the new development is located (Oslo Kommune, 2020).

The second aspect of challenges in Oslo is tied to the current drainage system. The fact that the municipality still have a patchwork of different solution and there are still areas with the combined system from 1950 means that under heavy rainfall sewage water and stormwater mixes (Johansen, T. A., 2001).

A problem that still is occurring in the current management of stormwater is that there is still dumping of polluted snow into the Oslo fjord. The city does not have a capacity for the amount of snow that is coming and occasionally approving special permits for dumping the snow in the ocean. Therefore, a future with increased precipitation during the winter will create greater challenges (Oslo havn, 2021).

Figure 23: The wanted stormwater management

part five
Helsinki, Finland

The present chapter serves to help to gain an understanding of Helsinki and Finland's management structure and grasp the current situation. Various factors contribute to the situation and this chapter, will give an overview of these.

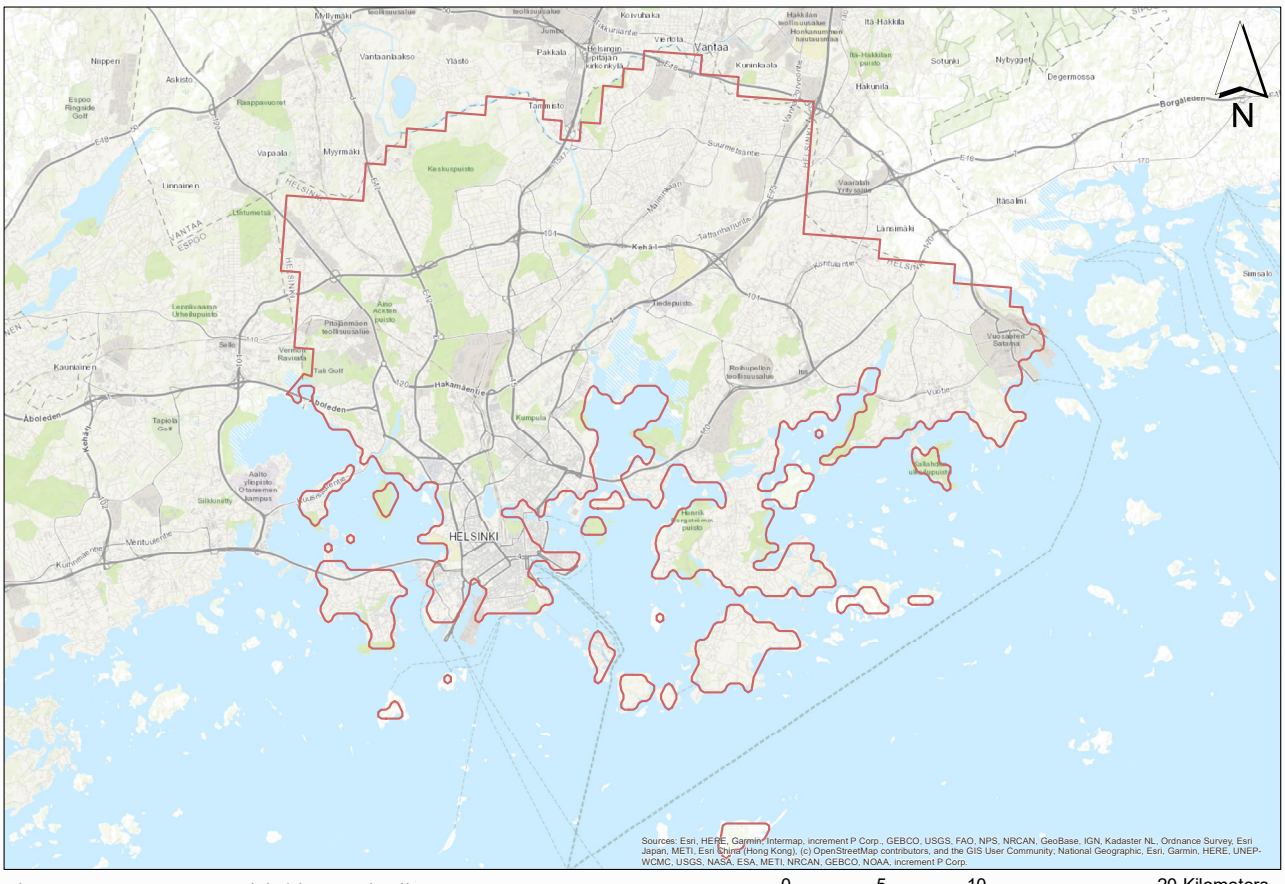


Figure 24: Map over Helsinki muncipality

5.1 National context

In Helsinki water falls under the responsibility of the Ministry of Environment. The ministry aims that Finland will become the world leader in effective water protection.

The EU water framework directive

Finland became a member of the European Union in 1995 and has therefore implemented the Water framework directive from its start in the year 2000 (EU, s.a-a).

This directive emphasizes that nature, citizens, and, industry need healthy lakes and groundwater. The directive is guiding the national principles for stormwater management in Finland. There are multiple frameworks and directives that are the result of the EUswater directive

Water protection program

To ensure this the ministry has a program that is split into different themes. The theme that brings the topic of stormwater is " Urban waters and harmful substances". The main goal here is to reduce the harmful substances in stormwater runoff and overflow from the sewage network. To achieve this the aim for a close connection between water management and urban spatial planning (Keto, s.a).

Finnish Laws

Environmental protection Act

The Act takes up the issue of protecting ground-water in section 17. The essence of this section is to work proactively and prevent damage in advance (Ministry of The Environment, 2023).

Water resource management Act

This Act takes up the issue of surface water and bodies of water- both artificial and natural (Ministry of the Environment, 2006). The Act is a part of the implementation of the Water framework directive from the EU to further focus on sustainability.

Water Act

The purpose of this Act is to, organize, promote, and coordinate the use of water resources and the aquatic environment towards social, economic, and ecological sustainability (Ministry of Agriculture and Forestry, 2011).

Water Service Act

This act brings up the topic of water services in households, but in addition, it applies to rainwater and meltwater (stormwater) (Ministry of Agriculture and Forestry, 2001). The Act focuses on continuing to have excellent water quality and securing water health for the future. According to this law, the city of Helsinki is also forced to pay a fee to the water management utilities if there were to be stormwater sewerage in public spaces.

5.2 Local context

Helsinki owns 64% of all land in the municipal area and nearly 34% of the green space is managed by the city itself (Helsinki, 2022).

The city has had a 3.7% annual increase in population during the last five years. The city itself is surrounded by other residential areas resulting in high pressure on the public spaces in the city center.

The main goal of Helsinki is to become the best functioning city in the world, this will also include stormwater management and accessibility to blue-green structures (City of Helsinki, 2021).

The general stormwater management responsibility is the municipality, which means that they are responsible for developing plans and taking an active role in planning (HSY, s.a)

Stormwater is defined as "rainwater or meltwater that is conveyed from soil surfaces, roofs of buildings, and other similar surfaces on built areas" (City of Helsinki, 2018).

 Figure 25: Helsinki city (Ylitalo, 2016).

5.3 Climate profile

According to the report " Helsinki's Guidelines for Adapting to climate change 2019- 2025" (2019), the temperature in the city is expected to increase by 2.3°C – 3.4 by 2050, compared to the period between 1971- 2000. The report also notes that this temperature increase will result in a natural increase in precipitation. Specifically, heavy rainfall during the summer is expected to increase by 10%, which will lead to shorter repetition intervals for extreme weather events.

Winter is projected to be the season that will experience the most significant changes. The temperature increase will cause a shorter snow-covered period, and the increase in precipitation and clouds will result in a generally wetter and darker winter. While the total snow-covered period is expected to shrink, the number of days with heavy snowfall (more than 10 cm/day) is anticipated to increase (City of Helsinki, 2019).

The average temperature during the winter months alone is expected to increase by two degrees by 2050.

The rise in sea level, expected to be around 30- 60 cm, by the end of the century, will impact flooding caused by stormwater. The report highlighted that the increase in frequency and intensification of extreme weather and the shortening of the snow-covered periods are central issues that need to be addressed in Helsinki (Helsinki, 2019)

Winter will become darker, and warmer with an increase in intense snowfall

Summer will become warmer with an increase in heavy rain

Figure 26: Heavy rain in Helsinki (Lehtikuva, 2019).

5.4 Historic mangement

Historically the main river, Vantaa has been an integral part of the city throughout history, bringing energy, sanitation, and drinking water. The river outlet is in the Gulf of Finland, and it has a large catchment area before reaching Helsinki.

For a considerable period, the only outlet for wastewater in the larger catchment area was the river Vantaa, leading to a significant level of pollution in the water, including the drinking water. After a century of back and forth of trying to cleanse the water in 1980 it was finally under strict control to maintain the city's hydrological source (Schönach, 2015).

Drainage systems have been a focus in historical water management. Since the 1950s new construction has focused on creating separate systems for stormwater and sewage systems. This has been successfully developed and means that this is the situation currently (HSY, s.a).

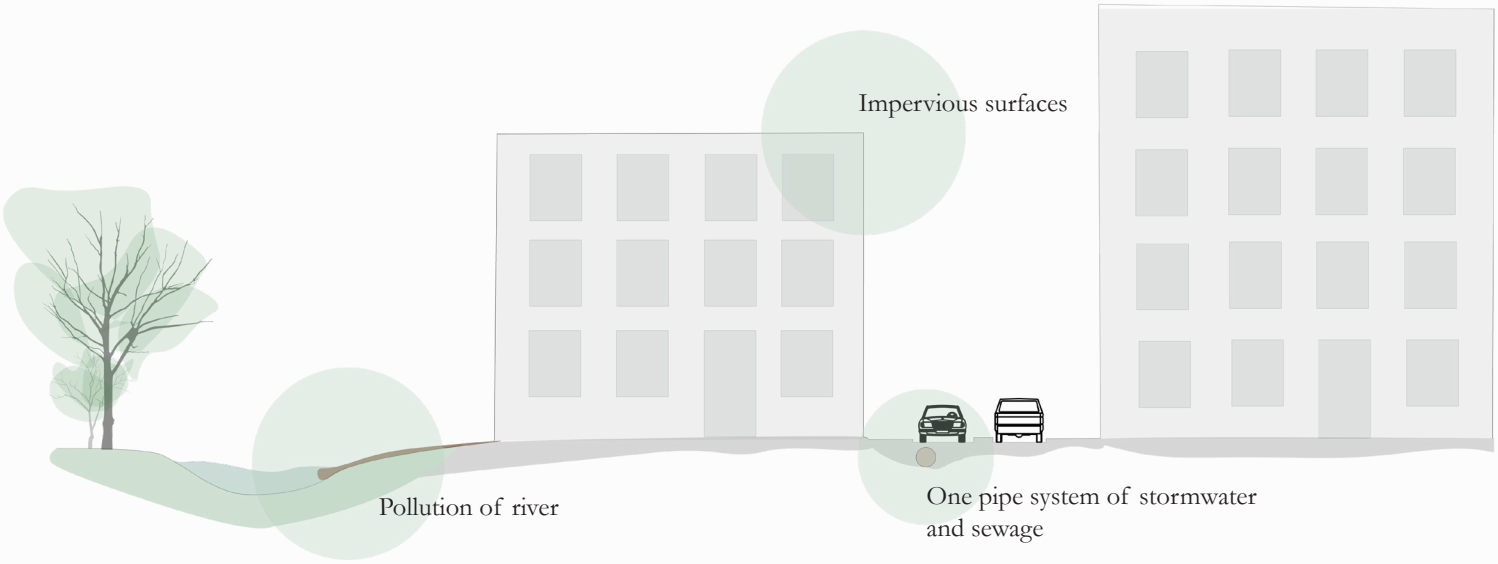


Figure 27: Conventional stormwater management section Helsinki

5.5 Current mangement

Responsibility for stormwater is divided into three main groups.

(1), The city is responsible for stormwater management as a whole. This included making plans, and flood routes, and constructing and maintaining the municipal stormwater system, which included open ditches and detention structures.

(2), Helsinki Regional Environmental Services (HSY) is responsible for maintaining and constructing the main stormwater drainage system.

(3) Owner of the property is responsible for stormwater at its property (HSY, s.a).

There are 7 challenges tied to the current stormwater management in Helsinki which are pointed out in the Risk document (City of Helsinki, 2019).

These seven challenges are,

(1) Sewer pipes are already under-dimensioned in the current situation,
(2) The use of alternative water management methods is insufficient,
(3) Stormwater consideration in new development is too weak,
(4) There is not enough clear provision or policies for integrating climate change adaptation,
(5) Lacks agreed clear implementation timeframes, implementer or budget,
(6) In flood situations, pipes clog due to too small dimension,
(7) Contaminated stormwater is conveyed into the gulf of Finland or other water bodies (City of Helsinki, 2019).

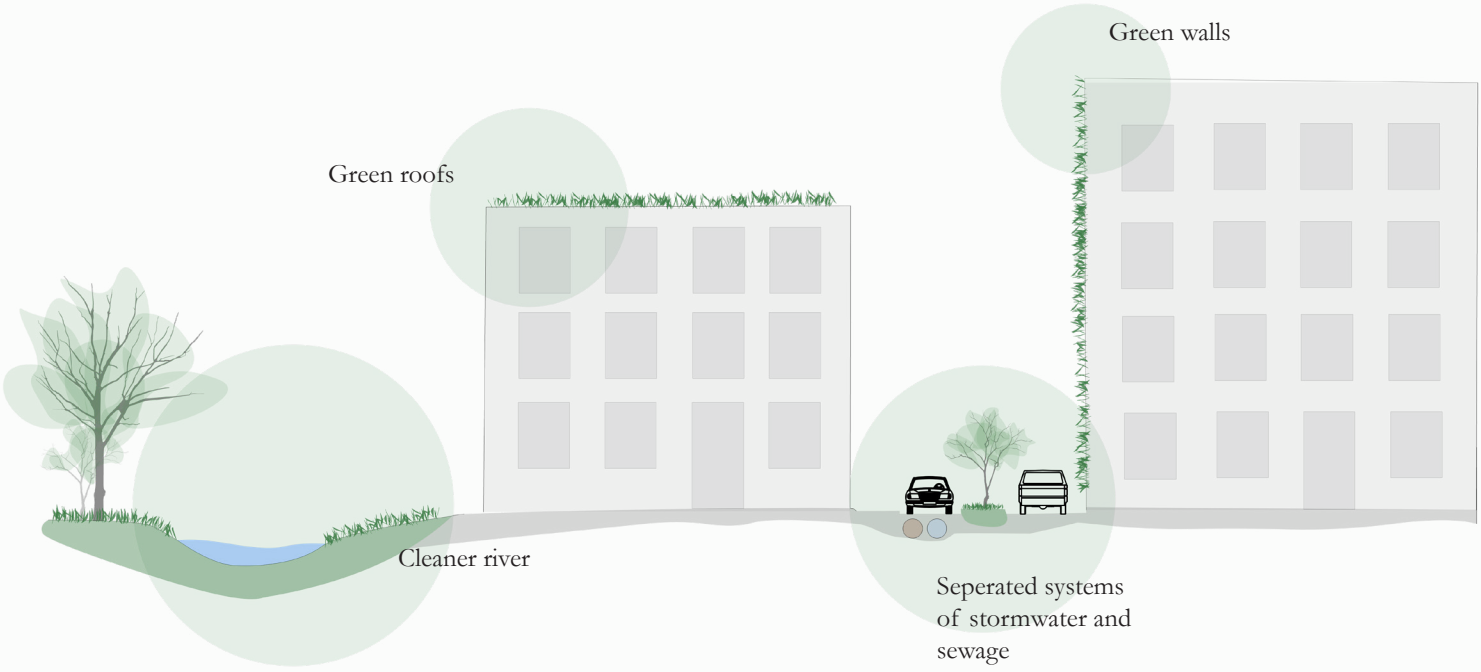


Figure 28; The wanted stormwater management in Helsinki

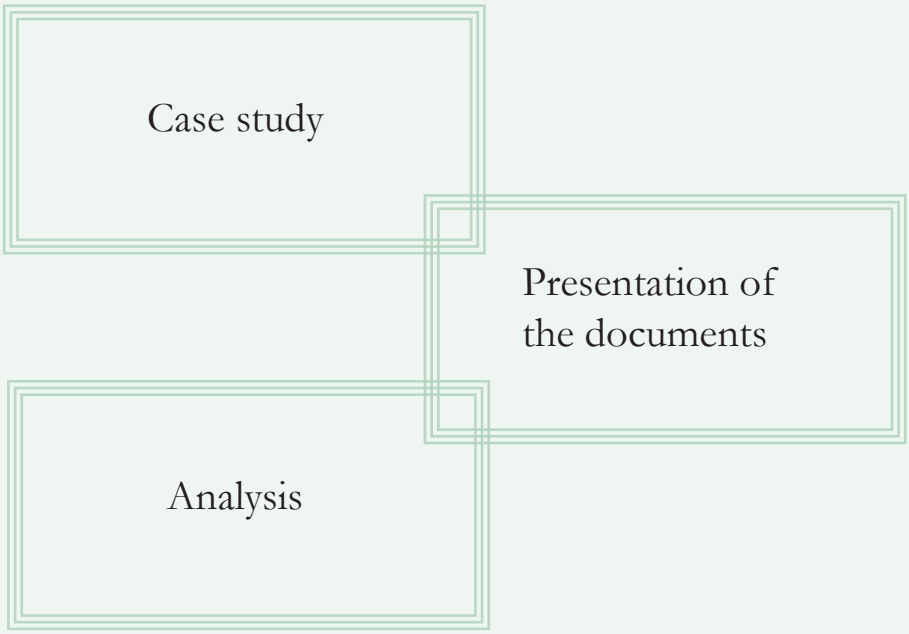
part six
the anlaysis

A critical aspect of this analysis is to approach each document through a concise lens similar to the related documents. A systematic guide has been developed to outline the step-by-step process employed in the analysis.

The first step is to present the findings of the case study.

Step two is present the document in a general matter.

Step three is analyzing the document in a detailed matter divided into three themes and three sub-questions in each theme.



Oslo

As a general document, the main function is to stake out a direction for more legally binding and more detailed documents, plans, and strategies.

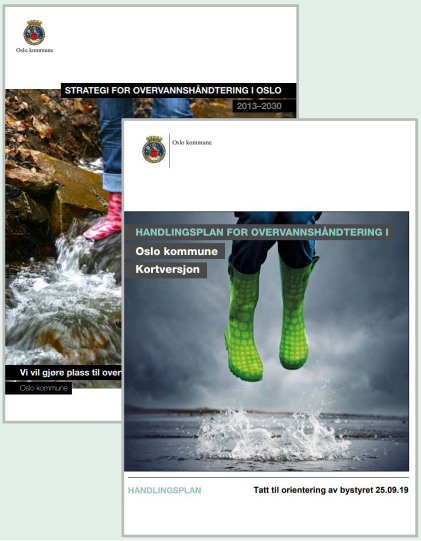
A overall city plan

These document aim to guide the muncipality in the right direction to become climate friendly and green cities.

Climate adaptation plan

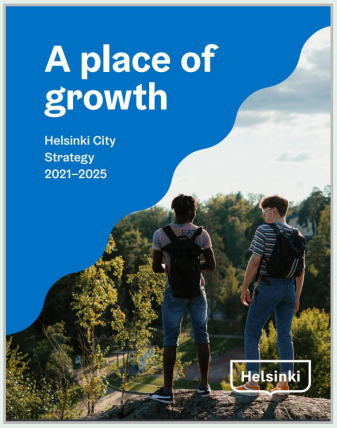
The aim for this is to be a guiding document which looks into the conrete steps in stormwater mangement.

Stormwater mangement plan



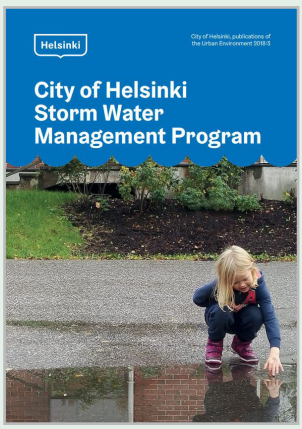
Helsinki

A overall city plan



Climate adaptation plan

Stormwater mangement plan



6.2 Presentation of documents

Our city, our future, municipality plan for 2018

Figure 29: Muncipality plan Oslo (Oslo kommune, 2019)

Vision, goals, and strategies against 2040. Approved by the city council on 30.01.2019.

A greener, warmer, and more creative city with room for everyone.

Priorities

1 Change of pace in climate and environmental politics

2 A socially sustainable city with equal rights

3 Active and sustainable municipality

The plan refers to the United Nations report as one of the important background documents.

Helsinki city strategi 2021- 2015

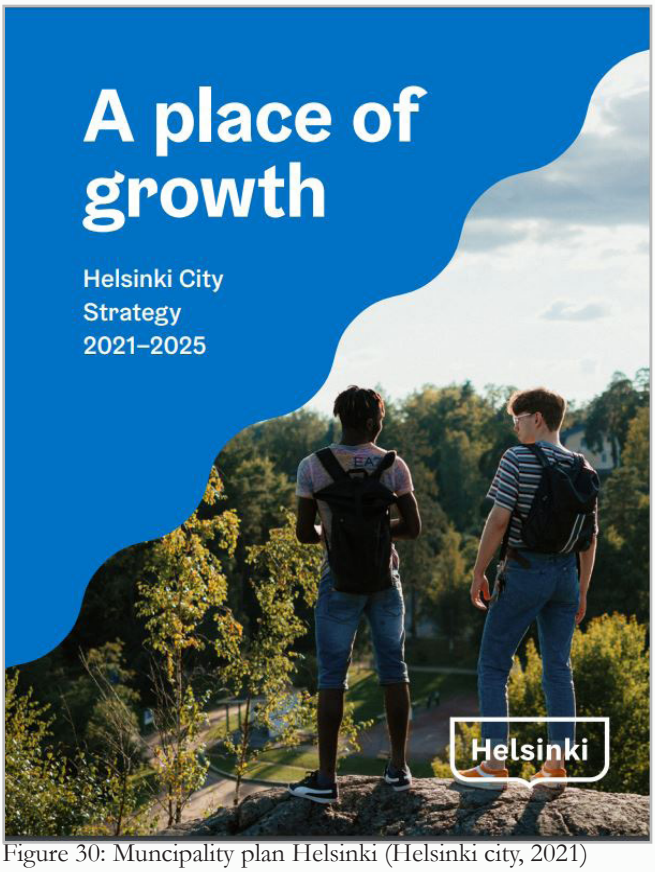


Figure 30: Muncipality plan Helsinki (Helsinki city, 2021)

Helsinki's goal is to become the most functioning city in the world.

Priorities

1. Become carbon neutral, and have a zero status by 2025
2. A socially sustainable city with equal rights
3. Prepare the city for extreme weather
4. Creating a safe and inclusive city
5. Expand its cultural capital

The city is proud to continue to evaluate and develop Helsinki in line with the UN's sustainable development goals.

Climate strategy for Oslo towards 2030

Figure 31: Climate strategy Oslo (Oslo kommune, 2020)

The plan was approved by the city council in 2020.

Priorities

1 Direct emission
The greenhouse gas emissions in 2030 have been reduced by 95 % compared to 2009 and with a partial target of 52% by 2023.

2 Climate robust
Its ability to withstand climate change has been strengthening towards 2030 and the city is being developed so that it is prepared for the changes towars 2100.

3 Forest and area
Nature must be managed so that the natural carbon storage in vegetation and soil are safeguarded and the absorption of greenhouses in forest and other vegetation increases towards 2030.

4 Energy
Oslo's overall energy consumption in 2030 has been reduced by 10% compared to 2009.

5 Indirect emission
Oslo´s contribution to greenhouse emissions outside the municipality is significantly lower in 2030 than in 2020

The goals is well-connected to the content of the document, especially SDG 8, 11, and 13 are emphasized.

Weather and climate risks in Helsinki

Figure 32: weather and risks in Helsinki (Helsinki city, 2019)

Published in 2019 by The urban environment division (2019: 32)

This report is a compilation of the latest research knowledge and the views of the city´s experts on the key weather and climate-related risks affecting Helsinki.

Priorities

1. The impact of weather and climate change must be taken into consideration in decision-making.
2. The increasing risk of flood.
3. Winter climate to see the greatest changes.
4. Better risk management requires information and adaptation measures.
5. The increasing risk caused by heat.
6. Tick-borne diseases will become more common.
7. Biodiversity is threatened by many factors.

Not mentioned.

Helsinki´s guidelines for adapting to climate change 2019-2025

Figure 33: Climate adaptation (Helsinki city, 2019)

Published by the central administration of Helsinki (2019:27)

The adaptation vision towards 2050 is that Helsinki is a climate-proof and safe city.

Priorities

1 Preparedness
1. Risk mapping
2. Planning and construction
3. Policy instruments
4. Disputation

2 Overall economy and business opportunities
1. Adaptation is integrated into urban development and business cooperation
2. Helsinki serves as a trial and innovation test area for Smart & Clean solutions
3. Developing an overall economic assessment of adaptation in investments

3 Climate robust
1. Integrating adaptation into the city management and control system
2. Planning stormwater management comprehensively
3. Preventing adverse impacts caused by changes in land use

4 Development and expertise
1. Making climate change adaptation part of the management of the city of Helsinki
2. Education and communication
3. The city as an example
4. Research and development
5. Cooperation

Not mentioned.

Strategy for stormwater management in Oslo municipality 2013-2030

Figure 34: Stormwater strategy Oslo (Oslo kommune, 2014)

Approved by the city council in 2014.
Published by the water and sewage department in Oslo municipality.

The plan is to stake out the course for future stormwater management in Oslo municipality

"We want to make space for stormwater in the city"

Priorities

1 Oslo will have stormwater management which will be with the help of open and local solutions.

2 Meet the climate change challenges or minimize the damage on people, buildings, property, and infrastructure.

3 Sustain the environment and secure good ecological and chemical state in the water.

4 Use stormwater as a resource in the urban landscape.

Not mentioned.

Action plan for stormwater management in Oslo municipality

Figure 35: Stormwater action plan Oslo(Oslo kommune, 2014)

Approved by the city council 2019.

In this action plan, the goal is to do the actions needed to reach the goals of the strategy (2014).

Priorities

1 Acquire more knowledge.

2 Prevent consequences.

3 Inform and guide better.

4 Develop model projects.

5 Cooperate more closely.

To achieve this, the three-step strategy should be followed:

- Small amounts of precipitation are infiltrated into the ground.
- Larger amounts of precipitation are detained and delayed.
- Extreme amounts of precipitation are safely directed through open floodways.

Not mentioned.

The City of Helsinki, Stormwater program

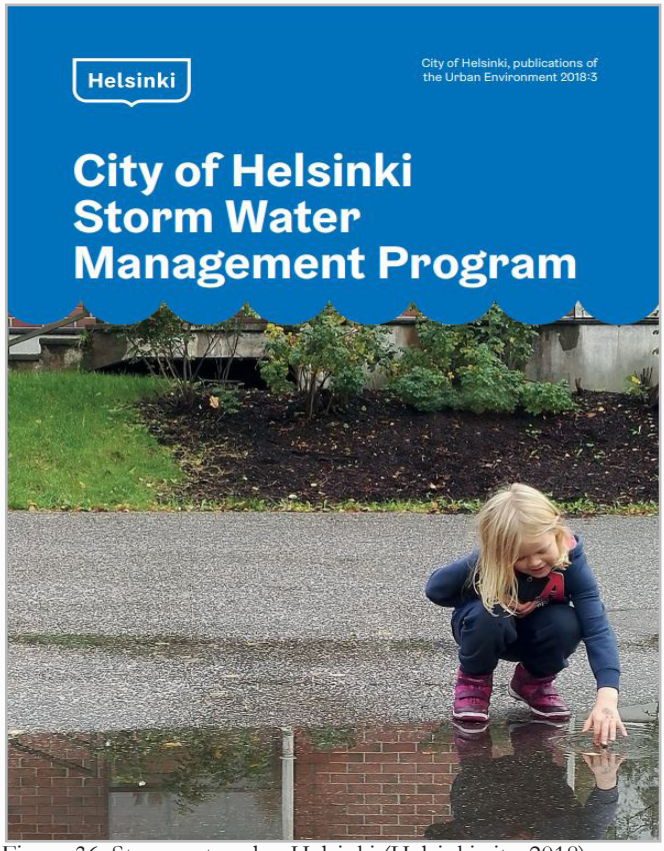


Figure 36: Stormwater plan Helsinki (Helsinki city, 2018)

City of Helsinki publication of the urban environment 2018:3.

The plan states that in 2015 stormwater became the municipalities responsibility.

Priorities

1 Developing systematic stormwater management, especially in areas where a local detailed plan is in force.

2 Infiltration and detention of stormwater at the source.

3 Preventing the impact and damages to the environment and property caused by stormwater while taking into account climate change.

4 Promote ending the practice that convey stormwater into wastewater sewer.

Not mentioned.

6.3 The analysis

In every catageory the analysis answers these three questions.

Climate adaptation

1. Is the plan making the reader aware of the change in climate that the region can expect?
2. How are they planning climate adaptation toward stormwater?
3. How is the plan facilitating (if there are any) the climate adaptation measures to be implemented on a lower level?

Our city, our future, Oslo municipality plan for 2018

Climate adaptation

1. A new and changing climate is presented, but not elaborated.

2. The importance of meeting the increase of precipitation with an equal amount of new adaptable spaces in the city is pointed out as one of the priorities.

3. The blue-green factor is an important tool to ensure climate adaptation in detailed planning.

In short; the plan facilitates climate adaptation through measures with a focus on green spaces, urban planning, flood prevention and water management.

Specific measures

1. Increase of green infrastructures, green roofs, rain gardens, and the preservation of important vegetation. In addition, daylighting rivers and an increase in preamble surfaces.

2. No

3. The measures, the plan focuses are on using the areas in the urban space in transformative ways.

Winter Conditions

1. It not mentioned

2. No

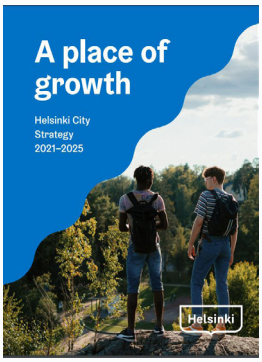
3. No

Specific measures

1. Are there measures that are focusing on blue/ green infrastructure?
2. Are there measures that are in plan for extreme rain events?
3. In what way is the implementation focusing on the built city?

Winter Conditions

1. How is the plan framing the new winter climate, and which issues are the plan forecasting?
2. Is the plan taking into consideration that the solutions during spring, summer, and autumn may not work in the winter?
3. Are there any measures that are designed specifically for the winter season?



A place of growth
Helsinki city strategi 2021- 2015

Climate adaptation

1. The new climate with its changes and challenges is noted early as one of the prioritized aspects to adapt to.

2. Focuses on adapting to the increased precipitation by improving the existing management structures and creating more effective green solutions.

3. This document emphasizes the necessity for more comprehensive strategies and actions in its own chapter.

In short; A strong climate adaptation commitment that outlines various strategies.

Specific measures

1. Blue-green structures, green roofs, walls, urban forests, and parks. In addition preamble surfaces and areas that manage and filter the stormwater.

2. One goal is to be prepared for extreme weather (rain) and pushing forward retention areas.

3. Permeable surfaces, green walls and roofs .

Winter Conditions

1. It not mentioned

2. No

3. No

In every catageory the analysis answers these three questions.

Climate adaptation

1. Is the plan making the reader aware of the change in climate that the region can expect?
2. Is stormwater adaptation a focus point in the document?
3. How well are they describing the challenges towards climate adaptation and stormwater?

Climate strategy for Oslo towards 2030.

Climate adaptation

1. First, the global change and then the local scale. Here it presents the increase in temperature, precipitation, and extreme weather.

2. Stormwater adaptation is a central focus in the document and is mentioned in two of the 16 focus points. Chapter 2,4 titled "climate adaptation", focuses on stormwater management.

3. The strategy emphasizes the importance of proactive, continuous adaptation measures instead of reactive development. It highlights the concept of a "climate robust" city which aims to be prepared for changes.

Specific measures

1. Among the specific measures, the significance of permeable surfaces is highlighted in addition to the implementation of blue green structure.

2. The adaptation measures primarily revolve around blue green structure, including the daylighting of rivers and streams, and the implementation of blue green factor. These factors align with the first two steps of the three step strategy. Other measures is the development of green roofs and rain gardens.

3. Extreme events is recognized as a challenge but not eloborated.

Winter Conditions

1. The plan is presenting the winter climate as a changing one, with higher temperatures which causes problems. Ice formatting, wet and heavy snow and other challenges related to a humid climate that fluctuate around zero will become more common.

2. They give a general precipitation increase (year around).

3. No.

Specific measures

1. Is the document specifying measures, especially for the new climate?
2. Are there measures that are focusing on blue/ green structures?
3. Are there measures that are in plan for extreme precipitation events?

Winter Conditions

1. How is the plan framing the new winter climate, and which issues are the plan forecasting?
2. In which way is the document specifying the stormwater increase during the winter?
3. Are there any measures that are designed specifically for the winter season?

Weather and climate risks in Helsinki

Climate adaptation

1. The document presents the changing and new weather well. Globally, regional and local are all presented, along with the risks coming for the city.

2. The several measures presented aim to reduce the risks associated with climate change, improve the management and increase the general resilience of the city to climate-related impacts.

3. The document goes thematically through all the different risks and hazards connected to the weather. It is mostly focused on chapters, 4,5, and 6.

Specific measures

1. The measures mentioned especially for the new climate is "The use of green and other preamble surfaces that infiltrate and delay torrential rain should be assessed carefully" and "Flood routes should be planned so that the water can be removed in a controlled manner"

2. Green structures and controlled flood routes is the main focus.

3. A deatiled stormwater mangement plan, a hazard map and a mapping flood routes are being planned.

Winter Conditions

1. It is going into details about the new winter both on stormwater and temperature increase, forecasted that winter will change. The winter increase in temperature will cause slippage, pluvial floods, a combination of a denser city and more precipitation.

2. They are presenting the increase in both snow and rain. And connected this to the temperature around zero which will cause more ice.

3. No

Helsinki´s guidelines for adapting to climate change 2019-2025

Climate adaptation

1. It introduces the global scale and then connects it to Helsinki and the local changes here. The main point here is temperature, sea level, and precipitation increase.

2. It takes a comprehensive step into climate adaptation for stormwater, introducing several important aspects and measures, both technical measures and societal ones.

3. This document bases itself on the previous document, meaning that they are establishing the main risks and challenges earlier in the chapter "5.2 climate risk assessment".

Specific measures

1. The need to increase the green surfaces in the city and are looking into a preamble and porous surfaces. In addition it focus on upgrading the existing network of pipes and culverts to increase their capacity and resilience. But the main focus it on natural solutions.

2. The focus on green roofs, green walls and developed rain gardens and bioswales.

3. It does mention the need for install retention ponds and basins to safely store water under extreme rain events.

Winter Conditions

1. The plan does frame the winter as the most changing season in the future and is presenting the new weather as greyer, wetter, warmer and wilder.

2. It predicts larger amounts of rain in winter and heavy snow fall in short periods of time, this causes more meltwater, again risking the winter river floods.

3. Sustainable drainage systems to manage stormwater runoff and snowmelt.

In every catageory the analysis answers these three questions.

Climate adaptation
1. Is the plan making the reader aware of the change in climate that the region can expect?
2. How are they planning climate adaptation toward stormwater?
3. How is the plan facilitating (if there are any) the climate adaptation measures to be implemented on a lower level?

Strategy for stormwater management in Oslo municipality 2013-2030

Climate adaptation

1. The plan definitely focuses on climate adaptation regarding stormwater management. The three-step strategy which is the key point in this document shows this. It points out four aspects of climate adaptation's importance: (1) Improving resilience and reducing risks, (2) Consider climate change in early process, (3) SuDS and (4) Engaging with the community.

2. The earlier four aspects go into a detailed level.

3. This strategy is a great example of what was wanted in the Overall city plan. (2018) and then actually completed. The red thread is very visible here.

Specific measures

1. The main measures made based on the new climate is upgrading existing structures and developing a detailed flood risk plan- finding the flood ways.

2. There is a focus on daylighting rivers, increasing the amount of green spaces, along with green roofs, rain gardens and green walls.

3. Extreme rain falls under step three in the strategy introduced in the document, but the concrete measures design for this step is retention ponds and basins.

Winter Conditions

1. There is no mention of this.

2. It is not.

3. No.

Specific measures
1. Are there measures that are focusing on blue/ green infrastructure?
2. Are there measures that are in plan for extreme rain events?
3. In what way are the implementation focusing on the built city?

Winter Conditions
1. How is the plan framing the new winter climate, and which issues are the plan forecasting?
2. Is the plan taking into consideration that the solutions during spring, summer, and autumn may not work in the winter?
3. Are there any measures that are designed specifically for the winter season?

Action plan for stormwater management in Oslo municipality

Climate adaptation
1. The key objective for developing this plan is the need to adapt to the changing climate. It identifies potential future impacts such as increased precipitation and more extreme frequent extreme weather.

2. The main way that climate adaptation strategies are being implemented in practice. These strategies are the "open floodway and retention network" and the "three-step strategy"

3. The red thread is very apparent, this document being the action plan based on the strategy makes the reader understand and visualize the implementation and what they are based on

Specific measures
1. There are several measures being taken regarding the new climate, both green-blue structures, new main and secondary floodways, areas to retain the water and SuDS solutions.

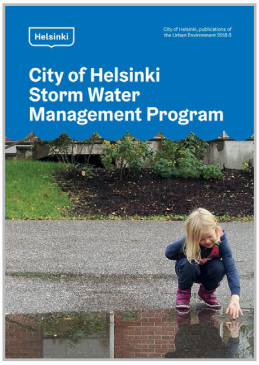
2. There are several measures that are under blue green structure, amount these are: green roofs, trees, rain gardens, green ditches, daylighting rivers.

3. Step three " secure safe floodway" are focusing on planned flood ways for extreme weather.

Winter Conditions
1. There is no mention of this.

2. It is not.

3.No.



The City of Helsinki, Stormwater program

Climate adaptation

1. Absolutely, the adaptation to the new weather is the main issue here, taking into account the different ways that stormwater measures need to adapt and how.

2. The document outlines a comprehensive strategy for adapting to climate change including goals, objectives, and the aim to reduce the city's vulnerability to climate change impact such as extreme weather, sea level rise, and changing precipitation patterns.

3. The red thread between the different documents is well executed. In all the previous overall documents this strategy is referred to.

Specific measures

1. There are a total of 38 different measures here which are organized by responsible group, priority order and which objective they fulfill.

2. There are several measures that in detail go into blue-green structures. Green structures, flood paths, increaseing preamble surfaces, the use of green factor and the blue-green network planning tool.

3. Not especially, but all the measures are designed to handle a larger amount of water.

Winter Conditions

1. The plan is referring to the document which is describing winter times as the warmer, wetter and wilder season.

2. It is not.

3.No.

part seven
discussion
the current situation

In this chapter, the first secondary research question will be discussed using the theoretical framework together with the results from the analysis.

"What are the similarities and differences in the current stormwater management in Oslo and Helsinki?"

To fully comprehend the current situation the discussion will first start with understanding the global framework that guides the regional, national, and local measures into place.

All these different frameworks are connected and influenced by each other, see figure 37.

7.1 Global context

The United Nations emphasizes the saying that "Climate change is global, but adaptation is local" (UN, s.a). This statement highlights the importance of understanding the connection between global frameworks and local measures when addressing climate change.

Local plans are shaped by national guidelines, which in turn are influenced by global frameworks. The parameters set by the global context guide the implementation of national guidelines, determining how they should be structured, how they should function, and to what extent.

In the context of climate change, both Norway and Finland are legally bound to follow several international frameworks, which they then are required to implement in their national guidelines and local measures.

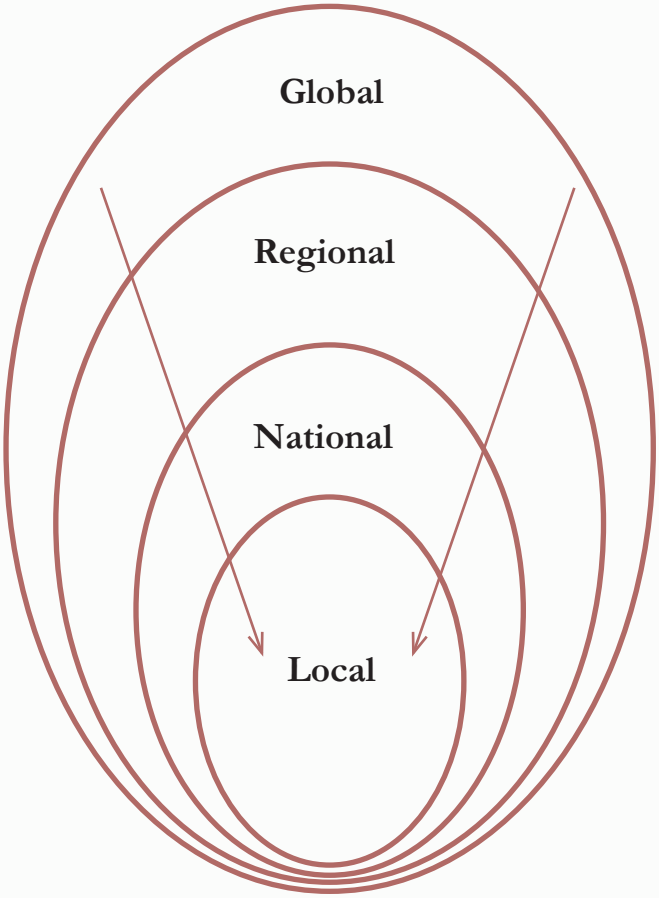


Figure 37: Framework structure

7.2 United Nations

Norway and Finland are bound by two United Nations frameworks that must be implemented in their national and local planning; the Paris Agreement and the Sustainable Development Goals (United Nations, 2023; United Nations, s.a).

While both frameworks are crucial in addressing climate change, the discussion will focus more on the Sustainable Development Goals (SDGs). These goals provide a more specific guidance on addressing climate change, making them particularly relevant to the issue at hand.

The analysis of the documents included a comment on how well the SDGs were emphasized in each presented document. This is an important aspect of the analysis because it demonstrates how effectively the authors set the global context on the agenda.

While both cities overall plans recognized the SDGs as an important framework that is essential to include in the local plans, only the climate adaptation documents for Oslo specifically mentioned which of the goals are in focus. This lack of emphasis on the SDGs in climate adaptation in Helsinki weakens the understanding of the SDG connection.

Although the Helsinki plans are in the spirit of the goals, the failure to connect the local climate adaptation to the SDGs diminishes the overall understanding of the issue.

In the local strategic plans for stormwater, neither city connected the management of stormwater to the SDGs, even though the plans are centered around topics that could easily be linked to specific goals, such as:
Clean water and sanitation (Goals 6), Sustainable cities and communities (Goals 11), Climate Action (Goal 13), and Life below water (Goal 14) (United Nations, 2023b).

7.3 Regional focus

On a regional level, the EU water directive is well integrated with each national legislation system. Each country has legislation that is framed to comply with the Water directive or integrated elements of the directive into other laws or guidelines (NVE, 2021).

The reason for the water directives' better integration than the SDGs or the Paris Agreement may be due to the directive's longer existence (over 20 years) (EU, s.a-b) compared to the newer SDGs and Paris Agreement, which have been around since 2015.

Overall, while climate adaptation is an ongoing theme in the different plans and strategies, the specific way that the local plans follow the international framework is missing at some points. If the plans referred back to the SDGs or Paris Agreement, it would help strengthen the understanding that this is not just an isolated issue, but a local reaction to a global situation.

7.4 Current plannning

The current planning focus in Oslo and Helsinki share similarities as well as differences, which can be attributed to their different origins and knowledge bases. These factors influence the emphasis of each city in their respective planning process: Furthermore, the historical water management practice in each city also plays a role in shaping the current planning practice. Historical planning is why the cities are focusing on slightly different aspects of measures.

An example of this is daylighting rivers. This is one of the main focuses in Oslo, and not in Helsinki. This stems from Oslo ducting the majority of rivers up until 1980, but Helsinki on the other hand did not.

Figure 38: Flooding in Oslo during summer (Pedersen, 2020)

Figure 39: Flooding in Helsinki during summer (Lehitkuva, 2019)

Both cities share a common focus on sustainable and resilient urban development. They both recognize the importance of incorporating nature-based solutions, green infrastructure, and SuDS into their practice to enhance the overall sustainability of the urban environment. Furthermore, both cities recognize the need for climate adaptive measures to address the impact of climate change and ensure the resilience of their communities.

7.5 Landowners resposebility

Both Helsinki and Oslo have a similar approach in assigning the responsibility of stormwater management to the landowner. This implies that stormwater management is expected to be incorporated into every aspect of urban space.

However, Helsinki has a more active role in the city's development as it owns 64.5% of all land within the municipality. This means that the city can undertake larger development projects and pilot projects for stormwater management (City of Helsinki, 2018).

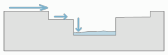
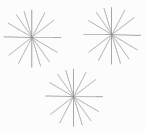
In contrast to Helsinki which owns 65.4% of the land in the municipality. Oslo´s ownership of land within the municipality is limited to only a small portion, such as parks, forests, and streets. It has not been possible to find the percentage of city-owned land in Oslo municipality.

The city still has significant influence in areas that require transformation, where new developers must comply with regulations for blue-green structures (Oslo Kommune, s.a). Therefore, Oslo's approach to stormwater management is focused on creating laws and regulations that developers must follow when designing and constructing new buildings or infrastructure. This approach places less emphasis on direct management by the city itself and therefore may be perceived as a weaker approach compared to Helsinki's more active role in owning and developing the city itself.

7.7 Comparing

Not adressed | Adressed | Emphasizes

Oslo		Helsinki
	Information 	Emphasized the importance of information about weather and stormwater out to the public. In addition to tailored training in stormwater management.
Create a cohesive green structure and a general increase, the importance of having this integrated into the city is emphasized.	Green spaces 	Increasing the general number of green spaces, creating a greener city. Switching the impervious surfaces with preamble surfaces to adapt to the wetter climate.
Green roofs will be help full to decrease the amount of water that goes into the drainage system.	Green roofs 	Focusing on creating green roofs to absorb and purify the rainwater.
Not addressed.	Green walls 	Green walls minimize the runoff of buildings.
Decrease the amount of pollution going into the fjord and ensure the water conveyed there is clean.	Blue structures 	Strengthening and protecting the blue, especially the Gulf of Finland against pollution and runoff.
Daylighting and restoring rivers and streams have been a focus to handle and purify the stormwater and handle floods.	Watercourses 	Restore and preserve the small watercourses in Helsinki. Updating the existing watercourse program.
Map and calculate the old flood routes and new in the built city. Work with the water rather than against it.	Flood routes 	Update and map the new and existing flood routes.

Oslo		Helsinki
Water quality is a problem and needs to be addressed.	Water quality 	Securing excellent quality of rivers and the Gulf of Finland.
Plans to switch out the entire sewage system to separated systems, to decrease sewage runoff.	Seperated sewage systems 	All sewage systems are separated from stormwater.
Step two in the three-step strategy focuses on this measure.	Retention spaces 	Not a specific measure, but priority.
A valuable tool in new development is to secure blue and green structures.	Blue-green factor 	A valuable tool in new development is to secure blue and green structures.
No mentioned.	Pilot projects 	Dedicate money and resources to do pilot projects and set an example.
Addressed, but not elaborated on.	Winter 	A point is made out to the risks with the new winter climate.
Not addressed.	Snow 	Not addressed.
Not addressed.	Ice 	Have a strategy regarding ice on roads, NASTA strategy.

part eight
discussion
new climate, new mangement?

In this chapter, the second secondary research question will be discussed using the theory together with the results of the analysis.

"How is stormwater management in Oslo and Helsinki addressing seasonal variations in the future, specifically the winter?"

8.1 The future is changing

The Nordics are particularly vulnerable to the impact of climate change. As the latest IPCC report highlights, the region is expected to experience higher than average temperature increase, particularly during the winter months. This in turn will lead to an increase in precipitation, causing challenges in future stormwater management (IPCC, 2021a).

There are **two concerns** that both cities need to adequately prepare for.

During the summer, both cities are looking at an increase in the probability of heavy to extreme rain.

The general increase of precipitation during winter, in Oslo, will be an increase of 30% and Helsinki is looking at a generally warmer, darker, and wetter winter.

As a result, the cities need to take steps to prepare for the potential consequences of these two concerns.

8.2 Heavy rain during summer

Helsinki is preparing itself for changing climate, with a particular focus on the 10% increased probability of heavy rain in the summer.

To address the threat of extreme rain and the consequences, both cities have made abundantly clear that it is a potential risk. Looking at experiences from Copenhagen and Malmö, both cities are working on figuring out how to create cities that can handle similar events.

Helsinki´s plan prioritizes the creation of pilot projects that aim for more effective stormwater management and integrate SuDS areas in the city. (City of Helsinki, 2018).

In Oslo, it is expected that the possibility of heavy rain will increase by 20% in the coming years. The city is focusing on step three of its overall stormwater strategy (Oslo Kommune, 2014). This step included points of retaining, storing, and slowing down the excess water. Although Helsinki has not implemented or suggested any specific measures to create retention spaces for extreme weather events, this issue is a priority in the stormwater plan. Both cities have put mapping flood routes throughout the city on the agenda. By mapping these, the city can then adapt its structures and measures where the problem is evident.

Oslo is seeing the risk and is stating that the increase in precipitation will become challenging but is behind Helsinki in risk calculation. Helsinki risk evaluations are more thorough, but similarly to Oslo there are few specific measures in place to address the extreme amount of water that could result from the changing precipitation patterns.

The new climate is forcing the municipalities to change the way they are planning and therefore the municipalities need to adapt sooner rather than later.

8.3 Planning for the future winter

It is essential to recognize that stormwater management is a critical aspect of climate adaptation in Oslo and Helsinki. Specific measures and implementations are necessary to mitigate the effect of the changing climate. This is especially important in the winter, where the risks and challenges are greater, and the consequences of poor stormwater management could be severe. It is imperative that cities prioritize this issue and work together to find solutions.

Winter is the season that will face the most climate changes (Norsk Klimaservicesenter, 2021). This is something that Helsinki has studied at depth in the risk evaluation and where Oslo has a significant weakness.

Both Helsinki and Oslo are aware of the potential climate change in their respective cities. However, Helsinki is taking a more proactive approach in terms of identifying the specific risks and challenges that the winter climate may bring.

By highlighting issues such as slippage, road ice, and winter depression, they can better understand the potential consequences of climate change and begin to develop targeted solutions to address these challenges. Despite the foundation that Helsinki has laid down in the risk evaluation, there are no measures specifically for the winter season.

Oslo's approach is more general in nature, with only a few sentences dedicated to the potential impact of climate change in the winter. In both cities, specific measures for winter do not exist in any plans or strategy. This does not exist, making it difficult for the city to adequately prepare for and respond to the challenges of changing winter weather.

Figure 40: Heavy snow in Oslo (Borgen, 2023)

Figure 41: Blizzard in Helsinki (Suomela, 2021)

The lack of specific measures for winter climate conditions in both Oslo and Helsinki's stormwater management plans is a significant weakness.

Despite conducting risk assessments and finding weak points in their respective ways, both cities have failed to adherently prepare for the winter season. This issue was clear during the previous winter, when Oslo's roads were in such treacherous condition that an unprecedented amount of salt was used, which can be detrimental to the environment and pollute water bodies downstream (Vegvesen, 2008).

The 2023 winter season in Oslo was unpredictable and the city almost ran out of sand and salt (Oslo, 2023). Helsinki, on the other hand, has recognized this problem and implemented the Nasta project which involved assessing measures to reduce the impact of weather on traffic, one point is the issues regarding snow and ice (City of Helsinki, 2019; Oslo, 2023).

Winter is a challenging season to manage stormwater. Frozen ground stops infiltration, snow needs to be stored until warmer weather and freezing rain makes the roads dangerous. Failure to prepare adequately can lead to severe consequences. As the climate continues to change, the challenges of winter stormwater management are only going to increase, making it even more crucial to develop specific measures tailored to the winter season.

Overall, it is important for cities to not only recognize the potential impact of climate change but also take proactive steps to address these changes. By developing targeted solutions that address the specific risks and challenges, cities can better prepare themselves for the changing climate and ensure the safety and well-being of their residents. To become resilient cities throughout the year, develop specific measures to correctly manage stormwater.

part nine
concluding
is Helsinki and Oslo prepared?

In the last and final chapter, the discussion will be summed up and answer the primary research question.

To which extent is climate adaptation part of planning for the increasing challenge of stormwater management in Oslo and Helsinki?

The aim of including climate adaptation in the planning of cities is to create climate-resilient cities that can withstand the changing climate and increasing stormwater.

9.1 Three aspects

As discussed in chapters seven and eight, both cities have adaptation plans that influence the development in each city. However, the documents go into different detailed levels regarding stormwater.

While working with the secondary research questions, I became aware that climate adaptation in stormwater management is best understood when looking at it from three distinct aspects.

First aspects: Managing and adapting to the general increase of precipitation during spring, summer, and fall.

Second aspects: Being able to handle the heavy rain expected during the summer months.

Third aspects: Managing the increase in precipitation during the winter together with the changing climatic conditions.

The concluding chapter will then answer these three aspects

Figure 42: Stormwater in the winter (Glasopor, 2020)

9.2 First aspects:

Managing and adapting to the general increase of precipitation during spring, summer, and fall.

Both cities have come quite far with climate adaptation for the general increase in precipitation and stormwater. The focus and increase of green infrastructure, green spaces, and blue structures within the city ensure that it can handle the expected increase. Both cities also have the importance of improving water quality and purifying the stormwater on the agenda and are focusing on creating open water management structures.

9.3 Second aspects:

Handle the heavy rain expected during the summer months.

In this aspect it is central to understand that the cities have different focus points. This means they are looking at different measures when implementing adaptation. In the case of heavy rainfall, the need for spaces that store and convey the rain without damaging the city is essential. Although both cities consider this a priority, Oslo has implemented it on a larger scale as a part of its three-step strategy.

Helsinki, with its significant amount of city-owned land, can implement specific measures reflecting its responsibility and ability to control development. In contrast, Oslo does not have as much city-owned land.

Therefore, it needs to reconsider its current property holdings and explore opportunities for making them more multifunctional and useful in increasing the city's resilience.

9.4 Third aspects:

Managing the increase in precipitation during the winter together with the changing climatic conditions.

Managing stormwater in winter is particularly challenging as several methods that work in spring, summer and fall do not work in winter.

Although Helsinki is one step ahead of Oslo in addressing the challenges and risks of stormwater management in the winter, both cities need to develop specific measures to manage stormwater effectively during the winter.

Helsinki has taken this significant step towards understanding and addressing the challenges by publishing the "Weather and climate change risk in Helsinki" document. Oslo has not done this, which sets the city one step behind Helsinki.

However, despite the risk document, Helsinki has only implemented one specific measure for winter management, which is the Nasta strategy. This indicates that winter stormwater management is often overlooked, resulting in challenging conditions for several months each year.

In conclusion, the cities are not adequately prepared for every aspect of the challenge of stormwater. Both cities have included climate adaptation measures in their planning to address the challenges of stormwater management. However, the two cities differ in the level of detail. The largest weakness is the expected increase in precipitation during winter.

This is a crucial and significant part of stormwater management where the climate adaptive measures are too small or not taken at all.

Reflection note

Reflecting on my master's journey, I acknowledge both the decision and actions I have taken, as well as the aspects I would approach differently given the opportunity.

A significant challenge that mpacted my thesis was my familiarity with Oslo municipality, my knowledge of the norwegian language and my prior experience in dealing with stormwater issues in Oslo. It became evident that I lacked comparable foundational knowledge about Helsinki, including knowing where to access relevant information and having direct access to local experts.

I hope that this thesis can bring more attention to stormwater management during the winter. Perhaps even encourage further researchers to explore the connection between future winter climate scenarios and current planning measures. Finding solutions and specific measures that the municipalities could implement to handle this season is important to create resilient cities.

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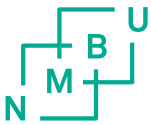

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