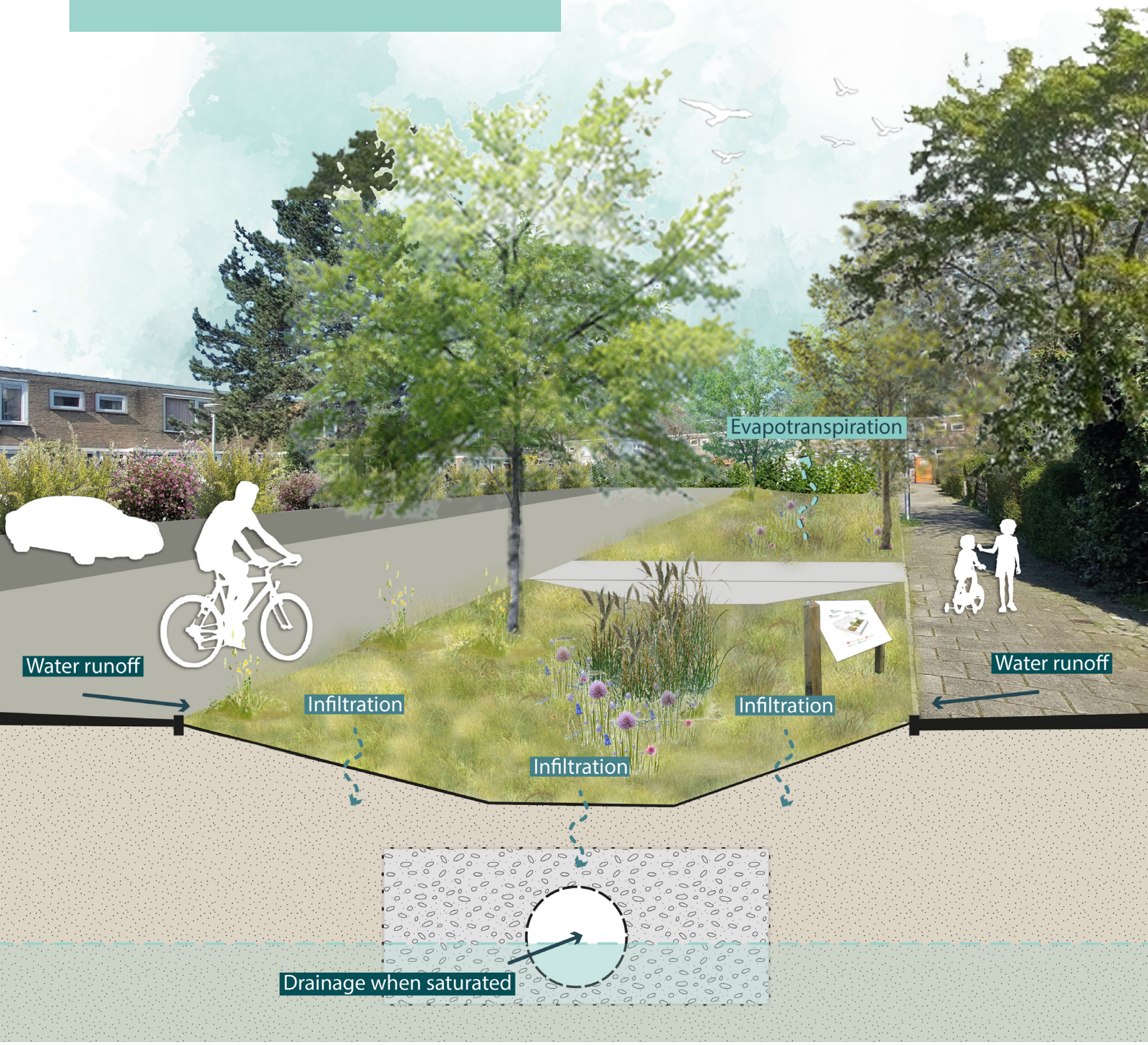
Master thesis

Water sensitive sustainable urban adaptation

Anne Leltz



Colofon

Water sensitive sustainable urban adaptation
Climate adaptation in existing Dutch neighborhoods | a case study in Delft

Master thesis

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AANDACHT ▪ AMBITIE ▪ ANDERS



Abstract

Abstract
This project answers the research question “How can we design with climate adaptation measures in existing neighborhoods in the Netherlands while respecting other aspects of sustainable development?” The methods used to carry out the research are mixed methods. Both deductive and inductive research is done. Theory describes the problem, and existing solutions and methods used, to do research. Through research by design, site specific problems are offered solutions. Later on, by linking the specific sites to the general theory, more general solutions are formed based on the design. This approach is chosen, because, by combining deductive and inductive research more general solutions can be found in a design on a small scale. This is necessary for this research because the problem is too big and very site specific to be solved from deductive research only. Lessons learnt are needed from practical examples to take steps towards answering the research question as a whole.
The project location for the research by design is the Abtswoudse polder in Delft. It is a diverse polder with many different neighborhood types. For the design part, one neighborhood selected based on the climatic and liveability problems and neighborhood type. One design location is worked out, due to the potential of the location because of the liveability and amount of public space. The research is set up in such a way that the method and selection used can be transferred to other locations in the Abtswoudse polder but also to other locations in the Netherlands. The designs are guided by general design principles based on the three main design tools in this project: climate adaptation measures, liveability criteria and sustainable development goals.
The answer to the main research question is: by setting up a framework with design tools that consist of the components: climate adaptation, spatial design and sustainable development. By using the tools to find the overlap between them, and make general design principles to make insightful how they have influenced the design interventions, we can design with climate adaptation measures in existing neighborhoods in the Netherlands while respecting other aspects of sustainable development.

Key words
Climate adaptation, Sustainable development, Liveability, Nature-based Solutions, Climate change, Sustainability, Delft

Preface

This report is written as graduation thesis for the master Architecture, Urbanism and Building Sciences, track Urbanism. The research studio in which the project is carried is Urban Metabolism and Climate. This research is also carried out in cooperation with civil engineering company AW Groep. They are building and transforming our built environment in the Netherlands focusing on sustainability. The company has embraced the Sustainable Development Goals form the United Nations and uses them to assess their work. This project will help in taking steps to integrate the SDGs further in their work and shows how they can have an effect on multiple scales and disciplines.

Unless otherwise indicated, all figures and drawings are by the author.

Aknowledgements

Writing this thesis would not have been possible without the support of many, whom I would like to thank in this section.

First of all, my mentors, Kristel and Frits. Not only your expertise and good ideas have helped me to keep going but also your endless energy, positivity and care. There was not a single moment that you were not enthusiastic, even in this strange corona year, that has not only been challenging for me but also for you, not being able to go to Delft. Thank you for not only being educators but also for really taking care and making this year fun where possible.

I would like to thank AW groep for offering me the chance to do this research at their company. This has not only motivated me towards the subject, but it was also very valuable for me to be able to go to the office every Wednesday, even during the lockdowns. Special thanks to Lars and Thijmen for the fun weekly meetings in which we discussed interesting projects connected to climate adaptation.

Furthermore, I would like to thank all my fellow students from the last five years for all the support, inspiration and good times.

Finally, I would like to thank my family and friends for all the support.

Motivation

Water sensitive sustainable urban adaptation

This research is carried out as the graduation project of the track Urbanism from the master Architecture, Urbanism and Building Sciences at TU Delft. The time span of this project is a whole year and is carried out within the studio of Urban Metabolism and Climate. The focus of this project within Urban Metabolism and Climate is on the urban water cycle in the Netherlands. The reason for this topic is because we need to rethink our way of managing water. We have a very big water cycle at the moment which can be approached more locally. Also, climate change is bringing challenges like flooding, drought and heat stress. Our current system is not ready to handle these problems. Other challenges, like liveability and biodiversity in our urban environment can be connected to the way we design with water. This is the reason for focusing on water and discovering what other sustainable redevelopments could be possible when tackling water issues.

My personal motivation for this topic is because from the first year on in my bachelor studies of architecture and the built environment, I have been interested in doing projects on sustainability. I remember that my very first design project in the first year in the bachelors, we had to design a house and I ended up designing an off-the-grid earthship. This earthship was constructed of waste materials and the house reused the water and generated its own electricity. At that time, I might not have understood exactly what I was doing but I think it is interesting how this house was exactly what this studio of urban metabolism and climate is about on the smallest scale and in very basic form. With this project I hope that I will fully understand what I am doing and to take the principles I already used then, to a bigger and more integrated scale to take steps to making better living environments for everyone.

Furthermore, this research is carried out in cooperation with the engineering company AW Groep. My interest in combining the research with the knowledge of a company that executes many projects in practice, is because I they have a lot of experience in current problems. Thereby, the company is taking very good steps in making their work as sustainable as possible. They have integrated the sustainable development goals (SDGs) from the United Nations in the entire company and work every day on improving their impact. The practical experience from AW Groep and their way of integrating the SDGs in their work have inspired me to come to the topic of my thesis: Water sensitive sustainable urban adaptation.



Summary

Water sensitive sustainable urban adaptation

Starting point

Problem field summary
Climate change is causing worldwide problems of which the consequences can be experienced throughout all scales. Climate change causes the average temperature to rise, more heavy rainfall and longer dry periods. Urban areas are not resistant for the expected climate change and thus have to adapt in order to be sustainable, which requires space. Redevelopment is needed. Thereby, urban areas cause even higher local temperatures due to a high proportion of stony materials (Kleerekoper, 2012). Water problems cause floods which come at a high cost, people living in these areas have a risk of damage to their belongings. When there are longer dry periods, there is a water shortage and nature is at risk of being destroyed. This problem is also occurring in The Netherlands. The existing built environment is not resilient and needs to be adapted. Climate adaptation is one aspect of sustainable development, however there are many more aspects. In order to apply climate adaptation measures, other aspects of sustainable development should be considered as well. Resilience means not focusing on one aspect and improving that to a maximum, but spreading the chances and developing on multiple sustainable qualities.

Problem focus
The problem of climate change and urbanization is too big to be solved in the scope of this project, and thus needs a specific focus. This project will focus on the urban water cycle in relation to climate change and sustainable adaptation in the Netherlands. The urban water cycle as it is now in the Netherlands consists of stormwater, surface water, water quality, water use and sewage water. The focus on water in relation to climate adaptation is because most climate change problems in the urban environment are related to water, like flooding and drought, or can be solved with water (and green) like the urban heat island effect. Because climate change adaptation needs space, there needs to be made room for measures in the built environment. This means that the surroundings of people will change and affect them. Redevelopment of urban areas, in order to adapt to climate change effects, can only be sustainable taking into account all aspects of sustainable development. Knowledge is lacking on the effects of adapting urban areas on sustainable development as a result of climate change adaptation.

Main research question
"How can we design with climate adaptation measures in existing neighborhoods in the Netherlands while respecting other aspects of sustainable development?"

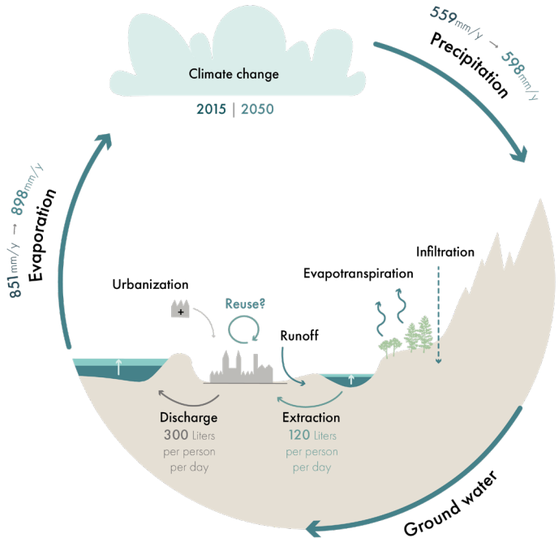


Figure 1: the urban water cycle
Diagram to show the relation between the urban water cycle, climate change and urbanization. Numbers based on (KNMI, 2015), (CBS, 2019) and (Aalbers, 2019). Illustrated by author.

Findings

From Core concepts to design tools
From the main research question, 3 core concepts were selected to form the theoretical framework. The three core concepts are: climate adaptation, liveability and sustainable development. In the theory chapter the overlap and differences between the concepts are discovered to find the focus of the project. The three concepts are converted to three design tools so that they can be used in the design process to find answers to the research question. The three tools used are: climate adaptation measures from the climate adaptation strategy from the municipality of Delft, liveability criteria from David Sim and the sustainable development goals from the United Nations. A framework is made out of the tools in which they are compared to find the overlap and make insightful which design choices can be made. To conclude the tools and use them as design input, general design principles are formed.

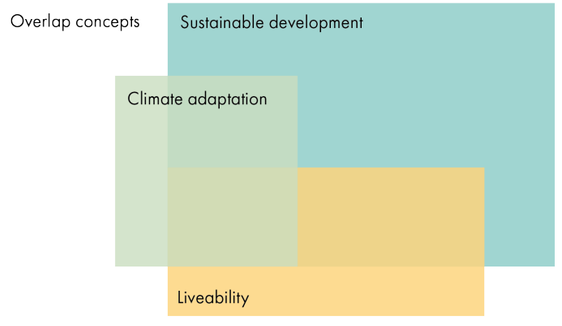


Figure 2: Core concepts in the project and their overlap.
Illustration by author.

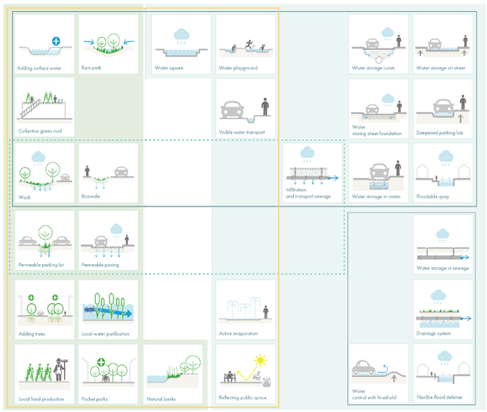


Figure 3: Overview climate adaptation measures
Overview based on climate adaptation strategy municipality of Delft (Gemeente Delft, 2019) edited by author



Figure 4: The 17 sustainable development goals by the United Nation (United Nations, n.d.)

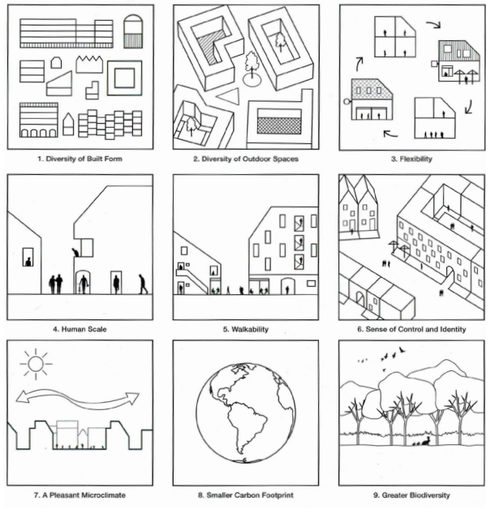
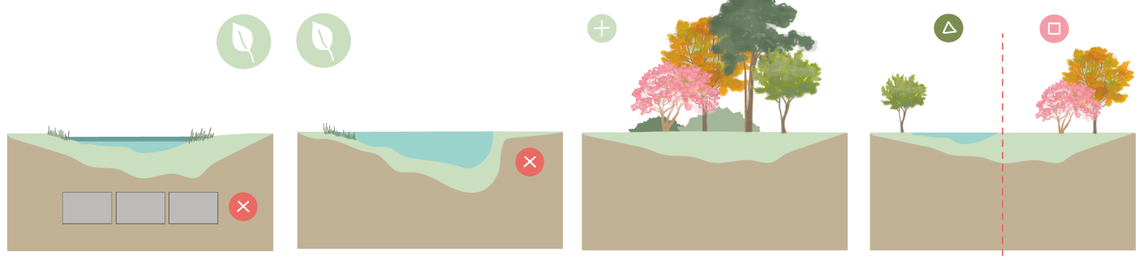


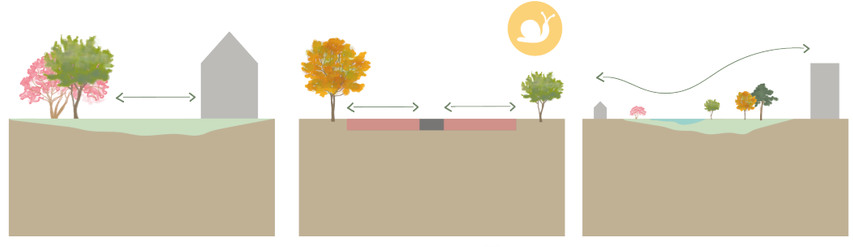
Figure 5: Liveability criteria by David Sim
Overview of the 9 liveability criteria by David Sim (Sim, 2019).

General design principles and redesigns
From the design tool analysis and their overlap, 7 general design principles are formulated as a starting point for the redesigns. They are general and can be used for all design locations. On the right page, the outcomes of some of the design areas are shown and their relation to the most important tools. All design areas are inspired by the same design principles but have a different outcome, due to their conditions. Using the tools and design principles in the design process can be both ways. It can be used as assessment to start the design process and discover possibilities. It can also be used when a design is already (partly) made to see if it can still improve on certain points. It is important that after using the general design principles as input for the design process, still make lists with the tools that are most relevant. This opens up new possibilities and makes insightful the differences between different designs.

The three design examples given on the right page show each a different character that belong to different tools. These are based on the analysis in the thesis on climate conditions, liveability and sustainable development. Using this holistic approach can help to see more aspects and make design choices comparable. For example: choosing to create a natural path to increase permeability to help prevent water problems and have a more positive impact on the natural environment, can be in conflict with other desires. For example, goal 10 reduce inequalities, by making spaces accessible to everyone. People in a wheelchair might not be able to go over these paths. This is just one example, but this approach helps to make a decision based on many aspects to help create sustainable and liveable neighborhoods that are adapted to the effects of climate change.



1. Nature-based solutions preferred over engineered solutions
2. Create natural banks
3. Use a variety of vegetation to contribute to biodiversity
4. Create diverse spaces with their own identity



5. Create more connection between public space and buildings
6. Prioritize slow traffic
7. Create gradients to connect to human scale and create variety

Figure 6: general design principles
Illustration by author.



Figure 7: Redesign purification pond
Illustration by author.





Figure 8: Redesign activity square
Illustration by author.





Figure 9: Redesign discovery wood
Illustration by author.



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In the cycle of nature there is no such thing as victory or defeat; there is only movement.

- Paulo Coelho

Introduction

1.

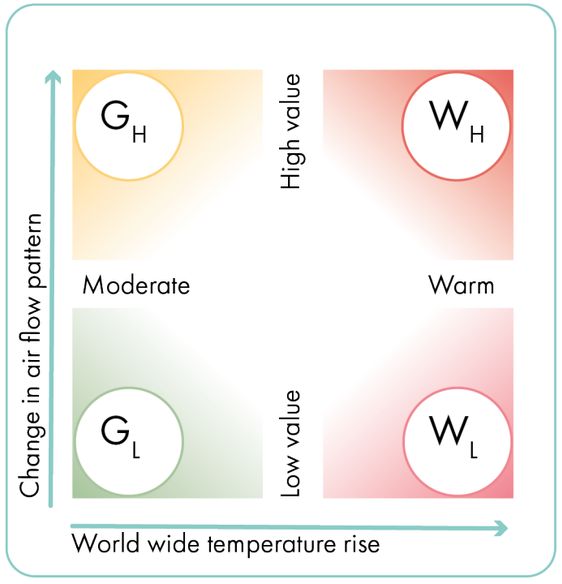
Climate change and the urban environment

This chapter is an introduction to the problem field this research will deal with. It shapes the outline of the project and illustrates the motivation to find solutions for the addressed problems. Climate problems and lack of space are worldwide challenges. This project will focus on these problems in the Netherlands only. The Netherlands is a high densely populated country in which water management plays a key role in allowing this to happen. Because a large area lies below sea level, water is constantly being pumped around the water system to keep the land dry and liveable. This chapter will analyze the different topics that the research will with deal in relation to the situation in the Netherlands. Later on, in this project, the design will focus on the scale of the neighborhood but will keep making links to the national scale of this chapter.

1.1 Climate change

The first worldwide problem this introduction will discuss, of which the effects are also occurring in the Netherlands, is climate change. In 1988 the Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations and the World Meteorological Organization (WMO), to provide policymakers with regular scientific assessments on the current state of knowledge about climate change (IPCC, 2020). The Netherlands is represented by the Koninklijk Nederlands Meteorologisch Instituut (KNMI). Based on the knowledge they share at IPCC and their own measurements they have been making climate scenarios for the Netherlands. This is done, so that policy makers and planners can take into account possible changes and their effects in relation to the Dutch climate. In 2014 the KNMI published their latest report elaborating on four climate change scenarios. They call the four scenarios GL, WH, GH and WL. The big letters stand for G: moderate (gematigd in dutch) and W: warm. The small letters stand for L: low values and H: high values, regarding air flow patterns. The four scenarios form a frame in which climate change could develop until 2050 and 2085 (figure 1).

Figure 1 : climate change scenarios
Diagram to show the relation between the four climate change scenarios by KNMI (KNMI, 2015). Illustration edited by author.



The four scenarios to take into account for the expected climate in the future have their differences based on temperature and flow patterns. However, there are general changes that can be identified for all of the four scenarios. In general, there will be a rising average temperature, more and more extreme precipitation, a rising sea level, small changes in the wind speeds, and less fog but more solar radiation. Because of the stony character of our built environment, urban areas will be affected by the effects of climate change first: “Cities are the first to experience impacts from climate change. Rising temperatures, heat waves, extreme precipitation events, flooding and droughts are causing economic losses, social insecurity and affecting health and human well-being” (Kabisch, Korn, Stadler, & Bonn, 2017). This quote addresses the importance of adaptation to climate change in cites. Because many people are living and working in urban areas, there is lots of interest in a safe surrounding.

General changes



Rising temperature

More, and more extreme precipitation

Rising sea level

Small changes in wind speed

Less fog, more solar radiation

To illustrate what the effects of climate change on precipitation are, KNMI has simulated a scenario compared to two days in august, in which over a 100mm rain fell (figure 2). They simulated the exact same circumstances, except for a temperature that is 2oC warmer. From the map can be concluded that the effect of a higher temperature on the rainfall is very big. The rainfall is much more intense and a lot of water will fall in the same amount of time. Right now, the Netherlands is dealing with precipitation that cannot be handled in urban areas already. This is expected to get only worse with a warmer climate in the future. Thereby comes the problem of heat stress in areas with a large proportion of pavement. Because stony materials warm up more and hold on to the warmth longer, urban areas heat up even more during heat waves.

Extreme precipitation

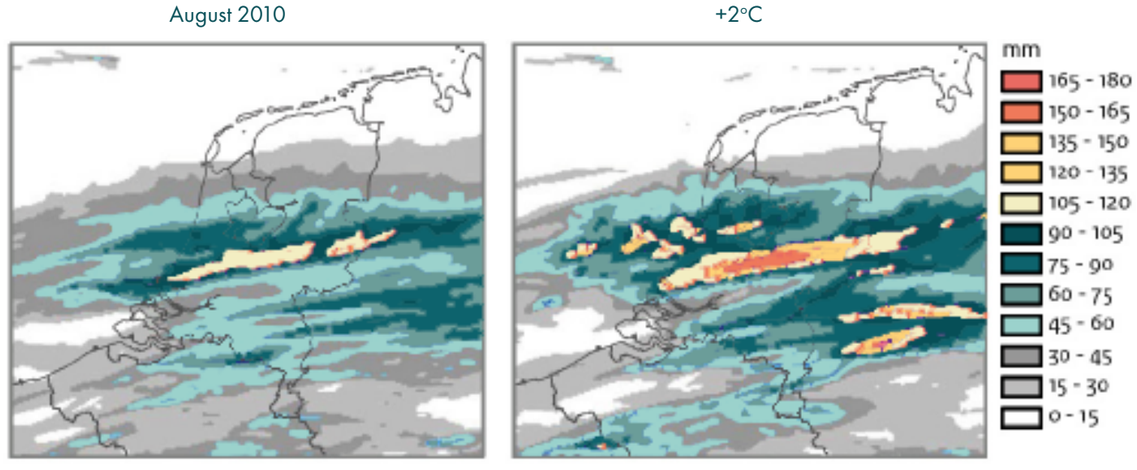


Figure 2: extreme precipitation
Diagram to show Situation with more than 100mm precipitation in two days in augus 2010 (left) and the transformation to a 2°C warmer climate (right) (KNMI, 2015) illustration edited by author.

1.2 Lack of space

It is clear that climate is changing and that urban areas have to deal with the effects of it, already causing problems. Solving these problems however, is not as easy as it seems. In order to take make interventions, space is needed. Space is the next problem arising, especially in a densely populated country like the Netherlands, more room is needed which is not available. Right now, 100% of the land is being used in the Netherlands (figure 2). The university of Wageningen has investigated how the land is distributed amongst different functions, which can be seen in the diagram. To meet the Dutch needs and goals set by the government towards 2050, about 11.5% extra space is needed. This means that decisions have to be made and that opportunities for multi-space use should be investigated. We need to rethink our way of land use.

The extra demand of space is due to the houses needed in the coming years, the energy transition that is crucial for a sustainable use of energy, climate adaptation measures that have to be applied and nature needs room to be recovered. This diagram shows the challenge of this project very well. Development and redevelopment of space is needed, however not everything will fit in the way we are used to apply it: new custom-made approaches are needed. Multi-space use solutions will play a key role in finding solutions in this project.

Dutch land use 2020-2050

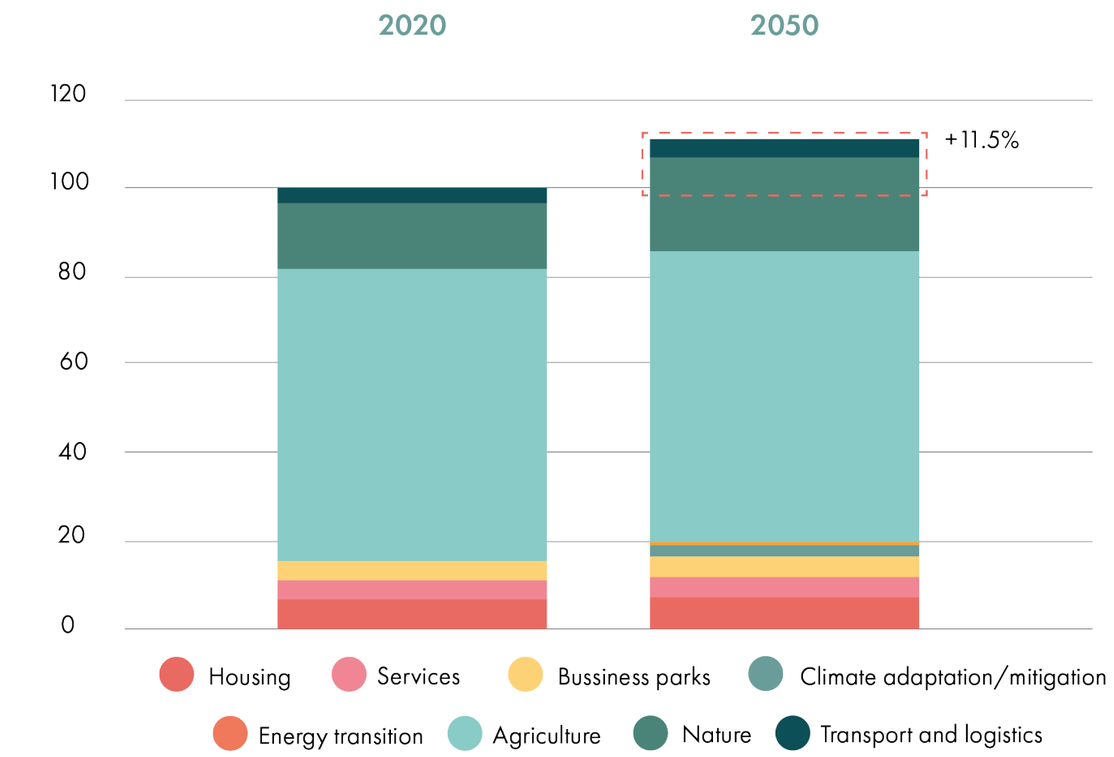


Figure 3: lack of space
Diagram to show the lack of space that is expected to occur in the Netherlands towards 2050 according to the plans made by the governance (NOS, 2020). Edited by author.

11.5% Lack of space

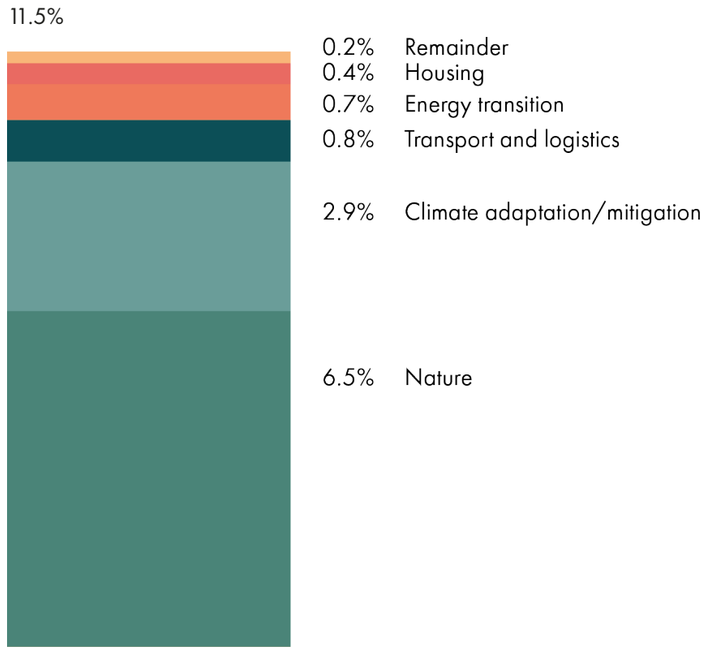


Figure 4: lack of space detail
Diagram to show the origin of the 11.5% extra space that is needed in the Netherlands towards 2050 according to the plans made by the governance (NOS, 2020). Diagram by author.

Taking a closer look at the extra 11.5% of land needed the origin of the demand of the extra land can be distinguished. More than half, 6.5%, of the extra demand comes from more space needed for nature. The Netherlands has made plans to restore nature and increase biodiversity. The second largest amount of extra space needed, comes from climate adaptation and mitigation. Our built environment is not resilient to the results of climate change and needs to be adapted. Furthermore, the Netherlands is extra prone to sea level rise and needs to reserve room for measures to make sure areas will not be flooded. The remainder of the 11.5% is divided amongst transportation and logistics, energy transition and housing and do not show big differences in distribution. In other words, most care when taking decisions should go to nature and climate adaptation according to the plans made by the Dutch government. This is a very interesting diagram for this thesis since it will focus on climate adaptation and shows the urgency of integrating climate adaptation well in Dutch urban areas. This is because a lot of space is needed to do so. Furthermore, blue and green play an important role in this project and nature-based solutions are further investigated. These solutions could help solving for example climate adaptation and at the same time make more room for nature, a multi-space solution. This is discussed further later on in the project.

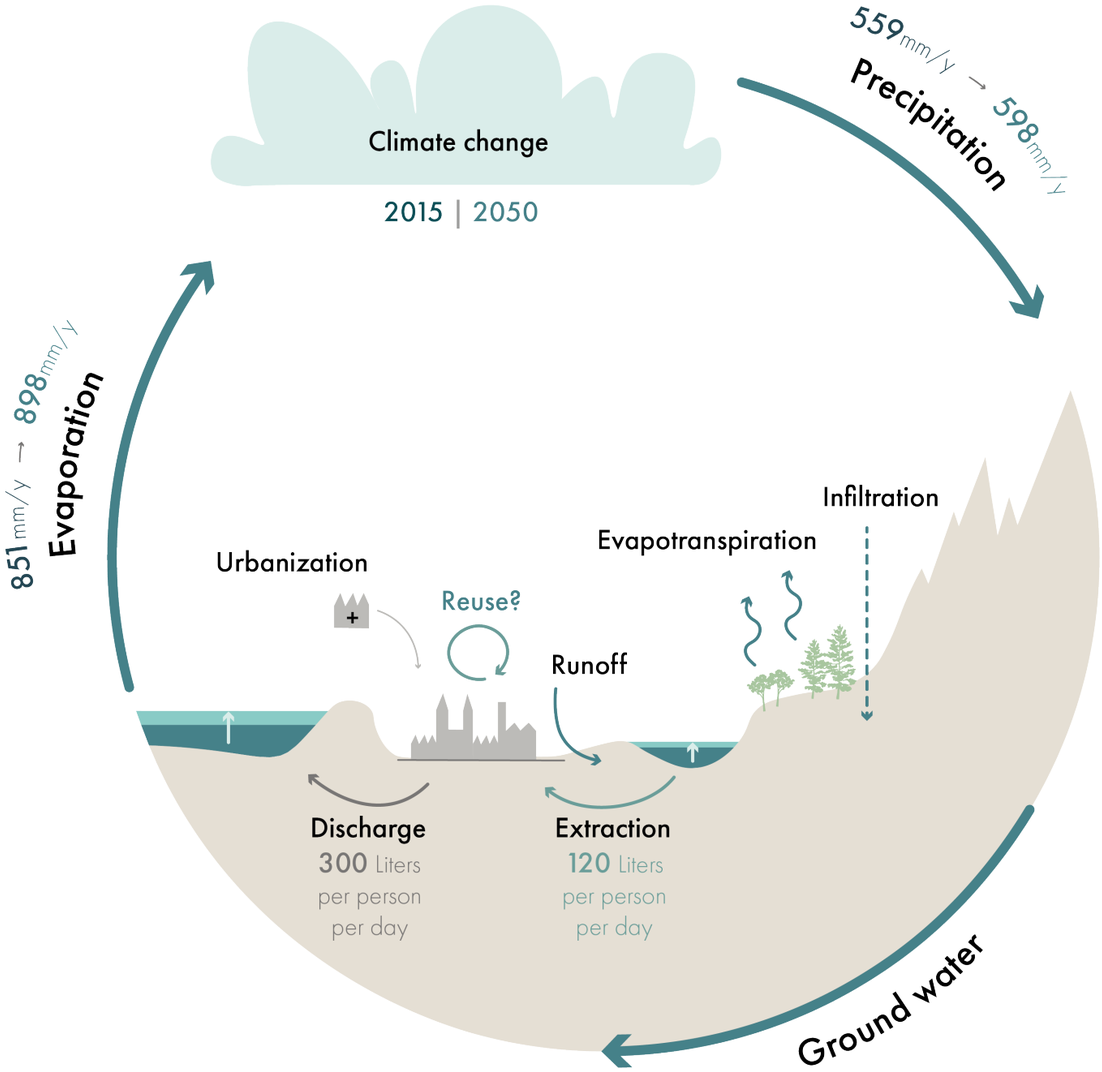


Figure 5: the urban water cycle
Diagram to show the relation between the urban water cycle, climate change and urbanization. Numbers based on (KNMI, 2015), (CBS, 2019) and (Aalbers, 2019). Illustrated by author.

1.3 The urban water cycle

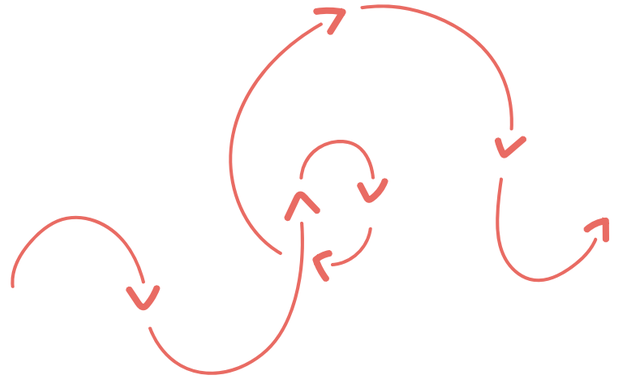
The problem of climate change and lack of space is too big to be solved in the scope of this project, and thus needs a specific focus. This project will focus on the urban water cycle in relation to climate change and lack of space. The urban water cycle as it is now in The Netherlands consists of stormwater, surface water, water quality, water use and sewage water. The focus on water in relation to climate adaptation is because most climate change problems in the urban environment have to do with water, like flooding and drought or can be solved with water (and green) like the urban heat island effect. Figure 5 shows a summary of the problems identified in this chapter. It shows how climate change will influence the water cycle; there will be more precipitation and evaporation. Furthermore, it shows the effect of the urban environment on the water cycle. The figure shows that in natural environments there is infiltration and evapotranspiration. This is a big problem for the urban environment. Because of the stony materials and lack of green there is water runoff and no infiltration and evapotranspiration. Thereby, comes the pressure on the land because of demand for space.

Conclusion

To conclude this chapter, there are several problems the Netherlands is dealing with in relation to this project. More space is needed in the Netherlands for housing, energy transition, climate adaptation measures and nature. At this time, many urban areas are not ready to handle the effects of the changing climate like extreme precipitation, longer dry periods and heat stress. The scope of this project is not big enough to investigate the effects of all problems on the national scale and has a specific focus. The focus of this project is on the urban water cycle in which the effects of climate change will become clear and is directly related to the built environment. National problems are translated to specific locations later on in the project and solutions for these locations will be related back to the national scale.

It is important to get results from experiment but the most important is the process in getting that results.

- Nik Ahmad Nizam



Methodology

2.

The design of the research

This thesis deals with climate change and sustainable adaptation, focusing on the urban water cycle. The purpose of the methodology chapter is to shape the process of the research carried out in order to answer the research questions. This chapter is thus the core for shaping the research of this project and is also used to explain the methods used and process carried out. By addressing different paragraphs, this chapter shapes and illustrates the research of this project. A roadmap (figure 1) communicates the structure of this chapter.

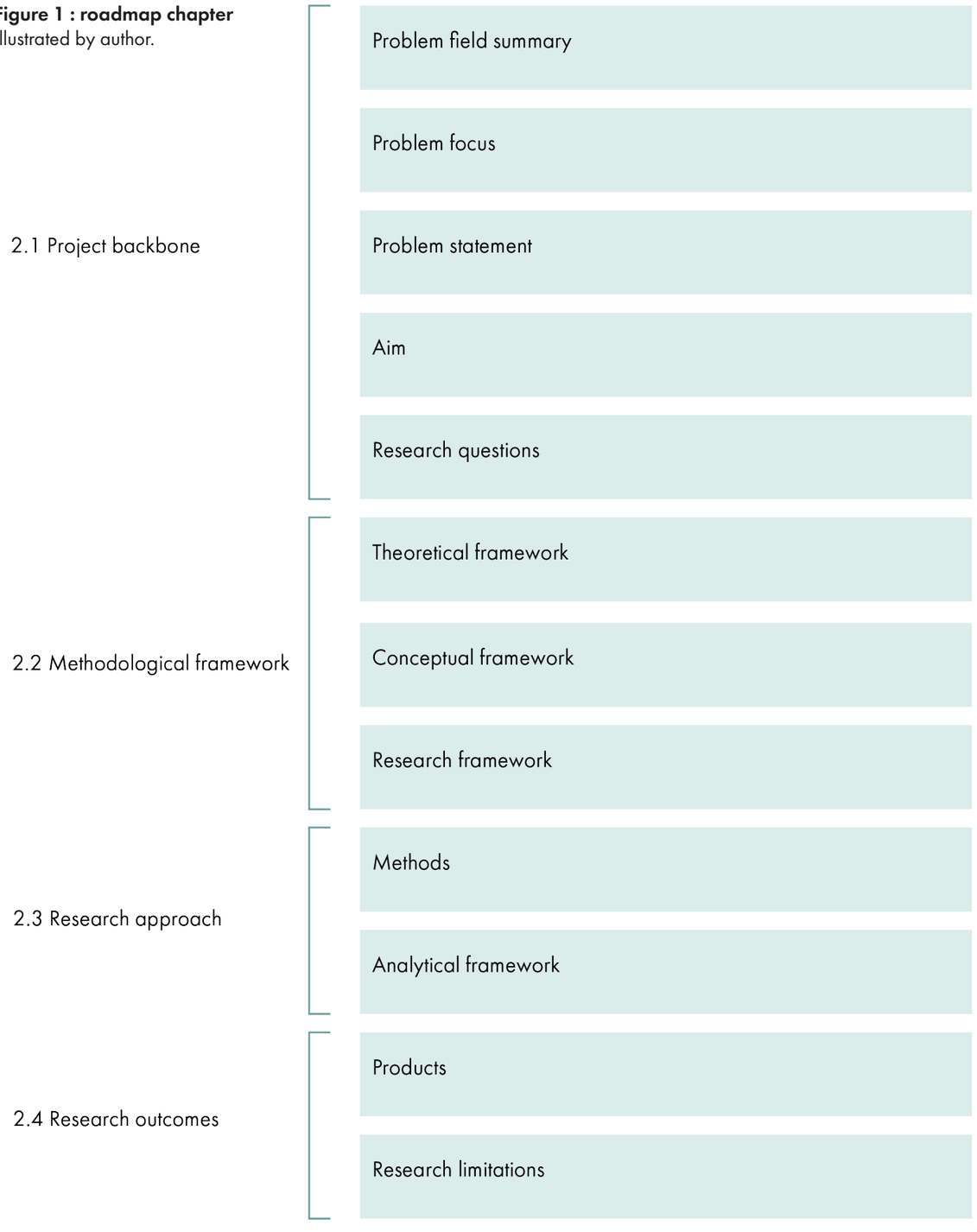
2.1 Project backbone
This paragraph is the foundation of the thesis. It consists of a summary of the problem analysis and explains the focus of the project. This analysis will lead to a problem statement and a set of research questions that are raised to find a solution for the identified problem. Furthermore, the aim of this research is addressed in this paragraph.

2.2 Methodological framework
Paragraph 2.2 illustrates the relation between different concepts studied in this thesis. It shows the relation between concepts and theory and how this is transformed into a research framework. The concepts used are deducted from the knowledge gap identified in paragraph 2.1. The focus of this paragraph is on conceptualizing the research process by showing relations between theory, concepts and processes in this project.

2.3 Research approach
This paragraph focusses on how the research to find answers to the research questions is carried out. Methods are described to illustrate the steps that will be taken to solve the problem identified. An analytical framework shows how the methods, research questions and theory are related. This framework will be further developed later in the research and design process and will not be in this chapter yet.

2.4 Research outcomes
Paragraph 2.4 provides an overview of the expected outcomes of the research. This will be a list of products, the societal and scientific relevance of the project and the limitations of the research. This paragraph will show how this research can be used for and what the boundaries of this project are.

Figure 1 : roadmap chapter
Illustrated by author.



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Climate change is causing worldwide problems of which the consequences can be experienced throughout all scales. Climate change causes the average temperature to rise, more heavy rainfall and longer dry periods. Urban areas are not resistant for the expected climate change and thus have to adapt in order to be sustainable, which requires space. Redevelopment is needed. Thereby, urban areas cause even higher local temperatures due to a high proportion of stony materials (Kleerekoper, 2012). Water problems cause floods which come at a high cost, people living in these areas have a risk of damage to their belongings. When there are longer dry periods, there is a water shortage and nature is at risk of being destroyed. This problem is also occurring in The Netherlands. The existing built environment is not resilient and needs to be adapted. Climate adaptation is one aspect of sustainable development, however there are many more aspects. In order to apply climate adaptation measures, other aspects of sustainable development should be considered as well. Resilience means not focusing on one aspect and improving that to a maximum, but spreading the chances and developing on multiple sustainable qualities.

Problem focus
The problem of climate change and urbanization is too big to be solved in the scope of this project, and thus needs a specific focus. This project will focus on the urban water cycle in relation to climate change and sustainable adaptation in the Netherlands. The urban water cycle as it is now in the Netherlands consists of stormwater, surface water, water quality, water use and sewage water. The focus on water in relation to climate adaptation is because most climate change problems in the urban environment are related to water, like flooding and drought, or can be solved with water (and green) like the urban heat island effect. Because climate change adaptation needs space, there needs to be made room for measures in the built environment. This means that the surroundings of people will change and affect them. Redevelopment of urban areas, in order to adapt to climate change effects, can only be sustainable taking into account all aspects of sustainable development. Knowledge is lacking on the effects of adapting urban areas on sustainable development as a result of climate change adaptation.

Problem statement
Climate change is affecting urban areas in the Netherlands. Heat stress, extreme precipitation and longer dry periods, are causing problems the built environment cannot deal with as they are now. The biggest part of the Netherlands is already built and thus a large improvement can be made in research for climate adaptation in existing neighborhoods. The big problem is, that existing neighborhoods deal with many stakeholders and space is limited. Custom made approach is needed to make room for adaptation measures. In order to convince parties for the implementation of adaptation measures in a new design, co-benefits can be helpful like aspects of sustainable development that are less obvious. To create a proper redesign for a sustainable, resilient built environment, there are many aspects to consider concerning sustainable development. Currently, there is a lack of insight in the effect climate adaptation measures and design have on sustainable development in general.

Research aim
The problem this project deals with occurring in urban areas in relation to the urban water cycle, is adaptation while there is a lack of space. Adaptation to new climate circumstances needs space while the space in urban areas is already scarce and belongs to many different stakeholders. This project is meant to investigate ways to solve the problem of climate adaptation in existing urban areas and find out how this redevelopment can contribute to other sustainable developments as well, like increasing the liveability and biodiversity.

The objectives of this research are:
- To position within the theoretical field and use the knowledge and methods on the topic gained in previous research.
- To analyze the trends that form the problem within the location to be studied.
- To identify the site-specific conditions in relation to the problem focus.
- To explore and design with the site to come up with solutions.
- To test the solutions in order to compare them.
- To reflect on the process and on the solutions in order to make more general conclusions.

Research questions
The main research question of this project will be:

"How can we design with climate adaptation measures in existing neighborhoods in the Netherlands while respecting other aspects of sustainable development?"

Aim: designing with climate adaptation measures
Condition: respecting other aspects of sustainable development
Context: existing neighborhoods in the Netherlands

Sub questions
Introduction
SQ: What problems can be defined in Dutch urban areas regarding climate change?

Theory
SQ: What is the relation between sustainability, liveability and climate adaptation?

Tools
SQ: What are climate adaptation measures and how can they relate to sustainable development?

SQ: What is the relation between the tools and the design?

Research location:
SQ: What problems can be identified in the research location in relation to blue and green?

Design:
SQ: How can the design location become climate adaptive?

SQ: Which interventions respect other aspects of sustainable development?

Recommendation
SQ : What do the outcomes mean to Urban designers and other professions?

SQ: How can the design principles and outcomes from this project be applied in other cases?

2.2 Methodological framework

This paragraph focusses on conceptualizing the research process by showing the relations between theory, concepts and processes in this thesis.

Theoretical framework
The theoretical framework (figure 2) is a result of a literature research carried out to find answers to the problem field that raised from the motivation of this project. The framework is shaped in the process of reading and selecting literature and using theory for the project. The theories form a base of the deductive research carried out that will form starting points for the inductive part of the project, the research by design. From the investigated literature three main concepts form the backbone of the project: climate change adaptation, liveability and sustainable adaptation. Each concept is supported by related theories. Climate change adaptation is supported by theories about the urban water system and theories about nature-based solutions. Liveability is supported by literature about green spaces and urban ecology. Lastly, sustainable development is supported by theories about resilience and the sustainable development goals.

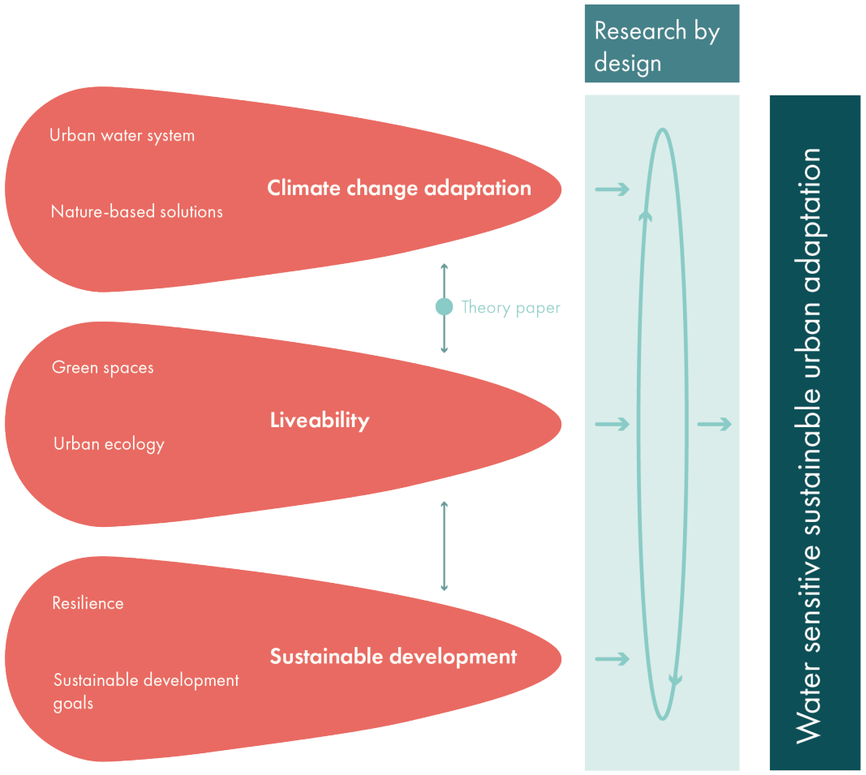
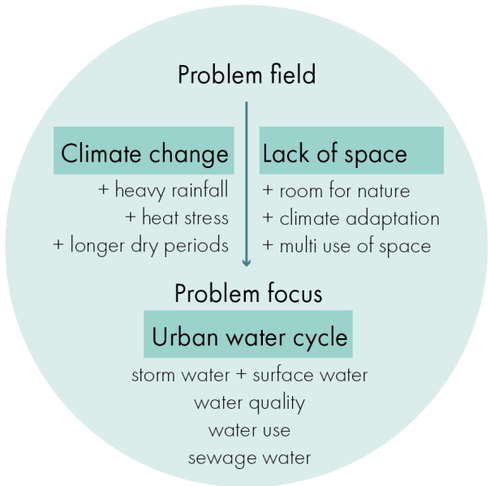


Figure 2 : theoretical framework
Illustrated by author.



Conceptual framework
The conceptual framework (figure 3) illustrates the relation between different concepts, that come forth from the problem field and focus and lead to the solution of this project. From the problem field and focus can be concluded that adaptation measures are needed to find solutions to the problems. However, these adaptation measures are dealing with three core concepts in this project: climate change adaptation, sustainable development and liveability. Just climate change adaptation will not solve the problems in this thesis and so the concepts sustainable development and liveability will help to form a more holistic approach and find answers to the research questions. The relation between the three core concepts is very important to understand in this project and they are investigated in this thesis. The results of the process will lead to water sensitive sustainable urban adaptation.

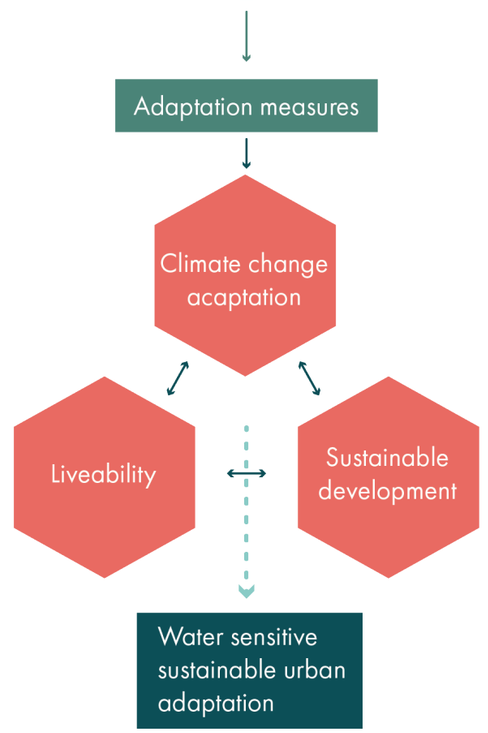


Figure 3 : conceptual framework
Illustrated by author.

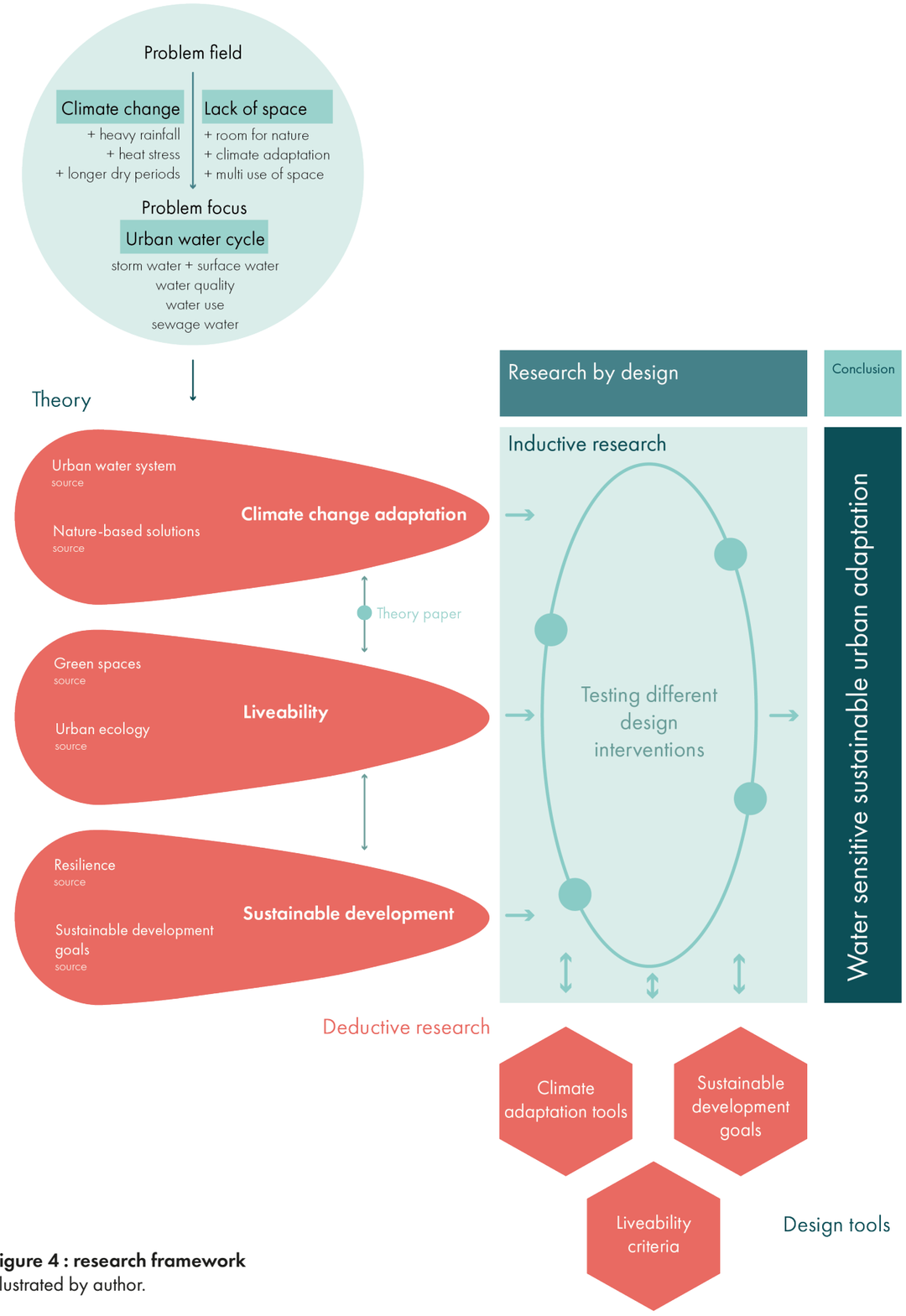


Figure 4 : research framework
Illustrated by author.

Research framework
The research framework (figure 4) illustrates the relation between the problem field, theory and tools (deductive research), and the research by design process (inductive research). The diagram shows the most important components to form the starting points for the research by design process. These components are the theories described earlier and the tools that have a prominent position in this project: the climate adaptation tools from the municipality of Delft, the Sustainable Development goals from the United Nation and the Liveability criteria by David Sim. The tools come forth from the theoretical framework and form the starting points for the design process. From the theory and tools general design principles guide the research by design process. The design process also influences the tools; how they are used and the general design principles that are formulated. The whole process is iterative and is concluded into recommendations about water sensitive sustainable urban adaptation. The theoretical framework is the base of the process and the tools and designs are the important outcomes of the process that form the final conclusions (figure 5).

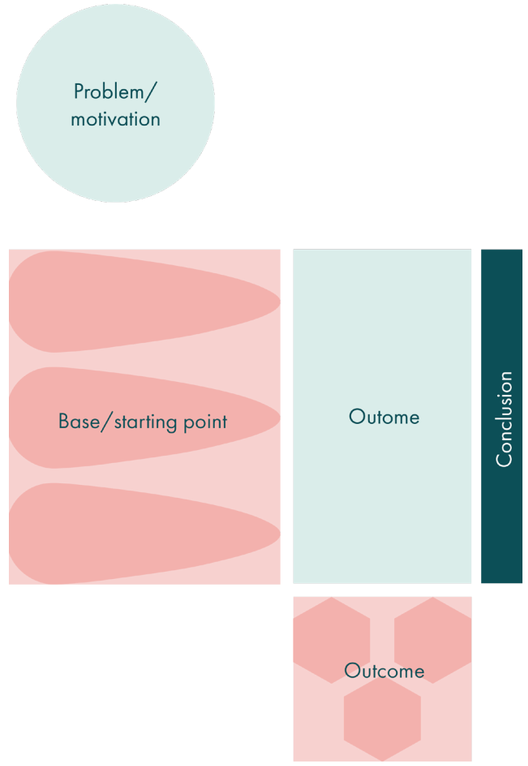


Figure 5 : research framework illustration
Illustrated by author.

2.3 Research approach

Methods
This paragraph elaborates on the methods used in this project to find answers to the research questions. The different methods used are described and the relation between the methods will be shown in a methods roadmap. The different methods used in this thesis are:

1. Literature review
2. Collecting and combining design tools
3. Categorizing design tools
4. Analysis
    - mapping site conditions
    - selecting design locations
    - problem identification
5. Research by design
6. Testing/comparing designs

The first part of this paragraph elaborates on the different methods used in detail. Each method is explained by the purpose and procedure. Also, other relevant aspects of the methods are illustrated. This way the steps taken in the research process can be followed and used later.

1: Literature review

Purpose	To collect theories and concepts and conduct them to own conclusions relevant to the thesis. Literature is the theoretical base and starting point of this thesis. From the motivation for this project, literature is selected and used to narrow down the problem focus and find openings to finding solutions to them. The main areas for the literature review are: climate change adaptation, liveability and sustainable development. A deepened theoretical research is carried out through a theoretical paper, which investigates the relation between the concepts of liveability and nature-based solutions.
Key words	Thesis Urban water system, Nature-based solutions, Green spaces, Urban ecology, Resilience, Sustainable development goals, Climate change adaptation, Liveability, Sustainable development Theory paper Liveability, Nature-based solutions, Environmental quality, Individual well-being, Natural elements
Search engines	Google Scholar, JSTOR, TU Delft online library
Document types	Books, reports, government reports, newspaper articles, peer-reviewed journals
Procedure	From the problem field emerged central themes that are synthesized into a theoretical framework (section 2.2). The theoretical framework is leading for the literature review and is conducted into key words that are used to find theories in search engines. Relevant literature is then selected and combined into conclusions to form starting points for the rest of the project.

2: Collecting and combining design tools

Purpose	To collect tools to use for the research by design (r&d) process. Tools are important parts for the r&d process, as they form a starting point and guide the process, it is what makes the project specific. The selected tools are used as input for the design process as well as measures to reflect on the designs after the process and see which interventions came from which tools. The tools will be the core of the project as they are an outcome of the theoretical base of the project and the starting point of the design process: they are the ingredients that form the flavor of the designs.
Starting point	The climate adaptation measures overview from the municipality of Delft is used as a base for climate adaptation measures (GemeenteDelft, 2019). The 9 liveability criteria from David Sim (Sim, 2019) are used as a base for spatial design to integrate liveability. The SDGs from the UN are used as tool the way they are used by AW Groep (AW Groep, 2020), to form starting points for the design. The different tools will be related to one another in an overview to show the differences and similarities.
Procedure	The tools are selected based on literature research. After this the tools will be explained and related to one another. From the conclusions starting points for general design principles will be formed.

3: Categorizing design tools

Purpose

To create an overview to show how the design tools relate to one another. The climate adaptation measures are used as interventions in the design process. The liveability criteria and sustainable development goals are used to guide and test the design interventions. Showing beforehand how the different tools relate will give insight in the importance of the tools and explain how they can be used in a design process.

Starting point

The climate adaptation measures from the municipality of Delft (GemeenteDelft, 2019). The 9 liveability criteria by David Sim (Sim, 2019). The 17 sustainable development goals by the United Nation as they are used by AW Groep (AW Groep, n.d.).

Procedure

The climate adaptation strategy document from the municipality of Delft is used to define the climate adaptation measures used in this project. The design locations are in Delft and this thesis will focus on the measures that are related to the scale of the street and neighborhood. Excluding measures based on private ground and measures at the city scale. The measures will be categorized based on categories based on literature and the description form the climate adaptation strategy from Delft. The measures will then be related to the SDGs from the UN to show how they are related. After this the 9 liveability criteria by David Sim will be explained and related to the SDGs. In the end general design principles are formed to guide the r&d process.

4: Analysis - Mapping site conditions

Purpose

To spatially understand the physical environment and relevant processes and systems.

Relevant scales

National scale, city scale and neighborhood scale

Sources

Pdok, Planbureau voor leefomgeving, CBS, DINOloket, Klimaateffectenatlas, Data platform Delft, Google maps

Procedure

Maps for the analysis will be created by selecting relevant information from the sources mentioned. They will be spatially related in the maps that will help communicate valuable conclusions to use for the research by design process. The relation between different aspects of the problem will be made visible in the variety of map analyses made, by including and excluding certain information in the maps.

4: Analysis - Selecting design locations

Purpose

To select design locations within Delft (since the climate adaptation strategy plays an important role in this project) that are relevant for this project and will help to give an answer to the research question.

Procedure

The design location for the project will be within the Abtswoudse polder in Delft. This is done because then there can be a thorough analysis for the properties of the polder concerning the water- and ecosystems. The selection of the design location will be made based on the analysis by mapping and will differ in the problems they are dealing with, the building age, proportion of public space, amount of water and green and typology. This way the approach can be transferred to other locations in the future.

4: Analysis - Problem identification

Purpose

To make the problems belonging to the neighborhood visible in maps, section and numbers. The problem identifications are based on the subjects: climatic flows, liveability and sustainable development goals. The identifications are inspired by the design tools and are in this method used as an assessment of the current situation.

Sources

Pdok, Planbureau voor leefomgeving, CBS, DINOloket, PBL, Klimaateffectenatlas, Data platform Delft, Google maps, field trips

Procedure

Use documents from Delft municipality, maps from the “klimaateffectenatlas” and the waterboard of Delfland and observations from field trips to conclude the present problems in the neighborhood. After the investigation of the problems, maps and tables are made to make them insightful. Later on, the problem maps and identification tables can be used to compare different designs, interventions and locations so conclusions can be formed and the project can be compared to other locations as well.

5: Research by design

Purpose

To propose a redesign for one neighborhood in detail using climate adaptation measures. To propose different design interventions to compare and reflect. Research by design is used to address the knowledge gap. It is an iterative process that switches between different scales and between specific problems and general theories.

Procedure

After the design locations are selected and analyzed, different design proposals will be made based on the starting points based on the deductive research. The different proposals will be compared to form conclusions and come up with a useful design, eventually to find answers to the research questions. The scale of focus in this method is the neighborhood and street scale for the specific locations and the national scale for the more general starting points.

6: Testing/comparing designs

Purpose

To test and compare the different designs made and measures taken in the adaptation proposals to formulate answers to the research questions. This method will be used to form a final conclusion for the project that will be the basis for the final product of this project: recommendations on climate adaptation interventions and their effect on the sustainable development goals.

Procedure

The testing and comparing designs and measures is done by using the design tools to create an overview of the relation between the designs and climate adaptation measures, liveability criteria and the sustainable development goals. An overview will be created to show what aspects of design relate to which tools. This overview will allow to form conclusions about the relation between the design tools and the designs, and about the relation between the different tools.

Methods roadmap

Figure 6 shows an overview of the process of how the different methods are applied. The methods used to give answers to the research questions, are not separate steps that can be taken one after another. The whole research is an iterative process and the separate methods are interrelated and involve one another. The roadmap is an abstract representation of what the process looks like. In reality many methods will start at the same time but some will take bigger steps in the beginning than others. The representation in figure 6 shows that the literature review is most prominent in the beginning of the research. This will lead to the combining and selecting design tools and a categorization of design tools. These methods are followed by the analyses. The analyses are followed by the research and design. This method will take steps further but will also influence earlier methods used like creating the design principles and categorizing design tools and thus also the analyses. After the research by design the testing and comparing of designs is the most important method to come to conclusions. However, this method will also first lead to a reflection that will influence the research by design and thus also earlier steps taken.

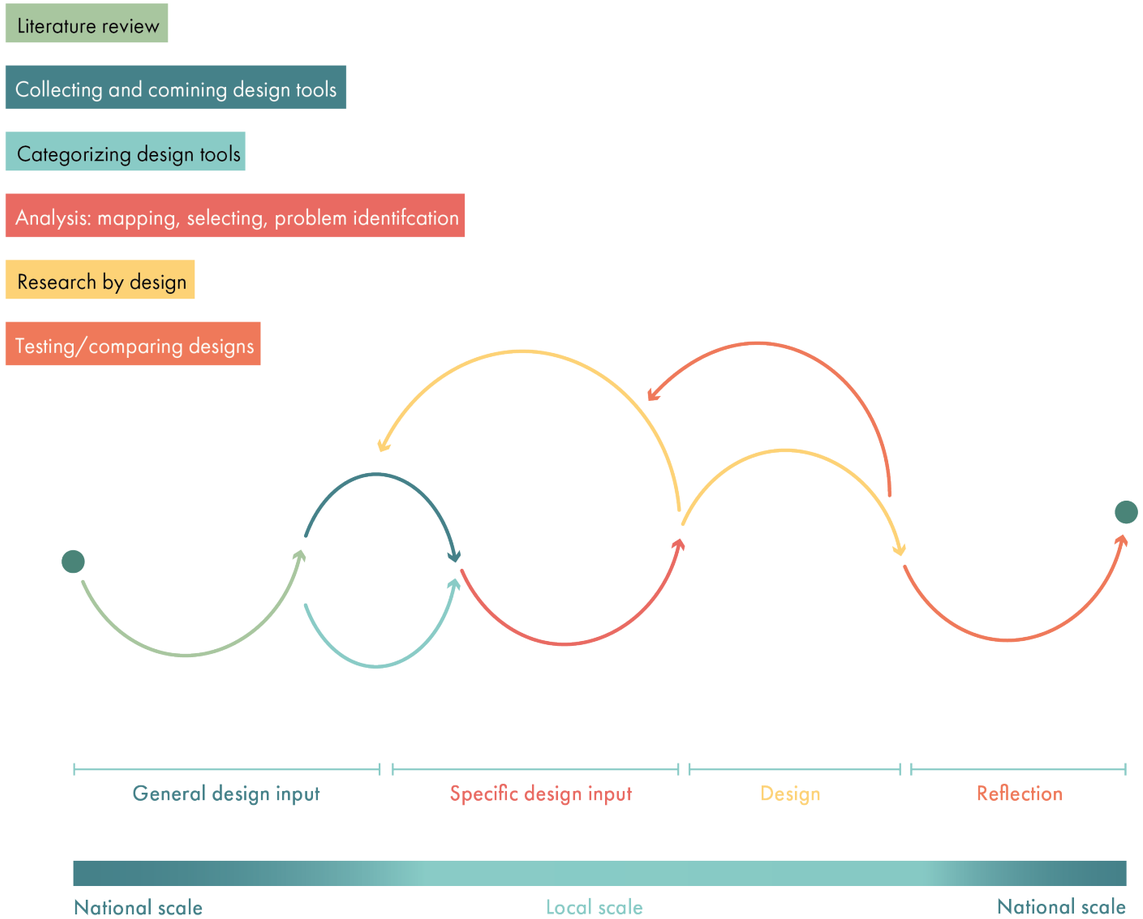


Figure 6 : roadmap methods
Illustrated by author.

Analytical framework
The diagram on the right shows the relation between the research questions posed in the project and the methods used to answer them. All methods will help to answer the main research question and the sub-research questions will each be answered by a combination of methods. The diagram shows that each method will be used to answer multiple research questions.

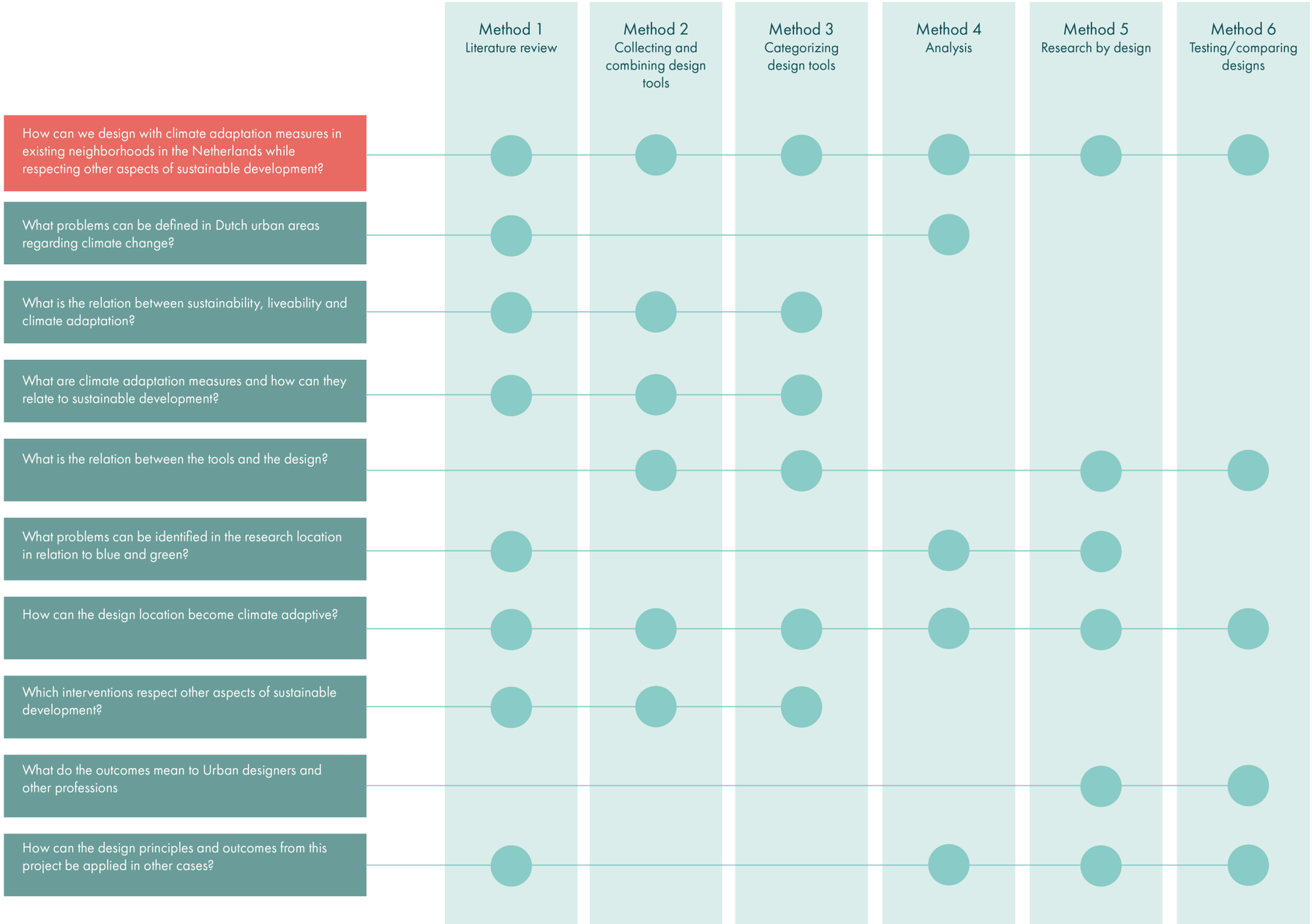


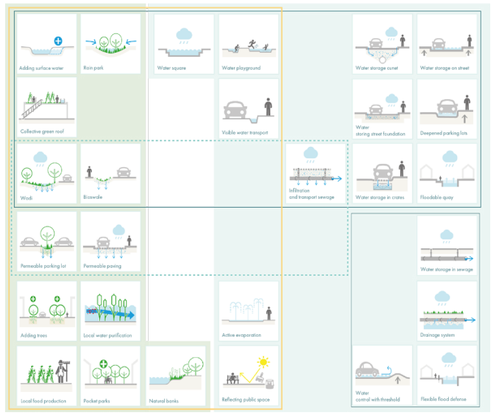
Figure 7 : analytical framework
Illustrated by author.

2.4 Research outcomes

Analyses
1: Blue/green system analysis
Analyses on different scale levels that analyse the research location on the topics blue and green. The water system and ecological structure are investigated and main principles are formed to use in the design.



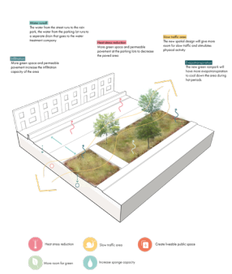
Tools
3: Set of design tools
A set of three selected design tools that give insight in what they entail and how they relate to one another. They are the base of the design process and could be applied as tool in other cases as well.

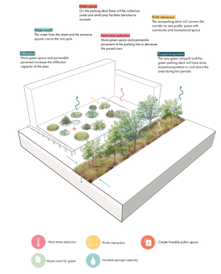


Design
5: Design
This product illustrates the different redesigns and shows which interventions are done. The communication of the designs consist of sections, maps and impressions.

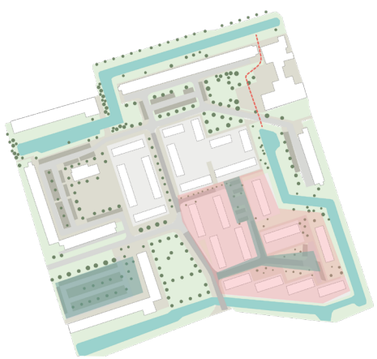


Conclusions
7: Recommendations
This product gives an advice about designing with the used design tools and how the conclusions made based on the designs could be used for other cases.

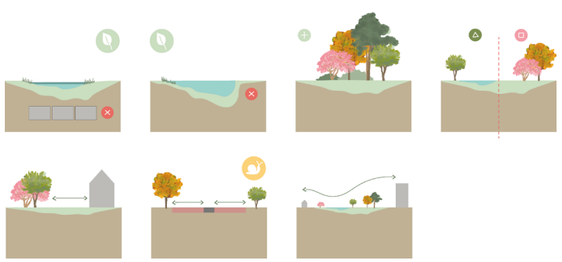




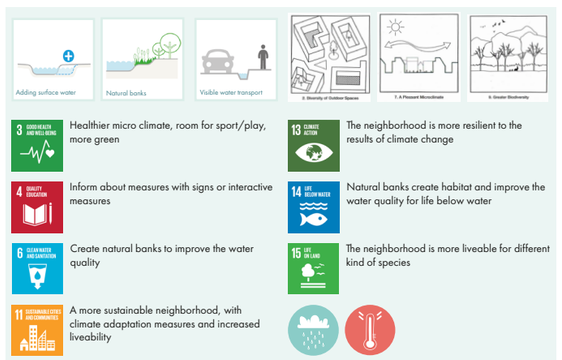
2: Location identification
Analysis of the design locations in maps, sections and numbers that make the different locations comparable. The identification are the motivation for the measures that are taken in the design.



4: Set of design principles
A conclusion of the input from the different design tools combined. They form a base for the design decisions that will be made later in the process.



6: Design tool analyses
This product will show the most important tools that represent the design made. A blue box will indicate for each design which tools are used. The different boxes can be used to compare the designs and interventions.



Research limitations

The chosen scope, methods and sources bring limitations with them that set the boundaries of this project. The project focus on climate adaptation in existing neighborhoods in the Netherlands will focus on redesigning public space, while applying adaptation measures. Problems in urban areas do not only deal with public space but often also with buildings and housing issues. These problems are not part of this thesis and will not be investigated. However, they do exist and could be investigated in further research.

The methods used determine the solutions that are found to the research questions. Other methods could help finding better answers to them, but a selection has been made in this project. Fieldwork could have been a bigger part in the project in which inhabitants and users could be questioned about their viewpoints. However, doing the entire project in times of corona made this method hard to use, and limited the input to online conversations with the municipality of Delft and the waterboard of Delfland. The method that has influenced the project mostly are the selection of the design tools. The tools make the project specific but also limit the aspects that are taken into account in the process. The choice to use these tools and not more, has to do with the scope of the project and the complexity of the tools.

The sources used in the project also limit the outcomes. Sources are always selected by the author and therefor, bias by selection is present in the thesis. Also, when maps are created, the data shown is selected and the image is a means of communication and not reality. The sources used and the selection should be considered carefully when reading the thesis.



Just living is not enough, said the butterfly. One must have sunshine, freedom and a little flower.

- Hans Christian Andersen

Theoretical paper

3.

Liveability and Nature-based Solutions

The relation between Nature-based Solutions and Liveability in the built environment
How can green spaces contribute to liveability in urban areas?

AR3U023 Theories of Urban Planning and Design
MSc Architecture, Urbanism and Building Sciences,
track Urbanism, Delft University of Technology
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25 November 2020

Abstract
Urban space is under pressure. More dwellings are needed in urban areas, while space is needed to make cities adaptable to climate change. As space is becoming scarcer, the challenge to keep and make spaces green is becoming bigger, even though green can have added value to the living environment. Nature-based solutions can solve multiple problems, they can help controlling the effects of climate change while making the living environment greener. Researchers have been examining the relation between green and liveability in the city. They show that green has a positive effect on the health of people, both mentally and physically. However, measuring health can be challenging and liveability is a subjectively perceived term. This makes it hard to give evidence to the positive effect of nature-based solutions on liveability. Still, many studies have investigated the conditions and elements of liveability and the concept of nature-based solutions. These theories are used to show the relation between nature-based solutions and liveability. The paper concludes that nature-based solutions can have a positive effect on the environmental quality and individual well-being as it uses natural elements to achieve environmental and societal goals.

Keywords
Liveability, Nature-based solutions, Environmental quality, Individual well-being, Natural elements

3.1 Introduction

Urban space is under pressure. Cities are expanding and climate is changing. The results of climate change bring demand for extra space due to climate change adaptation/ mitigation measures. These measures are needed in urban areas to prevent problems: "Cities are the first to experience impacts from climate change. Rising temperatures, heat waves, extreme precipitation events, flooding and droughts are causing economic losses, social insecurity and affecting health and human well-being" (Kabisch, Korn, Stadler, & Bonn, 2017). Making room for measures and urbanization can result into lack of space. A risk of lack of space is that it goes at the cost of liveability in urban areas, because space is given new functions and often (green) public space is under pressure. In order to adapt to the effects of climate change and to give more space to nature, nature-based solutions could be applied. To see what the effects of these solutions are on liveability in urban areas, this paper will answer the research question: "What is the relation between liveability and nature-based solutions?"

The motivation for this paper is to investigate the co-benefits of climate adaptation, starting with nature-based solutions. This paper is written as part of a graduation thesis about water driven sustainable urban adaptation in which research by design is a big part. The role of this paper is to form arguments for making decisions in the design process later on in the project. The reason for this subject is because the relation between nature-based solutions and liveability is understudied.

This theoretical research will be carried out by reviewing existing literature on the topics and conducting this to own conclusions. Citations form literature will be used and an explanation will show how it is interpreted in the paper. Diagrams will be used to illustrate how sources are understood. The limitations of this paper are that the paper is only a small part of the graduation thesis and thus will not go in depth too much. This scope results into a limited number of sources used to base the conclusions upon.

The research in this paper will start (chapter 3.2) with finding a definition for liveability that can be used in this paper: the different conditions and elements for liveability will be explored. After this, a definition for nature-based solutions will be formed. Then, the relation between liveability and nature-based solutions will be investigated (chapter 3.3). After this, a discussion (chapter 3.4) will explain the reach of the observations and the limitations of the methods used. The discussion will be followed by the conclusion (chapter 3.5) that gives a short overview of the findings in this paper. Lastly, a chapter about implications (chapter 3.6) will discuss the possibilities for further research on the topic.

3.2.1 Defining liveability

In order to investigate the relation between nature-based solutions and liveability, the concept of liveability needs to be defined for this paper. In order to do so, different theories about the concept are being compared. Finding a definition for liveability is challenging. The concept is broad and subjective and quite a number of different descriptions can be found. As the concept is subjective, the perception can differ across the world but also between cities or even within neighborhoods. Finding a definition for this paper will form a clear starting point for the discussion about the meaning of liveability that can be hold anywhere by anyone. The different explanations of the concept used, vary in describing the conditions for liveability and summing up the different elements that contribute to liveability. This chapter will first reflect on the different conditions used in theory to describe liveability (2.2) and later on, give an overview of the different elements (2.3).

3.2.2 Liveability conditions

The first description used for the comparison of different conditions is from Michael Southworth in "Measuring the Liveable City". In his paper he investigates the meaning of liveability and how it can be measured, using different examples to explain his proposed methods. In his paper he refers to liveability as follows: "What is a liveable city? The concept of liveability is complex and encompasses many aspects of urban life: how well the city works for us, as well as how comfortable and enjoyable our neighborhood and city are" (Southworth, 2003). In his explanation we can identify three conditions that form liveability: functionality, comfort and enjoyability. These conditions are very broad and subjective. Later in his paper he refers to the different conditions to be economic, social and physical form: "economic and social conditions are not the only factors that contribute to liveability. The physical form of a neighbourhood contributes significantly to its liveability" (Southworth, 2003). These aspects, physical form, social conditions and economic conditions, are already clearer since they can be measured better as they are less subjective. Another description for liveability conditions is from "World Cities: Achieving Liveability and Vibrancy", a book about urbanization and the quality of life, explaining the relation between liveability, sustainability and vibrancy. Liveability is explained as: "Liveability is generally defined by performance in three main areas: environmental quality, neighbourhood amenity and individual well-being" (Ling & Yuen, 2009). This definition focusses more on the neighborhood scale and individuals, and uses terms that are clearer to measure than Michael Southworth. All three descriptions show overlap and the relation between them is important to understand, to make clear the understanding of liveability in this paper. For this paper the conditions used for liveability will be from Ling and Yuen, since it is most measurable as it describes the performance of the three mentioned conditions. Figure 1 is a diagram to show the understanding in this paper of the relation between the three descriptions used. It links the conditions environmental quality, neighborhood amenity and individual well-being to the other given conditions. This way, it becomes clear how this paper understands the conditions that form liveability as there are different descriptions to explain the concept. In this paper, environmental quality relates to: comfort, enjoyability and physical form. Neighborhood amenity relates to: functionality, enjoyability, economic conditions and social conditions. Individual well-being relates to: comfort, enjoyability, economic conditions, social conditions and physical form.

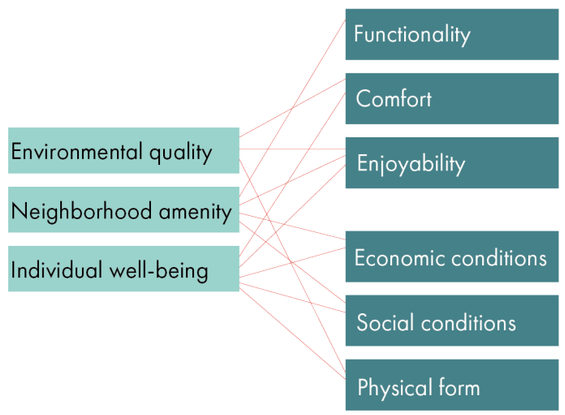

Figure 1: The relation between different conditions to describe liveability
Illustration by author

3.2.3 Liveability elements

This paragraph will show an overview from elements given in literature to shape the liveability conditions from the previous paragraph. To describe liveability, often a sum-up of elements is given that contribute to liveability. These elements can be categorized by the conditions: environmental quality, neighborhood amenity and individual well-being. This paragraph will first use quotes from literature in which the different elements can be identified. Then, it will create an overview of how the elements are linked to the three different conditions used.

First of all, the definition is being used form Harm Kaal in "A conceptual history of livability: Dutch scientists, politicians, policy makers and citizens and the quest for a liveable city", an article about the development of the concept liveability in the Netherlands. He states: "Giving a general description of a livable urban environment is almost like sketching utopia: livable places are safe and secure, have a decent infrastructure, high level of service provisions and are economically viable and environment-friendly" (Kaal, 2011). From his explanation five elements for liveability can be identified, liveable places are: safe/secure, have a decent infrastructure, have a high level of service provision, are economically viable and are environment-friendly. These elements can be found in figure 2.

The second description with elements to explain liveability is from "Urban liveability: Emerging lessons from Australia for exploring the potential for indicators to measure the social determinants of health", an article about measuring health and liveability: "Liveable cities are socially inclusive, affordable, accessible, healthy, safe and resilient to the impacts of climate change. They have attractive built and natural environments. Liveable cities provide choice and opportunity for people to live their lives, and raise their families to their fullest potential" (Badland, et al., 2014). From this description, nine elements can be identified, according to the paper, liveable cities are: socially inclusive, affordable, accessible, healthy, safe, resilient to climate change, attractive built environments, attractive natural environments, and provide choice and opportunities. These elements can be found in figure 2.

The third definition used is from Michael Southworth in Measuring the Liveable City where he describes what liveability means for residents : "For many urban residents, liveability includes such diverse qualities as the healthfulness of the environment, protection from natural disasters, and absence of crime, as well as opportunities for employment, affordability of housing, and the quality of schools and public services" (Southworth, 2003). The seven elements used in this definition are: a healthy environment, protection from natural disasters, absence of crime, opportunities for employment, affordable housing, quality of schools and public services. These elements can be found in figure 2.

Lastly, the description from Ling and Yuen is used to investigate elements used to describe liveability: "The key elements of a liveable city often include attractive public spaces, walkable, mixed use, higher density neighborhoods that support a range of green infrastructure and transport, affordable housing, vibrant, exciting, sociable, human-scaled pedestrian experiences" (Ling & Yuen, 2009). From this definition, ten elements can be found that relate to public space, neighborhoods, infrastructure and transport, and experiences. The elements are: attractive public space, walkable neighborhoods, mixed use neighborhoods, higher density neighborhoods, green infrastructure and transport, affordable housing, vibrant experiences, exciting experiences, sociable experiences, human-scaled pedestrian experiences. These elements can be found in figure 2.

	Environmental quality	Neighborhood amenity	Individual well-being
(Kaal, 2011)	Decent infrastructure Environment-friendly	High level of service provision Economically viable	Safe/secure
(Badland, et al., 2014)	Accessible Resilient to climate change Attractive built environment Attractive natural environment	Socially inclusive Affordable Choice & opportunity	Healthy Safe
(Southworth, 2003)	Healthy environment Protection from natural disasters	Opportunities for employment Affordable housing Quality of schools Public services	Absence of crime
(Ling & Yuen, 2009)	Attractive public space Walkable Green infrastructure & transport	Mixed-use neighborhoods High density neighborhoods Affordable housing	Vibrant experiences Exciting experiences Sociable experiences Human-scaled pedestrian experiences

Figure 2: The relation between different conditions to describe liveability and the elements used in different theories. Illustration by author

Figure 2 shows an overview of the elements given in the compared literature. The table shows how this paper understands the relation between the different elements given in the literature and the different conditions defined in the previous paragraph. The table shows how different theories overlap or differ from one another. It is important to show an overview of multiple sources and how they relate because the concept of liveability is complicated and subjective. This way, a clearer understanding of the concept is formed showing the relation between different perspectives. From the table can be concluded that some sources pay more attention to one condition in specific. Kaal uses the least elements to describe liveability in general, but still covers all conditions. Badland et al. focusses most on the environmental quality. Southworth pays most attention to neighborhood amenity in the sum-up, and Ling & Yuen pay most attention to Individual well-being in their elements. This shows the importance of comparing different sources because if too little sources are used not all aspects would be covered.

3.2.4 Liveability in this paper

To conclude the two paragraphs, a definition is given to liveability in this paper that is formed by the discussed literature. In this paper, the conditions that form liveability are environmental quality, neighborhood amenity and individual well-being. There are a lot of elements given in the literature used that contribute to these conditions. Figure 2 in the previous paragraph, shows an overview of the understanding of liveability in this paper based on different sources. It shows the interrelation between different elements, as well as the relation between the elements and the conditions earlier described. Since this paper is investigating the relation between nature-based solutions and liveability, most attention will be paid to the conditions: environmental quality and individual well-being and the elements that are related. This will become clear later in the paper.

3.3.1 Defining nature-based solutions

In order to understand the relation between nature-based solutions and liveability, nature-based solutions (NbS) need to be defined as well. For the definition, the book "Nature-based Solutions to Climate Change Adaptation in Urban Areas: Linkages between Science, Policy and Practice" is used. This book explores the challenges from climate change and urbanization and investigates the role of nature-based solutions in solving problems that come with these challenges. To give a definition to NBS in this paper, the following quote is used: "Traditionally, urban planners and practitioners in land and resource management have relied on conventional engineering solutions to adapt to climate change, but this may not always be cost-effective, sufficient or sustainable. Nature-based solutions can address societal challenges from climate change and urbanization in a sustainable way. By using ecosystem services, nature-based solutions are innovative solutions that use natural elements to achieve environmental and societal goals" (Kabisch, Korn, Stadler, & Bonn, 2017). From this quote, the following definition for this paper is formed: NbS are solutions to problems that come with urbanization and climate change that uses natural elements to achieve environmental and societal goals. Nature-based solutions are an alternative to mainly engineered solutions when they can be more cost efficient, sufficient and/or sustainable. NbS use natural elements that can have multiple benefits for people, planet and profit.

To explain the concept and origin of nature-based solutions, chapter 3 "Nature-Based Solutions and Climate Change – Four Shades of Green" from the book uses four related concepts to articulate their differences and show how they are connected. The concepts used in this chapter are nature-based solutions (NbS), green infrastructure (GI), ecosystem-based adaptation (EbA) and ecosystem services (ESS).

It is stated that NBS is the newest concept that it covers a combination of the other three concepts used. The concept of NBS is already defined, so the other concepts need to be

explained as well to understand the relation between them.
Green infrastructure: "GI stands for interconnected networks of all kinds of green spaces" (Pauleit, Zölch, Hansen, Randrup, & Konijnendijk van den Bosch, 2017). GI is more about planning and strategy as the core of the concept is about the network of green spaces, it is about linking and creating a system.
Ecosystem-based adaptation: "The concept of EbA is defined as "the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change"(CBD 2009:41)" (Pauleit, Zölch, Hansen, Randrup, & Konijnendijk van den Bosch, 2017). EbA has a main focus on climate change adaptation by using natural elements, it is similar to NBS but is less broad as the target of the concept is adaptation and solutions have a broader meaning that cover this aspect as well.
Ecosystem services: "Nature is the basis for the production of food, clean water and fresh air; natural elements such as trees and other vegetation act as filter for air pollution and can reduce the risk of flooding by runoff retention and infiltration. Also, nature has significant influence on humans, for example by providing restorative settings, for educational purposes, offering inspiration and promoting creativity. The provision of these services to humans by nature has been captured in the concept of ESS. Thus, ESS is basically a categorization of the broad range of 'benefits people obtain from ecosystems'" (Pauleit, Zölch, Hansen, Randrup, & Konijnendijk van den Bosch, 2017). The focus of ecosystem services lies on the perspective of people, it is about what they can gain from ecosystems in the broadest sense, it shows the multiple benefits that nature has besides solving climate change and urbanization problems.

The chapter explains the relation between the four concepts as follows: "it is suggested that NbS is an umbrella concept for EbA, GI and ESS. EbA is more specifically emphasizing nature's role for climate change adaptation and it can be considered as a subcategory of NbS. GI is a concept that emerged in planning; it can help to develop strategic approaches for systematically integrating NbS and EbA into urban development at various scales. Finally, ESS provides means for measuring and valuing nature's benefits. While the other concepts are more practical and solution oriented, the concept of ESS is a more abstract one with a very strong focus on valuation" (Pauleit, Zölch, Hansen, Randrup, & Konijnendijk van den Bosch, 2017).
From this can be concluded that nature-based solutions are solutions to problems that come with urbanization and climate change that uses natural elements to achieve environmental and societal goals. The concept is rather new and covers concepts that relate to climate change and urbanization that are longer known. It is an umbrella for the concepts of green infrastructure: used in planning to create green systems out of green spaces and NbS at multiple scales, ecosystem-based adaptation: measures that use natural elements to adapt the consequences of climate change is specific, and ecosystem services: using green as a solution to value all the benefits that nature has to people.

3.3.2 Nature-based solutions and human well-being

As the previous paragraph already illustrated, there are multiple benefits to NbS: it does not only solve problems that come with climate change and urbanization. There are big values that come with integrating nature in finding solutions. This paragraph focusses on the effect NbS can have on human well-being.

In chapter 11 "Effects of Urban Green Space on Environmental Health, Equity and Resilience", the relation between urban green space and health is investigated based on a large number of studies on the topic. They conclude form their research that green spaces can have a positive effect on people in urban areas: "Modern urban life style is associated with chronic stress, insufficient physical activity and exposure to anthropogenic environmental hazards. Urban green space, such as parks, playgrounds, and residential greenery, can promote mental and physical health and reduce morbidity and mortality in urban residents by providing psychological relaxation and stress alleviation, stimulating social cohesion, supporting physical activity, and reducing exposure to air pollutants, noise and excessive heat" (Braubach, et al., 2017). From this conclusion can be stated that the mental and physical aspects of health can be influenced positively by green spaces. Green spaces can contribute to the reduction of morbidity and mortality because of ecosystem services such as reducing stress, stimulation relaxation, supporting social cohesion, which support mental health, and because of ecosystem services such as, stimulating physical activity, reducing heat, noise and air pollution, supporting physical health.

Besides the positive effects of green spaces on health and well-being, there are also arguments for the negative influence of green spaces on health. In the same chapter about health and green spaces an argument is given: "although the evidence on adverse health impacts of urban green space is based on fewer studies and it is less consistent than the evidence of health benefits. Potential adverse health effects are associated with increased exposure to pesticides, allergenic pollen, arthropod vectors of infectious diseases, infectious agents in soils contaminated with animal faeces, and increased risk of injuries" (Braubach, et al., 2017). Green spaces can have adverse health effects because of allergenic pollen, pesticides, the spread of certain diseases and a higher risk for injuries. There is less evidence for the negative effects on health of green spaces then there is for the positive effects. Also, the negative effects do not weigh up to the positive effects, all the negative effects given are temporary, while the positive effects given can have an effect on the health of people for their entire life.

3.3.3 Relation nature-based solutions and liveability

When looking at the definition from NbS and the conditions from liveability that are defined, a big overlap can be found. As discussed, NbS uses natural elements to achieve environmental and societal goals. The three conditions environmental quality, neighborhood amenity and individual well-being could all three be seen as environmental and/or societal goals. However, NbS show less overlap with the elements. This paragraph is used to relate NbS to the relevant elements from figure 2.

Each element that relates to NbS from figure 2 will be discussed in this paragraph, this will also be shown in figure 3. The argumentation used to relate the elements to NbS is based on the previous paragraphs of this chapter about defining NbS and the relation between NbS and human well-being. Each condition for liveability from the table in figure 3 will be discussed separately.
Environmental quality: first of all, environment-friendly directly relates to NbS, as NbS offer green spaces that positively influence the environment, such as heat stress reduction, managing water and providing clean air. Secondly, NbS contribute to resilience to climate change, as they are developed to make urban areas adaptable to the results of climate change using natural elements. Furthermore, NbS contribute to attractive natural environments since they make the surrounding greener as they use natural elements. Also, NbS can contribute to a healthy environment as discussed in the previous paragraph, they can positively influence mental and physical aspects of health. Furthermore, protection from natural disasters can be linked to resilience to climate change but might need stronger protection. Still, natural elements can contribute to the protection and thus NbS relate to this aspect. Furthermore, green can contribute to attractive public spaces so NbS relates to this element as well. Lasty, green infrastructure and transport can be improved by NbS as well, as they also relate to GI.

Neighborhood amenity: the elements that belong to this condition do not have a direct relation with nature-

	Environmental quality	Neighborhood amenity	Individual well-being
(Kaal, 2011)	Decent infrastructure Environment-friendly	High level of service provision Economically viable	Safe/secure
(Badland, et al., 2014)	Accessible Resilient to climate change Attractive built environment Attractive natural environment	Socially inclusive Affordable Choice & opportunity	Healthy Safe
(Southworth, 2003)	Healthy environment Protection from natural disasters	Opportunities for employment Affordable housing Quality of schools Public services	Absence of crime
(Ling & Yuen, 2009)	Attractive public space Walkable Green infrastructure & transport	Mixed-use neighborhoods High density neighborhoods Affordable housing	Vibrant experiences Exciting experiences Sociable experiences Human-scaled pedestrian experiences

Figure 2: The relation between different conditions to describe liveability and the elements used in different theories. Illustration by author

based solutions.

Individual well-being: first of all, Safe/secure is being mentioned by different sources and relates to NbS in a way that NbS can contribute to the protection from climate change effects. Secondly, NbS can contribute to health(y) since they can influence physical and mental aspects of health. Furthermore, NbS can contribute to vibrant, exciting and sociable experiences, as they can have a positive effect on mental health and stimulate social cohesion. Lastly, NbS can help to create human-scaled pedestrian experiences since natural elements are of the same scale level as humans are and can thus help create human-scaled pedestrian experiences in urban areas.

3.4. Discussion

The findings in this paper have to be interpreted by taking certain aspects in consideration. First of all, the number of sources used is limited. There are many more theories about both liveability and nature-based solutions to be found. However, the scope of this paper is a given amount of time by the course and is not big enough to cover all relevant theories. This means that the theories used are biased by selection of the author. The sources that are used define how the concepts used are understood for this project, other theories might change the interpretation of the subject and influence the findings and conclusions. This has to be taken into account when reading this paper.

Additionally, the paragraph about liveability uses diagrams to show the understanding of the relation between different conditions and elements. The definitions of these conditions and elements could be defined more in order to substantiate the way the diagrams are organized. These diagrams are based on own interpretation and could have a different completion when made by someone else. It could be argued that some lines in figure 1 should be different, that the categorization of figure 2 should be done differently and that the relation between NbS and the liveability elements should be different too. It could be done differently, but this paper uses this method and completion to explain the interpretation of different sources, due to the scope of this paper.

Furthermore, the paper uses theory about green spaces and health effects. The sources used to base the text upon translates green spaces into nature-based solutions. This is also done in this paper. However, there is no evidence that green spaces and NbS can be translated into one another one to one. When forming conclusions about the health effects of NbS, one should consider the relation between green and NbS to form a personal understanding.

Lastly, the concept of liveability is subjective. This means that the interpretation can vary across the world, between cities and even within neighborhoods. The sources used are written by authors from nationalities from all over the world to give the most universal understanding possible. However, as stated before the number of sources used are limited and other sources would have given a different output.

3.5. Conclusion

To conclude this paper, the research question "What is the relation between liveability and nature-based solutions?" is answered. To answer this question, the concept of liveability is defined. Liveability is defined by different conditions and elements. The conditions that form liveability are environmental quality, neighborhood amenity and individual well-being (figure 1). Different elements from theories are put in a diagram in order to give an overview of the understanding of the different conditions in this paper (figure 2).

To investigate the relation between liveability and nature-based solutions, NbS is defined as well. NbS are solutions to problems that come with urbanization and climate change that uses natural elements to achieve environmental and societal goals. The concept of NbS is an umbrella for green infrastructure, ecosystem-based adaptation and ecosystem services.

In order to substantiate the relation between liveability and NbS, the effect of green spaces on health is investigated. Green spaces can have both negative and positive effects on health, however, there is more evidence for the positive effects than the negative effects and the positive effects are also bigger than the temporary negative effects.

Finally, the relation between liveability and NbS is examined in the last paragraph. The definition of NbS in this paper relates to the three conditions of liveability: environmental quality, neighborhood amenity and individual well-being could all three be seen as environmental and/or societal goals. However, not all elements relate to NbS. Figure 3 shows an overview of the elements that belong to NbS and which do not belong to NbS. This shows that there is no overlap to the elements that go with neighborhood amenity but there is much overlap with environmental quality and individual well-being. This brings forward the answer to the research question: nature-based solutions strive for all three conditions that form liveability: environmental quality, neighborhood amenity and individual well-being. However, they have most potential contribute to environmental quality and individual well-being.

3.6. Implications

Further research could be carried out to investigate the meaning of liveability for different points of view. For example, comparing the interpretation of the concept between different countries, cities or even within cities. This could contribute to the world wide understanding of the concept so that it can be used better. Furthermore, this paper is too small to really understand the relation between nature-based solutions and liveability but could be a proper starting point for research where actual measurements could be made. The sources used, already give indications on how liveability can be measured and perhaps this can be converted into a study for nature-based solutions in urban environments.

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The greatest threat to our planet is to belief that somebody else will safe it.

- Robert Swan



Core concepts

4.

Liveability, Sustainability & Climate Adaptation

4.1 Liveability and Sustainability

The paper about liveability and nature-based solutions has given an insight in the understanding of liveability. Besides liveability, sustainability is a core concept for this thesis. Both concepts have been given a lot of definitions in literature and practice and are sometimes confusing. This paragraph will put both terms together to understand the overlap and differences between the two for this project. The meaning for the terms is conducted from the paper "The needs of society: A new understanding of transitions, sustainability and liveability".

First of all, to give sustainability a meaning, the paper used a definition from the World Commission on Environment and Development. The definition used for sustainable development is: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (de Haan, et al., 2014). The paper states that two key concepts can be derived from this definition, 'meeting needs' is a central objective and there is emphasis on future generations: sustaining something in existence.

In the paper in chapter three of this report, the complex definition of liveability is defined by the conditions: environmental quality, neighborhood amenity and individual well-being. The focus in liveability is on the present and on the needs of human beings. This is also stated in the paper about sustainability and liveability. The paper states: "A key theme across the various definitions and applications of the concept is that it is inherently anthropocentric — liveability is a reflection of 'quality of life', 'wellbeing' and/or the satisfaction of the needs of 'the people'" (de Haan, et al., 2014)

In the comparison between the two concepts the following is stated:
- "There is a temporal distinction between sustainability (which by definition is about long-term, intergenerational conditions) and liveability (in which the emphasis switches to the 'here and now' and the direct delivery of benefits while retaining an expectation that these will continue in perpetuity).
- Sustainability and liveability both have their origins in the satisfaction of human needs. Though sustainability might have shifted from that origin as a consequence of the pragmatics of applying the concept, the inherent anthropocentric nature of liveability means that the relationship to human needs is more entrenched and is therefore less likely to shift.
- Both concepts recognise the essential relationships that humans have with their environment. While sustainability concerns itself with the maintenance of resources provided by the environment and environmental and ecological health, liveability effectively points a spotlight on their current environment." (de Haan, et al., 2014)

To conclude, both concepts deal with the relationship between humans and environment but have a different scope of time. Sustainability focusses on maintaining our environment and resources for the future while liveability focusses on 'here and now'. The other difference is that liveability focusses more on human needs and sustainability on economic, environmental and social dimensions, which will be further explained in the next paragraph.

4.2 Climate adaptation

Climate adaptation is the last core concept in this thesis. The meaning of climate adaptation is in the name: to adapt to the effects of climate change. The concept can be perceived as much simpler than the other two concepts, it is measurable. For example, the amount of water that climate adaptation measures help to manage, can simply be calculated. This way, also temperature reduction can be calculated. Climate adaptation reacts to the effects of climate change that occur here and now, as well as to the effects that are predicted in the scenarios by the KNMI. Climate adaptation is implemented to prevent our environments from damage as well as to create or maintain a healthier living environment.

4.3 Overlapping concepts

After having defined all concepts, overlaps amongst climate adaptation, sustainable development and liveability can be detected (figure 1). The place where these concepts overlap is the core focus of this project. The starting point is climate adaptation and the quest is to see where it can help improve liveability and sustainable development as well. Climate adaptation relates to liveability in a way that it helps improve micro climate conditions in the direct surrounding of people and create safety against the threat of the effects of climate change. Climate adaptation measures can especially help improve livability when using nature-bases solutions as concluded from the theoretical paper. Climate adaptation and sustainable development relate to one another, in a way that they both aim for meeting the needs of people now and in the future: a safe and healthy living environment. They differ in a way that sustainable development is much broader and covers many aspects that do not involve climate adaptation. This can be said about liveability as well. However, when redesigning urban areas for climate adaptation, these other aspects can be taken into account as well and that is what this project strives for.

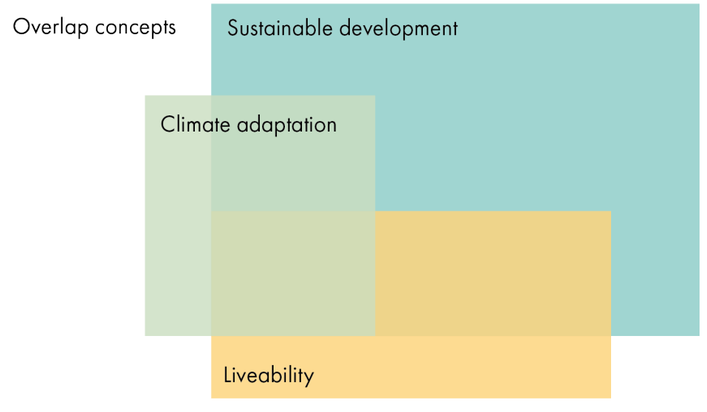


Figure 1: Core concepts in the project and their overlap.
Illustration by author.



Figure 2: Core concepts and their time frame
Illustration by author.

The concepts differ most in their time frame and the way they aim for something (figure 2). In the diagram can be seen that liveability specifically focusses on here and now and aims for the best on multiple aspects. Climate adaptation mainly focusses on scenarios that predict the changing climate and makes sure that our living environment is adapted to these scenarios before they are actually happening. Sustainable development is the most complicated concepts as it aims for an ideal situation for here and now as well as for the future on many aspects, not knowing what that future will be. This way sustainable development also focusses on preventing damaging changes to happen.

4.4 The sustainable development goals by the UN

In 2015 the United Nations introduced the Sustainable Development Goals (SDGs). The goals are set up to provide a framework for global sustainable development towards 2030:

"The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests." (UN, 2020)

The SDGs are following the Millennium Development Goals, which were set up as a framework for 2000 to 2015, to reduce the biggest problems in the world in the least developed nations (CBS, 2020). These millennium goals were less detailed and developed, the SDGs are meant for all nations and are used and formed by everyone. The development goals aim to create a balance between the three dimensions of sustainable development: the economic, social and environmental, this resulted into 17 SDGs (figure 3). The goals come with 169 associated targets to stimulate action. Everything is set up in a way that it can bring gain to, and be used by all nations. However, each country has their own challenges for sustainable development and thus the goals have to be approached differently everywhere to have the desired effect.

"The SDGs and targets are integrated and indivisible, global in nature and universally applicable, taking into account different national realities, capacities and levels of development and respecting national policies and priorities. Targets are defined as aspirational and global, with each government setting its own national targets guided by the global level of ambition but taking into account national circumstances." (UN, 2020)

To make the goals this general so they can be used all over the world on every different scale, also means that they lack specificity and are hard to measure. Therefore, every country sets up their own national targets to contribute to the global scale. Figure 3 shows a scheme that explains the process of the formation and application of the sustainable development goals. The balance between the core, economic, social and environmental values for sustainability form the basis for the 17 sustainable development goals towards 2030. From these worldwide goals, each nation sets up their own targets and goals that lead to a roadmap towards 2030 to achieve the 17 goals.



Figure 3: The formation of the SDGs on global level and application on national level.

The 17 development goals are:
1. **No poverty:** Social security and economical means
2. **Zero hunger:** End hunger, food security, promote sustainable agriculture
3. **Good health and well-being:** Better living quality
4. **Quality education:** Equal access to education and improve lifelong learning
5. **Gender equality:** Equal rights for men and women to facilities and equally represented in political and economic decision-making
6. **Clean water and sanitation:** Secure accessibility to sustainable management of water and sanitation for everyone
7. **Affordable and clean energy:** Secure accessibility to affordable, reliable and sustainable energy for everyone
8. **Decent work and economic growth:** Improve, durable, inclusive and sustainable economic growth, with valuable and complete work for everyone
9. **Industry, innovation and infrastructure:** Build resilient infrastructure, improve inclusive and sustainable industrialization and stimulate innovation
10. **Reduced inequalities:** Reduce inequalities between countries
11. **Sustainable cities and communities:** Make cities and human settlements inclusive, safe, dynamic and sustainable
12. **Responsible consumption and production:** Ensure sustainable consumption and production patterns
13. **Climate action:** Take action to fight climate change and the impact of climate change
14. **Life below water:** Preserve and make the use of oceans and seas sustainable: oceans absorb 30% CO2 and produce 50% oxygen
15. **Life on land:** Protect, recover and improve sustainable use of ecosystems. Stop deforestation and desertification and loss of biodiversity
16. **Peace, justice and strong institutions:** Without peace, safety and justice, there is no possibility for sustainable development
17. **Partnership for the goals:** To reach the goals in 2030, governments, companies, citizens and organizations have to cooperate



Figure 4: The 17 sustainable development goals by the United Nation (United Nations, n.d.)

4.5 The SDGs in the Netherlands

To use the SDGs in the Netherlands, alliances with coordinators are created to gain insight on the greatest challenges. They form the basis of the targets the Netherlands has set with a roadmap to achieve them. The biggest challenges in the Netherlands deal with the climate goals, energy goals and life on land goals (CBS, 2020). The progress the Netherlands makes on the 17 goals is being measured by the central agency of statistics (CBS). This way everyone can get insight in what is achieved and still can be done. A report of the progress is published every year and individuals and organizations can use this as an inspiration to set their own goals to contribute to the whole.

4.6 The SDGs in this project

In this research, the SDGs are a starting point for the research by design process, as well as an assessment tool to assess different measures and combinations of them in a design. Since this project is carried out in cooperation with AW Groep, their way of using the SDGs in practice is the base for how it is used in this research. At AW Groep, the SDGs are integrated within the whole company, every team, project, design and performance can be assessed with and inspired by the sustainable development goals. In order to make a difference this holistic approach is used. To give an insight on the assessment of different goals, the SDG wheel is used (figure 5). A completed wheel gives insight in the impact a project, design, team or performance potentially can have on each goal: positive and negative. Since every goal is unique it is hard to fill in the wheel using numbers to define the diagram. The solution AW Groep has found for this is to fill in the wheel by relatively comparing the goals. They investigate for every goal what aspects deal with the goals and what choices they can make. This gives insight of the impact an individual goal can have and can be relatively compared to the impact of other goals: the bigger and more dominant the list of aspects the bigger the impact. A completed SDG wheel is thus an impression of the potential of different goals relatively compared, for a specific project or process.

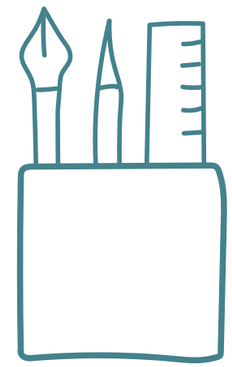
This is something that also can be done when making a design. For this project the SDG wheel will be used to investigate the possibilities in a location on a neighborhood scale: it is used as analysis before the design is made. This way possibilities can arise on aspects that might have been forgotten if the SDGs were not investigated before the design process. Furthermore, the goals will be used through the scales in the design process: first on the neighborhood scale to investigate problems and possibilities, then on measurement scales to see what effect the measures can have on the interventions, then on design scale to see what a new design can do to the neighborhood as a whole. This will not be done by using the will but simply indicating the related SDGs. The same will be done for the climate adaptation measures and liveability criteria, they will be indicated as well. This will be explained further in the next chapter.



Figure 5: SDG assessment
The SDG wheel as it is used at AW Groep to assess projects (AW Groep, n.d.)

When the only tool you own is a hammer, every problem begins to resemble a nail.

- Abraham Maslow



Design tools

5.

Measures, Sustainability and Liveability

From the theoretical chapter and core concepts, three design tools have been selected and combined to form the foundation of the research by design process. For each concept a tool is selected to use in this project. For climate adaptation, the climate adaptation measures from the municipality of Delft have been selected, since the research location is in Delft. For liveability, the nine liveability criteria by David Sim have been selected to use for the design process. For sustainable development, the 17 sustainable development goals from the United Nation have been selected. Figure 1 shows a diagram similar to the one in the previous chapter for how the concepts overlap. This diagram shows how this accounts for the design tools used. The climate adaptation measures are the starting point for this project and the project focus will be on the overlap between the adaptation measures, liveability criteria and sustainable development goals.

The next paragraphs will explain how the selected tools will be used in this project and show how they relate to one another. The conclusion for this chapter explains how the tools are going to be used in the design process and give a list of general design principles.



Figure 2: Heavy rainfall in Delft
Image from the climate adaptation strategy of Delft to show the effects of climate change in the city (Gemeente Delft, 2019).

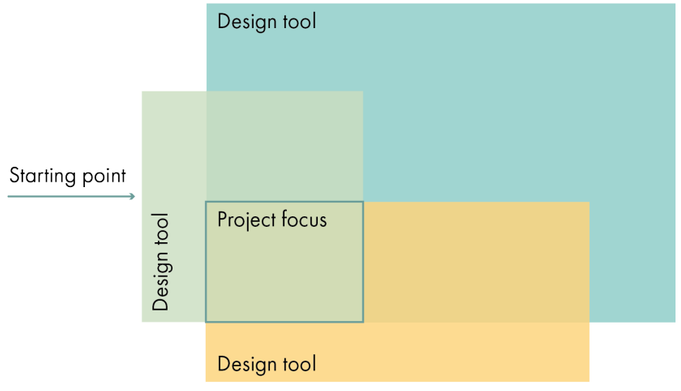


Figure 1: Core concepts as design tools
Illustration by author

5.1 Climate adaptation measures

The municipality of Delft has published a climate adaptation strategy in 2019 to communicate their approach towards a sustainable Delft (Gemeente Delft, 2019). In their strategy they offer a climate adaptation measures toolbox. In this project this toolbox forms the base of the measures that will be used in the design process. This is done because the research location is also in Delft and the toolbox gives a very complete overview of possible measures. The toolbox consists of 75 measures that can be applied on different scales: building, garden, street, neighborhood and city. For this project, only the measures offered for street and neighborhood will be used. This is done because the designs deal with public areas, so buildings and gardens are excluded. The city scale is not the scale of focus for interventions in this project. The fact that the designs will not make use of building, garden and city interventions, does not mean that it can inspire stakeholders to do interventions on these scales as well. The measures for the street and neighborhood are together 27 interventions that can be applied. In order to use the interventions in the design, they are categorized in this project. The biggest categorization is based on whether the measures are nature-based solutions or engineered solutions. This is done, because the paper earlier in this project investigated nature-based solutions and links them to some sustainable development goals like life on land and good health and well-being and liveability. The other categorizations are based on the impact they have on the effects of climate change. The different categories are: heat stress reduction, storm water collection, infiltration and storm water drain measures. Figure 2 shows the overview of the measures that will be used in the design process.

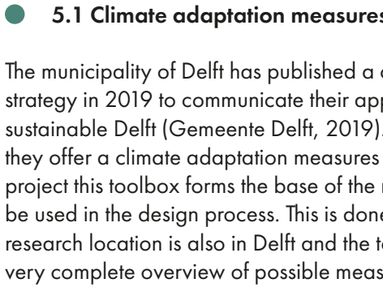
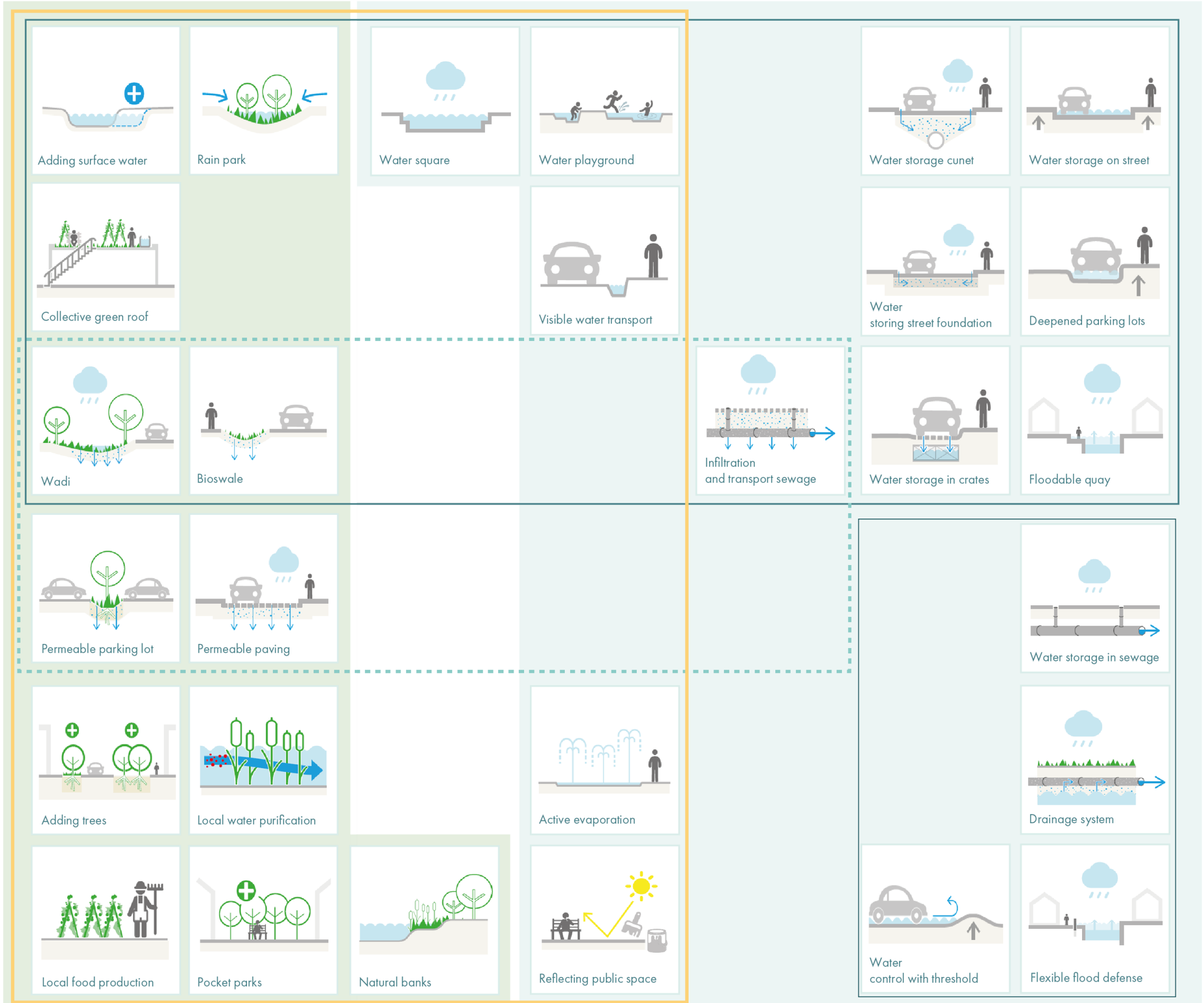


Figure 3: Overview climate adaptation measures
Overview based on climate adaptation strategy municipality of Delft (Gemeente Delft, 2019) edited by author



5.2 The SDGs and climate adaptation measures

To make clear how the measures relate to the sustainable development goals, an overview has been created. In this overview, the measure is explained, related to the problem they solve (water or heat) and the SDGs they relate to. This overview is based on own conclusions from theory and the method used by AW Groep. If a measure is linked to one or more goals, it means they can relate to that goal in a certain way in a design, not more than that, they do not reach they goal on their own but can help improve the goal in a viewpoint from urban design. It is important to note that when matching goals to measures, it is specific for the profession from which it is done. This overview is created from the viewpoint of an urban designer and based on own conclusions and experiences in design and research.

Because this project is carried out as an urban design project, it is suggested that all measures would help reaching the goal 11: sustainable cities and communities. The focus area of the design are neighborhoods in urban areas and thus all interventions should contribute to making the city more sustainable and not the other way around.



Goal 11: sustainable cities and communities.



The climate adaptation measure with a brief description.

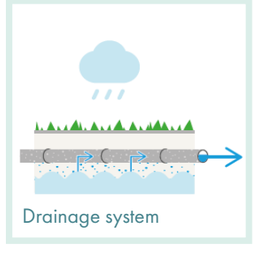


The climate adaptation measure helps to solve water related problems.

The climate adaptation measure helps to solve heat related problems.



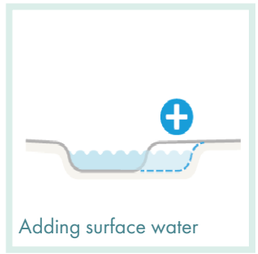
The sustainable development goals the climate adaptation measure relates to.







Drainage system: A drainage system can offer solutions in places with a high ground water level, so the water will not reach the surface. A perforated tube collects the water and transports it towards surface water.







Adding surface water: Om een grotere natuurlijke buffer te creëren kan men meer oppervlaktewater toevoegen. Dit kan worden gedaan op vrijwel alle schaalniveaus. Door in de tuin een vijver aan te leggen kan men eenvoudig lokaal regenwater opvangen. Door bijvoorbeeld een rivier te verbreden of te verdiepen zorgt men voor kleinere overstromingskans.

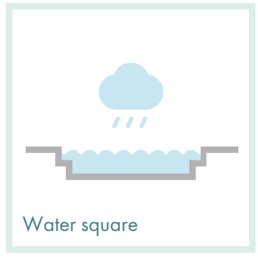








Rain park: A rain park is a lower green area where rainwater can be collected. It is a garden that does not contain water in dry circumstances, but can fill itself with rainwater during rainfall. This way rainwater can infiltrate slowly to relieve the sewage system. It is important that the plants in the rain park can deal with dry and wet circumstances.







Water square: A water square is a deepened square where rainwater from the surrounding collects and can be buffered temporarily. A water square combines different urban functions. When it is dry it can be used to play, sport or relax. When it rains, the water flows towards it and it via a rainwater sewage or open drains and functions as a buffer.







Water playground: A place where children can play with reused rainwater is place to create consciousness around water use. On warm days these places can offer cooling and rainwater can be buffered. Water playgrounds can have an educational aspect.

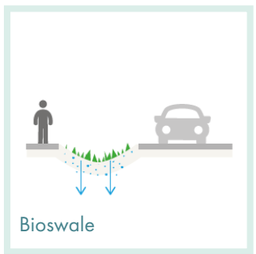








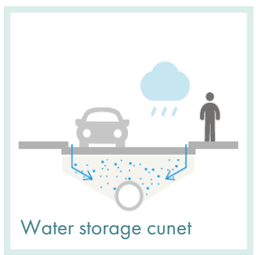
Wadi: An infiltration field or wadi is a deepened green space where water can be leaded towards. In dry circumstances this is a dry area and can have another function like a playground or park.







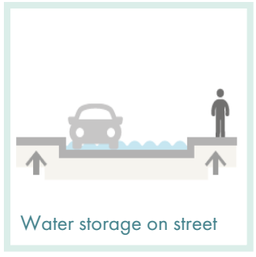
Bioswale: In urban areas there is less space available for infiltration, because of paved areas for traffic. A bioswale is a linear raingarden that is applicable in urbanized areas.







Water storage cunet: The space between the sewage and the street (cunet) is often filled with sand. By filling it with a grainier sand or other material, the water storing capacity increases.







Water storage on street: When a street profile is laid out hollow, there is possibility to buffer a layer of water on the street. Traditional storm drains have to be removed or placed higher so they can serve as an overflow.

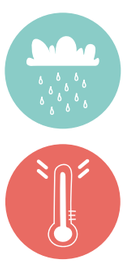






Local food production: Local food production is a nice example for efficient use of space in urban areas, food can be produced and rainwater can be collected and reused. Thereby, it can have an educative and social value for the neighborhood.

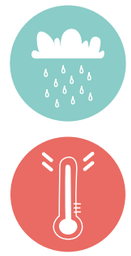






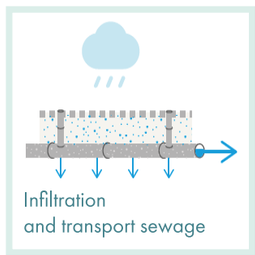
Pocket park: Local parks can offer cooling during warm days. By adding trees, there are more places with shadow and evapotranspiration takes place more.







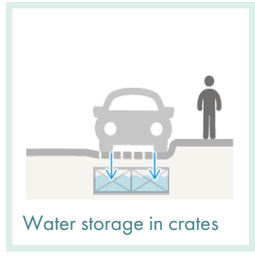
Natural banks: In many urban areas water is simply functional with hard quays. By making banks with a gradual slope with plants, there is more room for water. Furthermore, it improves the water quality and biodiversity.







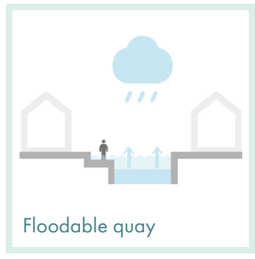
Infiltration and transport sewage: When rainwater is collected separately from black water, an infiltration and transport sewage can be installed. This is a perforated tube that makes sure water can infiltrate during normal rainfall. When there is heavy rainfall, the tube functions as a traditional sewage and transports the water out of the area.







Water storage in crates: Under the public space there can be a possibility to place infiltration crates. This way it is possible to create a relatively big hollow space to store big amounts of rain water. The crates release the water after the rainfall gradually.







Floodable quay: Water bodies in the city are often dimensioned for a maximum water level, this way the distance to the water is sometimes quite big from the street. By making public space closer tot the water and allow flooding in these places water can be buffered.







Permeable parking lot: Parking lots are in general large paved surfaces. By adding green strips between the parking lots, rain water can be collected and infiltrated.



Permeable paving: There are multiple forms of permeable pavements. There are forms where there are open spaces between the stones in the seam. Furthermore, there are stones that are made form a different material with a higher permeability so the water can infiltrate better through the stone.



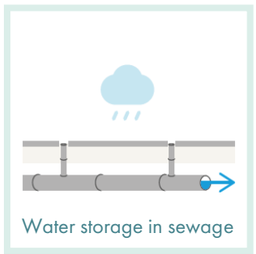
Adding trees: By placing more trees, there will be more places with shadow. During extreme warm days, this can offer coolness. Thereby, trees add to the infiltration capacity and to the spatial quality of the street.



Local water purification: Local water purification, purifies water closer to the source. Especially when developing new residential areas there is potential to purify rainwater and grey water more locally and reuse it. This reduces transport and purification costs.



Water control with threshold: When a shallow layer of water on street is allowed, thresholds can be used to manage the water in the right places. This way they function as a flood defense. When this street has a reasonable permeability, the water has time to infiltrate in the soil.



Water storage in sewage: The choice can be made to replace the current sewage system with a system with a larger radius. This way, the capacity is expanded in a traditional way.



Reflecting public space: By making use of light reflecting colors in public spaces, heating up of these surfaces on warm days can be limited.



Water storing street foundation: When the street foundation is made of an as grainy as possible, strong material, there arise hollow spaces under the street. This way, it is possible to buffer precipitation in the street foundation and/or infiltrate in the ground.



Deepened parking lot: When parking lots are placed lower than the street, they can buffer a layer of water during heavy rainfall. When the parking lots are surrounded by a higher sidewalk and street, people can step out of the car without getting their feet wet.



Collective green roof: A collective green roof is a good tool to create consciousness for efficient use of space in urban areas. Thereby, it is efficient for cooling a building. A collective green roof can have multiple uses, for example for food production or a public roof park.



Visible water transport: Making clean water streams visible in urban areas, improves consciousness around water. Thereby, it makes it simpler to lead water to the desired places.

5.3 Conclusion climate adaptation measures

To conclude the overview from climate adaptation measures and SDGs, a few important notions can be made. First of all, nature-based measures relate to many more SDGs than engineered solutions. This has to do with their link with liveability; for humans as well as other species. This way it also contributes to the goals life below water and life on land. Also, nature-based measures can help solve both heat stress problems, as well as water problems, while engineered solutions often only solve one of the two.

Furthermore, the goals can have an educative connection when the interventions are made visible. This way they can teach about climate adaptation and nature inclusivity for example. Adding signs to measures can make the measures understandable for everyone, even children and increase awareness about climate change and climate adaptation. This can inspire people to do interventions on their private property as well. Urban design cannot directly influence educational systems and the quality of education at schools, however the designs can have educative value and bring awareness; this is how goal 4 is used in this project.

Also, the way interventions are executed can be related to goal 12: responsible consumption and production. Using renewable or recycled materials for the interventions can contribute to reaching goal number 12. Using renewable energy to realize interventions can contribute to responsible production. This goal is important to take into account in the execution.

Lastly, the way in which the measures will be designed can affect goal 10: reduced inequalities. If the measures secure accessibility to everyone the effect can be positive, if it excludes people from accessibility (think about elderly people and wheel chairs), it can have a negative impact on goal number 10.



Goal 4: Quality education



Goal 10: Reduced inequalities



Goal 12: Responsible consumption and production

5.4 Urban design and liveability

The second tool for this project are the 9 liveability criteria by David Sim in his book Soft City. His book is about creating liveable cities and is concluded with the 9 criteria (figure 4). This tool is selected for this project because the literature studied about liveability lack to give core principles that can be used for urban design. As this book is written by an urban designer, the theory and the experiences of the writer have been converted into practical tools to use when designing urban environments.

In this paragraph, the 9 criteria are explained and related to some SDGs from the viewpoint of urban design, like it was done with the adaptation measures. Not all criteria will be relevant for this project, because this project focusses on adapting public space and will not research the form and functions of buildings and alter them in the design. After the overview, a conclusion will sum-up the most important findings.

Like the climate adaptation measures, all liveability criteria are related to goal 11: sustainable cities and communities since the project concerns urban design.

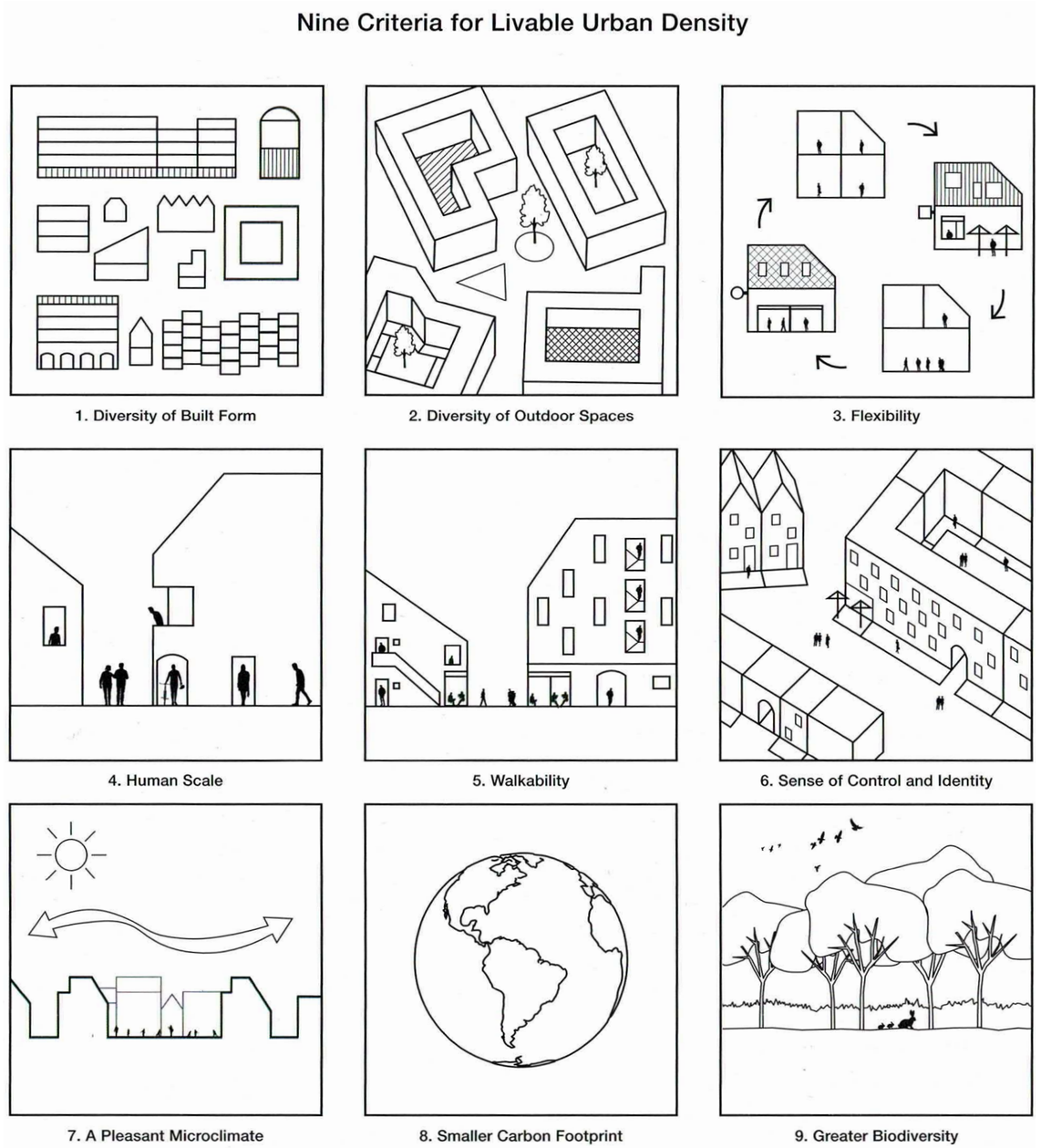
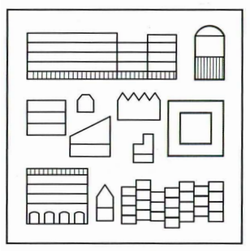
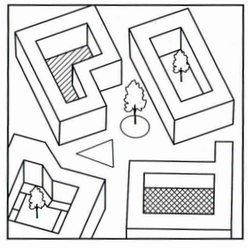


Figure 4: Liveability criteria by David Sim
Overview of the 9 liveability criteria by David Sim (Sim, 2019).



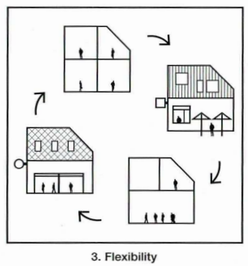
1. Diversity of Built Form

1. Diversity of Built Form: "Densely built, urban form should accommodate a broad range of building types (different typologies, shapes, dimensions, and spatial conditions in close proximity to each other. Buildings should be physically respectful of each other while remaining organizationally independent."



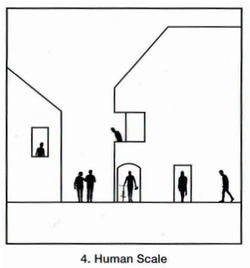
2. Diversity of Outdoor Spaces

2. Diversity of Outdoor Spaces: "Dense urban form should accommodate different kinds of outdoor spaces, in close proximity to each other, in response to the wide spectrum of needs for public and private life."



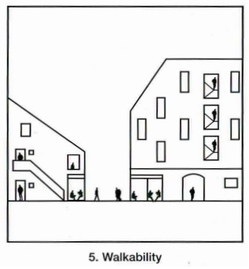
3. Flexibility

3. Flexibility: "Dense and diverse urban form, with both buildings and spaces, should be flexible and responsive to change (including densification), at all scales, in the short, medium, and long term."



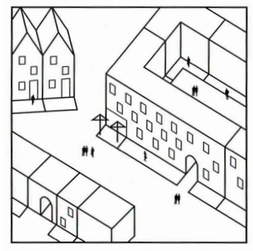
4. Human Scale

4. Human Scale: "Urban form should deliver density at a human scale, meaning at dimensions and with details that can offer comfort and well-being to people living in and around the buildings and the spaces in between."



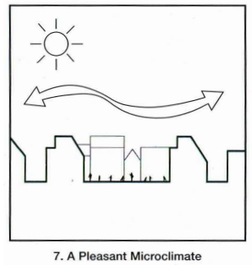
5. Walkability

5. Walkability: The built form should allow for easy accessibility and connectedness. In the simplest terms, accessibility is about being able to move quickly with the least amount of effort, in, out, and through buildings and between as many different spaces and places as possible. It also means walkability at a neighborhood scale, with walking as the most comfortable and convenient option for short distances."



6. Sense of Control and Identity

6. Sense of Control and Identity: "The built form should offer people, as individuals and in smaller and larger groups, better control over the spaces around them. The spaces should foster a sense of identity as well as aid orientation and navigation."



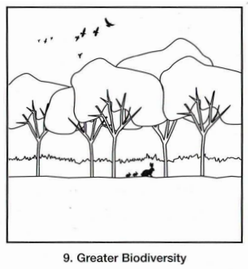
7. A Pleasant Microclimate

7. Pleasant Microclimate: "Creating a pleasant microclimate with a built form allows people to spend more time outdoors."



8. Smaller Carbon Footprint

8. Smaller Carbon: "The built form should use fewer resources in construction and operation while promoting behaviors and lifestyles with a smaller carbon foot print, such as walking and cycling."



9. Greater Biodiversity

9. Greater Biodiversity: "Urban form should accommodate natural life. The layout, size and shape of the buildings and use of spaces should accommodate natural life and make greater biodiversity possible."

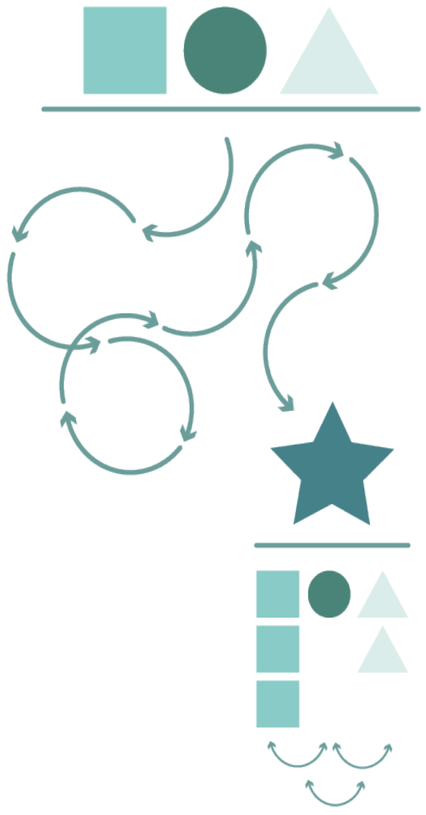
5.5 Conclusion liveability criteria

To conclude this paragraph, not all liveability criteria will be relevant in this project. Diversity of built form and flexibility relate to buildings and they are not taken into account in the research by design process; the focus lies on public space. All other criteria will play a role in the design process. All criteria show relation to a sustainable development goal. The goal that shows the most relation to the criteria is 3: good health and well-being. This is an observation that was already made in the theoretical paper in which one of the aspects of liveability is individual well-being. Liveability criteria concerning “planet” aspects relate to multiple SDGs, the rest of the criteria show the strongest relation to just one goal. All criteria are related to goal 11: sustainable cities and communities.

5.6 Conclusion design tools

To conclude this chapter, all tools show overlapping aspects with one another, yet have a specific focus. This is the reason the combination of the three tools were selected: it makes this project approach specific. From the overviews with relations between the tools, already conclusions can be formed that will guide the design process: it makes the focus of this project clear, in this area the solutions for the problems are most likely to be found. The tools will be used at different scale levels in the design process: as analysis on the neighborhood scale and as assessment on the scale of measures and designs as a whole. This will allow to conclude after the designs have been made which design choices are based on which tools (figure 5). This is an important step to take in the recommendations, so that the tools and approach can be used in other projects as well if they show a desired result.

On the next pages, the set of general design principles can be found that conclude this chapter and form the starting point for the design process.



Different design tools

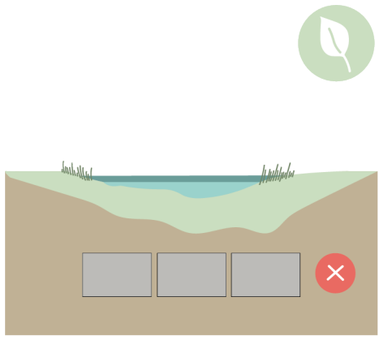
Final design

Reflection on design choices

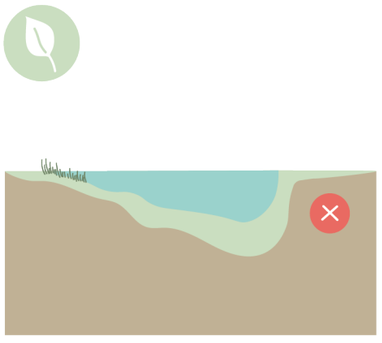
Figure 5: Relation tools and design
Illustration by author.

5.7 General design principles

This overview shows the findings from this chapter about the different tools that form the base of the research by design process. They are the main input and will help by making design decisions later in the process.



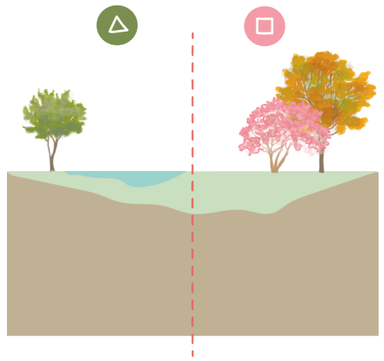
1. Nature-based solutions preferred over engineered solutions: From the climate adaptation measures overview, combined with the SDGs, a conclusion can be formed that nature-based solutions will have a more positive effect than engineered solutions. NBS often reduce both water and heat problems while engineered solutions mostly only solve one problem at the time. From the theoretical paper a positive relation between liveability an NBS was concluded as well.



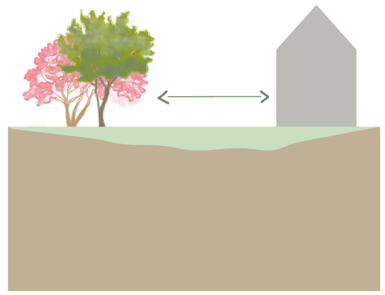
2. Create natural banks: Since the project focusses a lot on water, climate adaptation measures dealing with surface water play an important role. Form the climate adaptation measures overview can be seen that natural banks show a positive effect on many SDGs and will help improve aspects of liveability for people and other species as well.



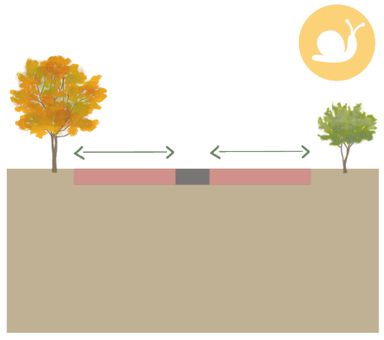
3. Use a variety of vegetation to contribute to biodiversity: Biodiversity is an important goal mentioned in the multiple design tools. David Sim mentions biodiversity as one of the nine liveability criteria. In the Sustainable Development Goals, biodiversity is supported by goals 14 and 15: life below water and life on land. The overview of the climate adaptation measures show that they can contribute to more biodiversity as well by using nature-based solutions.



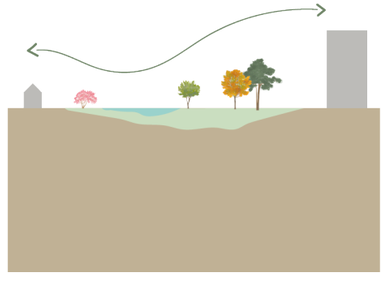
4. Create diverse spaces with their own identity: Diverse public spaces can contribute to liveabililty, as well as sustainable development. Diversity can give room to more diverse use of species and has more chance to offer a likeable spot for everyone. A mix of functions suit better to different users. Diverse spaces are more likely to have an own identity that makes a neighborhood or public space recognizable.



5. Create more connection between public space and buildings; "eyes on the street": Creating a better connection between buildings and public space can offer a safer feeling and add to liveability in the neighborhood. This principle does not directly relate to adaptation measures or sustainable development goals but can contribute to the design as a whole and is valued as an important principle in this project to improve the experience in the neighborhood.



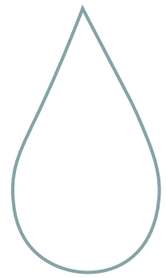
6. Prioritize slow traffic: Making walking and cycling priority in a design can come forth from all three tools. Designing streets that slow down car traffic can make room for adaptation measures. Stimulating active transport can contribute to good health and well being. It is a more sustainable way of traffic and adds to liveability as well.



7. Create gradients to connect to human scale and create variety: Human scale is an important liveability criteria and is also highly valued in this project. Scale is an important factor in experience and can determine if a place is experienced as pleasant or not. Also it can contribute to a more pleasant micro climate. Furthermore, creating gradients can allow for more types of vegetation and animals and contribute to biodiversity.

Water is the driving force of all nature

- Leonardo da Vinci



Research location

6.

Abtswoudse polder Delft









6.1 The Abtswoudse polder and Delft

The research location for this project is the Abtswoudse polder in Delft. It is a large polder that is connected to most parts in Delft. The northern part of the polder is on the edge of the historic inner city. This part of the polder also has a historical character and was already early developed. The eastern part of the polder is framed by the Schie and close to the TU Delft campus. The southern and western part of the polder are connected to recreational and agricultural land.

The polder itself consists of many different characters. There are many different neighborhood types that will be addressed in the next chapter. The main function of the polder is housing and where the polder is connected to the Schie, the polder has industrial and logistical functions. The southern part of the polder is agricultural land and a recreational area. The pictures on the right show an impression of some of the different neighborhood types within the polder.

Figure 1 shows where Delft is located in South Holland in the Netherlands. The expanded view shows where the Abtswoudse polder is located within Delft.

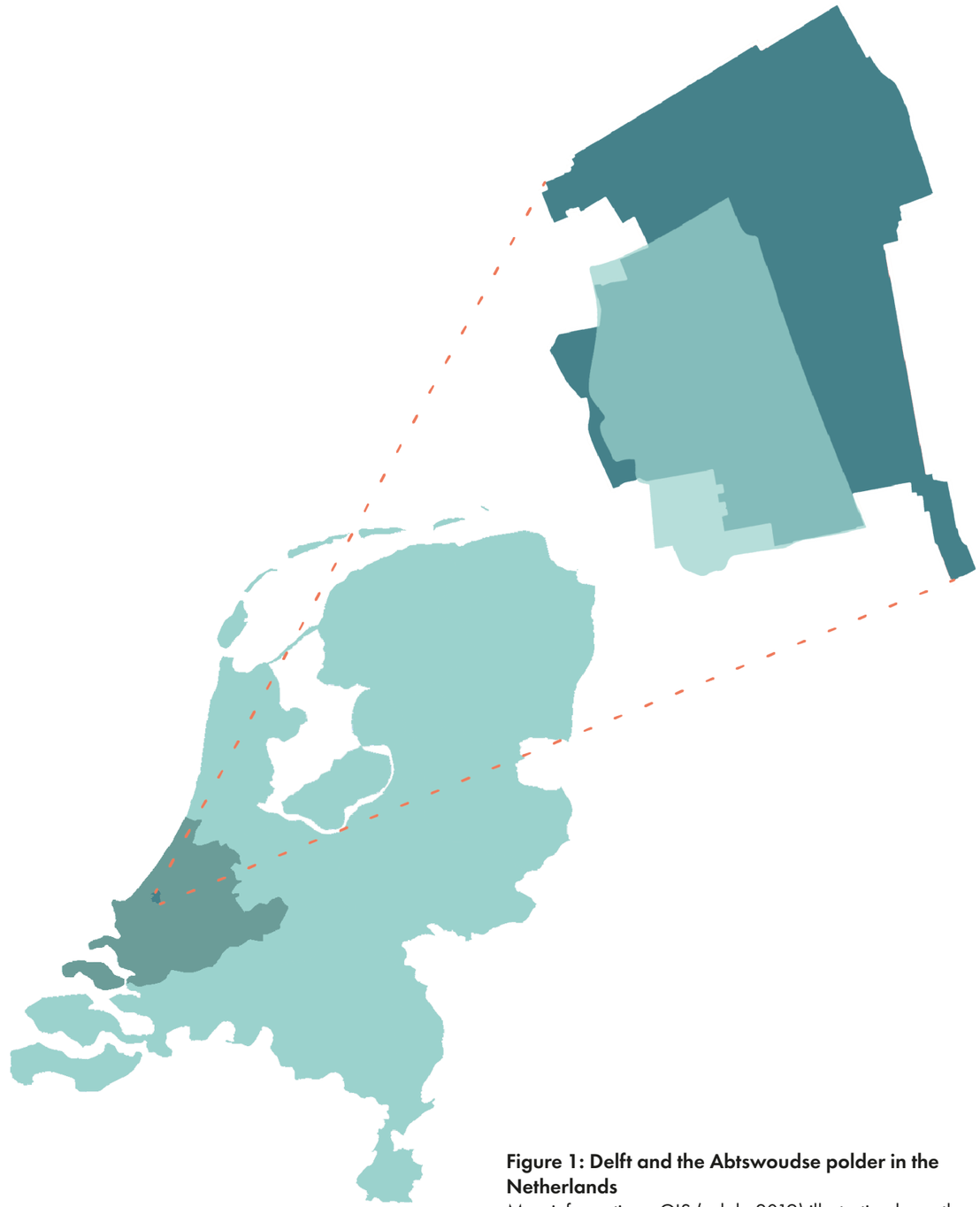


Figure 1: Delft and the Abtswoudse polder in the Netherlands
Map information qGIS (pdok, 2019) illustration by author

6.2 The development of the Abtswoudse polder

The Abtswoudse polder started to be inhabited from an early age on (figure 3). From 1850 to 1950 the function of the polder was mainly agricultural and some industries along the Schie. Westerkwartier is the oldest neighborhood in the polder and is often identified with the historic inner city. From 1960 on, large developments in the polder started to happen. Around every ten years large new neighborhoods were built within the polder. Each building phase has its own character that can be identified from the map (figure 2). From low rise to high rise, old to new, high density to low density, almost everything can be found in the Abtswoudse polder.

Figure 4 shows how the Abtswoudse polder is connected to the rest of the city and in general what functions within the city are around the polder

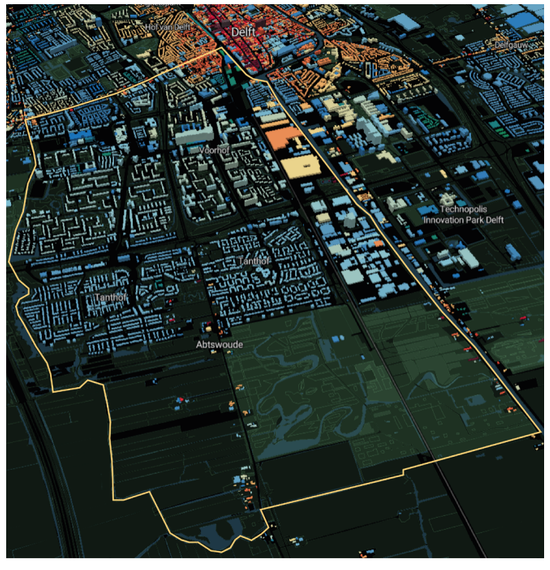


Figure 2: Building ages Abtswoudse polder
Building ages in the Abtswoudse polder (Parallel, 2020)

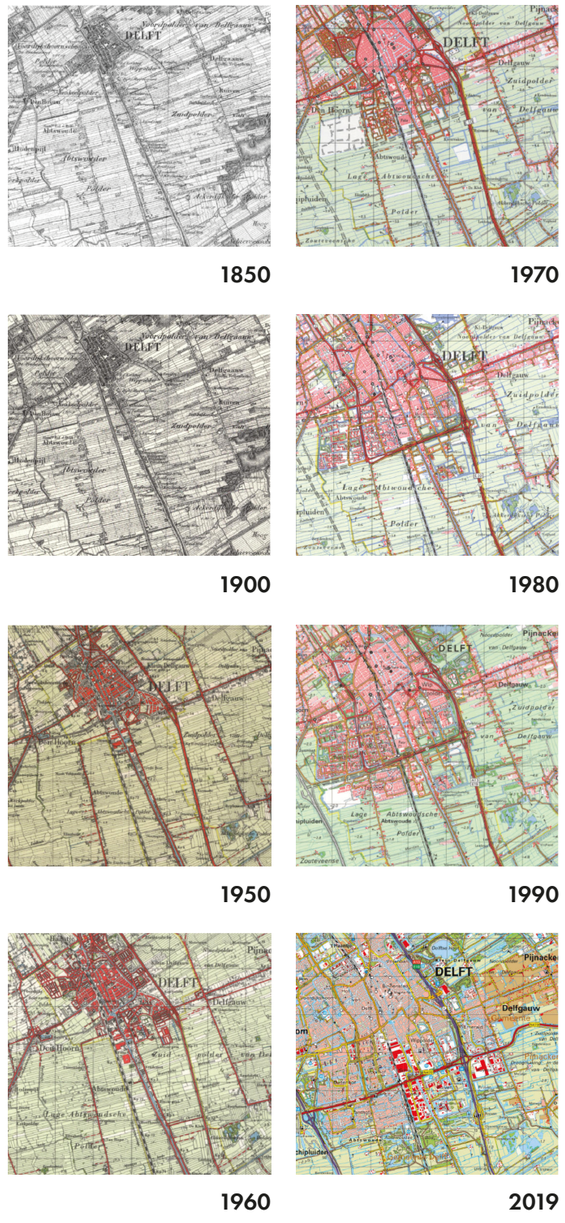


Figure 3: Development of the Abtswoudse polder
Historical maps (Kadaster, n.d.) edited by author



Figure 4: Delft and the Abtswoudse polder
Aerial photo from Delft (pdok, 2019) edited by author

6.3 The position of Delft in the water system

The water system of Delft is part of the waterboard of Delfland that reaches from The Hague to Rotterdam and covers a big part of South Holland. The water system of Delfland is a complex system as it forms a boundary with the sea and needs strong sea defenses to protect the land. Furthermore, the rest of the area consist mostly of polders and lies below sea level. The different levels of water have different water qualities; the water in the polder has a better quality than the boezem water which is the regional flood defense. The criteria for water quality are connected to the functions that are connected to the water. Living areas and nature areas have the highest water quality. However, the water in the polder is connected to the boezem water and thus interaction between different water qualities takes place. In a normal situation there is no inlet form the boezem into the polder (figure 5), however in periods of drought there is a shortage of water in the polder and inlet from the boezem is needed. This goes at the cost of water quality.

If water is managed more locally and kept in the area where the rain falls, less interaction between the different waters is necessary. For this project the local neighborhood designs can help reducing the need to manage the water in the Abtswoudse polder with the boezem water and improve the water quality within the whole polder. The project will not have a direct impact on the water quality in other polders, but the principles used could be applied there as well to make a bigger difference.

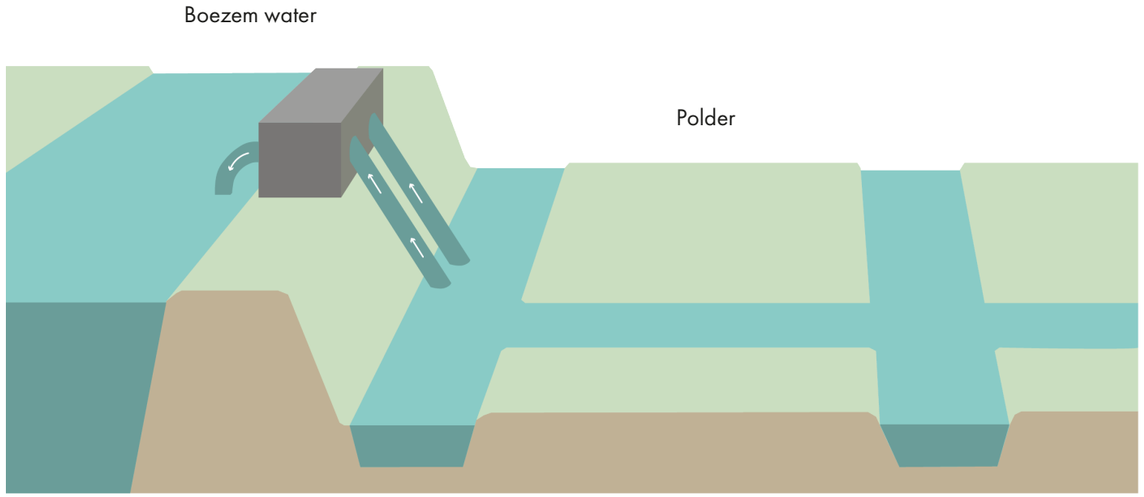


Figure 5: The polder system
Interaction between polder and boezem water via a pumping station, illustration by author

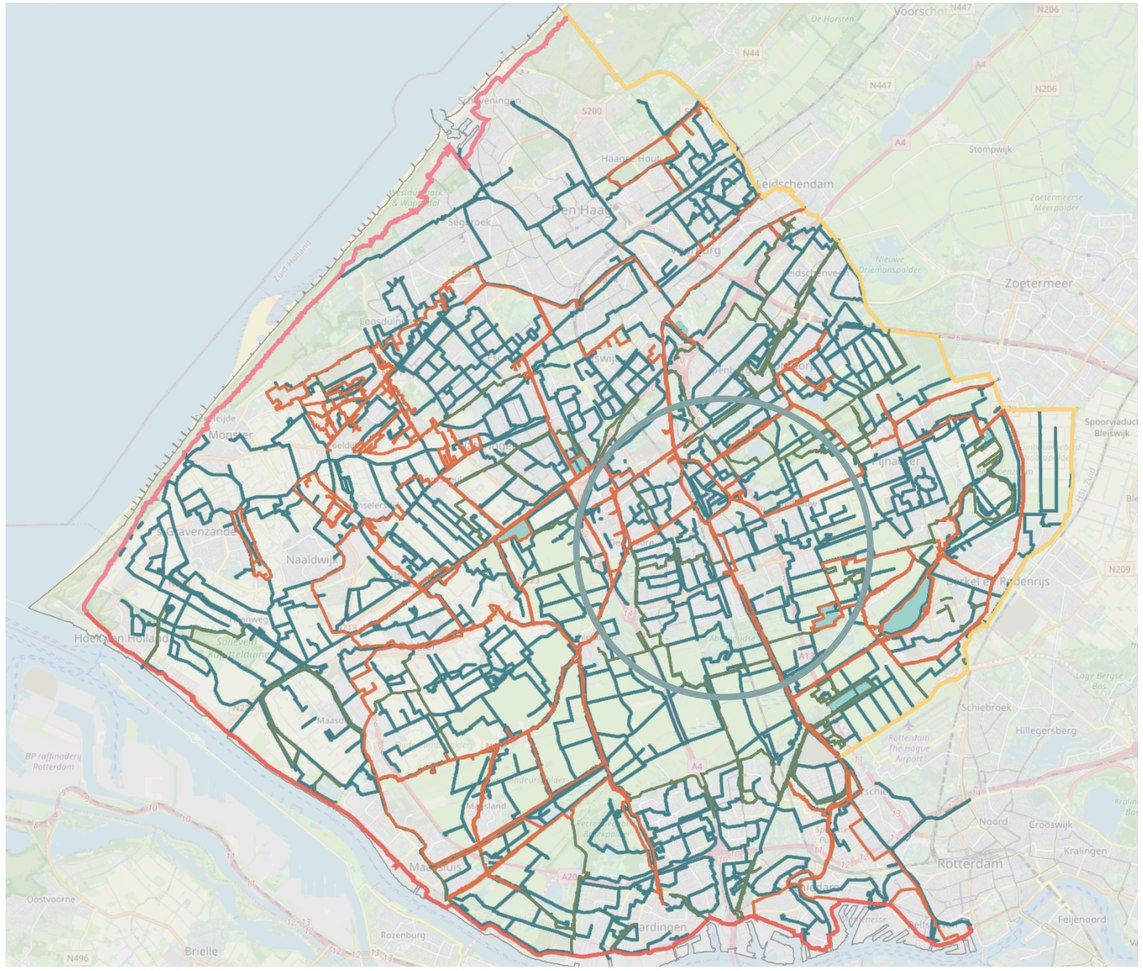


Figure 6: The regional water system
Map from the water board of Delfland (Hoogheemraadschap van Delfland, 2021) edited by author

6.4 The water system in the Abtswoudse polder

The water system of the Abtswoudse polder consists of the high and the low Abtswoudse polder which are separated by a polderkade but are connected and work in one system. The Ground and water level gradient in the polder goes from North to South from high to low which causes water to naturally flow towards the south. There are three main pumping stations in the polder are indicated in figure 8. Here the water is regulated between the polders and the boezem water. The little arrow on the west indicates a dike that floods when there is too much water in the polder, that causes no problems at the moment according to the water board. Figure 9 indicates the water problems in the Abtswoudse polder based on analyses by the water board of Delfland. The high Abtswoudse polder is dealing with a shortage of surface water indicated with squares. Right now, this does not cause problems because it can be compensated with the surplus of water capacity in the low Abtswoudse polder to where the water flows naturally. However, that does not mean that the high polder could be more robust on its own by adding more surface water. Furthermore, the high Abtswoudse polder has a combined sewage system that can cause the water quality to worsen and can put too much pressure on the sewage system. Both polders are dealing with a poor water quality, either due to a combined system, water inlet from the boezem and problems like bird poop and falling leaves. Lastly, both polders are dealing with too narrow culverst. This slows down the water flow and puts more pressure on the system. Replacing culverts with surface water or with broader culverts would make improvements for a more robust system.

Figure 7: Ground level gradient

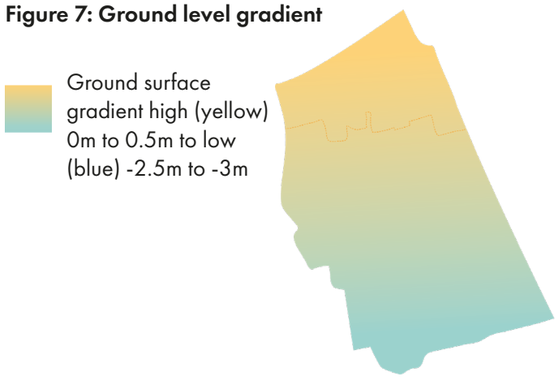


Figure 8: Pumps

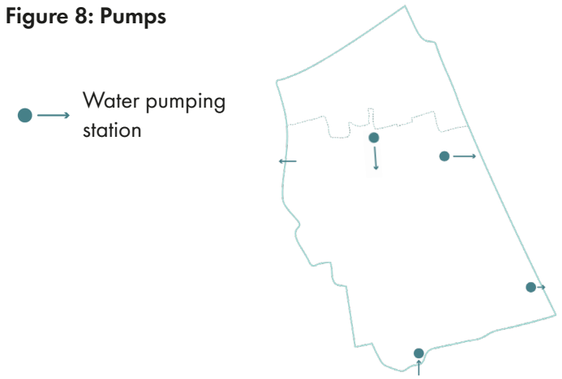


Figure 9: Water problems

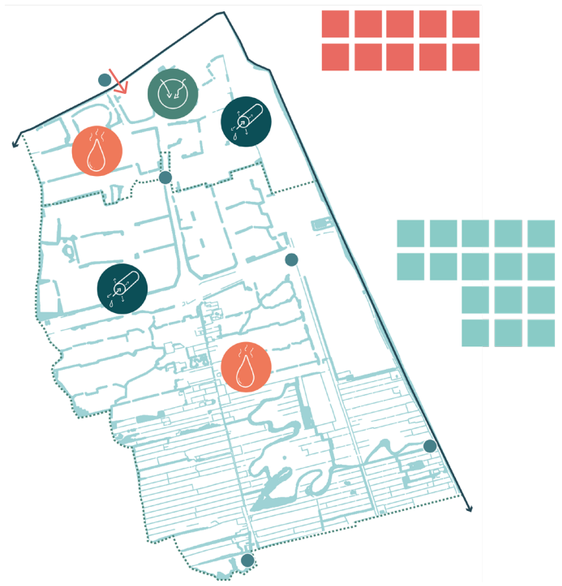




Figure 10: Water in the Abtswoudse polder
Water map (pdok, n.d.) Map from the water board of Delfland (Hoogheemraadschap van Delfland, 2021)edited by author

6.5 Water management principles

This paragraph concludes the water system analysis with the most important principles that will be applied in the design process. The principles are inspired by the principles of the thesis from Ingrid Staps: Early Adaptation of Water in Urban Plans (Staps, 2021), in which she combines urban design and water management.

Retain, store, drain
Water reaches the city by different means: as surface water, groundwater, precipitation or as drinking water through the piping system. Drinking water is regulated by sewage system plants and comes from groundwater or surface water. The groundwater level is influenced by extraction, reclamation and the number of paved surfaces. Precipitation that falls in urban areas is often discharged as soon as possible. In recent years policies have changed this and now buffering and infiltrating the water on location is key and then discharge the water slowly. This water management principle can bae expressed as "retain, store and drain". Figure 11.1 shows how this principle works. Number 1 shows how water can be retained in green areas and water bodies. Number 2 shows how water can be stored in for example a WADI. Lastly, 3 shows that if there is an excessive amount of water it can be drained to the bosom water. The principle is based on the water management page of Urban Green Blue Grids (Groen Blauwe Netwerken, n.d.)

Circulation principle
In figure 11.2 the circulation principle is illustrated. The circulation principle entails that all water in the polder is connected and circulates; there are no dead ends. The circulation of water is important for the water quality. In the neighborhood designs this principle should be taken into account when creating new water bodies or reducing surface water. Replacing or culverts by surface water, or widening culverts, can improve the circulation of the water system.

Natural banks
Figure 11.3 shows the principles of natural banks. Natural banks can help improve the water quality due to the types of plants that can grow in the shallow layer. These types of plants purify the water. Furthermore, the natural banks have ecological value as they offer habitat for different types of species. Natural banks have a very gentle slope in order to create the desired gradients. When there is too little space for creating the slope, the choice can be made to create a wet berm as shown on the right in figure 11.3.

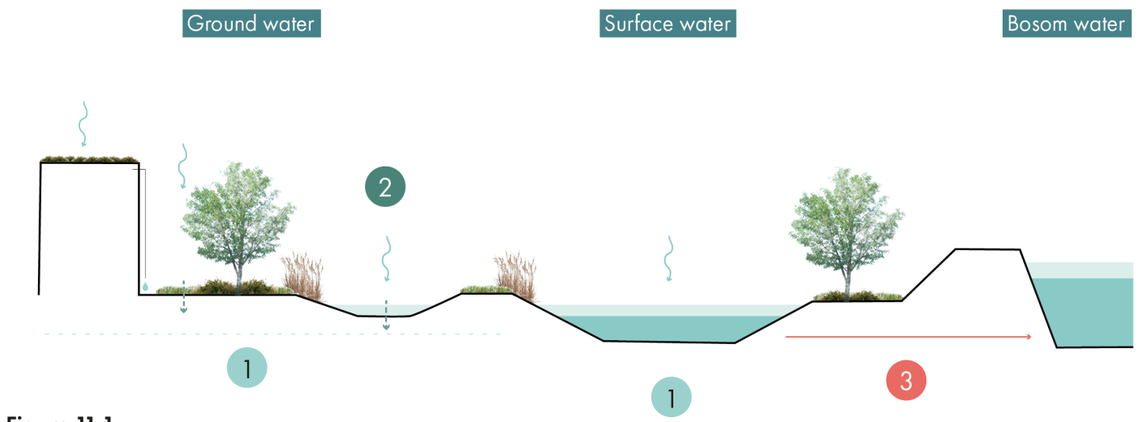


Figure 11.1

Circulation principle

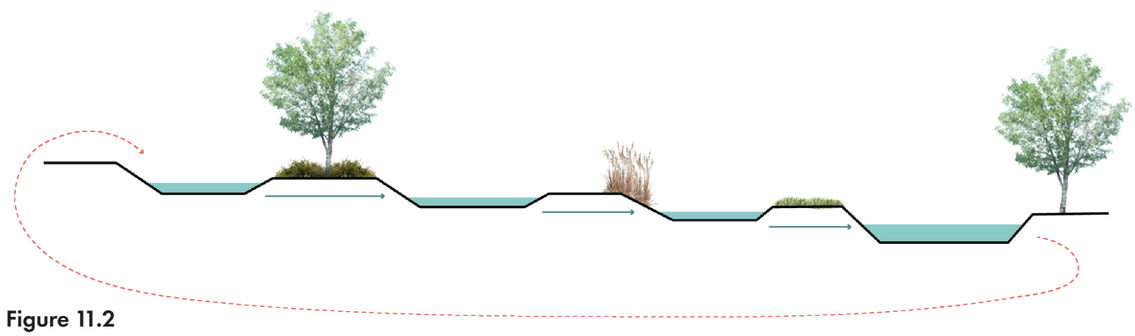


Figure 11.2

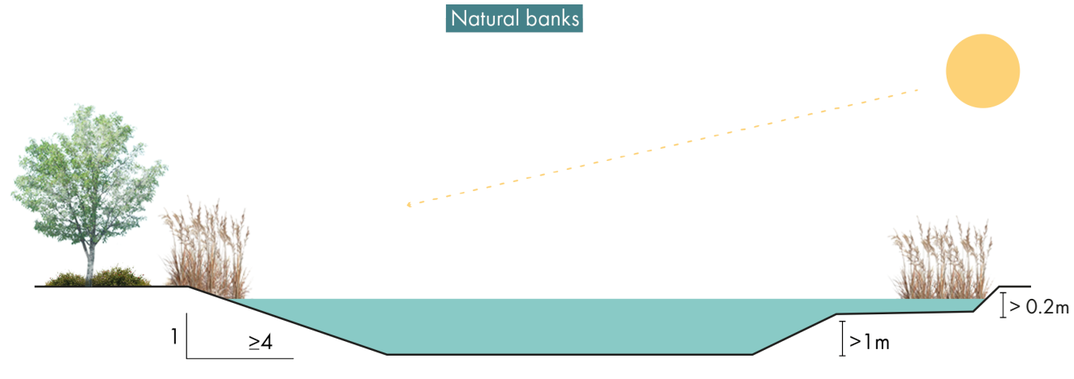


Figure 11.3

Figure 11: Water management principles
Illustrated by author, based on (Staps, 2021)

6.6 Green structure in South Holland

When talking about water, it is important to take the green into account as well, the two are tightly connected. Water in the region of Delfland is always connected in order to flow around. However, the same cannot be said about the green and ecology structure in South Holland. Green systems do not work the same as blue structures since they concern many different species including both plants and animals. For each species, ecological structures have a different scale level since they have a different capacity to move around and spread. In order to understand for this project how green structures can be improved, analyses at different scale levels are shown and a conclusion about ecology principles will help forming starting points for the design project.

Main ecological structure South Holland
In figure 12 a map shows the main ecological structure in South Holland. The red circle indicates the position of Delft. Delft is connected to existing nature and agricultural land. Green in the region of Delft could help expanding the living areas of species that live in the surrounding natural areas. If there is possibility to form a connection with the area around, green in the city could contribute to the natural areas.

Green structure
The green structure map of South Holland shows that in Delft, urban green connects the green areas around the city. The finer the connections are, the more species they support. In order to understand the green structure in Delft better, a bigger scale level is necessary. Figure 14 shows the role of Delft in the regional green structure; it forms an important connection for the green areas around the city. The main green structure in Delft mostly connects green in the north with green in the south. From the provincial maps can be concluded that the southern ecology connections in Delft are most important since they are most connected to the natural areas.



Figure 14: Ecology structure Delft
Map from ecology plan Delft (Gemeente Delft, 2004)

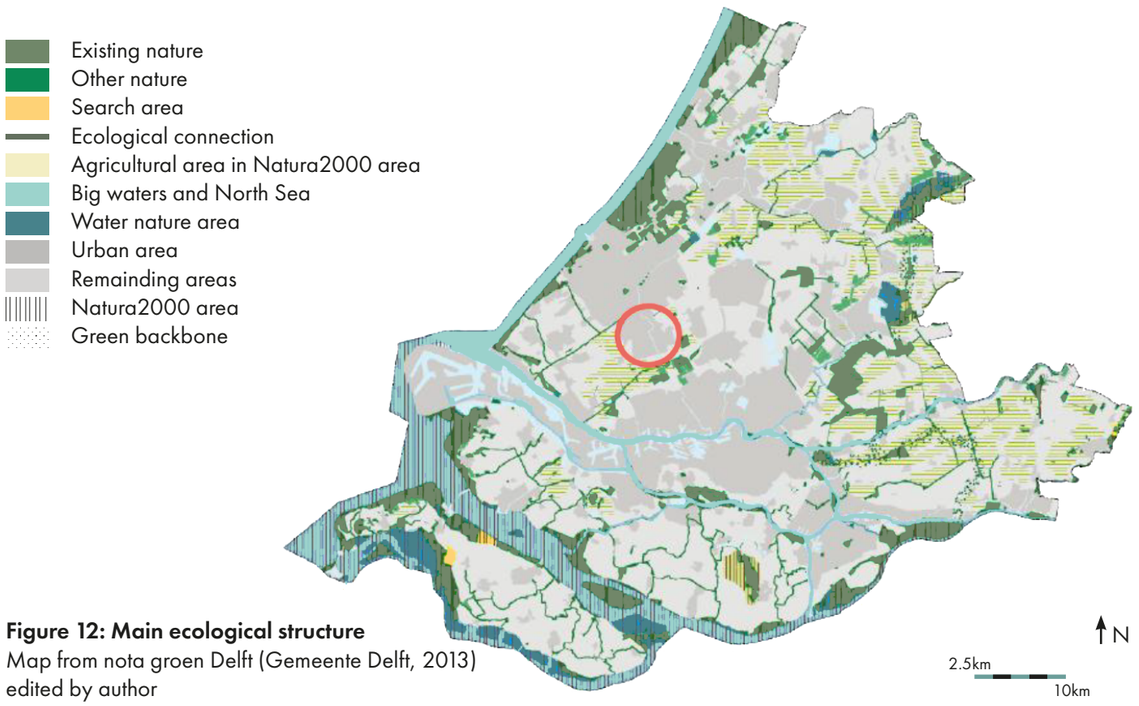


Figure 12: Main ecological structure
Map from nota groen Delft (Gemeente Delft, 2013)
edited by author

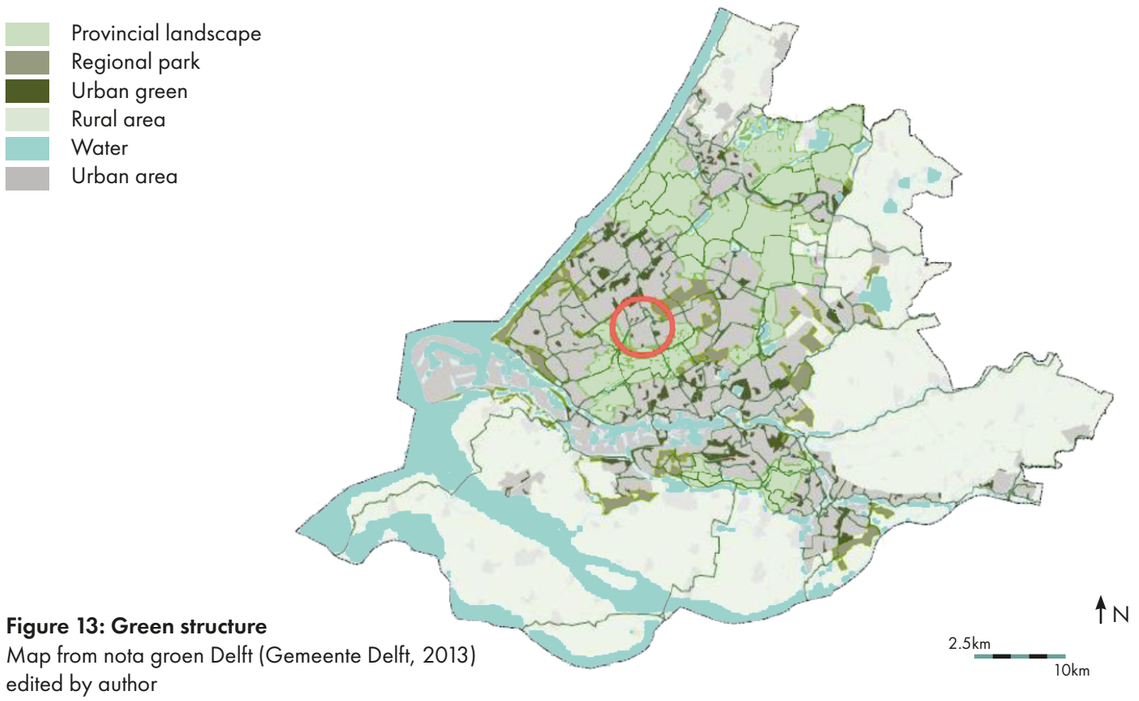


Figure 13: Green structure
Map from nota groen Delft (Gemeente Delft, 2013)
edited by author

6.7 Green structure in Delft

The map in figure 15 shows that Delft is surrounded by green. To increase the living area of species in these green areas, connections through the urban areas are needed. The map shows that in Delft there is a primary and a secondary ecological structure that help connect the green areas. Furthermore, the water structure and tree structure contribute to the ecological connection as well. Green and blue in neighborhood can play an important role in the ecological connection too. The more green there is, the smaller the steps are to cross land that is not natural and more species can spread. From the map can be concluded that the north-south connection is better than the east-west connection. This is mainly due to the train rails that runs from north to south, creating a large barrier. Furthermore, there are not many big green areas within the city of Delft like city parks with a lot of green. This makes it important to try to make the living areas greener so the barrier of the city becomes smaller.

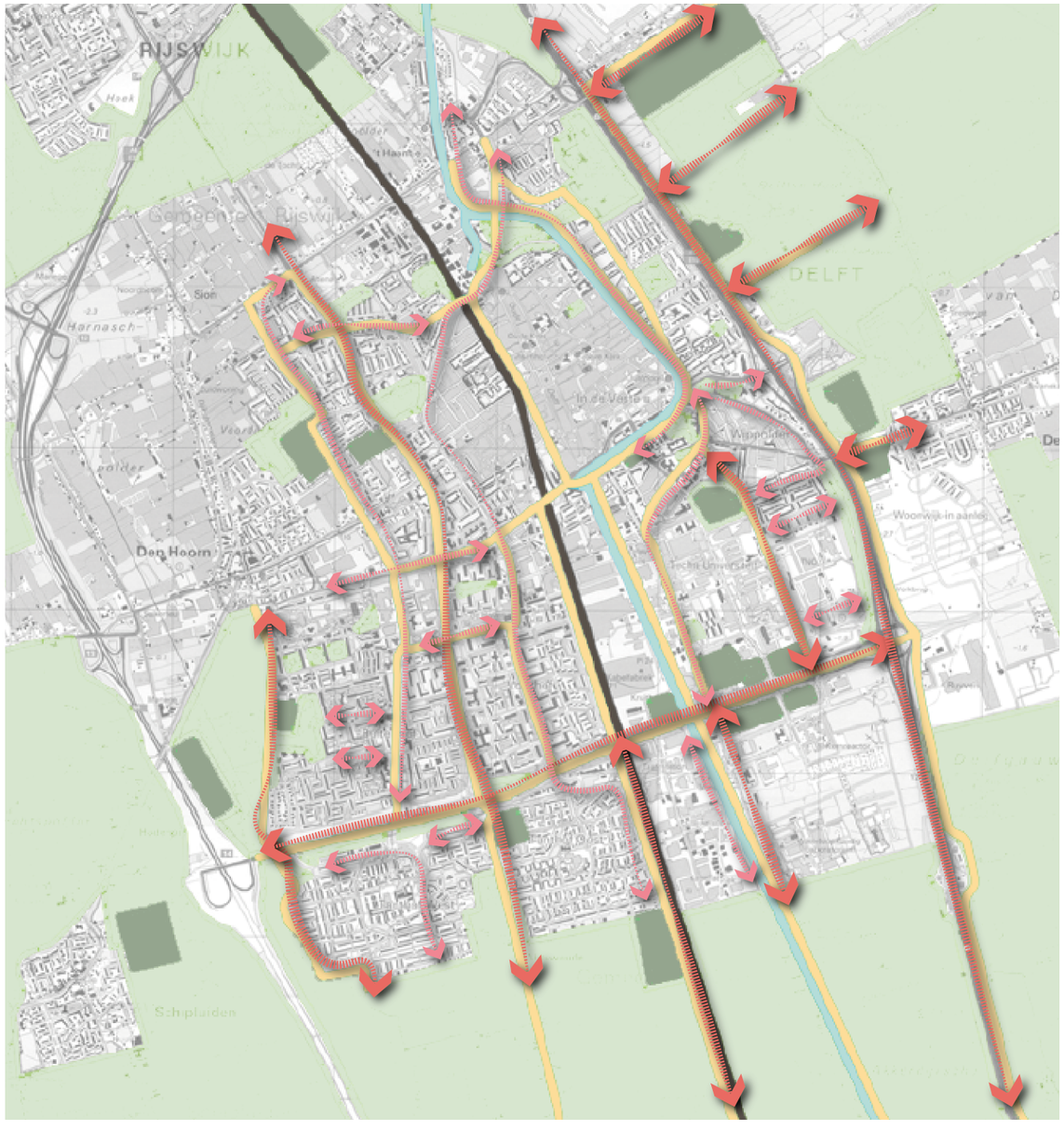


Figure 15: Ecology structure Delft
Map from ecology plan Delft (Gemeente Delft, 2004)

6.8 Ecological principles

Ecological network
Figure 16.1 illustrates the concept of an ecological network. The concept is based on “Connectivity and Ecological Networks” (Harrison, White, & Odell, 2016). It explains how an ecological works with different components. The different components in the network are: the core area, buffer zone, stepping stones, landscape corridors linear corridors and restoration areas. The bigger core areas and restoration zones are situated in rural areas and are the basis of the system. The interesting components for urban areas are linear corridors and stepping stones. Linear corridors can be found along main infrastructures especially when connected to water. Stepping stones are the most interesting components in this project as they relate most to the scale of the neighborhood. Stepping stones are: “smaller areas of quality habitat that are intended to aid movement of individuals by serving as islands of favourable habitat in between larger core nature areas. These are also ‘nodes’ in the ecological network” (Harrison, White, & Odell, 2016).

Diversity of species
The second ecological principle is diversity of species. Diversity of species supports biodiversity. Diversity of species can be achieved by creating diversity of circumstances like gradients. When using gradients from dry to wet, warm to colder and sunny to shade, the biggest range of species can find a habitat in the area.



Figure 15: Ecology principles
Illustrated by author, based on (

Adaptation is a vital part of a response to the challenge of climate change.

- Nicholas Stern



Design locations

7.

Abtswoudse Polder

In the research location the Abtswoudse polder in Delft one neighborhood has been selected as design location. Early on in the project the idea was to work out multiple neighborhoods within the polder. Due to the time scope en the desired amount of detail, the dicision was made to only do one location. However, the project is set up so that the approach can still be transferred to other locations for further research. For this reason the information used to select the location are shown first. This can make clear the differences and similarities between different loations. The design location Voorhof has been selected based on neighborhood typology and maps from the klimaateffectenatlas (Klimaateffectatlas, n.d.) which can be found in de appendix. The reason to work out Voorhof in detail deals with the public/private relation which will be discussed in the next paragraph. This way there was more room for a redesign in Voorhof because there is a lot of public space that also is not really used: there are a lot of opportunities to improve. Also, the sewage system in Voorhof is older than 30 years and will soon have to be replaced, this way the redesign could be interesting for the municipality to look at before doing that.



Figure 1: Design locations in the Abtswoudse polder
Aerial photo from Delft (pdok, 2019) edited by author

7.1 Design locations in the Abtswoudse polder

To further explain the choice for the design location, two maps from PBL about spatial differentiation and integration have been used (PBL, n.d.). The first map used (figure 2) is a map that shows the property in Delft. The whole polder has a different ratio of public/private. Voorhof has the biggest amount of public space, so the most room for interventions in this project. Most buildings are owned by housing organizations so there is not much privately owned. Other locations in the neighborhood have a smaller amount of public space and a larger amount of private space.

However, comparing the property map to the liveability map (figure 3) shows an interesting relation. The area with the smallest amount of public space, is evaluated with the highest score on liveability. The area with a big amount of public space, Voorhof, is ranked with a low score on liveability. This makes the decision to choose for a detailed design in Voorhof logical: the biggest difference can be made based on these 2 maps.



Figure 2: Property
Map from PBL (PBL, n.d.) edited by author



Figure 3: Liveability
Map from PBL (PBL, n.d.) edited by author

Voorhof

Multatuli buurt

Voorhof is a neighborhood in Delft south-west of the historical center. The neighborhood was built after the second world warm mostly in the 1960s. The neighborhood is characterized by ‘modern urbanism’: a spatial design with a lot of green in between repeated ensembles of high- and low-rise buildings, with separation of functions. The large amount of public green in the neighborhood is part of the main ecological structure in Delft, however the types of green are not very diverse. The neighborhood can also be identified by the dynamic housing market. A large part of the dwellings in Voorhof are rented and the housing stock is flexible. The neighborhood description is based on the “Woonvisie Delft 2016-2023” (Gemeente Delft, 2016) .
The redesign in Voorhof focusses on one of the ensembles called the Multatuli buurt. It consists of low- and high-rise buildings and a lot of public green in between. The ensemble is surrounded by surface water. The pictures on the right show an impression of the design location. Typical for the location is the focus on car traffic and the public areas of green that seem to have no function and are unused.
This chapter will start with an identification for the neighborhood so the location can be compared to the design proposal and other locations for further research as well. The identification is followed by an analysis on climatic problems, liveability and sustainability. The chapter is concluded with a design proposal.



Figure 4: Voorhof in the Abtswoudse polder.
Aerial photo from Delft (pdok, 2019) edited by author





Figure 5: Design location
Photographs taken by author





Identification

The table below shows an identification of the neighborhood so it can be compared with the redesign and other locations. The identification is based on information from PDOK (pdok, 2019), PBL (PBL, n.d.),Woonvisie Delft (Gemeente Delft, 2016), DINOloket (DINOloket, n.d.), Van Essen instruments (Van Essen Instruments, n.d.) and Klimaat effecten atlas (Klimaateffectatlas, n.d.). Figure 6 shows the current situation of the design location.

Surface water %	10.3%
Green %	17.8%
Pavement %	46.3%
FSI	0,50 - 1,00
MXI	70 - >85
Ratio public/private	70/30
Building type	High-rise appartment blocks and low rise row houses
Building block type	After war building blocks in stamp patterns
Amenities	Primary school, self defense sports club, small shops from entrepeneurs
Ground water level	-1.8m to -2.8m
Soil type	Clay and some peat in the lower layers
Ground surface level	-1.6m
Leefbarometer	Weak

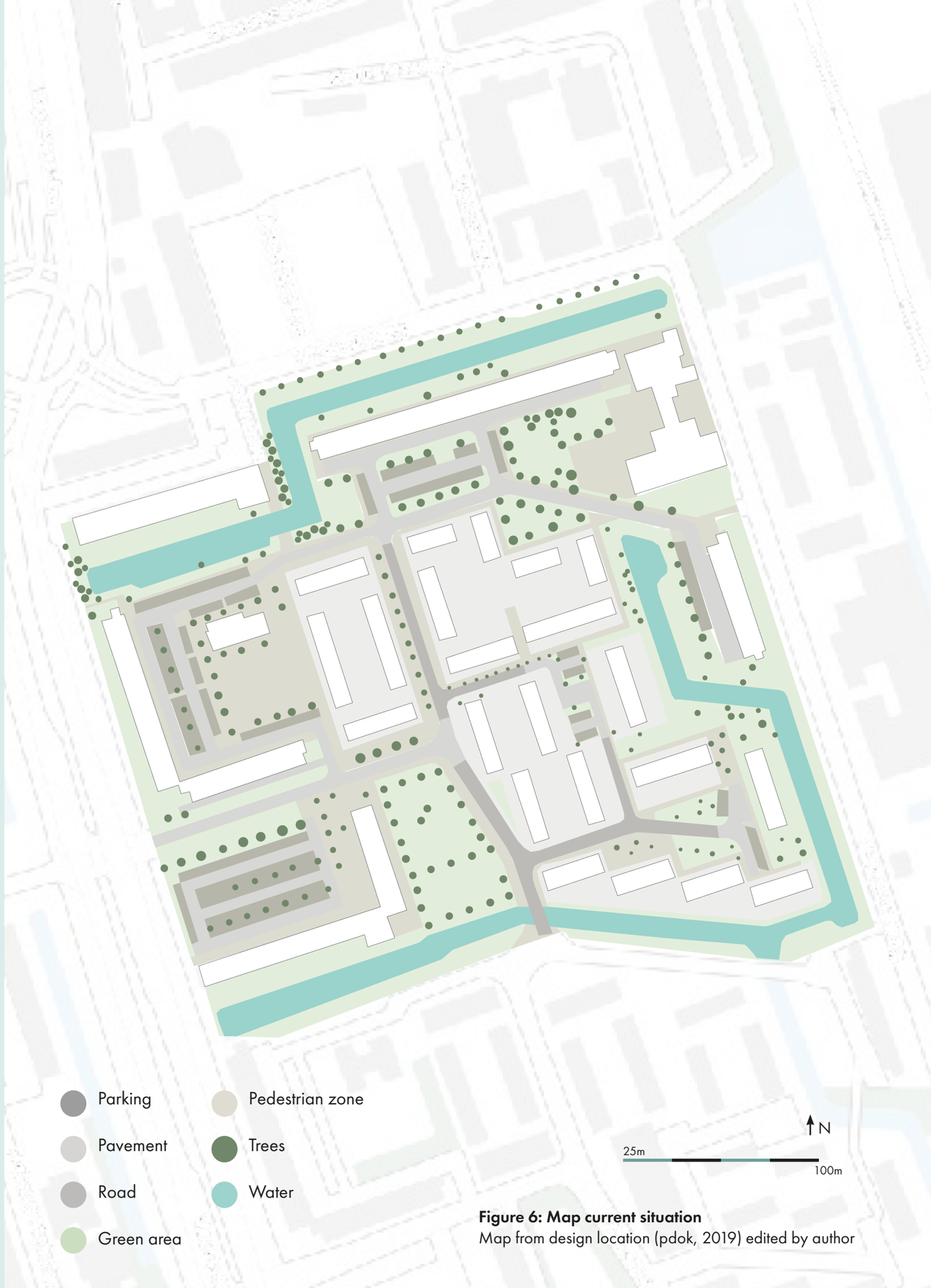


Figure 6: Map current situation
Map from design location (pdok, 2019) edited by author

Analysis

Problem analysis index

This index introduces the problems that can occur in the neighborhood and exlplains briefly what effect they can have.

Prone to heat stress: Problem based on observations in the "klimaateffectenatlas". Heat stress is often a result of large amounts of stony materials. Heat stress can cause an unhealthy micro climate and result in a poor water quality.

Homogeneous green: Problem based on observations in field trips. Homogeneous green causes lack of biodiversity which influences insects, birds and small mammals.

Ratio green/pavement: Problem based on "klimaateffectenatals". The ratio between green and pavement determines the amount of water that can be infiltrated into the ground due to differences in permeability. It also determines the amount of heat stress. Pavement can cause heat stress and water on the streets.

Prone to water stress: Problem based on "klimaateffectenatlas". Water stress is mostly caused by the amount of pavement in neighborhoods and is calculated by a simulation for heavy rainfall. Water stress can cause damage to the built environment and lower water qualities.

Long/narrow culverts: Problem based on maps from the waterboard of Delfland. Long and/or narrow culverts cause hiccups in the circulation of the water system and can cause locally poor water quality.

Lack of interection buildings and public space: Problem based on observations in field trips. Lack of interaction between buildings and public space can negatively influence the experience in public spaces. It can create an unsafe and less lively feeling.

Lack of function and diversity in public space: Problem based on observations in field trips. A lack of function and diversity in public space can result into unused public spaces and a less lively ambiance.

Lack of human scale: Problem based on observations in field trips. By lack of human scale, gradients are missing that help connect humans to their spatial surrounding and places can be experienced as unpleasant.

Lack of identity: Problem based on observations in field trips. Lack of identity can cause people to feel unattached to places and result in less appreciation and care taken to places. Places can also become underused.

Priority on car traffic: Problem based on observations in field trips. Priority on car traffic causes high amounts of pavement and little space for green, walking and biking. It discourages activity and often goes at the cost of public spaces and functions.

Micro climate analysis and problems

The micro climate analysis shows the biggest problems occuring in the design location concerning water, heat, green and pavement.

- Prone to heat stress
- Homogeneous green
- Pavement/Green : 50/50
- Prone to water stress
- Long culvert

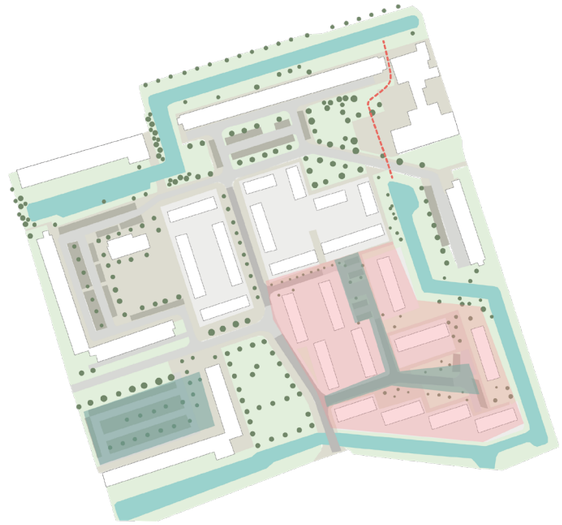


Figure 7: Problem map micro climate
Map based on Klimaateffecten atlas (Klimaateffectatlas, 2019)

Spatial quality analysis and problems

The spatial quality analysis shows the biggest problems occuring in the design location concerning interaction with public space, public space functions, human scale, identity and traffic.

- Lack of interaction between buildings and public space
- Poorly used public space + lack of diversity
- Lack of human scale
- Lack of identity
- Priority on car traffic



Figure 8: Problem map liveability
Map based on field trips



Figure 9: Sustainable development inventarisation
Map based on field trips

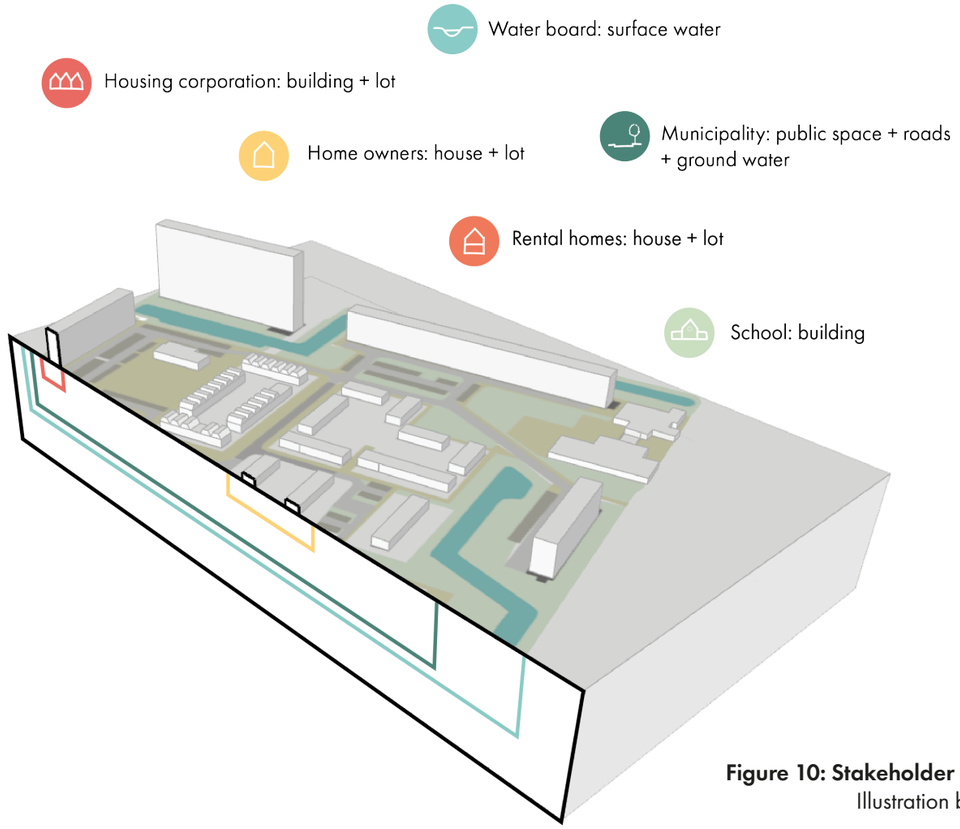


Figure 10: Stakeholder analysis
Illustration by author

SDGs analysis

For the SDGs analysis, the 17 goals are interpreted from the viewpoint of an urban designer. The goals are linked to possibilities in specific places in the area. The SDG wheel is an indication of possibilities and threats regarding the different goals. The method from AW groep is used to fill in the impact wheel. The possibilities and problems for each goals are relatively compared to each other and based on that the wheel has been completed. according to the wheel, goals 3, 6, 11, 12, 13, 14 and 15 have can the biggest impact.

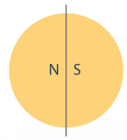
2. Create shared food gardens or yards.
3. Stimulate activity and create healthier micro climates.
4. Use visible climate adaptation measures next to the school and inform about climate adaptation and biodiversity.
6. Use helofytes to naturally clean the water, material use, waste water disposal, natural banks.
7. Integrate room for energy transition.
8. Create room for startups in the neighborhood.
9. Connect the area with public transport.
10. Make facilities accesible to all, give more quality to public space
11. All interventions should contribute to a sustainable city and community
12. Make use of reusable materials or reuse materials from the site for new interventions.
13. Solve water stress and heat stress by increasing the sponge function of the area by using green/blue.
14. Make natural banks to improve water quality and life related to water.
15. Increase biodiversity, by applying mosaic mowing and introduce more (native) species
17. Inform the neighborhood about the SDGs and the design and make room for participation.

Stakeholder analysis

The diagram above shows the relation between different stakeholders and their land possession. It is important to show this in a diagram because the use of land will influence the ground below and important for this project; the ground water. If an owner has a lot of pavement on their piece of land there will be less infiltration of water in the ground and this can result in a lower ground water level. Furthermore it can cause water on the streets or in private gardens. Lastly, it can influence the temperature of the microclimate and cause heat stress. For this project the design interventions will be in the public space so the most important stakeholder is the municipality. However, interventions will influence all users of the neighborhood. Because water is a crucial aspect for this project, other stakeholders will influence the project as well. The way in which they treat water will influence the groundwater in the neighborhood.

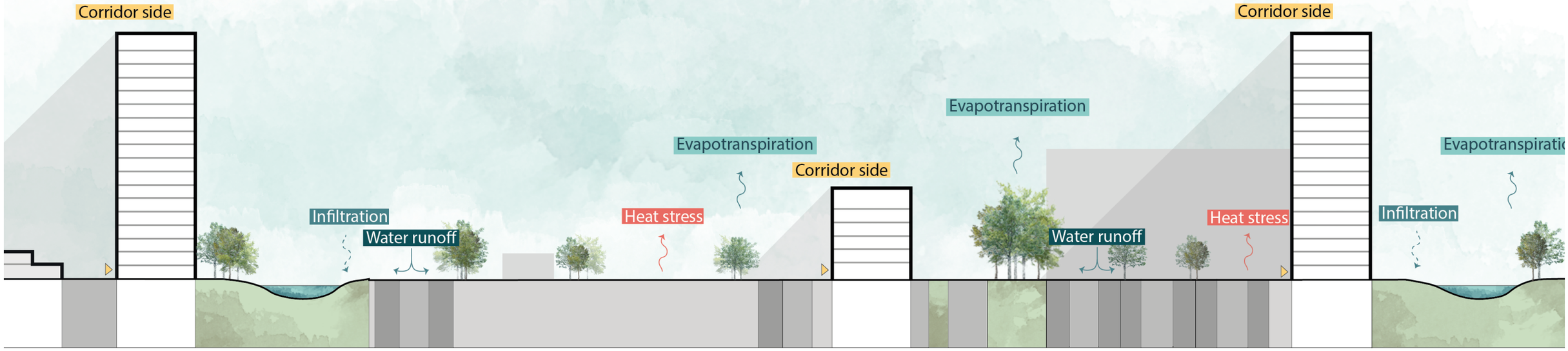
Analysis

- **Neighborhood analysis section**





Climatic flows



Sustainable development goals

3: The neighborhood is car oriented and public space does not stimulate activity.

6: There are long culverts in the neighborhood and no natural banks to purify the water.

11: There is a high potential for improvement of the neighborhood on all aspects.

13: The neighborhood is prone to heat stress and water stress.

14: There are no natural banks to improve life below water.

15: There is not much biodiversity due to homogeneous types of vegetation.

Liveability criteria

Diversity of outdoor space: The public spaces are homogeneous throughout the neighborhood concerning function, character and vegetation.

Human scale: There are no gradients to connect the public space with the high buildings; the buildings and trees are very high and public spaces are very wide.

Walkability: The neighborhood is car oriented: public space is designed to move through the neighborhood by car and around the parking places.

Sense of control & identity: The public spaces and buildings are homogeneous throughout the neighborhood concerning function, character and vegetation.

A pleasant microclimate: The amount of pavement can cause water on the streets during heavy rainfall and heat stress during heat waves.

Biodiversity: The neighborhood has homogeneous types of vegetation; the neighborhood consists of the same trees and grass that is kept short.

Design proposal

Now that the design location has been analysed, a design proposal can be made. The design proposal will help finding solutions to the current problems that were identified in the analysis. For the design proposal, the general design principles based on the three main design tools were used. To test how each tool has influenced different interventions, there are sections (blue boxes) for each intervention that indicate which measures, criteria and goals are related to the design. Also, the water management principles and ecological principles were used in the design.

The map on the right shows the map of the redesign in Voorhof. In general, the water structure has been improved by replacing the long culvert with new surface water. This will improve the water circulation in the Abtswoudse polder. Furthermore, to improve water quality, natural banks have been added. Where possible, pavement has been replaced by green or permeable paving. The public areas in the neighborhood have been given new functions and can each be identified with their own character. The rest of this chapter will go deeper into the design at specific locations.

The redesign has changed the numbers in the neighborhood which were shown at the identification. The surface water has increased with 4.1%, increasing the capacitiy to handle the water in the neighborhood during heavy rainfall. 2.9% of pavement has been replaced by green. Note that the percentage of green was already high in the neighborhood. For this reason, the biggest change was in the types of green instead of in the amount of green. Bringing more variety in vegetation stimulates biodiversity in the neighborhood.

Surface water %	**10.3% + 4.1% = 14.4%**
Green %	**17.8% + 2.9% = 20.7%**
Pavement %	**46.3% - 2.9% = 43.4%**

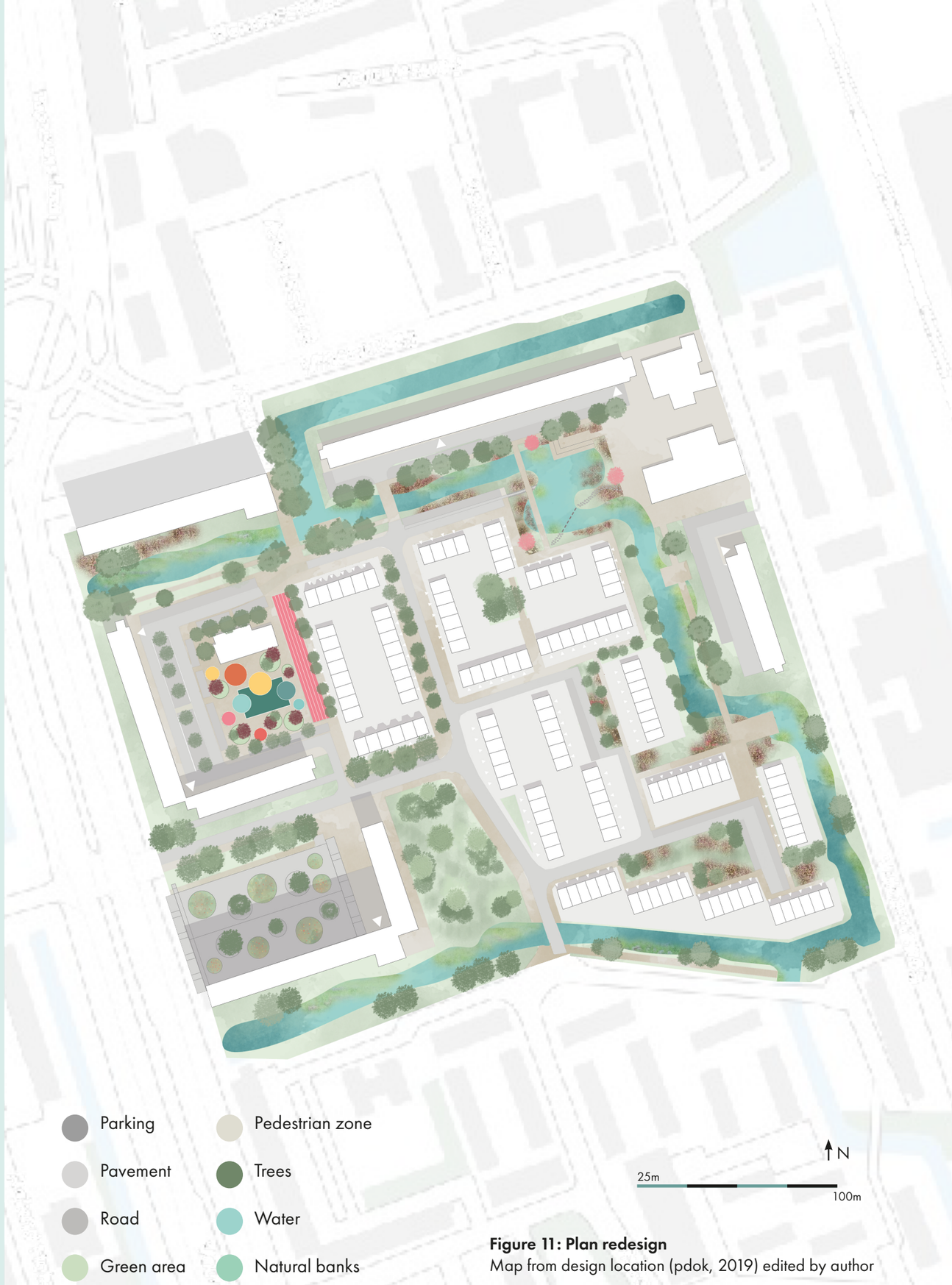


Figure 11: Plan redesign
Map from design location (pdok, 2019) edited by author

Design proposal

Blue/Green robustness

The blue/green structure is very important in the neighborhood. It not only helps to solve climatic problems, it is also a big influencer for the experience for the users of public space. The existing blue/green system has been expanded, to create a robust system that can help prevent water and heat problems. The system connects with public and private spaces in the neighborhood and there for needs to be carefully designed. The aim is to create a continues natural system that connects to the current situation and the redesign.

The concept of the blue/green structure (figure 12) is that there is a hard and functional atmosphere on the outside of the neighborhood and a soft and natural inside that connects to the public areas. The natural public areas can be experienced from orthogonal slow traffic routes that connects the public areas within the neighborhood.

The water banks within the neighborhood have different appearances according to their function and location. For the redesign, four different types of banks are used. The first type are natural banks that are not accessible. They are oriented on the sunny side of the water and seperate the public space from the water. The second type are natural banks that are accessible. They form an alternation with the first type to create special places where users can experience the water and are still a bit separated from the public space around. The third type are not natural banks with places to sit by the water. They are places where people can retreat and connect with the water. The last type (4) are not natural banks to walk by the water. This type can be used as a recreational route. The rest of the banks which are mostly connected to private backyards keep the character they have.

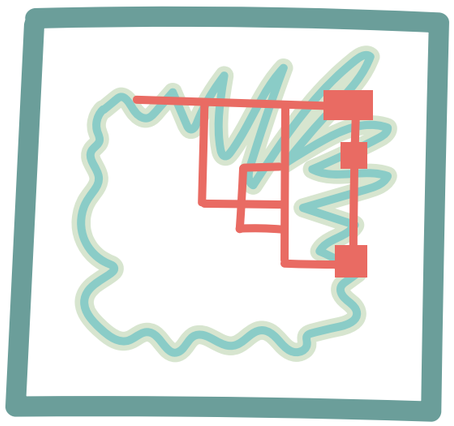
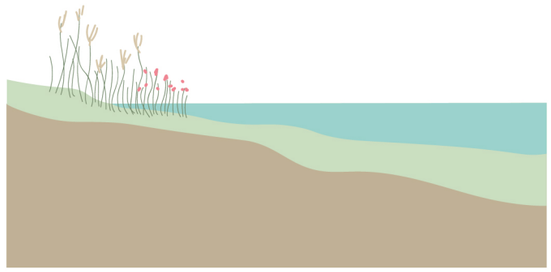
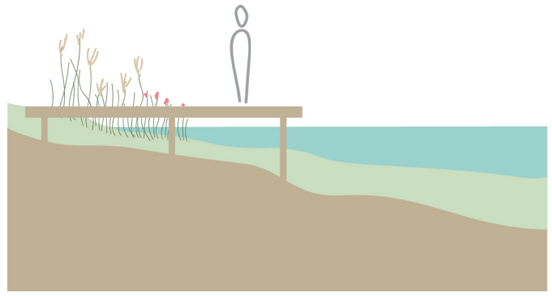


Figure 12: Design concept blue/green
Illustration by author

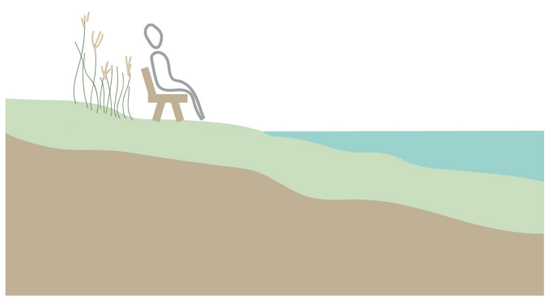


1. Natural banks - not accessible

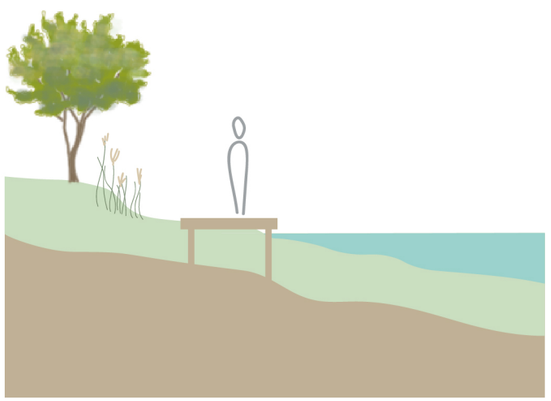


2. Natural banks - accessible





3. Not natural banks - to sit by the water



4. Not natural banks - to walk by the water

Design proposal

Recreative route

The recreational route throughout the neighborhood is the connector of the design. It is designed in straight lines to oppose the natural character of the new public spaces. The route has to be recognizable in order to connect all the different spaces in the redesign and create continuity. As the route goes over land and water, there are separate appearances to go over. The route over water is inspired by the Marker Wadden route which is constructed from wood and creates a path over water. The route over water is inspired by Werkspoorpad from Flux with integrated elements from Rainaway tiles. This way, the path has a permeable character that stands for the core of the redesign: climate adaptation. The path helps create awareness and brings the design together as a whole.



Recreative route reference 1: Flux Werkspoorpad (Flux, n.d.) a recreational route designed around a logistic area through a narrow strip of green, to create a safe slow traffic route.

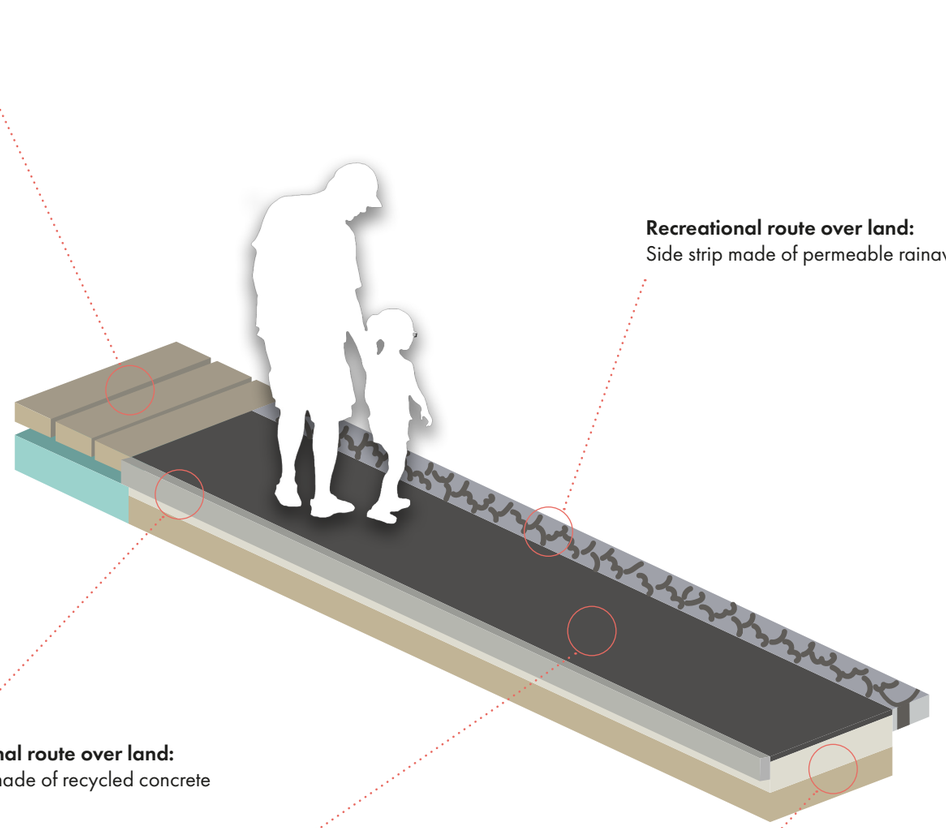


Recreative route reference 1: Rain Away tiles (Rainaway, 2020). Tiles designed to make room for infiltration in pavements. The designs are meant to create a well-designed image as well as raise awareness.



Recreative route reference 1: Marker Wadden (Natuurmonumenten, n.d.). A route over water in between reclaimed islands within the Markermeer lake to connect to the water.

Recreational route over water:
Platform path made of wood or recycled materials



Recreational route over land:
Side strip made of permeable rainaway tiles

Recreational route over land:
Side strip made of recycled concrete

Recreational route over land:
Top layer made of lava in mixed granulate

Width of the path is 1000mm extended with plathforms at recreational places

Recreational route over land:
Foundation made of mixed granulate and a layer of sand beneath

Design proposal

Design areas

The redesign is devided in 5 design areas that support the general design concept. The 5 areas will be described in detail in the rest of the chapter.

Area 2: activity square

The second character of the redesign is movement and meeting. The location of the public space is already at a playground in the current situation. However, the current playground does not connect well to the surrounding as it is seperated by dense green and has too little functions to be used by different users. The new design is a playfull composition of circles that alternate between green circles and circles with a play/sport function. The green circles are lower spots where water can be buffered and infiltrate. The other circles will have sport and play elements that can be used by all different ages to make the area more functional and makes it a place of encounters. On the side is a running track that replaces the side walk to stimulate activity. The vegetation in this public space is clusters to create more connection with the buildings but at the same time provide shelter for animals. The trees chosen show bright autumn colors to connect to the dynamic character of the public space.

Area 3: discovery wood

The third character of the redesign is retreat and discovery. In contrast to the other two characters, in this area people can find a spot for themselves without being seen by everyone; a place for retreat. This does not only apply to people but also to animals. The connection with the water has been increased by creating a gentle slope. The ground taken away along the edges of the water have been placed on the northern side of the public space. This way a variety of ground levels is created and gradients will allow for many different types of vegetation and animals to find a habitat. This improves biodiversity. For the people, natural play elements and furniture has been added to give the place more function. For children a discovery route is created along the many different types of vegetation and stimulates activity. The bushes and trees will be a mix of plants with fruits and nuts. These can be consumed by the neighborhood and creates awareness of the origin of food for children.



Area 1: purification pond

The first character of the redesign is relaxation and purification. The location of the public space is along the new surface water and embraces the central pond. Along the edges of the water, natural banks with different types of helofytes will purify the water and help improve the micro climate. The public space is open and users can use the area to meet and relax. The choice for new vegetation is different types of grasses, wild flowers and blossom trees. These types of vegetation are good for insects and birds and help improve biodiversity. They also give a colorful and calm ambiance that make the place identifiable. A perfect place to take a stroll, run or just stay and relax. The new element connected to the school yard forms a boundary with the water, so children can stay safe at the school yard. On the other side the element consists of steps where water flows that is being pumped up and can be used to sit on and play with. This will be highlighted further on the next pages.

Area 4: living street

The fourth character of the redesign is safety and comfort. The location are streets in the low-rise-building part and are connected to front yards. The streets are used to navigate through the neighborhood and park cars. New green rain parks will help collect rain water and help reduce heat stress. The vegetation will stimulate biodiversity and increase liveability for people living in the street. The redesign prioritizes slow traffic to stimulate active mobility and increase safety.

Area 5: parking deck park

The last character of the redesign is extension and collectivity. The location is on top of the current parking lot that takes up all public space. The new deck will provide inhabitants with a place outside where they can relax and can have collective yards. The inhabitants of the building have balconies at the south side which can become extremely hot during summer. The new public space creates a green cool area where people can recreate. The water from the deck and the building will be visibly transported to existing green areas. The parking deck connects to human scale and creates more liveliness as it connects to the entrances of the building.

Design proposal

Design references

Area 1: purification pond



Gellerup Bypark
Aarhus
SLA





Kronsberg project
Hannover
Studio Dreiseitl







Area 4: living street

Area 2: activity square

Bredäng park
Stockholm
Nivå Landskapsarkitektur



Park ‘n Play
Copenhagen
JAJA architects





Area 3: discovery wood

Tumbling Bay Playground
London
LUC











Area 5: parking deck park



Lucie Aubrac School
Toulouse
Laurens&Loustau Architectes

Area 1: purification pond

Purification pond

The first area in the redesign is the purification pond. It can be considered as the central area of the redesign as it is the place with the highes blue green robustness. This area is where inhabitants can connect most with the water as the public space gradually changes into water. The recreational route with platforms allow people to come very close to, and go over the water through the natural banks. The open space allows the sun in the area so people and the natural banks can benefit from the sunny area.





Current situation
Photo taken by author

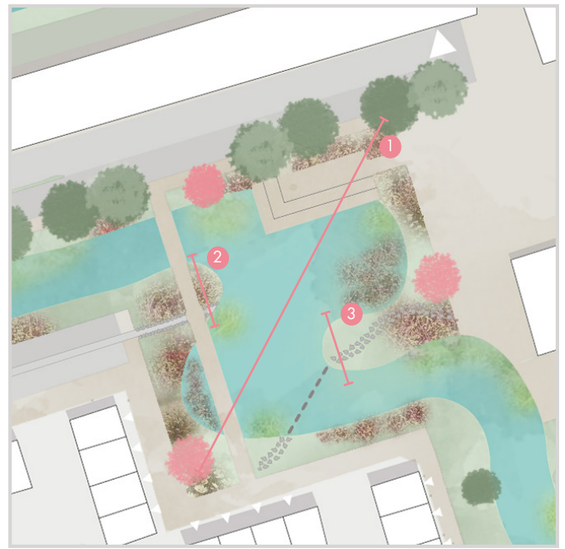
Map current situation

In the current situation there is no surface water connection but a long culvert that goes underneath the parking area and a dense green zone that feels unsafe. The trees in front of the residential building in the north will remain as they block the sun from the building in the summer and create a healthier micro climate for inhabitants.



Map redesign

In the redesign the new purification pond forms a new public space. It is designed for slow traffic as the accessibilty for the car has been removed from the area. Important parts of the design are the natural shapes of water and green, the orthogonal recreational route and the platforms that allow people to recreate by the water. From the street a visible drainage ditch guides the water from the street towards the pond to increase awareness.



N
40m
10m

Area 1: purification pond

Section 1 redesign



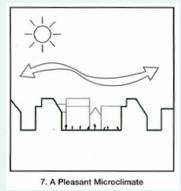
Tools redesign

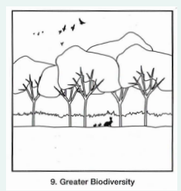














Healthier micro climate, room for sport/play, more green



The neighborhood is more resilient to the results of climate change



Inform about measures with signs or interactive measures



Natural banks create habitat and improve the water quality for life below water



Create natural banks to improve the water quality



The neighborhood is more liveable for different kind of species



A more sustainable neighborhood, with climate adaptation measures and increased liveability



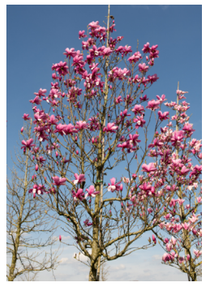


Detail and vegetation



Purification pond reference 1: Transition greenery to platform to water. Schilperoortpark Leiden photo by author.

Purification pond reference 2: Magnolia 'Spectrum'



Purification pond reference 3: Butomus umbellatus



Purification pond reference 4: Schoenoplectus lacustris



Purification pond reference 5: Wildflower mix cruydthoeck



The transition from the greenery to the platform to the water is inspired by the Schilperoortpark in Leiden. The concrete boundary and higher greenery form a pleasant boundary between the walking and sitting area. The steps create a gradient to the water which can also be used to sit on.

The vegetation in the are will exist of some trees and mostly high grasses, wild flowers and helofytes, to create a peaceful ambience. The vegetation help improve the microclimate with their purifying and cooling effect. The area is a perfect habitat for insects.

Area 1: purification pond

Section 2 redesign





Purification pond reference 6: Drainage ditch. In the redesign the water from the street will be guided to the pond with a drainage ditch constructed from pebbles and stones. The ditch will reduce the chance for water on the street and create awareness about water use.

Section 3 redesign



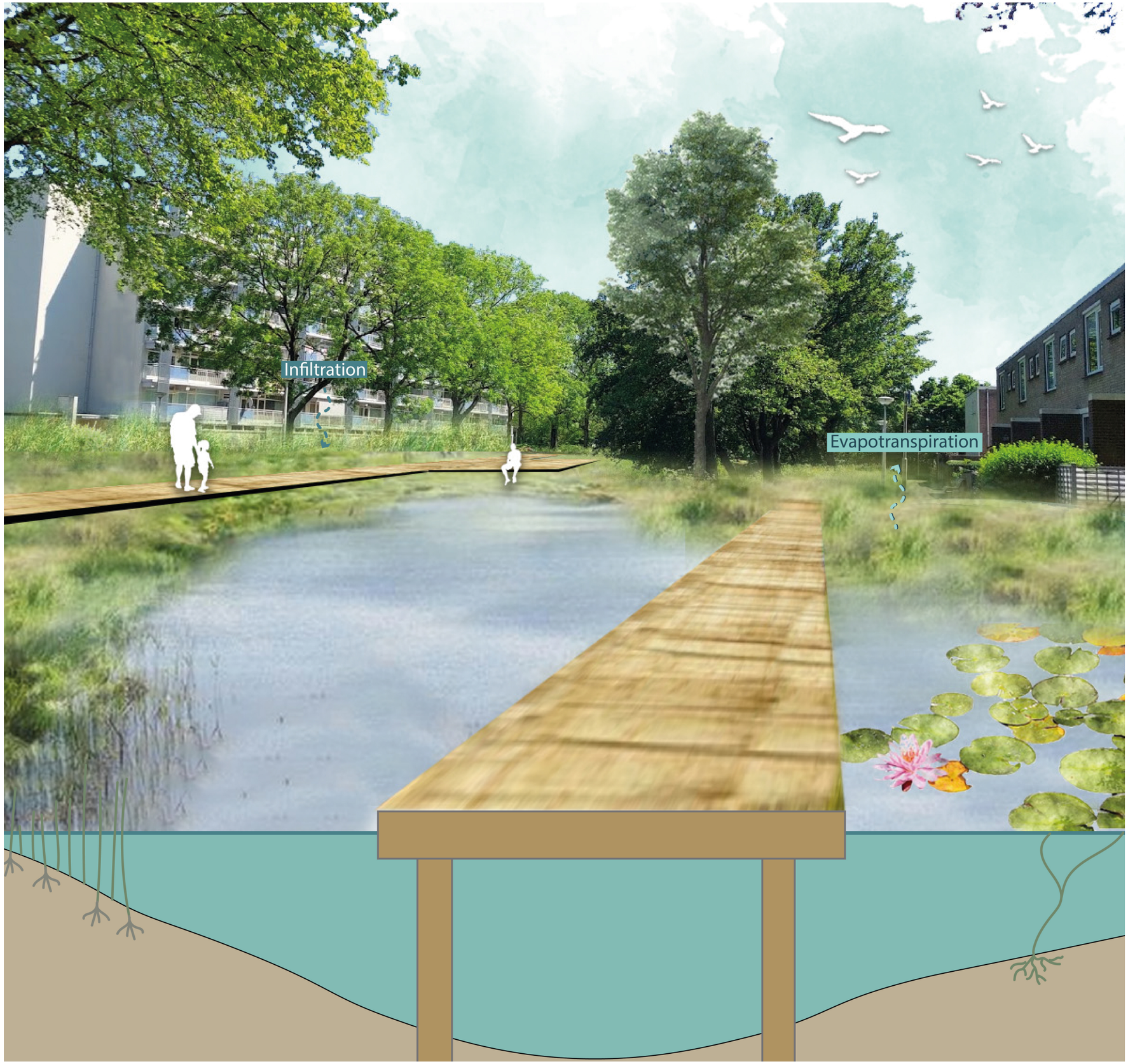


Purification pond reference 7: “trekvlot”. To cross the pond, children (and adults) can use a pull raft. This playfull element creates a connection with the water. The pond is the shallowest here, so it will be safer for children to go over in case they fall off.

Area 1: purification pond

- **Purification pond impression**

This impression shows the ambience of the purification pond area. The surface water increases the buffercapacity and make the neighborhood more robust as it can deal with more water during heavy rainfall.



Area 2: activity square

Activity square

The second area in the redesign is the activity square. It is the place of meeting and movement in the area. The public space has sport and play elements for all ages so inhabitants have a place to sport in their neighborhood. The colors and shapes in the design are meant to stimulate activity.





Current situation
Photo taken by author

Map current situation

In the current situation there is a quite empty playground seperated by the public space around by dense green. This creates an unsafe feeling. The large amounts of pavements can cause water and heat problems.



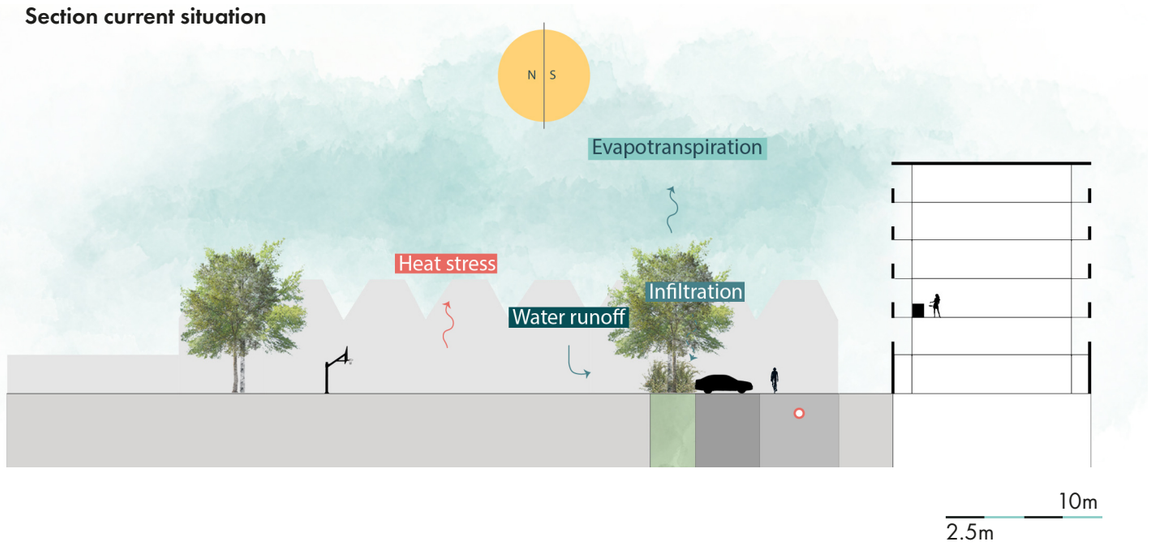
Map redesign

In the redesign the playground has been redesigned with alternation of sport/play circles and circular raingardens to collect water and create habitat for small mammals and birds. The playground is more accessible and connected to the streets around.

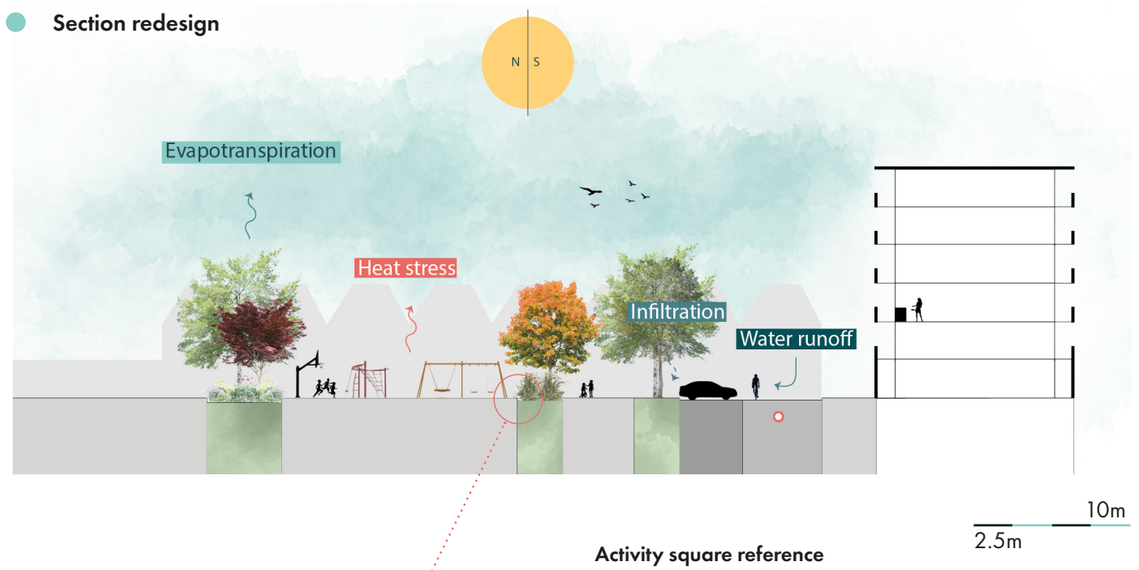


Area 2: activity square

Section current situation



Section redesign



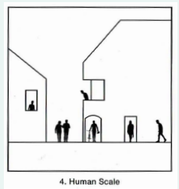
Tools redesign

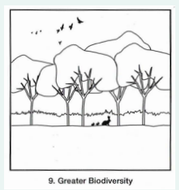














Healthier micro climate, room for sport/play, more green



Inform about measures with signs or interactive measures



Public facilities are accessible to everyone



A more sustainable neighborhood, with climate adaptation measures and increased liveability



Use renewable or recycled materials for the realisation of the design



The neighborhood is more resilient to the results of climate change



The neighborhood is more liveable for different kind of species





Detail and vegetation





Activity square reference 1: asphalt color coating/green circles transition

The transition between the square and the circular rain gardens will be realized with a descending concrete border that lets the water into the rain garden all around. This way, during heavy rainfall, the rainwater will be collected in the green circles.

Activity square reference 2: Acer truncatum x platanoides 'Warrenred'



Activity square reference 3: Euonymus europaeus



Activity square reference 4: Acer rubrum



Activity square reference 5: Photinia villosa laevis



The vegetation in the rain gardena will exist of trees and shrubs to create habitat for small mammals, birds and insects. The examples of vegetation given have expressive autumn colors to give more character to the place and make seasons more experienceable.

Area 2: activity square

- **Activity square impression**

This impression shows the ambience of the activity square area. The impression shows that the water that falls in the area will flow towards the raingardens where it can infiltrate into the ground.

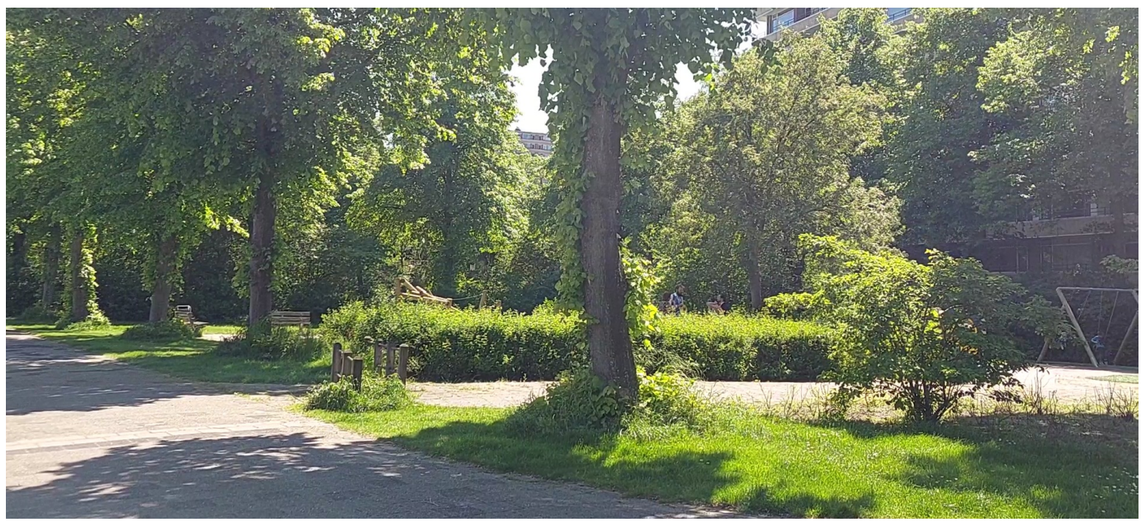


Area 3: discovery wood

Discovery wood

The third area in the redesign is the discovery wood. The area consists of hight differences, gradually going towards the surface water in the south. The gradients create different conditions allowing a variety of vegetation to improve biodiversity. The area has spots for children to discover as well as plants and trees to discover that grow fruits and nuts that are edible.

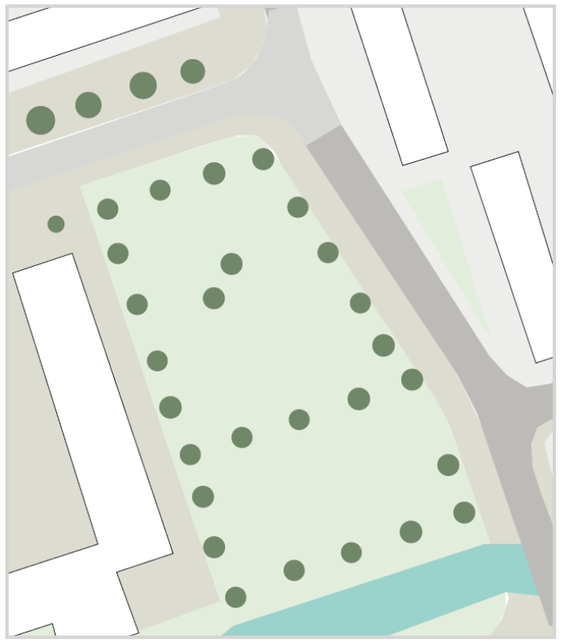




Current situation
Photo taken by author

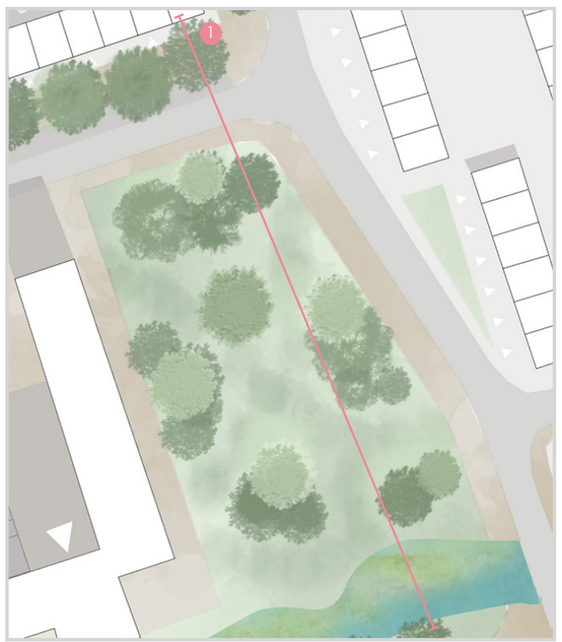
Map current situation

In the current situation the green area is very closed of from the streets around by dense bushes and create an unsafe feeling. There are not many play elements and the football field in the south even seems unused. The vegetation in the area is homogeneous.



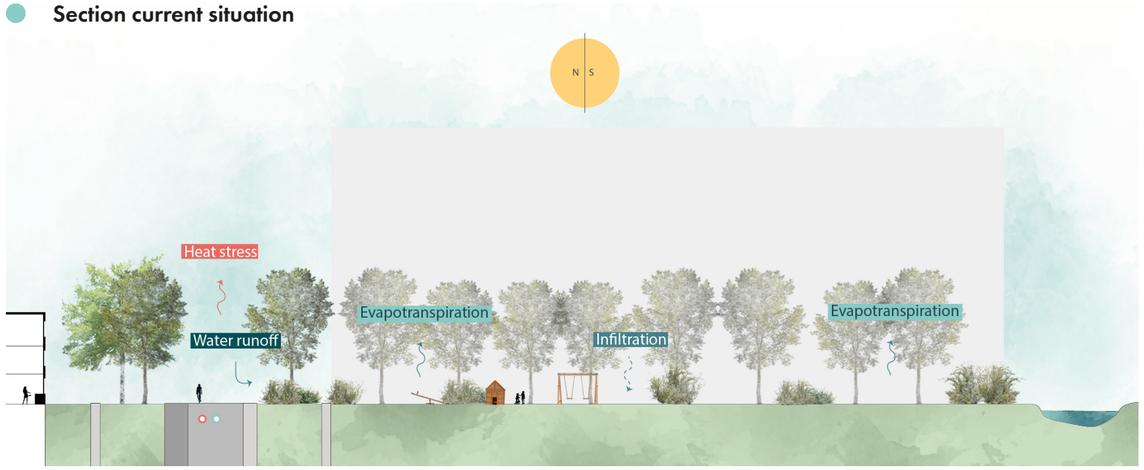
Map redesign

In the redesign the area has been reorganized, in which trees and bushes form groups so that the area can be seen from the streets around to create a safer feeling. The gradients of the ground and water level allow for a variety of vegetation.

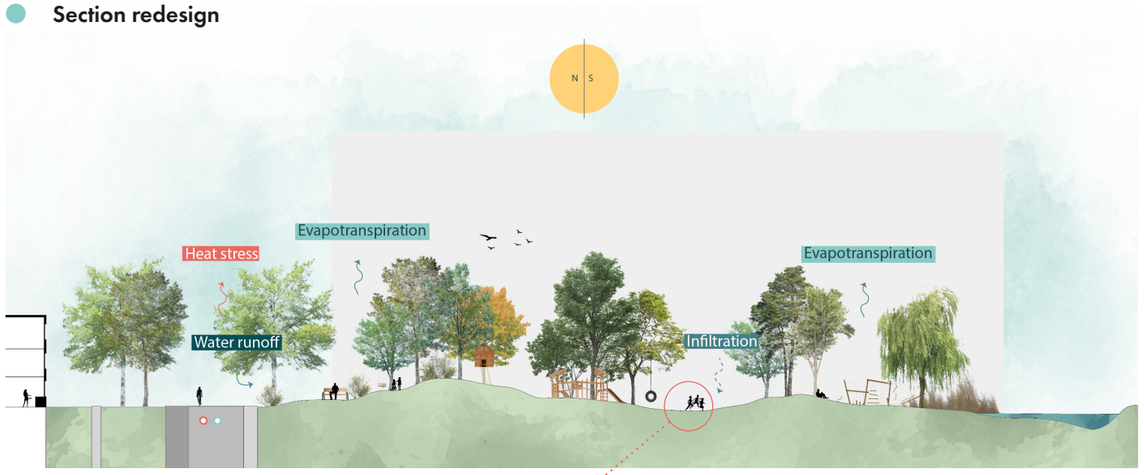


Area 3: discovery wood

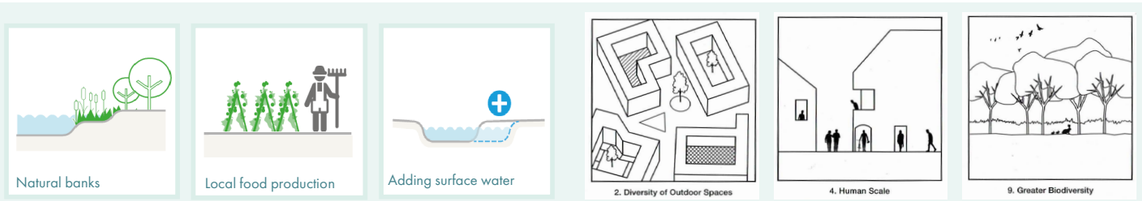
Section current situation



Section redesign

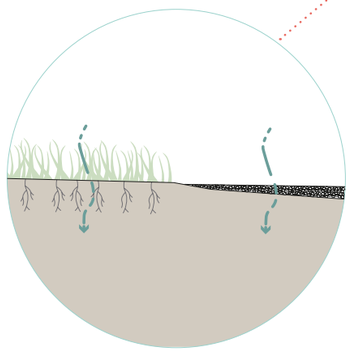


Tools redesign



- **3 GOOD HEALTH AND WELL-BEING** — Healthier micro climate, room for sport/play, more green
- **2 ZERO HUNGER** — Inform about plants that produce food and how to collect and consume them
- **6 CLEAN WATER AND SANITATION** — Create natural banks to improve the water quality
- **11 SUSTAINABLE CITIES AND COMMUNITIES** — A more sustainable neighborhood, with climate adaptation measures and increased liveability
- **13 CLIMATE ACTION** — The neighborhood is more resilient to the results of climate change
- **14 LIFE BELOW WATER** — Natural banks create habitat and improve the water quality for life below water
- **15 LIFE ON LAND** — The neighborhood is more liveable for different kind of species

Detail and vegetation





Discovery wood reference 1: path through the wood Heemtuinen Delft photo by author

The transition between the paths and green zones will be realized with a shell path that lets rain water through. This way, the whole discovery wood are is infiltratable to keep the water local. The height differences will guide the water towards the surface water.

Discovery wood reference 2: Pinus Sylvestris



Discovery wood reference 4: Centaurea jacea





Discovery wood reference 3: Prunus padus



Discovery wood reference 5: Vaccinium myrtillus

The vegetation in the discovery wood will exist of trees an shrubs that grow nuts and fruits that people and animals can eat and discover. The examples of such plants given are Pinus sylvestris, Prunis padus, Centaurea jacea and Vaccinium myrtillus.

Area 3: discovery wood

Discovery wood impression

This impression shows the ambience of the discovery wood area. The impression shows that the area will remain cool because of the shadow and evapotranspiraton and water can infiltrate in the entire area.



Area 4: living street

Living street

The fourth area in the redesign is the living street. The living street is a design in which the emphasis from the car and pavement goes to slow traffic and green/blue. Living street are better adapted to the results of climate change as they have a cooling effect and can let water infiltrate. The quality of public space also increases by prioritizing slow traffic and creating a more green design.





Current situation
Photo taken by author

Map current situation

In the current situation the street is designed around parking lots. This makes the street angular causing cars to drive slow, but also giving little space to cyclist, pedestrians and green.



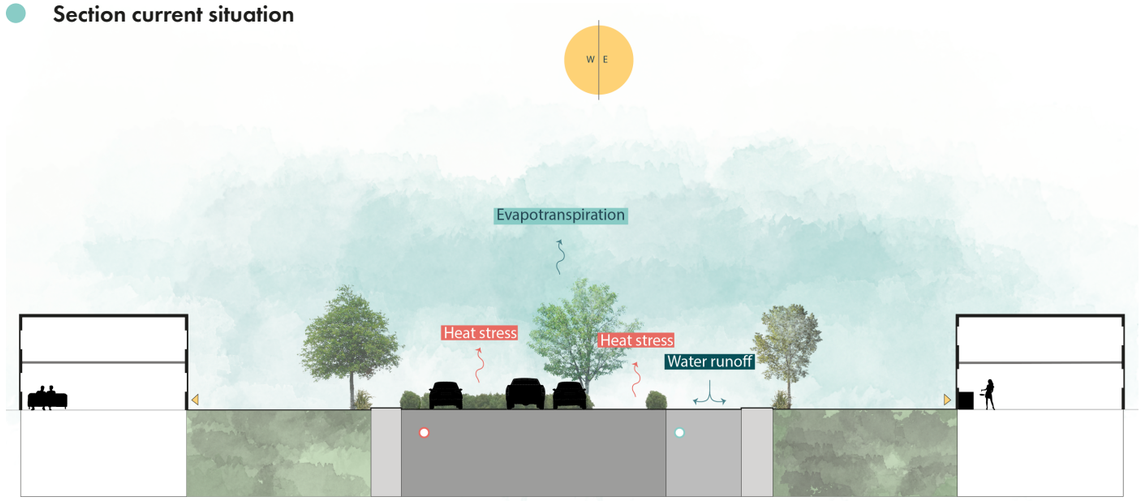
Map redesign

In the redesign the parking lots have been replaced to the west side where there is the most shade, causing the pavement to heat up the least and making sure the new strip of green gets a lot of sunlight. The new layout is more efficient. This way a new strip of green can be realized. This can help improve the microclimate and liveability in the street. In the green zone there is also space for small play elements for children.

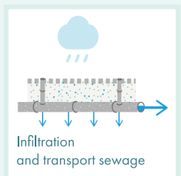


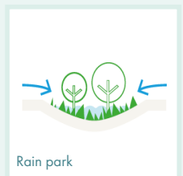
Area 4: living street

Section current situation

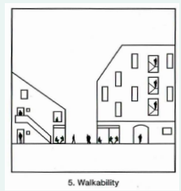


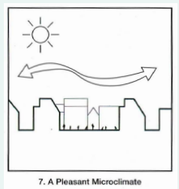
Tools redesign

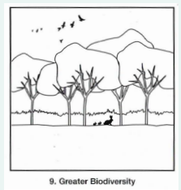














Healthier micro climate, room for sport/play, more green



Inform about measures with signs or interactive measures



Public facilities are accessible to everyone



A more sustainable neighborhood, with climate adaptation measures and increased liveability



Use renewable or recycled materials for the realisation of the design



The neighborhood is more resilient to the results of climate change

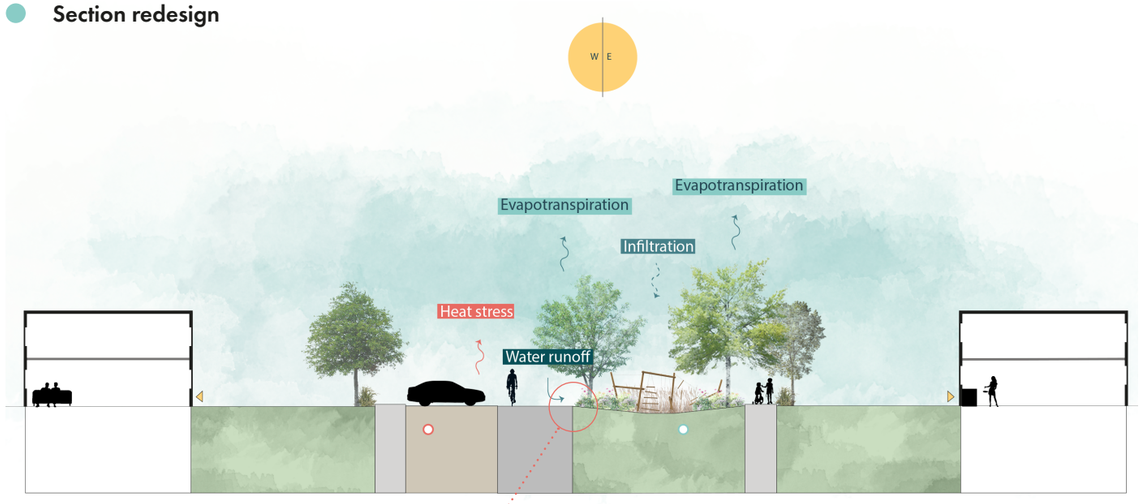


The neighborhood is more liveable for different kind of species

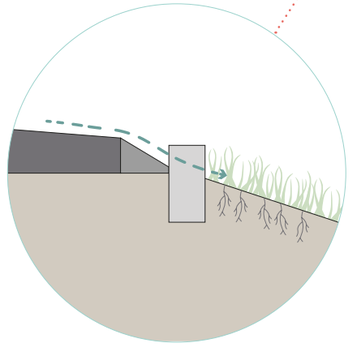




Section redesign



Detail and vegetation





Living street reference 1:
street/raingarden transition

The transition between the street and the rain garden will be realized with a descending concrete border that lets the water into the raingarden at places every few metres. This way, during heavy rainfall, the street will remain dry and the rain garden collects the water.

Living street reference 2:
Alnus glutinosa

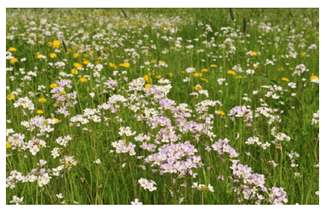




Living street reference 3:
Butomus umbellatus

Living street reference 4:
Centaurea jacea





Living street reference 5:
Cardamine pratensis

The vegetation in the rain garden will exist of some trees, like the Alnus glutinosa, helofytes like the Butomus umbellatus, higher ascending plant species like the Centaurea jacea, and lower plants like the Cardamine pratensis (GroenBlauwe Netwerken, n.d.)

Area 4: living street

- **Living street impression**

This impression shows how the living street works. The new green area works as a buffer zone where water can be collected during heavy rain and later infiltrate. If the ground is saturated with water, the water will be drained to surface water with an IT sewage. The reason for the IT sewage is because of the soil type with low permeability and the high ground water level. In other cases the rain park can be realized without an IT sewage.



Area 5: Parking deck park

Parking deck park

The fifth area in the redesign is the parking deck park. The parking deck will be created to bridge the death plinth and create a new public area that connects to the building. This will give the deck a semi-public character. Futher more there will be green areas on the deck that can function as collective yards in which communities can grow vegetables an herbs. The cutouts in the deck make sure the current trees can go through the deck. This makes the deck more pleasant because of the presence of green and the parking lot underneath safer, because there is more light and interaction with the deck above. The green areas on the deck will not only function as yards but can als buffer the water in periods of heavy rain.

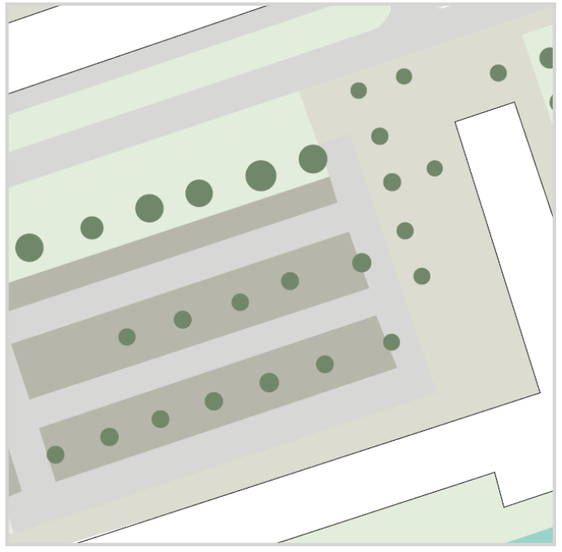




Current situation
Photo taken by author

Map current situation

In the current situation there is a lot of pavement and the area is designed for the car. There is no interaction with the building because the plinth is filled with garage boxes and is two stories high.



Map redesign

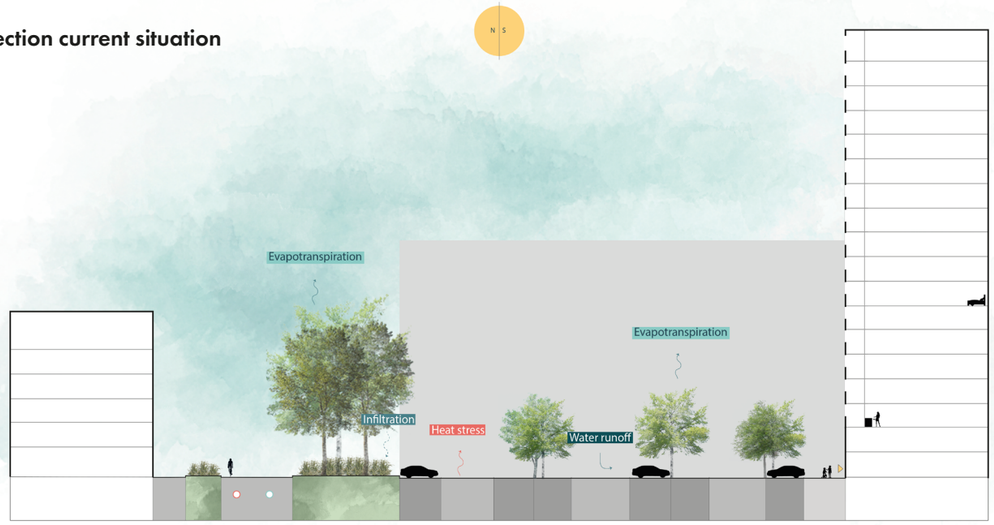
In the redesign a new deck has been created that connects to the lowest corridor of the building. A new public space is created that connects to the building. The deck will help in managing the water during heavy rainfall.



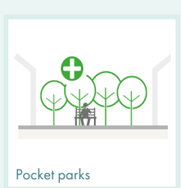
N 40m 10m

Area 5: Parking deck park

Section current situation

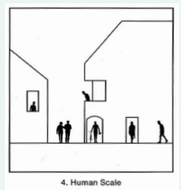


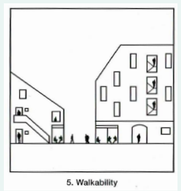
Tools redesign

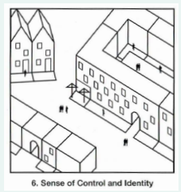












3 GOOD HEALTH AND WELL-BEING — Healthier micro climate, room for sport/play, more green

4 QUALITY EDUCATION — Inform about measures with signs or interactive measures

10 REDUCED INEQUALITIES — Public facilities are accessible to everyone

11 SUSTAINABLE CITIES AND COMMUNITIES — A more sustainable neighborhood, with climate adaptation measures and increased liveability

12 RESPONSIBLE CONSUMPTION AND PRODUCTION — Use renewable or recycled materials for the realisation of the design

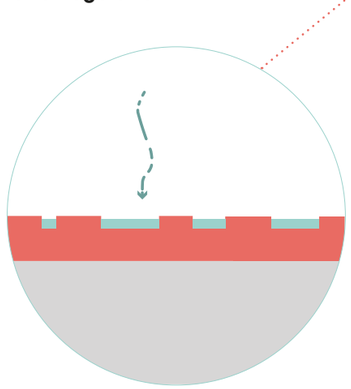
13 CLIMATE ACTION — The neighborhood is more resilient to the results of climate change

15 LIFE ON LAND — The neighborhood is more liveable for different kind of species

Section redesign



Detail and vegetation





Parking deck reference 1: Rainaway tiles for visible water transport

The parking deck park will be covered with rainaway tiles. The rainwater from the rooftops will be collected and flow via the tiles toward the green raingarden at street level. The hight difference in the parking deck will be a place where small water falls will apear during and shortly after rainfall.

Parking deck reference 2:
Allium schoenoprasum



Parking deck reference 3:
Cucurbita pepo



Parking deck reference 4:
Origanum vulgare



Parking deck reference 5:
Lavandula



The vegetation on the parking deck can be collective yards. In the green areas, inhabitants can grow their own herbs, vegetables or have flower gardens. These types of vegetation can help improve biodiversity as they are valuable to insects like bees.

Area 5: Parking deck park

Parking deck park impression

This impression shows the ambience of the parking deck park. The new deck connects to the building and gives more room to green and blue. Water will be collected on the deck and guided towards the green areas at ground level where it can infiltrate.



The water is always deeper than what it reflects

- Marty Rubin



Conclusion

8.

Research questions and recommendations

To conclude this thesis, this chapter will answer the research questions with the insights the previous chapters have given in the research. This chapter will subsequentially answer the sub questions and lastly answer the main research question. After the research questions are answered, a paragraph will give recommendations of how to use the results of the project for other cases or how to continue research.

8.1 Answers to subquestions

What problems can be defined in Dutch urban areas regarding climate change?
From the chapters in this thesis can be concluded that problems occurring in Dutch urban areas due to the result of climate change are dealing with water and heat. Climate change in general causes heavier rainfall, warmer summers and longer dry periods. These consequences can be experienced in the whole country but are most problematic in urban areas. In urban areas the percentage of pavement is very high and reinforces the effect. Pavements have a low permeability and causes water to runoff. This water cannot be drained and causes overload in the sewage resulting in water on the streets. Furthermore, the water does not infiltrate in the ground and can cause a shortage of ground water on the long term. Thereby, pavements and other stony materials in the city warm up during warm days and collect the heat. This causes the urban heat island effect, making cities even warmer than their surroundings. This can cause well-being problems even resulting in higher death numbers in heat waves.

What is the relation between sustainability, liveability and climate adaptation?
From the theory chapter can be concluded that there is an overlap between the concepts sustainable development, liveability and climate adaptation. Climate adaptation relates to liveability in a way that it helps improve micro climate conditions in the direct surrounding of people and create safety against the threat of the effects of climate change. Climate adaptation measures can especially help improve livability when using nature-based solutions. Climate adaptation and sustainable development relate to one another, in a way that they both aim for meeting the needs of people now and in the future: a safe and healthy living environment. They differ in a way that sustainable development is much broader and covers many aspects that do not involve climate adaptation. This can be said about liveability as well. Liveability and sustainability both deal with the relationship between humans and environment but have a different scope of time. Sustainability focusses on maintaining our environment and resources for the future while liveability focusses on 'here and now'. The other difference is that liveability focusses more on human needs and sustainability on economic, environmental and social dimensions. The overlap of the concept is the core focus of this thesis.

What are climate adaptation measures and how can they relate to sustainable development?
Climate adaptation measures are measures to adapt (in this project urban areas) to the effects of climate change. The set of climate adaptation measures used in this project are based on the climate adaptation strategy from the municipality of Delft. The selected measures for this thesis are the measures for the street and neighborhood, due to the focus on public space. Based on literature about nature-based solutions, the overview of the measures and their properties, an overview of the relation between the measures and SDGs is made. From this overview can be concluded that from the viewpoint of an urban designer, all measures contribute to goals 11 and 13. Nature-based measures contribute to goals 3, 15 and mostly 14. Goals 2, 4, 6, 9, 12 and 17 only relate to some measures and the other goals do not relate to any measures. The overview can be found on page 69-75.

What is the relation between the tools and the design?
The tools selected in this thesis make the project specific and function as input for the design process. The experiment in this project is to see how the tools influence the design and what lessons can be learned from this approach. Each intervention in the design is substantiated with the components of the different goals they relate to; the measures that are used, the sustainable development goals that are relevant and the liveability criteria that are used in the design. The tools can be used on forehand of the design to formulate general design principles but also afterwards to analyze and see if there are more solutions possible.

What problems can be identified in the research location in relation to blue and green?
From chapter 6 can be concluded that both the blue and the green system can be improved in Delft. The water system analysis shows that there are problems in Delft concerning water capacity and water quality. The water management principles retain-store-drain, circulation and natural banks could help improve the system. These principles can be found on page 95. From the green analysis can be concluded that there are barriers and gaps in the ecosystem structure in Delft that could be improved with the ecological network principle and variety of vegetation. These principles can be found on page 101.

How can the design location become climate adaptive?
In order to make the design locations climate adaptive, they were first analyzed to acknowledge the relevant problems. Concluding from the different design interventions, the measures taken are first of all dependent on the circumstances. Depending on the soil type and ground water level, measures can be selected. From the chapter about design tools was concluded that nature-based solutions are preferred over engineered solutions. However, if the soil is clay or peat and the ground water level is already high, it is harder to implement measures that improve infiltration (retain). In these cases, buffering (store) and sometimes drainage (drain) is needed. If the situation is technically solved, liveability criteria and sustainable development goals shape the redesign.

Which interventions respect other aspects of sustainable development?
From the overview of pages 69 - 75 can be concluded that all measures relate to at least one of the sustainable development goals. Designing the measures in such a way in the intervention that they also support the liveability criteria, makes the relation with the SDG goals even bigger. The interventions that respect other aspects of sustainable development can be derived from the general design principles. The general design principles from chapter 5 on page 82-83 conclude the overlap between the three different design tools. Following these principles when designing would result in interventions that respect other aspects of sustainable development.

What do the outcomes mean to Urban designers and other professions?
The thesis is written from the viewpoint of an urban designer. The problem in the project is solved with a spatial design that is typical for urbanism. Other urban designers could first of all use the approach of the project for their own work. The combination of the selected design tools could help for finding solutions to similar problems from the ones in this project. The general design principles are a conclusion of the combination of tools and could be used in other projects, therefor they are general principles. The interventions in the design locations can also be used in other cases, however, they are site specific and come with certain conditions, which have to be taken into account when transferring the outcomes to other cases.

Along the process of the thesis a lot of contact has been made with other professions as well. First of all, the project was largely motivated by the cooperation with AW Groep an engineering company. They execute a lot of projects and highly value the sustainable development goals. This way, the outcomes of the research can give interesting insights for their field of work. The overview of measures and their relation to the SDGs gives insight in their effect on the sustainable development goals with measures they are already taking but also makes them comparable. This overview can help in decision making when selecting measures that have to be applied in locations. Showing the relation to liveability and sustainability can help choosing for better design options than just trying to solve a water or heat problem.

Furthermore, a lot of contact has been made with the municipality. The outcomes of the project could help the municipality of Delft to substantiate their climate adaptation strategy. When the municipality wants to adapt an existing neighborhood, there are a lot of stakeholders involved who might not be very happy with interventions in their street in the first plays. By communicating the co-benefits to them, the value of climate adaptation can be made more appealing.

Lastly, there has been contact with the waterboard of Delfland as well. The research could be interesting to them, as it combines the scale of the waterboard and the municipality and shows how they can help each other; small scale interventions can help improve the entire water system. The project can be a means of communication between the municipality and water board to show examples of what both parties can do to solve the occurring problems.

How can the design principles and outcomes from this project be applied in other cases?
Like concluded earlier, the design principles have been set up to be general, so they can be applied in any case in the Netherlands with comparable problems; the principles can lead to site specific interventions. The interventions designed for the locations are less transferable to other cases. They are custom made and are connected to specific conditions that are described in the thesis. The most important conditions when talking about climate adaptation measures are the soil type and ground water level. The most important conditions to look at when looking at sustainability and liveability are density, neighborhood type and quality of public space. When cases are comparable to the conditions described, they could use the same interventions. When cases differ on conditions, alterations need to be made in the interventions so they have the desired effect. For this thesis, design locations were selected that can be found in many cities in the Netherlands when talking about neighborhood types, so lessons learned from this project can be used there as well. The condition that is most likely to differ is the soil type and ground water level.

8.2 Answer to the main question

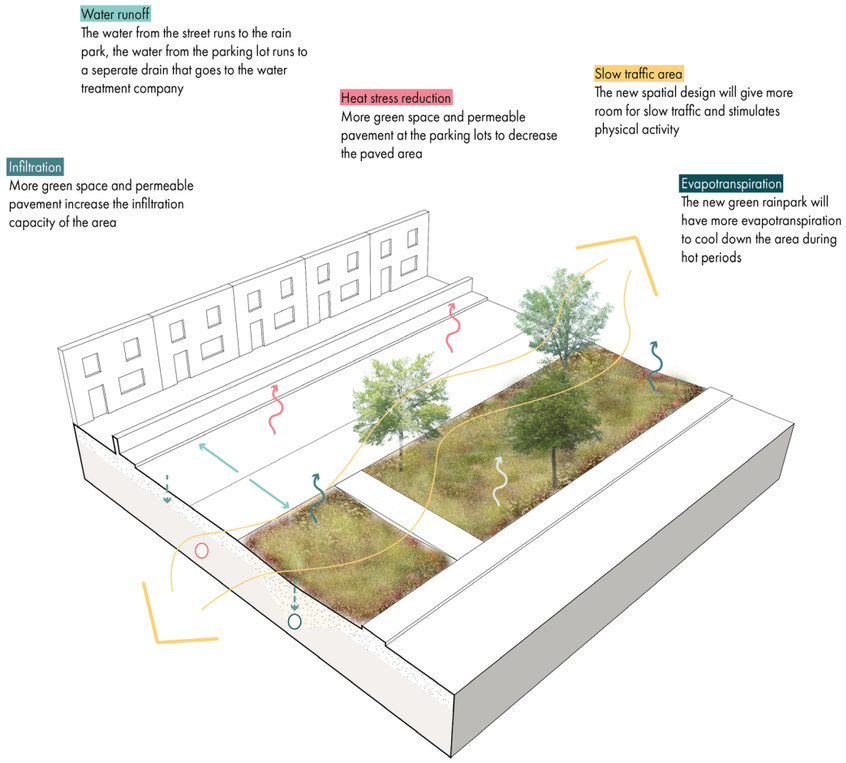
"How can we design with climate adaptation measures in existing neighborhoods in the Netherlands while respecting other aspects of sustainable development?"
Concluding the project, is to answer the main research question. First of all, to design with climate adaptation measures in existing neighborhoods in the Netherlands while respecting other aspects of sustainable development, climate adaptation measures are needed. The adaptation measures from the climate adaptation strategy of Delft municipality shows a very complete list with measures that can be used. For existing neighborhoods, the measures for the public spaces are selected, because the rest of the space is already owned by stakeholders and cannot just be changed. Furthermore, the relation with design and adaptation measures can be better secured by combining them with liveability criteria. The criteria from David Sim are very practical and help in establishing a design with climate adaptation measures. Lastly, to respect other aspects of sustainable development than just climate adaptation, the sustainable development goals can be used, to highlight all the aspects of sustainable development. In order to find useful outcomes of this input, a search for the overlap between the three tools is needed. The overlap results into general design principles that guide the design process. After the designs have been made, the ingredients for the design can be recognized for the different tools. This has given insight in the usefulness of using the different tools in the design process. The final products have shown that in this project the use of the three main tools for the design have been useful and have helped to answer the main research question: "How can we design with climate adaptation measures in existing neighborhoods in the Netherlands while respecting other aspects of sustainable development?" The answer to the question is: by setting up a framework with design tools that consist of the components: climate adaptation, spatial design and sustainable development, and using them to find the overlap between them, to make general design principles and make insightful how they have influenced the design interventions.

8.3 Additional conclusions

Tools and interventions
Comparing all the blue boxes in the design chapter that summarize the design tools used for each intervention, conclusions can be made. First of all, not all tools are used and the tools that are used are based on the conditions that come forth from the analyses. The tools used are a communication of the design decisions that are made to create the redesign. They are not the only options possible but they were seen as the most important tools to use for that specific location. Furthermore, the different scales throughout the design chapter show how the decisions based on the tools can change. For example, goal 4 education and goal 12 renewable consumption and production are goals that are used in the design interventions, by making them visible and realizing them from recycled or renewable materials, but cannot be found on the neighborhood scale in the analysis. Being aware of the different effect of the scales on the tools is important when using the approach researched in this thesis.

On the right page is an example of a design intervention used in the project but generalized so the principle can be used in other locations as well. The design decisions made are shown with the tools that belong to them. Comparing this general intervention to the design location in the thesis (area 4 living street) shows that fewer tools are used. This makes clear that specific conditions in a location guide the tools that can be used and can offer opportunities to improve a design by using more tools to make the design more complete on different aspects. From the example can also be concluded that all three tools were necessary to use in the approach since some design decisions are based on liveability criteria and sustainable development goals only and might have gotten less attention when only making a neighborhood adapted to the effects of climate change.

General design intervention analysis



Scales and transferability
In this thesis the tools were used to form different interventions. The interventions together formed a redesign to make the neighborhood more liveable, sustainable and adapted to climate change effects. The redesign of this project can help improve the blue and green system in the studied polder. Especially if other neighborhoods in the polder would be redesigned with the same approach a difference can be made.
For further research, the interventions and general design principles can be used but have to be adapted to specific conditions in the neighborhood and the polder (or no polder) in which they are. The same approach of analysis and design iteratively used in this thesis has to be used to properly adapt interventions to different conditions. This way the same approach can be used in other urban areas in the Netherlands as well.

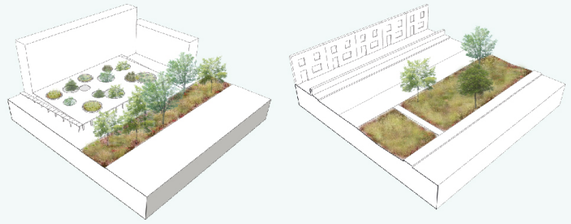
This thesis

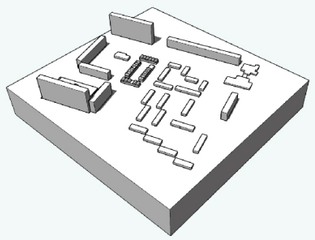


More liveable and sustainable neighborhood adapted to climate change effects

Improved blue and green system in the polder

Research location

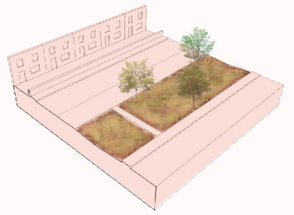


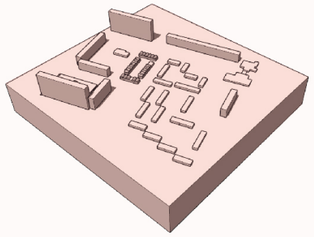




Further research

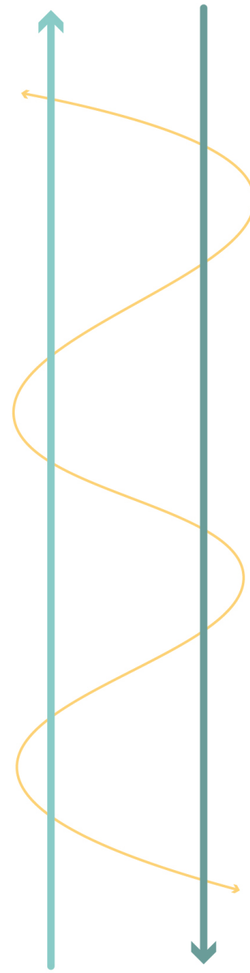
Different conditions







Analysis Design



Reflection

9.

Project and process

This chapter is a reflection on the project. The chapter will discuss the relevance of the project, ethical considerations, approach, viewpoints and the research and design relationship. The reflection will help to position the research done in the scientific field and to make understandable how the results can be used by others. The final paragraph will discuss the implications of the project and give recommendations for further research.

9.1 Project relevance

Societal relevance
The project contributes to national efforts to adapt urban areas to the results of climate change. The project aims to create an approach for designing a healthier living environment for people and other species and protect them for the effects of future climate change. This research could help for adapting other neighborhoods in the Netherlands as well besides the chosen design location. This will help taking a step in reaching climate adaptation goals. This will be needed since climate problems are becoming bigger, influencing many processes. Thereby, the subjects of liveability and sustainability take steps to not only technically solve the climatic problems but also help improve the urban environment. Liveability criteria help creating a surrounding that is healthier, more pleasant and diverse. Sustainable development goals help create surroundings that are fair, accessible, resilient and contribute to the balance of economic, environmental and social aspects of sustainable development. Because the project is meant to be transferable to other cases in the Netherlands as well, the project is relevant to many people and could help create more sustainable, resilient and liveable urban environments.

Academic relevance
Big efforts have already been made in designing new neighborhoods in a circular and sustainable way concerning people planet & prosperity. However, a big challenge lies in the neighborhoods that have already been built: they are much more complex. These neighborhoods involve many stakeholders and need to be transformed instead of newly developed. Also, there is often a lack of space. Every context of a project is different and thus often asks for custom made solutions. By analyzing specific neighborhoods in detail and combining existing scientific knowledge, new solutions and approaches are developed that might be useful for other locations as well, looking at differences and similarities. This could help taking steps towards a more sustainable built environment in the Netherlands. Also, the project can help making steps in developing new design approaches for transforming existing neighborhoods to make them climate adaptive and more liveable. These approaches can be helpful for urban designers and the people they cooperate with like municipalities, water boards and engineers.

Professional relevance
This project is approached from the viewpoint of urban designers but along the process other disciplines came along as well. To begin with, this research is carried out in cooperation with AW groep, an engineering company. Their viewpoints have influenced the project and the result could help their field of expertise. Furthermore, in the research a lot of contact was made with the municipality of Delft and the waterboard of Delfland. They were able to offer useful information for the project but were interested in the project themselves as well. Like discussed in the conclusion of this thesis, the role of urban designer is often integrating knowledge of different professions. Therefore, this research is useful for different kind of professions besides urban planning and urban design, concerning climate adaptation in urban areas.

9.2 Ethical considerations

The ethical relevance of the project is that it strives for creating a sustainable living environment for now and for the future. This means a healthier microclimate and protection against climate change. Creating this in public spaces will influence many users. Since this project only deals with adaptation in public areas, it is important that the changes made, are considered carefully for each stakeholder. Public space is accessible to everyone and should have a positive influence on everyone. In order to create a redesign that does not only adapt to climate change, but is also fair, increases a healthier environment and more liveable environment, the SDGs and liveability criteria were used. Not all aspects are equally used in the project, but they did help to make choices in the redesign that carefully considered different stakeholders. Restorative spatial justice and the rights of the planet have inspired the project to integrate the SDGs and liveability criteria into the project. Further research could be carried out to assess the redesigns better, concerning all aspects of sustainable development and liveability by doing case studies. Due to the time limit and scope of this project, this thesis focused on using liveability and sustainability as tools for making a climate adaptive redesign.

9.3 Approach

This research started with a theoretical framework that came out of the motivation for this project. This theoretical framework has set the guidelines for the entire thesis. The theoretical framework has led to the design tools that make this project very specific. For this project, climate adaptation measures from the municipality of Delft, Liveability criteria from David Sim and the SDGs from the UN form the basis of the design process. These tools were selected, to show a more complete way of designing for climate adaptation. Climate adaptation is not only a technical solution that has to be implemented to be ready for the effects of climate change; they create possibilities to improve liveability in the neighborhood and contribute to the sustainable development goals. The data used in this thesis are mainly theoretical papers, pdok data, data from PBL and CBS, the klimaateffecten atlas, and many documents from the municipality of Delft. The hardest part was not finding the data, but combining it in an effective way. A lot of data has been used in the process but not all data was necessary to be displayed to express the message of the thesis. A careful selection has been made to answer the research questions. It is important to realize that a different set of data and tools would have led to a different thesis with different outcomes. Therefore, when using the thesis for further research carefully consider the sources used and be critical about the way they are used. Due to the time scope, generalizations have been made based on the data that could be worked out further, like the water and green analyses. They have been made from the viewpoint of an urban designer, but could be worked out much better by landscape architects, biologists and water managers.

9.4 The relation between research and design

The design in this project was greatly influenced by the research done in advance: the literature research, site analyses and the use of design tools. However, the design which started halfway the process has had a big influence on the way the research was shaped in the thesis. Along the design, the use of the tools became clear and arguments were found to structure the theory in such a way that they support the designs made. The iterative research and design process was very important in this project, because the design process was shaped in a different way, by making use of different tools to show more aspects of urban design then just making a neighborhood climate adaptive. The design is an important component of this project; the research location and the design process make the project specific and have added conclusions to the research that would not have been found without making designs.

9.5 Viewpoints in the project

The use of the sustainable development goals and the liveability criteria in the project, besides the climate adaptation measures, are meant to represent multiple viewpoints in the research. The main goal of the project is to show how existing neighborhoods can become climate adaptive. The reason for using liveability criteria and sustainable development goals as design tools, is because urban areas are dealing with many people and little space. The philosophy of this thesis is that by using these tools, the redesign will be better for people planet and profit than if they were not used. However, the different stakeholders do not yet play a very important role in this project and could be researched further. The goal of the thesis was finding out a way to design with the intended design tools and make conclusions based on the outcomes to answer the research questions. A very interesting addition to this project could be to investigate from different points of view from different stakeholders, how the liveability criteria and sustainable development goals would affect them differently. Other interesting additions could be researching separate goals and criteria and completely make a design from one viewpoint. Afterwards comparing these different designs

from one viewpoint only could give interesting insights in the compromises that are made when designing with an holistic approach as was done in this project.

9.6 The relation to the master track

The project relates to many different topics of the research program of urbanism. It relates to Planning Complex Cities in a way that it investigates policymaking and the spatial impact of this. It also looks at the SDGs and can reflect on spatial justice. The project also relates to Urban fabrics since it researches the local scale by designing and looks at the bigger system and scale at the same time. The relation between public and private is a very interesting topic in the project since there are many stakeholders involved and influences the number of interventions that can be done. Urban ecology also forms strong relation to the project since the blue and green are tightly connected and the research will focus on nature-based solutions. The project would not directly be placed in the Transitional territories' studio, since the mega scale will not be as prominent in this project. However, the outcomes of this research could be interesting to be used for other projects in Transitional territories since they also deal with the relation between nature and the built environment.

9.7 Scope of the research

The scope of the research focusses on the Netherlands, the location of the research by design part is about the Abtswoudse polder in Delft. The topic of the research is on the urban water cycle, focusing on existing neighborhoods and climate adaptation. An important component in the research and design is using the sustainable development goals set up by the United Nations and the way they are used in practice by AW groep. Other important components are the climate adaptation measures from the municipality of Delft and the liveability criteria by David Sim. The set of design tools are very specific for this project and this approach could be transferred to other cases as well. The outcomes of the research are specific for the Netherlands and could be used for comparable cities in the Netherlands with the same types of neighborhoods. An important condition to take into account when doing so, are the soil and water properties, which determine the types of measures that could be taken. The research does not yet look very deep into all aspects of sustainability and liveability and this is something that could be researched further. Also, an interesting follow up research could be on looking at the cases form one specific sustainability goal or liveability criterium. Comparing different outcomes could give insight on where they overlap and where they differ.

In the end the decision was made to select one neighborhood in the Abtswoudse polder to make a redesign. Earlier on in the project five locations were selected that were brought back to three later on. The choice to do more neighborhoods first was to make the outcomes of the research more general as different locations could be compared. The decision to work out one location in the end in more detail was made very late. This way the entire research was set up to make the approach of the research and design process transferrable to multiple locations. The neighborhood identification and the location selection paragraph are useful to look at when researching other locations and making them comparable to the outcomes of this research. Because there was only one location worked out in the end, this could be done in more detail and the tools were better tested as a whole design instead of only separate interventions. This has helped to understand how the different tools work on different scales and how the redesign can contribute to the bigger scale water and green system.

9.8 The project and the pandemic

This thesis is made during the corona pandemic, from the beginning until the end. The pandemic has influenced the way in which the project was carried out. On school education was hardly possible and also field trips were harder to organize. Interaction with other students and exchange of ideas and knowledge is something that was being missed the most. However, the pandemic has also given new insights in the way our way of life. Being locked up in our houses made us realize how important our direct surrounding is and how much it influences our well-being. The value of close-by nature and qualitative public spaces have become much more prominent. Also, people in the Netherlands have been making more use of slow traffic means. People are biking and walking much more than before the lock downs. The focus of this thesis to improve liveability and use nature-based solutions while adapting to climate change, could be appreciated more by people now that the pandemic has happened, because they are more connected to their home and direct surroundings.

9.9 Digital and physical designing

As this project was made during several lockdowns, the computer has played a more prominent role than ever. Even mentor meetings were online and made it hard to sketch around the table. This way it was sometimes hard to take the project off the screen and design in a physical way like we would normally do. Printing maps and sections and sketching over them have eventually helped to design faster and get things on paper. Another tool that has helped to get more insight in the project was making models of a location in the project on different scales (1:200 and 1:100). This way the spatial relations where more experienceable and helped making decisions in design. Also, site visits and other excursions in the last few weeks (appendix) have helped to get more grip on design decisions and their effect on spatial experiences. Taking the project off the computer at times has played a crucial role in improving the designs and could have been done more and better in further research.





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Appendices

11.

1. Fieldtrip references
2. SDGs and measures overview
3. SDG assessment overview
4. Klimaateffectenatlas maps

Leiden

1.

Schilperoortpark

Project information

Studio Hartzema & EDM Tuin en Landschap
Leiden Bio Science Park
2020



PLANKAART SCHILPEROORTPARK LEIDEN











Pictures taken by author during a field trip to Leiden at the 27th of May 2021





Utrecht

1.

Maximapark

Project information

West 8
Leidsche Rijn Utrecht
2011









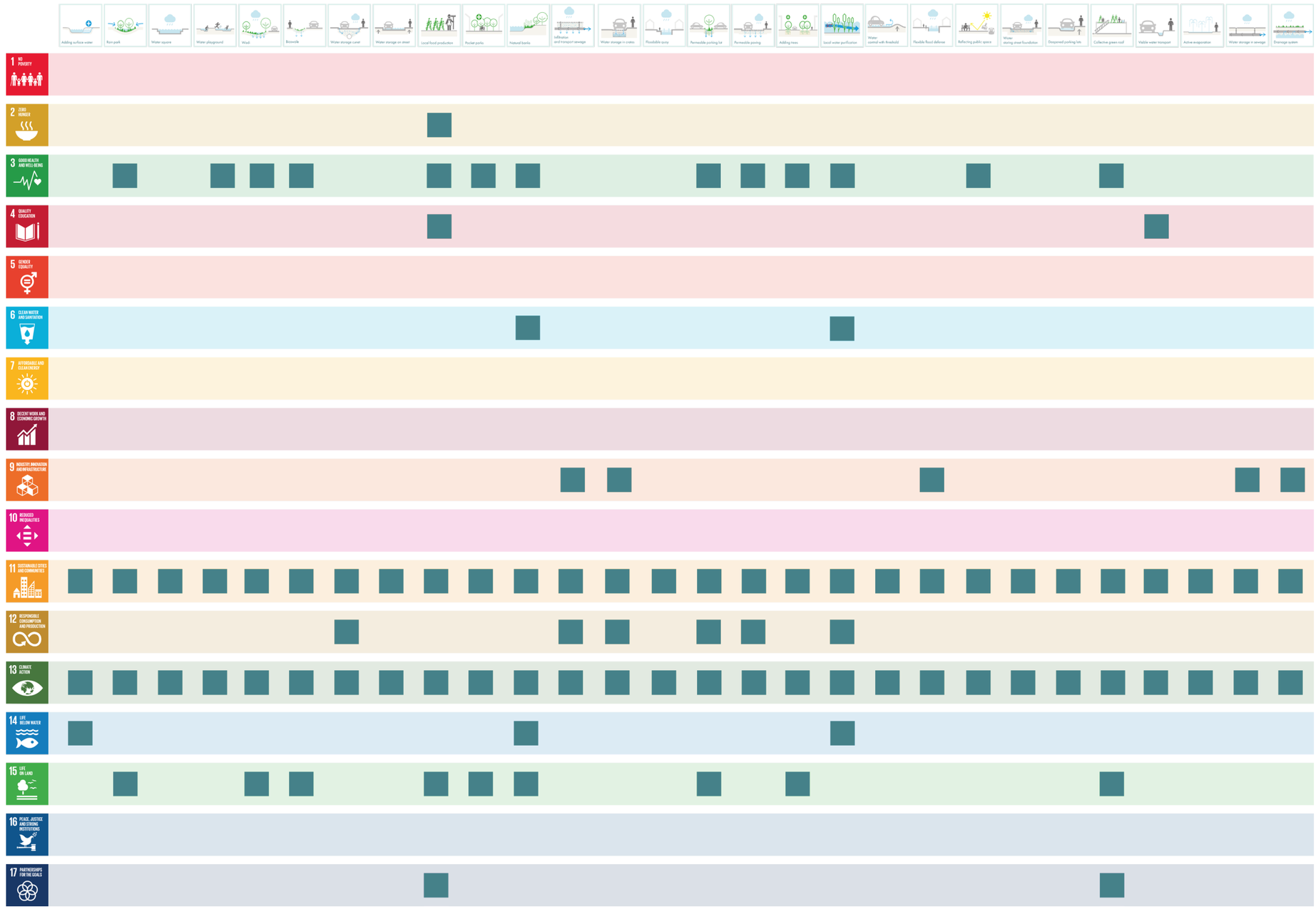


Pictures taken by author during a field trip to Utrecht at the 3rd of July 2021



Overview

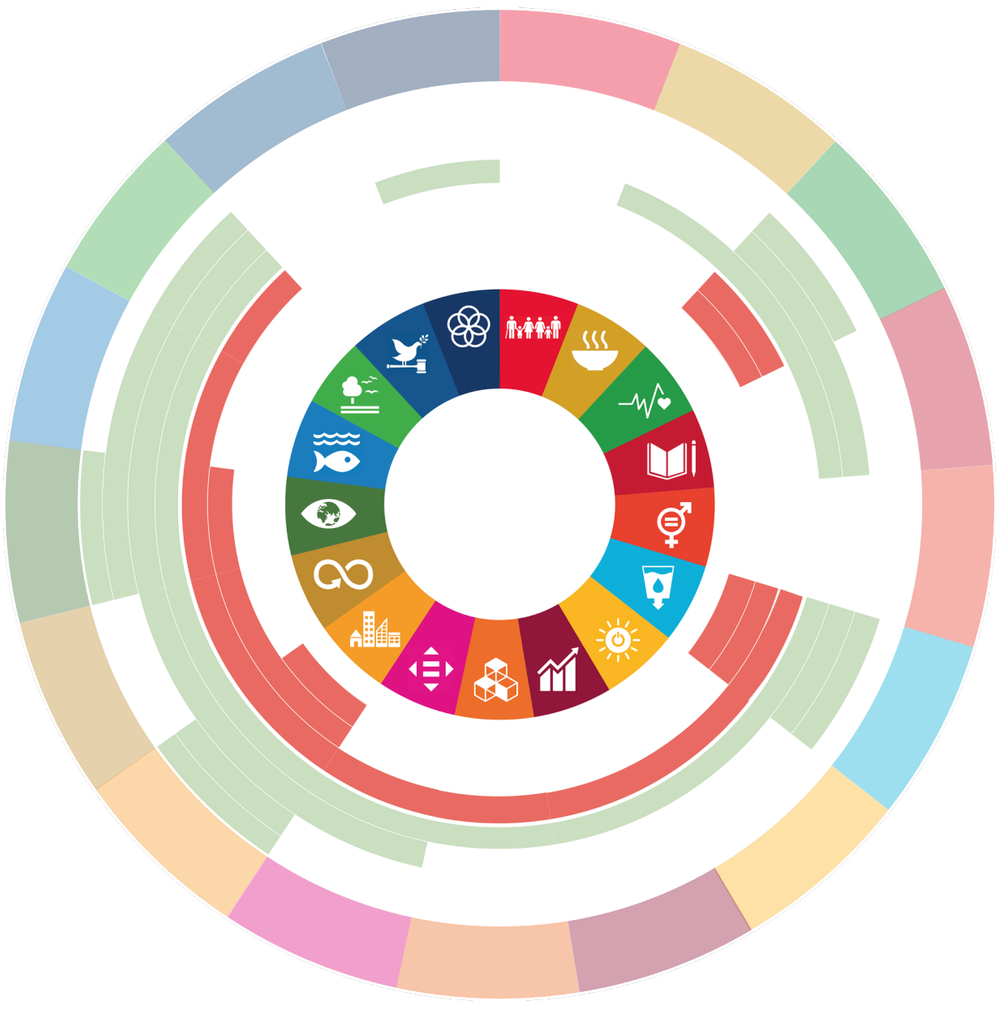
2. SDGs & measures



Overview

3. SDGs impact wheel

Elaboration on the SDG-SWOT analysis for the selected neighborhood in Voorhof illustrated with the SDG impact wheel.



SDG impact wheel Voorhof

	Potential positive impact	Potential negative impact
1. No poverty		
2. Zero hunger	Stimulate local food production to raise awareness and create local loops	
3. Good health and well-being	Healthy micro climate, stimulate activity, prioritize slow traffic	Car oriented design, reduce green, unhealthy micro climate
4. Quality education	Create room for discoveries, inform about interventions and make them visible	Hide interventions from view
5. Gender equality		
6. Clean water and sanitation	Stimulate water flow, local water purification, local water cycle, infiltration	Water runoff, water contamination
7. Affordable and clean energy	Energy transition integrated in design, flexible design for transition, renewable energy use in realization	Unrenewable energy use in realization, energy transition not in design
8. Decent work and economic growth	Realization and maintanance by local companies and workers	
9. Industry, innovation and infrastructure	Accessible neighborhood, water managing infrastructures	No redevelopment
10. Reduced inequalities	Accessibility for all users	Not accessible for all users
11. Sustainable cities and communities	Qualitative public space, urban green, adapted to climate change, diversity of public space	Poor quality of public space, lack of green, prone to heat and water stress, no diversity of public spaces
12. Responsible consumption and production	Minimallize material use, reuse materials, soil balance, biobased materials	Use new materials, create waste
13. Climate action	Decrease heat and water stress, improve sponge capacity, make room for green	Increase paved areas, less room for green
14. Life below water	Natural river banks, purifying vegetation	Hard water quays, water contamination, disturb natural life
15. Life on land	Create more green, use ecological network principles, leave room for spontaneity	Reduce green, disturb natural life, maintain every bit of nature
16. Peace, justice and strong institutions		
17. Partnership for the goals	Neighborhood participation, collective facilities	

Delft

4. Klimaateffecten atlas maps

Maps from the “Klimaateffecten Atlas” used in the project for the location selection and problem identification (Klimaateffectenatlas, n.d.)

Water percentage

- < 1 %
- 1 - 2,5 %
- 2,5 - 5 %
- 5 - 10 %
- > 10 %



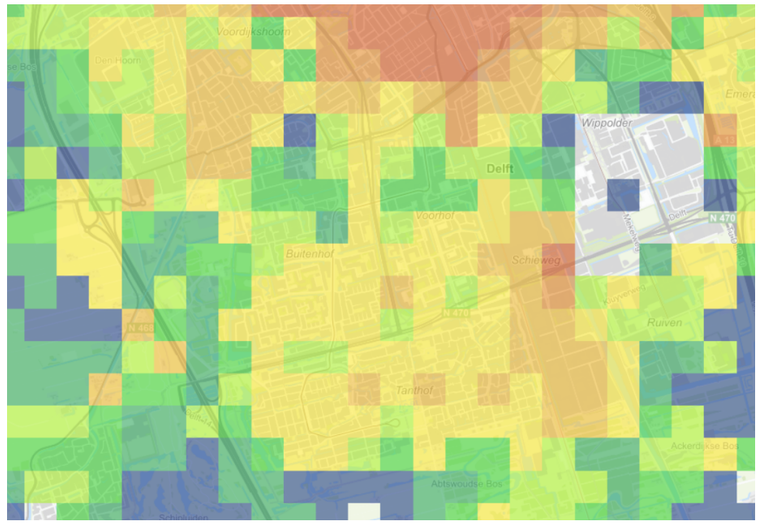
Neighborhood types

- Historische binnenstad
- Stedelijk bouwblok
- Vooroorlogs bouwblok
- Volkswijk
- Tuinstad laagbouw
- Tuinstad hoogbouw
- Naoorlogse woonwijk
- Bloemkoolwijk
- Hoogbouw
- Vinex
- Vernieuwd
- Villa
- Bedrijf



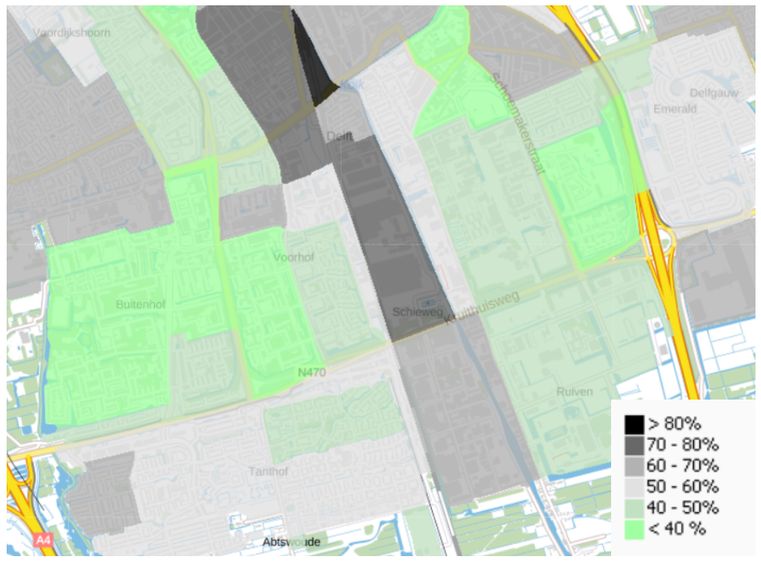
Average highest ground water level below ground level

- < 0,2 m
- 0,2 - 0,4 m
- 0,4 - 0,6 m
- 0,6 - 0,8 m
- 0,8 - 1 m
- 1 - 1,5 m
- 1,5 - 2 m
- > 2m



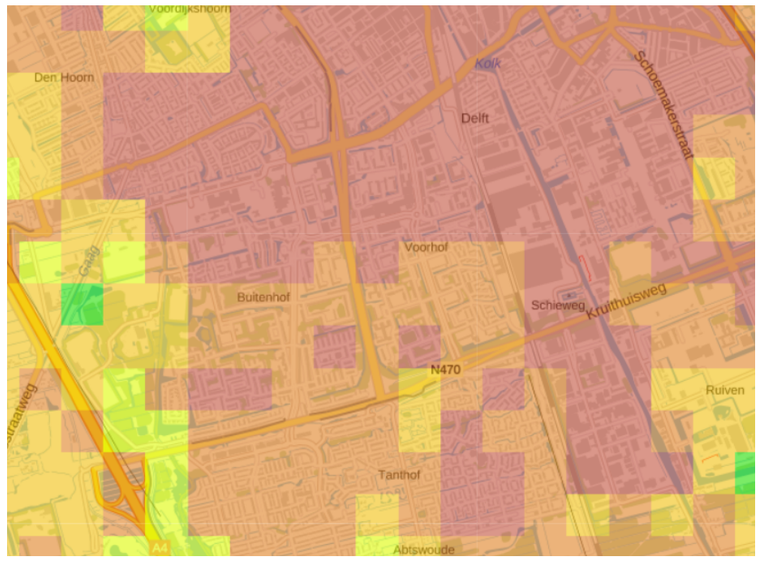
Pavement percentage

- > 80 %
- 70 - 80 %
- 60 - 70 %
- 50 - 60 %
- 40 - 50 %
- < 40 %



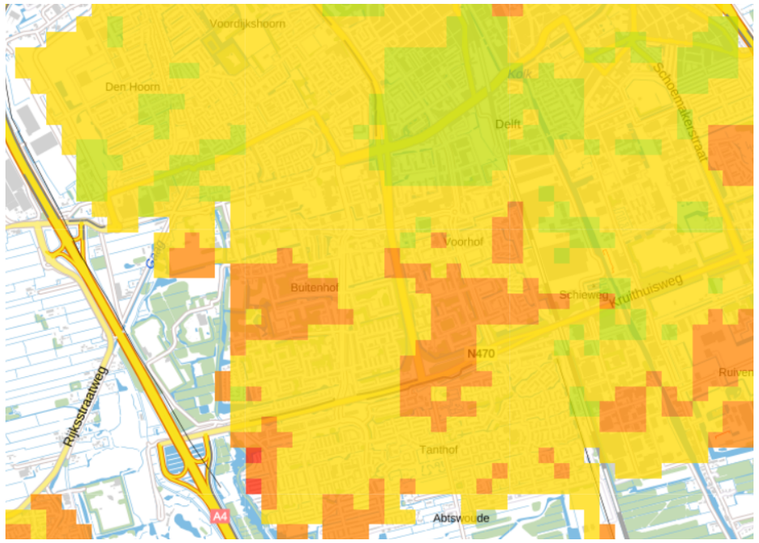
Average lowest ground water level below ground level

- 0,6 - 0,8 m
- 0,8 - 1 m
- 1 - 1,5 m
- 1,5 - 2m
- > 2m



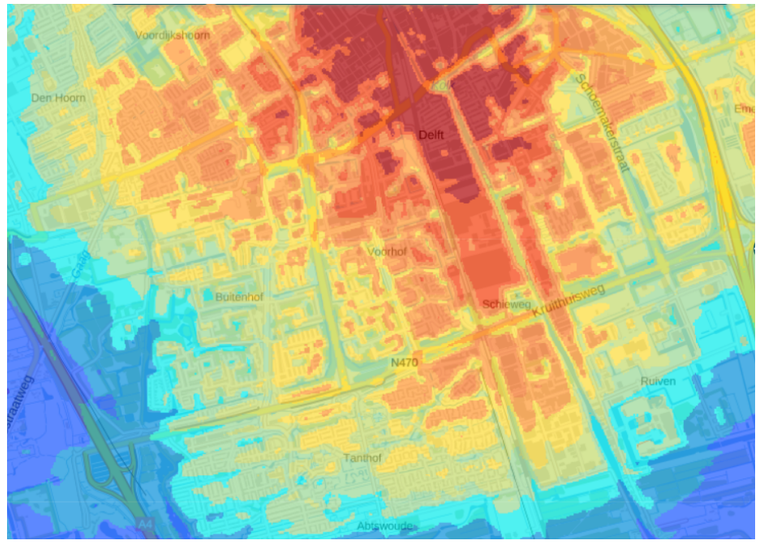
Subsidence

- Not sensitive
- 1 - 10 cm
- 10 - 25 cm
- 25 - 50 cm
- 50 - 100 cm
- > 100 cm



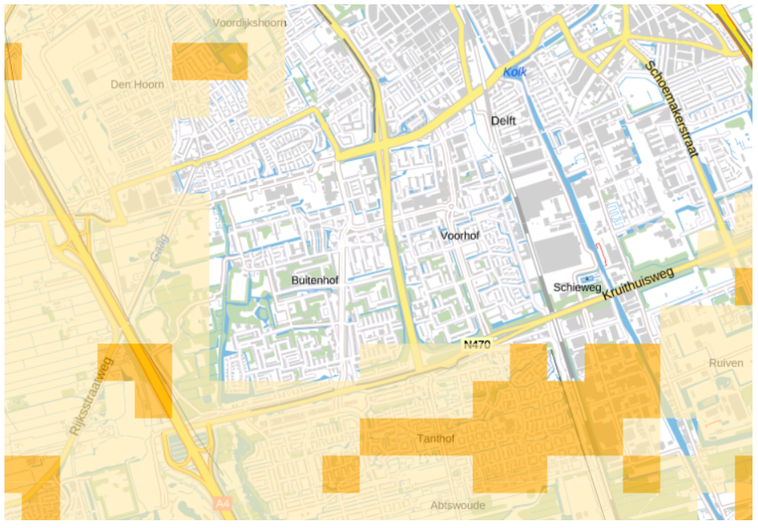
Heat island effect

- 0 - 0,2 °C
- 0,2 - 0,4 °C
- 0,4 - 0,6 °C
- 0,6 - 0,8 °C
- 0,8 - 1 °C
- 1 - 1,2 °C
- 1,2 - 1,4 °C
- 1,4 - 1,6 °C
- 1,6 - 1,8 °C
- 1,8 - 2 °C
- > 2 °C



Risk on drought stress

- Low
- Medium
- High



Water depth short rainfall 1:1000 year

- 5 - 10 cm
- 10 - 15 cm
- 15 - 20 cm
- 20 - 30 cm
- > 30 cm



Heat stress caused by warm nights

- 1 day
- 1 week
- 2 weeks



Green percentage

- 10 %
- 10 -20 %
- 20 - 30 %
- 30 - 40 %
- 40 - 50 %
- > 50 %

