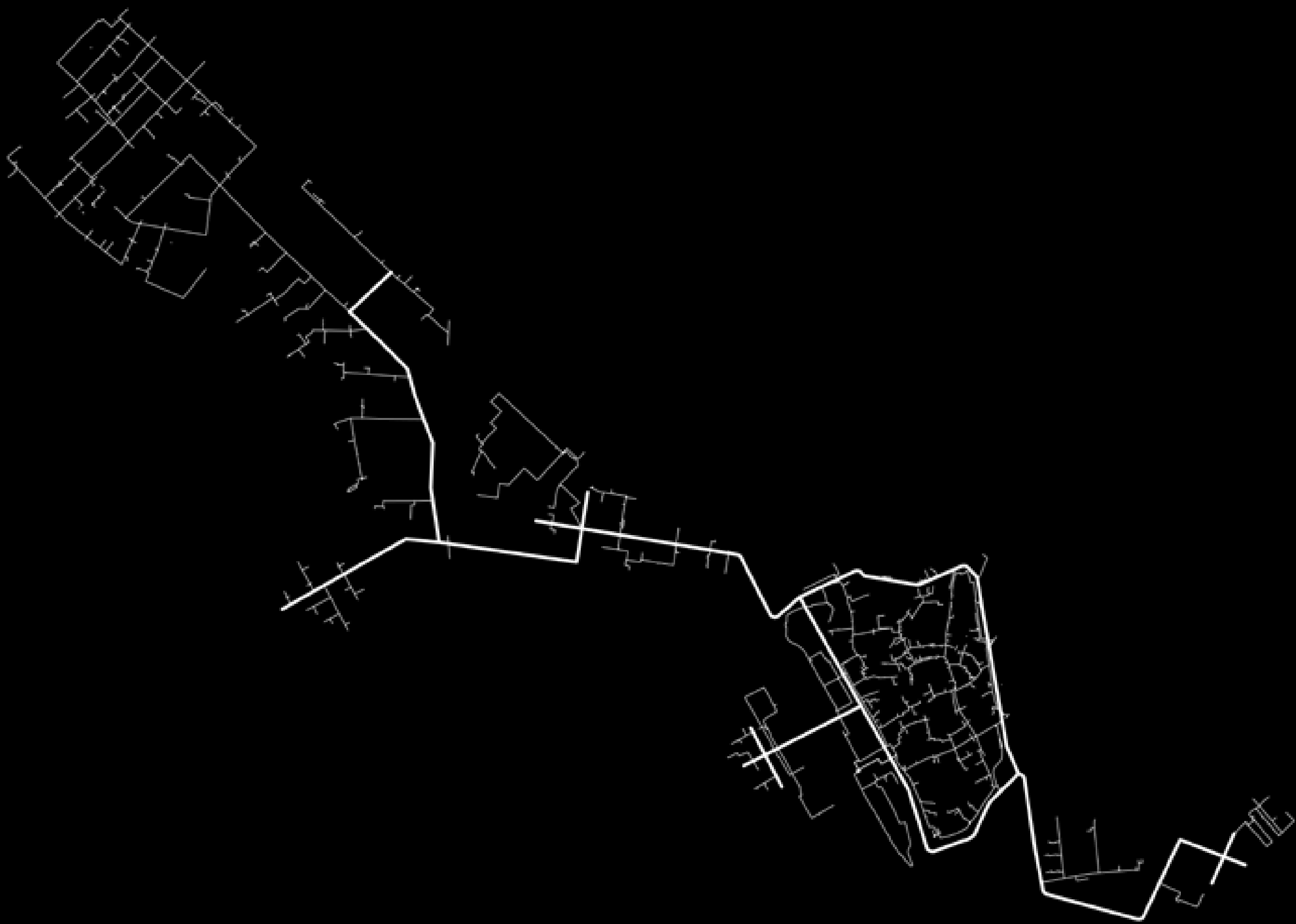
BRIDGING UTRECHT

INFRASTRUCTURE AS STRATEGY



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INFRASTRUCTURE AS STRATEGY

Exploring in what way a landscape design can contribute
to the implementation of a district-cooling network
in relation to the existing infrastructures in the city of Utrecht

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PREFACE

When we started the master Landscape Architecture our mutual ambition was to combine our practical backgrounds with landscape architectural research. During the courses of the master we both focused on this ambition and we strove to take position as landscape architects. The ambition to combine research and practice extends to this thesis work.

Our fascination for the case of infrastructures in Utrecht originates from a project we work on with Happyland Collective. Happyland Collective is a professional collective of spatial designers, which we founded together in 2011. The bottom-up approach of the collective was the reason for inhabitants to involve us in the Oosterspoorbaan project in Utrecht. This project is a local initiative to transform the southern part of an old railway into a valuable place for the people of Utrecht. This project was our incentive to make the infrastructures in Utrecht our case for our landscape architecture master thesis.

We saw this thesis as an opportunity to explore to what extent and in what way a landscape design can contribute to the implementation of a district-cooling network in relation to the infrastructures in the city of Utrecht.

The results of the thesis can serve as an inspiration for landscape architects, researchers, educators, and other interested parties to broaden their view. The thesis can help the synthetic thinking processes concerning the developed values, the project area or the related challenges and solutions.

This report has partly been revised during a completion phase, because the first examination was not satisfactory. During the completion phase we rewrote the introduction, reflection on the thesis phases, reasonings and considerations, reflection on data, and final conclusion chapter. It is important to note that the goal of the completion phase was not to make this thesis work a good scientific product, but to make it a passable product in the light of the Msc standards.

Firstly we would like to thank Paul Roncken for the feedback and input he gave us during the entire thesis process. Secondly we would like to thank professor Adri van den Brink for his helpfulness during the completion phase and our second examiner Marlies Brinkhuijsen. And finally we would like to thank the experts that have given us their opinions, information and support that helped to refine the ideas and strengthen the content of this project.

Marie Baartmans & Marijn P. Struik

SUMMARY

In the light of the necessity of CO2 emission reduction worldwide we looked at the energy use in the Netherlands. Looking at the energy use in the Netherlands utilitarian buildings cause 77.6% of the total CO2 emission (CBS, 2014; Stedin, 2013). The largest part (30%) of the total energy use of utilitarian buildings in the Netherlands is used for cooling and heating (Van den Dobbelsteen, 2013). In this thesis we chose to focus on cooling energy production, because this is possible to connect to natural sources, as they have a lower temperature.

A district-cooling network supplied by renewable sources is one possible solution for renewable cooling energy production. We chose this option as the focus of our research, because a district-cooling network offers the possibility to connect many different renewable sources together for a renewable cooling energy production. As we conduct our research in the context of a landscape architecture master education we will explore the implementation of a district-cooling network supplied by renewable sources in a spatial setting. For this implementation we selected the case of Utrecht, because it has a growing demand for cooling in relation to an ambition for CO2 emission reduction (Harting and Van der Weide, 2013). This case constitutes the spatial problem of 'how to implement a district-cooling network in the urban fabric of an existing city?'

The knowledge gap that we addressed with this research is that there is no research done on the implementation of a district-cooling network in relation to existing infrastructures from a landscape architectural point of view. We want to research the topic from a landscape architectural point of view, as we think landscape architecture can contribute in terms of designing for the integration of systems with the existing urban landscape.

The objective of this research was to explore in what way a landscape design can contribute to the implementation of a district-cooling network in relation to the infrastructures in the city of Utrecht. Based on this objective we formulated the following general research question and specific research questions as the main focus of the research: '*In what way can a landscape design contribute to the implementation of a district-cooling network in relation to the infrastructures in the city of Utrecht?*' The three specific research question that are connected to the mapping, bundling and designing phases of the thesis are described in paragraph 1.2.

The essence of landscape architecture evolves around synthesizing complex problems and their possible spatial solutions. Dealing with this complexity would render quantitative research inadequate (Creswell, 2009). In order to address the complex problems we chose to conduct a qualitative research (Creswell, 2009).

In this thesis we combine research and design in the form of research- or evidence-based design. Evidence-based design is 'a process for the conscientious, explicit, and judicious use of current best evidence from research and practice in the making of critical decisions about the design of each individual and unique project' (Hamilton and Watkins, 2009 in Deming and Swaffield, 2011, p. 239).

The case of Utrecht constitutes coherence between the district-cooling network and existing infrastructures in the city. The prepositions of landscape infrastructures fit our topic well as it matches the landscape architecture field with the topic of a large-scale infrastructural implementation. Our choice for Bélanger's work on landscape infrastructures as a compass allows us as landscape architects to interfere with the field of civil engineering. We used the thesis work on landscape infrastructures by Pierre Bélanger (Bélanger, 2009; Bélanger, 2010; Bélanger, 2013) to guide our thesis process. His work gives a method on how the interaction between infrastructures can be defined, from which we built further and on which we reflected during our process.

In the mapping phase (chapter 2) we explored the current infrastructures in Utrecht. We mapped them according to the five biophysical systems of Bélanger: water resources, waste cycling, energy generation, food production, and mass mobility. The final result of the mapping phase was a thorough knowledge of the existing infrastructures in Utrecht. We based the mapping phase on data and maps from mostly official organizations and used additional (unrecorded) interviews with experts for confirmation. The outcomes of this process made for the best possible data under the circumstances.

In the bundling phase (chapter 3) we described the coherence between the district-cooling network and the relevant existing infrastructures in Utrecht. The infrastructures from the mapping phase that we thought could be connected to the district-cooling network are fast- and slow traffic mobility, surface water, and thermal energy storage systems. We also included the problems and opportunities that arise when seeking this coherence concerning surface- and groundwater pollution.

The design challenge we formulated based on the mapping and bundling processes was to explore how the development of a district-cooling network supplied by renewable sources can cohere with existing infrastructures. We wanted to research where and how this network can be implemented and in what ways the network can be related to road infrastructures, slow traffic mobility, and renewable sources, like thermal energy storage, and cooling from surface water.

We designed a strategy for the development of a district-cooling network supplied by renewable cooling sources. This collective system serves the demand for cooling of office buildings, educational buildings, shops, and industries in the city of Utrecht. The district-cooling system consists of a main distribution pipeline, thermal energy storage clusters, surface water sources and connecting hubs. The cooling supply consists of cooling energy gained from groundwater by means of thermal energy storage systems and cooling energy gained from surface water by means of deep water shafts. These systems are renewable and contribute to solving ground- and surface water pollution.

The answer to the general research question is that we think a landscape design can contribute to the implementation of a district-cooling network in relation to the infrastructures in the city of Utrecht by spatially integrating these systems. For example the main distribution pipeline of the district-cooling network can be spatial integrated with road infrastructures (paragraph 3.2). This spatial integration can be used to solve other problems as well, such as fixing missing links in the slow traffic mobility network or optimizing the surface water quality in the inner city (chapter 4).

The research we conducted was not valid or reliable, which has severely lessened the siginificance of the outcomes. The discussion of significance, validity and reliability of the outcomes, and reflections on the process of the research and the use of landscape infrastructures by Pierre Bélanger as a compass are described in paragraph s 5.2 and 5.3.

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1.1 TECHNICAL AND SPATIAL PROBLEMS

Societal trends as a context
One of the major global issues of the past decades is climate change. Globally the temperatures are increasing, the polar ice masses are melting, and sea levels are rising. The cause for these changes is the emission of greenhouse gases, the most significant of which is Carbon Dioxide (CO2) caused by the use of fossil fuels (IGES Ltd, 2012). The temperature of the surface has globally increased by 0.74 °C in the twentieth century, and it will probably continue to rise by 1.1 to 6.4 °C according to the Intergovernmental Panel on Climate Change (IPCC) of the United Nations (IPCC, 2014).

The CO2 emission is globally still increasing, though many OECD countries show a emission reduction and the world wide financial crisis has caused a two-year dip. The 'global CO2 emissions increased by 3% in 2011, compared to the previous year, reaching an all-time high of 34 billion tonnes' (Olivier, Janssens-Maenhout, and Peters, 2013, p. 9). The past ten years the average increase was 2.7% of annual CO2 emissions. 'So, with a 3% increase in 2011, global CO2 emissions resumed this decadal trend' (Olivier, Janssens-Maenhout, and Peters, 2013, p. 9).

Many countries, Including the Netherlands, have been working together to reduce the emission of CO2 and other greenhouse gases. A global scheme to set 'internationally binding emission reduction targets', the Kyoto Protocol, is now in its second commitment period (2012 to 2020) with a goal of reducing 18% of the emission of greenhouse gases compared to the levels of 1990 (United Nations Framework Convention on Climate Change, 2014). The reduction of CO2 emissions is necessary, because slow down and eventually stop the global climate change.

Societal problem as the focus of the research
In the light of the necessity of CO2 emission reduction worldwide we looked at the energy use in the Netherlands. The choice for zooming in on the Dutch context is a personal one, as we consider this our future work area and want to deepen our knowledge about it. Looking at the energy use in the Netherlands utilitarian buildings cause 77.6% of the total CO2 emission (calculation: in 2012 the total CO2 emission was 165.300 million kilograms of which 128.300 million kilograms was caused by stationary sources) (CBS, 2014; Stedin, 2013). According to Prof. Dr. Ir. Andy van den Dobbelsteen, Head of the Department of Architectural Engineering and Technology and Professor of Climate Design and Sustainability at TU Delft, the largest part (by his estimation 30%) of the total energy use of utilitarian buildings in the Netherlands is used for cooling and heating (Van den Dobbelsteen, 2013). He estimates that in modern utilitarian buildings the share of cooling and heating is equal, so both 15% of the total energy use (Van den Dobbelsteen, 2013). In these lines of reasoning we chose to focus on cooling/heating of utilitarian buildings, because it covers the largest part (30%) of the largest CO2 emission cause (77.6%) in the Netherlands.

In this thesis we chose to focus on cooling energy production, because this is possible to connect to natural sources, as they have a lower temperature. Another reason for focussing on cooling energy is the choice for the case of Utrecht, which in our process came long before we formulated our topic. This chosen case has a cooling demand, and heating is already supplied in a sustainable way in the case area. So we focus on cooling energy in our research.

Possible solution as the focus of the research
A district-cooling network supplied by renewable sources is one possible solution to the problem described in the previous paragraph. We chose this option as the focus of our research, because a district-cooling network offers the possibility to connect many different renewable sources together for a renewable cooling energy production. Also, as described before, we started our thesis process with a case and the district-cooling network is needed in this case. One year later the storyline of the thesis is different, but the process was such that the need for a district-cooling network was constituted by the case. We will explain the workings of a district-cooling network supplied by renewable sources by means of the example of the Zuidas reference project in Amsterdam (Gemeente Amsterdam, 2011; Roelen, 2009). This is the only developed district-cooling network in the Dutch context at the moment of writing this thesis.

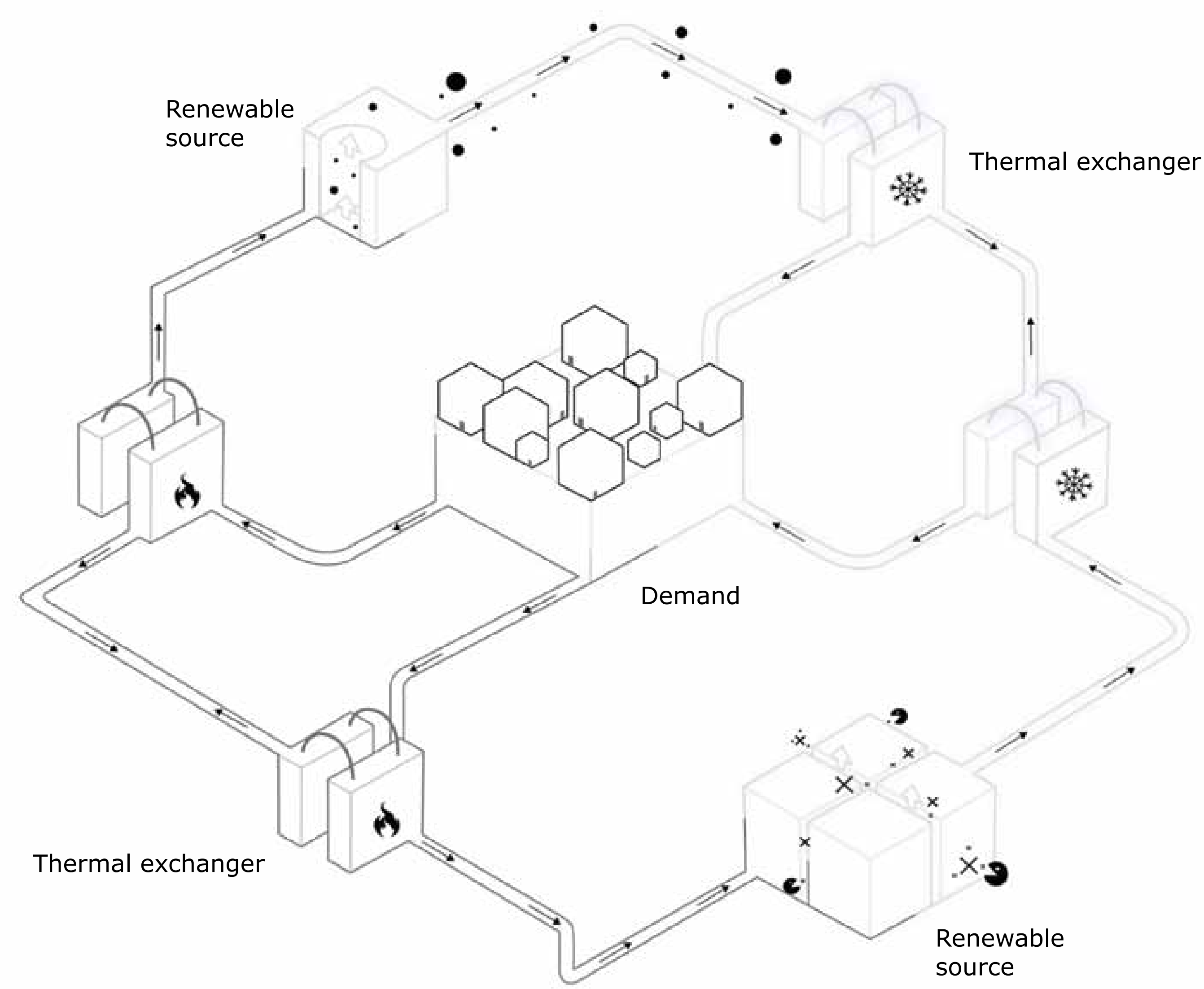


Figure 3. Workings of the district-cooling network fed by renewable sources

A district-cooling network contains three main elements: a client, a distribution network and a source. The client can be any building with a cooling demand for climate control (figure 3). In the case of the Zuidas the client is a group of companies on the Zuidas that have developed the district-cooling network together (Gemeente Amsterdam, 2011). The distribution network connects the clients to the cooling sources. This network makes a collective system possible, which according to developers of the Zuidas project is by definition more efficient than a collection of individual systems, because the peak levels can be levelled out in a collective system and many individual backup installations can be replaced by one main backup system with a lower energy usage (Gemeente Amsterdam, 2011). The sources that produce cooling energy for the network could be, for example, electricity that can power air conditioning, heating energy that can be transformed to cooling energy through a process of adsorption, or sources that directly produce cooling energy. In the Zuidas reference project the district-cooling network is supplied by a renewable energy source: surface water. The cold water from a deep water body (Gemeente Amsterdam, 2011) is used in this case for extracting the cooling energy that is transported back to the clients through the distribution network.

The outcomes of using a district-cooling network supplied by renewable sources seem very promising. In the Zuidas the district-cooling system supplied by surface water sources has caused a 75% reduction of CO2 emissions in comparison to the original cooling system (Roelen, 2009).

Linking problem and solution to spatial organisation
In this thesis we focus on a district-cooling network supplied by renewable sources as described in the previous paragraphs. As we conduct our research in the context of a landscape architecture master education we will explore the implementation of a district-cooling network supplied by renewable sources in a spatial setting. For this implementation we selected the case of Utrecht, because it has a growing demand for cooling in relation to an ambition for CO2 emission reduction as we elaborate further in this paragraph.

Experts Arno Harting, Environmental Advisor Sustainable Building and Energy at Gemeente Utrecht, and Sieb van der Weide, Coordinator of Underground Infrastructures at Gemeente Utrecht, both underlined the need for a district-cooling network in Utrecht. They stated there is a current cooling demand (figure 1) in the city of Utrecht, which will increase in the future (figure 2) and could be serviced by a collective district-cooling system (see Email Correspondence).

In the current situation in Utrecht clusters of office buildings, educational buildings, shops, and industries are using much energy to produce cooling for their temperature control in summer. As the Municipality of Utrecht has the ambition to become CO2 neutral in 2030 (Gemeente Utrecht, 2012, p. 5) we reasoned that this energy used for cooling will have to be supplied by renewable sources in the future. The vast assignment for Utrecht to become CO2 neutral in 2030 is described by the municipality as 'only possible if the entire scope of energy saving and renewable sources for energy generation are to be deployed' (Gemeente Utrecht, 2012, p. 5). We assume a collective district-cooling system supplied by renewable cooling sources can contribute to the ambition of the municipality.

This case constitutes the spatial problem of 'how to implement a district-cooling network in the urban fabric of an existing city?' We will focus on coherence with existing infrastructures as one possible solution to this problem, because in the case of Utrecht infrastructures are a major feature, causing many issues and dominating the urban realm (Dienst Stadsontwikkeling, 2012a). Infrastructures are defined in this case as 'the basic system of essential services that support a city, a region or a nation' (Bélanger, 2013, p. 69). In a city like Utrecht, in which infrastructures play such a central role, the functioning of the city depends on the state of its infrastructures (Bélanger, 2013, p. 69).

Contribution of landscape architecture
We presuppose that as landscape architects we can contribute to the implementation of a district-cooling network in relation to existing infrastructures in Utrecht in terms of integration. Landscape architecture offers a 'multi-layered understanding of landscape: its spatial structure, visual landscape, history, context, and the underlying ecological, economic and social processes' (Nijhuis, Jauslin, and de Vries, 2012). We presuppose that with this understanding landscape architects can integrate systems with the existing urban landscape. As 'designers can generate meaningful new architectural, urban, and regional forms by integrating the works of the estranged disciplines of architecture, civil and structural engineering, landscape architecture, and biology' (Strang, in Swaffield 2002, p.p. 223). We reflect on our actual contribution as landscape architects to the topic in the final reflection of the thesis (paragraph 5.3).

Knowledge gap
Existing research on district-cooling networks in relation to other infrastructures is done by civil engineering firms such as Arcadis (Arcadis, 2009) or by energy production companies like Nuon in the case of the Zuidas reference project (Gemeente Amsterdam, 2011; Roelen, 2009). This category of research contains mainly qualitative studies focusing on approaches from a perspective on technical development of and energy production by a district-cooling network. What we conclude is that there is no research done on the implementation of a district-cooling network in relation to existing infrastructures from a landscape architectural point of view. We want to research the topic from a landscape architectural point of view, as we think landscape architecture can contribute in terms of designing for the integration of systems with the existing urban landscape as described in the previous paragraph.

Objective and research questions
The objective of this research is to explore to what extent and in what way a landscape design can contribute to the implementation of a district-cooling network in relation to the infrastructures in the city of Utrecht. Based on this objective we formulated the following general research question and specific research questions as the main focus of the research:

In what way can a landscape design contribute to the implementation of a district-cooling network in relation to the infrastructures in the city of Utrecht?

1. What are the existing infrastructures in the city of Utrecht in terms of water, waste, energy, food and mobility?
2. What is the possible spatial and technical coherence between a district-cooling network and the current infrastructures in Utrecht?
3. How can one possible spatial and technical solution for a district-cooling network be implemented in coherence with infrastructures in Utrecht?

Worldview
We both come from a practical background, having studied landscape design at Hogeschool Van Hall-Larenstein and working for two years at various design studios. We started the master landscape architecture in order to find more substantiation for our work as designers. As we made this thesis with a problem centred approach, we suppose we have a pragmatic worldview (Creswell, 2009). Also we were guided by the position of Pierre Bélanger, who describes the need to design, which according to him is by definition a practical act, and states that research is only a precondition to come to a design (Bélanger, 2013, pp. 245, 394, 571). We agree with this described relationship between design and research and it fits our practical backgrounds and envisioned future development as designers well. Also we think that the need to design an intervention in order to connect a district-cooling network to existing infrastructures in Utrecht invites us to be practical. However, we think our practical background and ideas will form a challenge to fit the scientific context and meet the requirements of this thesis work.

Research focus
In this thesis we focus on a district-cooling network supplied by renewable sources as a possible solution for CO_2 emission through the production of cooling energy. This focus constitutes the problem of implementing a new district-cooling network in the existing urban fabric of a city. In order to address this spatial problem we zoom in on the coherence of such a network with existing infrastructures.

These lines of thought that together form the topic are based on the assumption that a district-cooling network is needed. This necessity is twofold: firstly CO_2 emission reduction is vital for a clean environment to which a district-cooling network supplied by renewable sources could contribute, and secondly the demand for cooling energy by utilitarian buildings will probably increase in the future.

1.2 RESEARCH STRUCTURE

However, these assumptions could be found untrue in the future, when for example the demand for cooling decreases as less utilitarian buildings are developed or through the development of new technologies that will render a district-cooling network irrelevant. Thus the assumptions that are the fundament of our topic could change in future and make this thesis less relevant.

Research strategy
The essence of landscape architecture evolves around synthesizing complex problems and their possible spatial solutions. Dealing with this complexity would render quantitative research inadequate (Creswell, 2009). In order to address the complex problems as explained in paragraph 1.1 we chose to conduct a qualitative research (Creswell, 2009).

In this thesis we combine research and design in the form of research- or evidence-based design. Evidence-based design is 'a process for the conscientious, explicit, and judicious use of current best evidence from research and practice in the making of critical decisions about the design of each individual and unique project' (Hamilton and Watkins, 2009 in Deming and Swaffield, 2011, p. 239).

We use descriptive- and projective strategies as described by Deming and Swaffield (Deming and Swaffield, 2011). In the mapping and bundling phases, which should serve as an inventory of the existing infrastructures and explanation of the possible coherence with a district-cooling network and existing infrastructures we will use descriptive strategies. 'Descriptive research strategies produce new knowledge by systematically collecting and recording information that is readily available to the investigator and does not require complex analysis in order for it to be understood' (Deming and Swaffield, 2011, p. 65). In the designing phase of the thesis we will come to one possible solution for the implementation of a district-cooling network in coherence with existing infrastructures, which dictates the use of projective strategies (Deming and Swaffield, 2011, p. 205).

Significance
In this paragraph we shortly describe the significance we presuppose our thesis could have in terms of academic, societal and landscape architectural values.

Academic value
The envisioned academic value of the research is that we want to contribute reflection on the use of research-based-design as a research strategy. And secondly we intend to use the landscape infrastructures concept (paragraph 3.1) as a compass for our research and our contribution will be reflection on this use of compass.

Societal value
In terms of societal value we think we can contribute one possible solution for the implementation of a district-cooling network in relation to infrastructures in Utrecht as an inspiration.

Landscape architectural value
The value of our work for the landscape architectural field could be to show an example of the integration of a large-scale system in an existing urban context.

Validity and reliability
In this paragraph we explain the presupposed validity and reliability of our thesis work. The described validity and reliability as described above have for a large part not been realized during the first phase of the thesis process. The first version of the thesis was unsatisfactory and had to be improved during a completion phase, thus in the current document the validity and reliability of the first version of the thesis and the final version of the thesis are discussed in paragraph 5.2.

We intend to ensure the internal validity ask the participants in our research to confirm our findings (Trochim and Donnelly, 2007, p. 149; in Kumar, 2011, p. 185) or by triangulating our data in order to be able to judge the trustworthiness of the data. 'External validity refers to the degree to which the results of qualitative research can be generalized or transferred to other contexts or settings' (Trochim and Donnelly, 2007, p. 149; in Kumar, 2011, p. 185). This can only be ensured to some extent by keeping 'extensive and detailed record of the process for others to follow and replicate' (Kumar, 2011, p. 185). In order to ensure the reliability of the thesis we should give a detailed description of the process of collection, interpretation, integration and evaluation of the data. Also we should keep an 'extensive and detailed record of the process' (Kumar, 2011, p. 185) and give a clear description of the designer's bias or how and when the worldview described in this introduction chapter has influenced the research.

Structure of the report

This thesis report describes our process and the results of the research. It consists of a summary, introduction (chapter 1), mapping phase (chapter 2), bundling phase (chapter 3), designing phase (chapter 4), and the conclusion, discussion and reflection (chapter 5). In table 1 the report structure is linked to the process phases, and research questions.

The specific research questions will be answered in chapters 2, 3, and 4. The answers to these questions range from a broad investigation of existing infrastructures in Utrecht in the mapping chapter, to a specific selection of infrastructures that can be related to the district-cooling network in the bundling chapter, to a possible implementation of the district-cooling network in coherence with the selected infrastructures in the designing chapter. The content and main methodology of the chapters is shortly described below.

Chapter 1 forms the introduction to our thesis. It describes the technical and spatial problems, focus on possible solutions, choice of case, research gap, -objective, -questions, -strategy, and the theoretical context of the thesis.

Chapter 2 describes the mapping of the existing infrastructures in Utrecht in terms of water resources, waste cycling, energy generation, food production and mass mobility. As a compass we used the checklist of biophysical systems by Pierre Bélanger (Bélanger, 2013).

The general methods of this phase are literature- and map studies. The information shown and described in the mapping is all that we found and that we could translate to maps, though the data was not collected, interpreted, integrated and evaluated in a structured way. We based the mapping phase on data and maps from mostly official organizations and used additional (unrecorded) interviews with experts for confirmation. The outcomes of this process made for the best possible data under the circumstances. The mapping phase shows more information that we actually needed in the bundling phase.

Chapter 3 explains the selection of infrastructures from the mapping phase that can be related to the district-cooling network. This phase was hard to structure, as it did not really have an underlying methodology. The selection of the infrastructures is done by means of two criteria: (1) an existing infrastructure should produce cooling energy, and (2) an existing infrastructure should be able to accommodate the pipelines of the district-cooling network between the demand areas. We selected surface water, and thermal energy storage as sources and mobility routes as accommodation for the pipeline. The coherence of these systems to the district-cooling network is described in the bundling chapter.

Chapter 4 explains our design, which consists of a strategy, plan elements, and detail design. The main method of this phase is designing based on research, because it forms the core of landscape architecture (Creswell & Plano Clark, 2011, p. 47 in Lenzholzer, Duchhart, and Koh, 2013, p. 120) and it can be used to propose a possible implementation of the district-cooling network in coherence with existing infrastructures. In the design phase we sketched possible options on the scales of the city (1:15.000), the plan elements (1:5000), and details (1:500). These sketches formed the basis for visualizing the outcomes into plans and thus solving spatial issues and strengthening the proposed interventions.

Chapter 5 describes the conclusion, discussion, and reflection of the entire thesis work. The conclusion answers the specific and general research questions, thus explaining the outcomes of the research. Then follows the discussion of implications, significance, validity and reliability of these outcomes. And finally we reflect on the process of the research and the use of landscape infrastructures by Pierre Bélanger as a compass.

Table 1. Schematical image of the research structure

Report structure	Process phases	Specific research questions
Chapter 2	Mapping phase	What are the existing infrastructures in the city of Utrecht in terms of water, waste, energy, food and mobility?
Chapter 3	Bundling phase	What is the possible spatial and technical coherence between a district-cooling network and the current infrastructures in Utrecht?
Chapter 4	Designing phase	How can one possible spatial and technical solution for a district-cooling network be implemented in coherence with infrastructures in Utrecht?

Introducing landscape infrastructures

The case of Utrecht constitutes coherence between the district-cooling network and existing infrastructures in the city. The prepositions of landscape infrastructures fit our topic well as it matches the landscape architecture field with the topic of a large-scale infrastructural implementation. Our choice for Bélanger's work on landscape infrastructures as a compass allows us as landscape architects to interfere with the field of civil engineering. We used the thesis work on landscape infrastructures by Pierre Bélanger (Bélanger, 2009; Bélanger, 2010; Bélanger, 2013) to guide our thesis process. His work gives a method on how the interaction between infrastructures can be defined, from which we built further and on which we reflected during our process.

While searching for literature on landscape infrastructures we found, besides the articles of Bélanger that are written between 2007 and 2012, an article on landscape infrastructures by Gary Strang from as far back as 1996. Despite that Bélanger states that he has formulated the term 'landscape infrastructures' by himself (Bélanger, 2013, p. 444) we see the article of Gary Strang as a starting point. His article gives the first ideas on landscape as infrastructure: 'infrastructures as a type of landscape and landscape as a type of infrastructure' (Strang, 1996). Bélanger gives this idea more body: 'the merger of biophysical systems with contemporary infrastructure is now rapidly becoming the dominant order for urban regions' (Bélanger, 2010). We interpreted this merger of biophysical systems with contemporary infrastructure as the definition of landscape infrastructures. Bélanger himself stated that his work is not yet evolved enough to be a theory, but he states landscape infrastructures can be used as an analytical tool and design strategy (P. Bélanger, lecture TU Delft, May 21, 2013). His work in the form of articles represents, as he states, a 'position that outlines a series of scales, strategies and systems for understanding and influencing urbanization through contemporary patterns, processes and precedents by an absence of geospatial knowledge and geographic thought in the design disciplines' (Bélanger, 2013, p. 51).

Theoretical context of landscape infrastructures

To get an idea about the theoretical context of landscape infrastructures we used literature that Bélanger describes as interrelated writings. Bélanger refers to writings on landscape, ecology, and infrastructure by Alan Berger, James Corner, Richard Forman, Chris Reed, Nina-Marie Lister, Eduardo Rico, Kelly Shannon and Charles Waldheim as important literature on strategies for urban environments and infrastructures (Bélanger, 2013, p. 392). The landscape architecture concepts that we deduced from these writings are, besides landscape infrastructures, 'design with nature' and 'landscape urbanism'. Also we added the concept of 'landscape machines', because we are part of the landscape machine research group of Ir. Paul Roncken from the landscape architecture chairgroup at Wageningen University.

Landscape infrastructures

The concept of landscape infrastructures integrates the two aspects landscape and urbanism by approaching it as one entity. Landscape urbanism, for example, tries to find strategies to deal with these two entities. The concept of landscape infrastructures is described by Bélanger as an approach for designing the synthesis between biophysical systems and contemporary infrastructure towards 'infrastructural ecologies' (Bélanger, 2013). He describes a mapping method regarding space and flows of water, waste, energy, food, and mobility as an instrument that can be used to get a clear overview of the complexity of urban economies. By analyzing landscapes as infrastructures planning strategies can be made to form synthetic landscapes. On the aspect of design Bélanger gives a list of services and performances that are important in a landscape infrastructure design process: 'flexibility, synergies, cross-collaborations, speeds & scales, distribution & disaggregation, and regionalization' (Bélanger, 2013, p. 387-389).

1.3 THEORETICAL BACKGROUND

Design with nature

Design with nature is a concept on regional planning of natural resources in relation to the environment. The landscape architect Ian MacHarg developed his idea during the seventies. In his work ecological planning is done by the use of map overlays. The analysis and comparison of physical natural resources (geology, habitat, water, soil, etc.) detects information through which the best locations and ways to implement social occupation can be discovered (Reed, 2010). Besides his environmental concern Ian McHarg did not pay attention to the relationship between analysis and design (Swaffield, 2002).

Landscape urbanism

In the summary of the Landscape Urbanism Reader by Charles Waldheim landscape is described as the essential organizing model for urban regions (Waldheim, 2006). While reading the book it becomes clear that the discussion of landscape urbanism was developing already, but Charles Waldheim articulated the term 'landscape urbanism' in 1997 (Waldheim, 2006). From an article by Shanti Fjord Levy we deduced that landscape urbanism deals with planning by looking at ecological processes as a basis for urbanism and with designing the social occupation by engaging experimental human scale. The idea of experimental human scale refers to meaning, identity, and sense of place (Fjord Levy et al, 2006). Besides this description James Corner describes a list of methods that need to be included to come to landscape urbanism: 'processes over time, the staging of surfaces, the operational or working method and the imaginary' (Corner, 2006).

Landscape machines

According to Roncken et al, a landscape machine firstly can be understood as a productive landscape that addresses an existing malfunction in a productive landscape (Roncken et al, 2011). Secondly, a landscape machine stimulates nature or maximizes natural processes and can be seen as a state of constant flux. And thirdly, a landscape machine is something that has to be conceptualized, designed and developed in three stages: an initial stage, a growth stage, and a yield stage (Stremke et al, 2012). Besides an interaction with the landscape the concept of landscape machines uses thermodynamics and energy diagrams as instruments to integrate scientific knowledge with design to make a landscape machine more quantifiable. The physical experience of the landscape machine deals with a human involvement towards a future sublime. Which means according to Paul Roncken: 'an aesthetic interaction that is challenging instead of conforming to familiar standards of beautification' (Roncken et al, 2011).

Similarities and differences

In 1960 Ian McHarg presented in his book Design With Nature an ecological method for regional planning and design; ecology as the 'study of the interactions of organisms and the environment' (Forman, 2010, p. 312). In the field of landscape architecture many subspecialties have evolved after that. This shift opened up new trends and combinations, like landscape urbanism, landscape infrastructures, and landscape machines. It is interesting to see that all three concepts described above refer to Ian McHarg and use mapping as an important tool for analyzing data. Another similarity between the four concepts is that they all use ecology as an important corner stone. This generates possibilities to bring nature and society together and develop hybrid forms. However, ecology as the core in these four concepts still gives the possibility to create four different approaches on how symbiotic relationships can be created.

It is clear that the design with nature, landscape urbanism, landscape infrastructures, and landscape machines approaches show that large-scale implementations can no longer be seen as a single aspect. Whereas landscape urbanism, landscape infrastructures, and landscape machines approach a case as a system design, the concept of design with nature focuses more on the physical aspect of ecology. System design is more about the understanding of how the physical situation supports movement by means of flow.

Besides the aspect of ecology it is interesting to take note of when something can be called for example a landscape machine or a landscape infrastructure. Two of the concepts offer a list on how to approach a specific case to come to landscape urbanism or a landscape machine. The concepts of design with nature and landscape infrastructure on the other hand have their own mapping methods to come to a landscape infrastructure or a design with nature strategy.

So what about the aspects of planning and design? Design with nature and landscape infrastructures are more concerned about planning and strategies where landscape urbanism and landscape machines take, besides planning and strategy, even a step further. They offer aesthetical ideas on how to experience the concepts. Landscape urbanism talks about meaning and identity and the concept of landscape machines refers to a future sublime. To conclude, the concept of landscape machines uses instruments on thermodynamics and energy diagrams to make the design more quantifiable.

Critical reflection on landscape infrastructures by others

To get an idea on what other authors say about landscape infrastructures we looked broader than the material that Bélanger perceives as interrelated. In the material that refers to Bélanger we could not find many critical views on the concept of landscape infrastructures. We eventually used an article by Sven Stremke, Paul Roncken, and Riccardo Pulselli and a lecture of Thomas Hauck at the ECLAS 2013 conference in Hamburg as sources to review some perspectives of others on the work of Bélanger.

Sven Stremke, Paul Roncken, and Riccardo Pulselli state in their article that infrastructures cannot be seen as landscape or one entity, because looking at system design networks are just one aspect of a bigger whole (Stremke, et al, 2012). In the lecture by Thomas Hauck at the ECLAS 2013 conference in Hamburg, Hauck explained conclusions of a comparison that was made between the concept of landscape machines, green infrastructures and landscape infrastructures. He questions 'if this new universal landscape pattern is flexible and open enough to incorporate results of democratic decisions that contradict this new order e.g' (Hauck, et al, 2013). Besides this aspect Hauck says that one of the problems of the concept of landscape infrastructures is that the integration of infrastructures does not state 'if they are the most efficient technical and also sustainable solutions' (Hauck, et al, 2013). He concludes that a landscape infrastructure is a functionalistic approach to design; 'this might prove problematic if this kind of infrastructure is not a socially preferred option or perceived as a destruction of the traditional pattern of landscape' (Hauck, et al, 2013). To overcome this situation he arguments to include the aesthetic theory 'land as palimpsest' (Corboz, 1983).

Role of landscape infrastructures in this research

Bélanger states in his thesis that ecology becomes the new engineering (Bélanger, 2013, p. 445). The importance of ecology derives from environmentalism; from this consciousness the idea arises that ecology can be seen as an approach that can deal with big societal problems (Forman, 2010). Therefore the integration of ecology becomes essential for other disciplines like architecture, urbanism, civil engineering and landscape architecture, as they can no longer focus on a content driven profession alone. The method of landscape infrastructures is a strategy for landscape architecture, civil engineering and urban planning to deal with the aspect of ecological engineering of urbanization (Bélanger, 2013, p. 445).

The question that needs to be asked is, 'what do Bélanger's prepositions mean for landscape architects?' (Prof. Ir. D.F. Sijmons, colloquium commentary, May 13, 2013). We try to answer this question as well as possible with the information that we found on landscape infrastructures and its context. We think landscape infrastructures become useful for landscape architecture when constructing symbiotic relationships on a strategic level to contribute to understanding and tweaking patterns and processes of urbanization (Bélanger, 2013). Therefore the method of Bélanger is useful in relation to regional planning. On the aspect of design, which is the core activity of landscape architecture, we need to borrow aesthetics from other concepts, like landscape urbanism or landscape machines.

2. MAPPING

Mapping the existing infrastructures in Utrecht

To explore the current infrastructures in Utrecht we mapped them according to the five biophysical systems of Bélanger: water resources, waste cycling, energy generation, food production, and mass mobility as previously explained in the introduction chapter. The specific research question we answer with the mapping phase is: *'What are the existing infrastructures in the city of Utrecht in terms of water, waste, energy, food and mobility?'*

We looked at all the aspects we deduced were needed to map the five themes, which caused us to map more information that we needed for the next phases of the thesis work. We chose to include the excess information, because the mapping phase is a product in itself, which shows our mapping experiment within the lines of thought of Pierre Bélanger. The mapping is not directly connected to the subsequent phases of bundling and designing, but it did offer us knowledge about the systems and infrastructures of Utrecht.

Compass

In his thesis Bélanger describes the need to map systems in order to understand them: 'representation through the mapping of complex levels of information is instrumental to the design of infrastructure and ecology. Whether by diagrams or maps, composite imaging provides an important alternative to the conventional orthographic methods of visualization inherited from engineers and architects' (Bélanger, 2013, p. 371).

Bélanger offers a broad checklist of biophysical systems: water resources, waste cycling, energy generation, food production, and mass mobility (Bélanger, 2013). Our interpretation of this line of thought was that the biophysical systems are equivalent to infrastructures. We used these five themes and Bélanger's general views as a compass for this phase of the process.

Methods

Mapping is in the context of this thesis defined as the process of researching and visualizing systems conducted in order to understand the workings of existing infrastructures in Utrecht as well as possible. The methods that we used to operationalize the mapping phase are chosen by ourselves as to optimally fit our case and scale levels.

The general methods of this phase are literature- and map studies. The information shown and described in the mapping is all that we found and that we could translate to maps, though the data was not collected, interpreted, integrated and evaluated in a structured way. We based the mapping phase on data and maps from mostly official organizations and used additional (unrecorded) interviews with experts for confirmation. The outcomes of this process made for the best possible data under the circumstances. The mapping phase shows more information that we actually needed in the bundling phase.

2.1 INTRODUCTION MAPPING

We mapped the systems in Utrecht by means of listing, literature- and map studies, visualizing, interviewing experts and summarizing. We started by investigating what systems are present in Utrecht through policy documents and municipality information. We listed the items per category of the biophysical systems of Bélanger as described above. The listed items are described in the introduction at the beginning op each paragraph.

We collected the data by searching for policy documents, websites and reports by official organizations, like the municipality, province, water board, etc. We selected data that seemed relevant to our five themes and which was no older than ten years (2003-2013). We collected the data from May to July 2013, which is especially relevant for material from websites.

We then reviewed information on these items, searching for descriptions of the workings of a system, maps of the system and quantities. We conducted this reviewing process in an unstructured way and we did not record the reviews. In this inventory we generally looked at nodes (points of interest), routes (the ways by which elements are distributed) and flows (the amounts and characters of the distributed elements).

When having found enough information to map a system, we used Geographic Information System (GIS), AutoCAD, and Adobe Illustrator to draw the layer belonging to a particular item on the list. For all systems we looked at the city within its context. We made the maps ourselves, but they are based on layers and pieces of information from the sources mentioned in the caption of each map. Also we devised a scale of five levels (by means of deduction) to show the amounts of flow in the map per theme. This total process resulted in one map with all systems and quantities for every biophysical system.

To check the mapping we consulted several experts (table 5 and expert profiles) on water, waste, energy, food, and mobility. We asked these experts for a check of specific layers of information from the mapping we had conducted. During these interviews we shortly described our project and context and discussed specific aspects of the mapping outcomes. The interviews were not recorded on tape or in writing, and are thus not useable as source material for our research.

Missing information

The aspects on which we did not have access to any information or maps fall in the categories of water resources, energy generation and food production. In the category of water resources we did not have access to mapped information about drinking water distribution, because this information was not available from Vitens. In the category of energy generation we could not access information about the electricity cables and gas network. This information was not available to us, because the energy companies cannot share this content as it concerns highly detailed and possibly classified information. In the category of food production we could not access data on quantities of food production, consumption and distribution. This information was not available to us, because it does not seem to exist for the city of Utrecht, which was confirmed by Louis de Jel of Lekker Utrechs. Also we did not have access to information about data distribution (servers, phone lines and internet) as this information is highly detailed and possibly classified. These systems could thus not be included in our mapping process.

Figure 8. Water resources in Utrecht (Map based on Van Bijnen, Rebergen and Moens, 2009, p. 12; Provincie Utrecht, 2012, p. 39)

Main surface water system

Amsterdam Rijnkanaal

Surface water

Stream direction

Lock

Drinking water extraction

Ground water protection zone

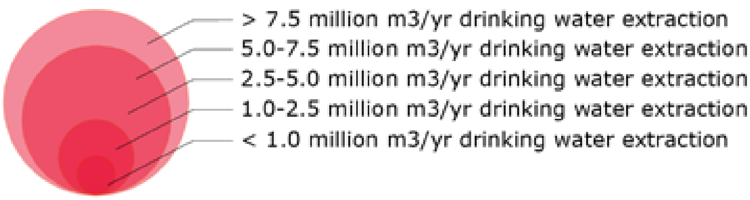
2.2 WATER RESOURCES

To map the water resources in Utrecht we used information on the surface water system, the drinking water distribution network and drinking water extraction.

Surface water system

In a larger hydrological context Utrecht is situated on slightly higher ground in the system of the rivers Lek, Kromme Rijn and Vecht under influence of water coming from the Utrechtse Heuvelrug moraine. The main surface water system in the city of Utrecht comprises of the Kromme Rijn, the Singel and canals, the Merwedekanaal, the Vaartse Rjjn and the Vecht all of which are on +0.6m NAP and the Vecht on -0.4m NAP (figure 8) (Van Bijnen, Rebergen and Moens, 2009, p. 12). We judge the data from this source as usable, because the municipality of Utrecht published the document. Their experts have access to many layers of information about Utrecht, so we assume that the content of this document is well supported by information. The fresh water to sluice the waterways is mostly supplied by the Kromme Rijn. After moving through the Singel and canals it leaves the city by means of the Weertsluis and is pumped into the river Vecht and finally debouches in the IJmeer. In the situation when the water levels in the Kromme Rijn are quite low due to drought in summer fresh water is pumped by the Noordersluis from the Amsterdam Rijnkanaal into the Merwedekanaal and Vaartse Rijn (Van Bijnen, Rebergen and Moens, 2009). The main transport water for Utrecht is the Amsterdam Rijnkanaal with a level of -0.4m NAP (Van Bijnen, Rebergen and Moens, 2009, p. 12). It connects Utrecht with Amsterdam, Rotterdam, the east of the Netherlands, Belgium and Germany. The Vaartse Rijn passes under the Amsterdam Rijnkanaal by means of a culvert.

Figure 9. Quantities of water resources in Utrecht (Map based on Van Bijnen, Rebergen and Moens, 2009, p. 12; Provincie Utrecht, 2012, p. 39)



Drinking water system

The drinking water system of Utrecht is managed by Vitens, with main extraction points at Groenekan, De Meern and Leidsche Rijn (figure 8). These sources are connected to the other sources from the region, like Zeist, Bilthoven, Woudenberg, Blokland, Soestduinen, Bunnik and Beerschoten (Provincie Utrecht, 2012). We judge the data from this source as usable, because the Province of Utrecht published the document. Also local municipalities, water boards, and drinking water companies were involved. We think these involved stakeholders together have all the available knowledge in relation to the drinking water system in store, because these parties are responsible for the policies, planning, management, and implementation of drinking water extraction. Together the sources in Utrecht and its context provide drinking water for the entire region. Most sources are fit for multiple land use as long as there is no threat for the drinking water extraction through infiltration of damaging materials (Provincie Utrecht, 2012). For example the drinking water extraction at Groenekan has a groundwater protection zone and a hundred year attention contour to secure the protection of the source (Provincie Utrecht, 2012). The drinking water extraction in Groenekan has authorization for 7.5 million m3 extraction per year, but roughly 3 million m3 of this allowed amount is currently extracted (Provincie Utrecht, 2012). The margin secures the supply when the demand will increase in the future. The sources of drinking water extraction in Utrecht all deliver to a ring of transport ducts connecting the sources to the distribution network. From the main transport ring a network of smaller drinking water ducts distributes the water throughout the city. The pressure in this network is created by accelerator installations set at intervals along the ring duct (Provincie Utrecht, 2012). To ensure a steady extraction while the demand knows peaks during the day, 'Clean water cellars' (reinwaterkelders) are used to store the water. The drinking water supply in Leidsche Rijn and De Meern is under threat on the long term, as pollution slowly moves towards the sources. This process is explained in detail in the next paragraph.

Spatial impact

For the spatial impact of the water resources the surface water is most prominent. The surface water is an important base layer of the environment of Utrecht and the water bodies and sluices are clearly visible in the landscape. Drinking water extraction sources are mostly open, grassy landscapes, and some are accessible for recreation like the Waterwinpark in Leidsche Rijn. The pipelines for drinking water distribution are underground and thus have only a spatial impact in relation to planning and construction of new developments.

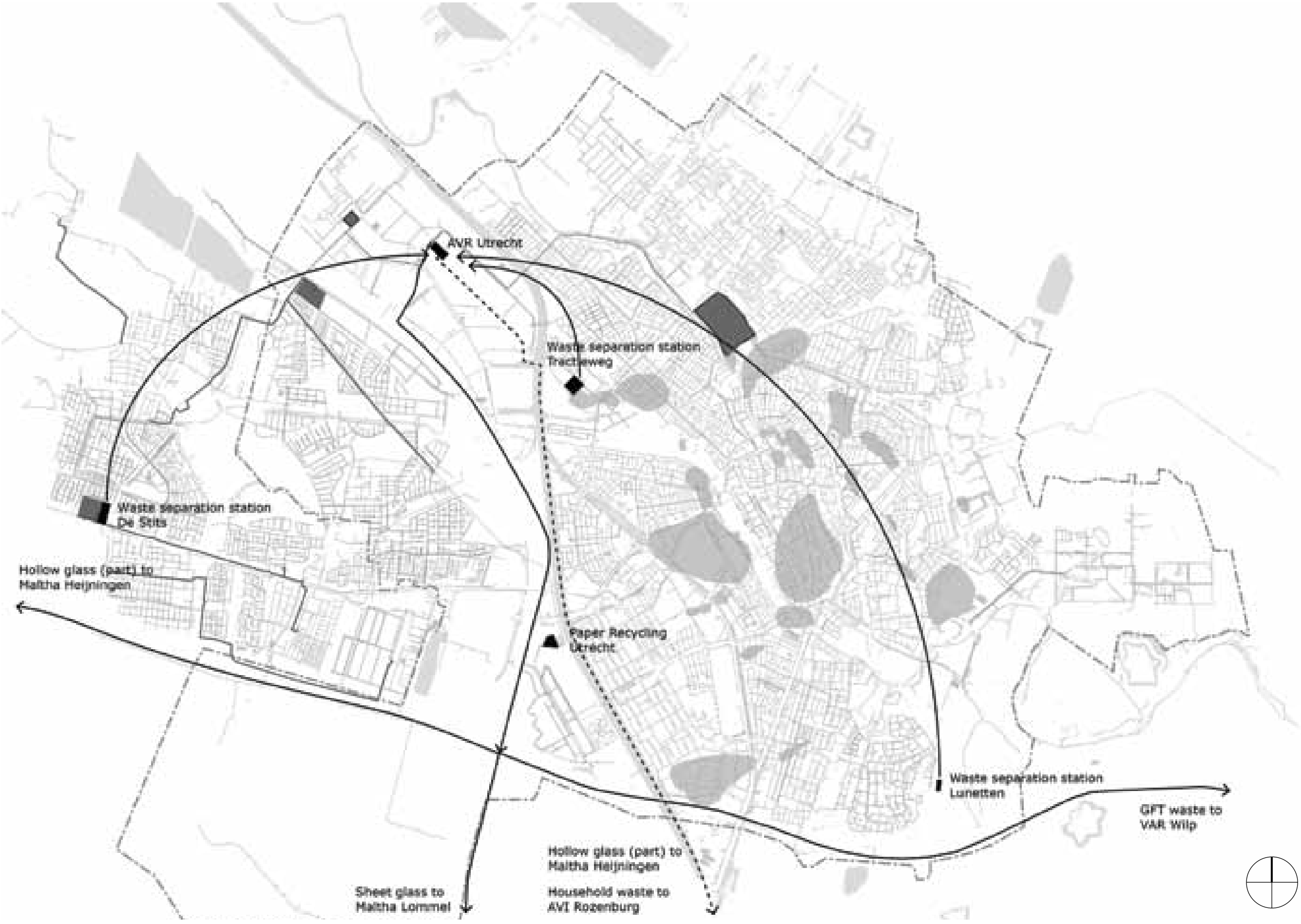


Figure 10. Waste cycling in Utrecht (Map based on AVU, 2012, pp. 8-10, 14; Hoogheemraadschap De Stichtse Rijnlanden, 2013)

RWZI (sewage water purification installation)

RWZI with dredge fermentation installation

Purified water shed

Sewers

Waste stations

Waste transport by truck

Waste transport by ship

Ground water pollution

2.3 WASTE CYCLING

To map the waste cycling and distributing systems in Utrecht we used information on waste collection, distribution and processing systems for household waste, vegetal waste, glass and paper. Also we mapped the sewage system, surface water pollution, groundwater pollution, and soil pollution.

Household waste cycle
The city of Utrecht produces 110.000 tons of household waste and the province in total produces 225.800 tons of household waste per year (AVU, 2012). We judge the data from this source as usable, because it is the most recent document on waste cycling and because Afval Verwijdering Utrecht published it. As the AVU is the governmental organisation that is responsible for all waste in Utrecht, we assume that the content of this document is well supported by all available information on waste cycling. The household waste is collected in every street per municipality in individual containers of deep ground containers and picked up by garbage trucks from many different providers. The collection takes all waste from the city of Utrecht to the AVR Utrecht in Lage Weide (figure 10) which then ships daily over the Amsterdam Rijnkanaal to the AVI Rozenburg, the household waste processing installation in Rotterdam (AVU, 2012, p. 8). Other waste collection in the province goes to ROVA Amersfoort and VOF AOV Veenendaal to be transported by road to the AVI Duiven. The installations in Rozenburg and Duiven burn the waste and together provide energy for 22.000 households every year (AVU, 2012). The bulk household waste, like old furniture, building materials, electrical applications and toxic materials, is collected at the three waste separation stations in the city and processed there. In the city of Utrecht 12.200 tons per year are collected. At all the waste separation stations in the province in total 39.200 tons per year are collected.

Vegetal waste cycle
The vegetal waste, comprising of 9000 tons per year for the city and 100.500 tons per year for the province (AVU, 2012), is collected in a process similar to the household waste collection, with the addition of the material that is produced by the management of green spaces by the municipality.

The vegetal waste is brought to the AVR Utrecht and from there transported by truck via the A2 and A12 to Wilp (figure 10) (AVU, 2012, p. 9). Here the vegetal waste is fermented and the outcome of this process is electricity from biogas.

Glass waste cycle
The glass waste collected yearly in Utrecht is separated in sheet glass and hollow glass. The sheet glass from the city is 137.876 tons per year and from the province 555.215 tons per year (AVU, 2012). This type of glass is collected in the waste separation stations and shipped over water to the glass processing company Maltha in Lommel, Belgium (figure 10). The hollow glass collected from the city in bottle banks is 6.200 tons per year and from the province 27.100 tons per year (AVU, 2012). This type of glass is transported by boat and truck to Maltha in Heijningen (figure 10). The total production of recycled glass material for the glass industry from the processing of sheet glass and hollow glass together is 27 million kilos (AVU, 2012, p. 10).

Paper waste cycle
In the city of Utrecht 8.600 tons of paper are collected every year and in the province 64.300 tons per year (AVU, 2012). This collection is done by schools, churches, and organisations and at the waste separation stations. The paper is brought to Paper Recycling Utrecht in Papendal for processing (figure 10). In total the paper industry receives 62 million kilos of recycles paper material per year (AVU, 2012, p. 10)

Wastewater cycle
The wastewater in the city of Utrecht is distributed from buildings and hard surfaces to a main transport sewer by means a network of smaller sewer pipes covering the entire city (figure 10). The main transport sewer then brings the wastewater to the sewage water purification installations (RWZI's) in Overvecht, De Meern and Lage Weide (figure 10) (Hoogheemraadschap De Stichtse Rijnlanden, 2013). We judge the data from this source as usable, because the Hoogheemraadschap De Stichtse Rijnlanden is responsible for all aspects of the

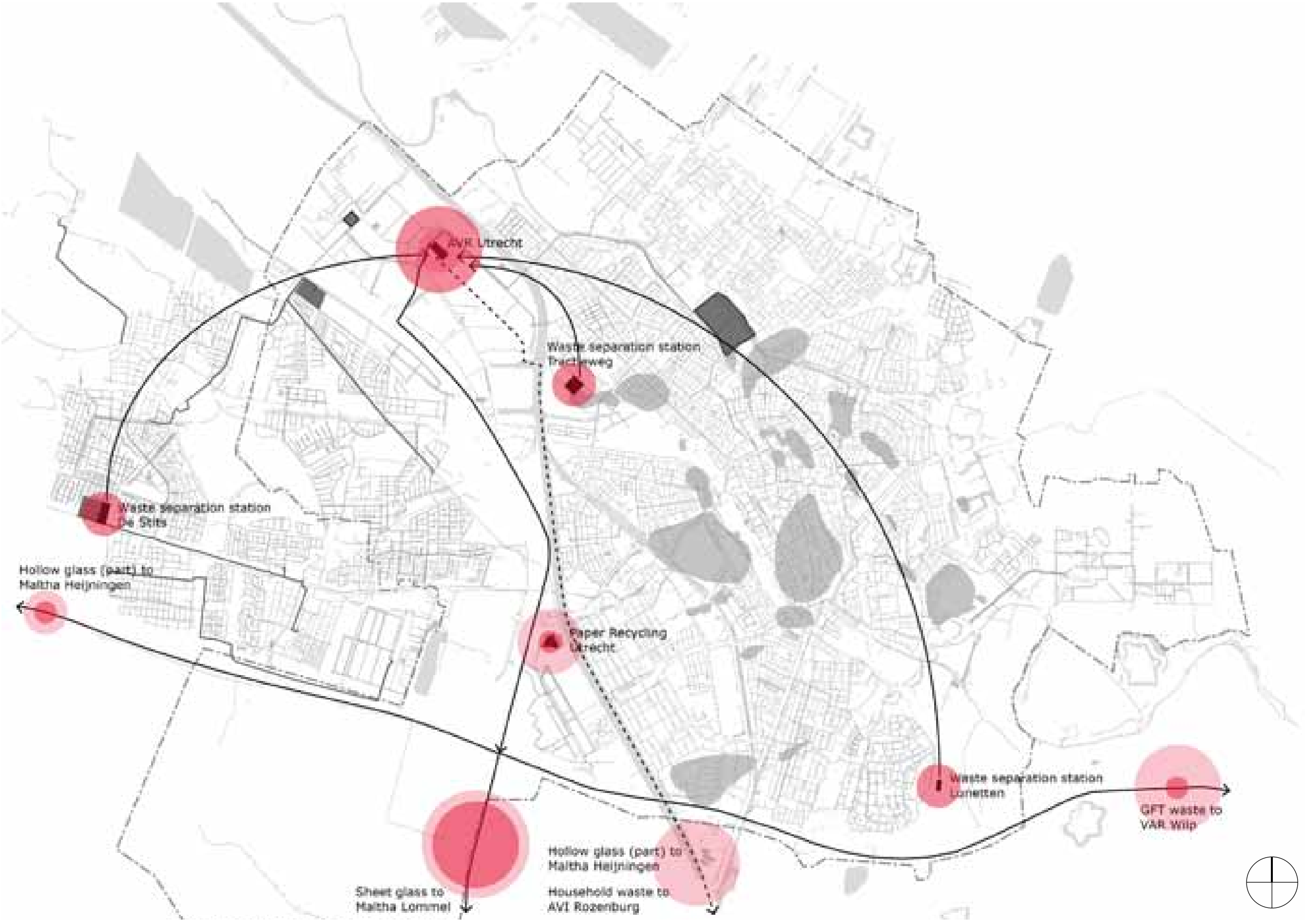
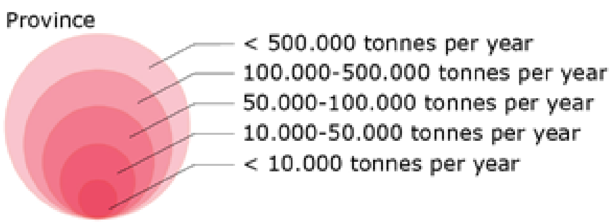
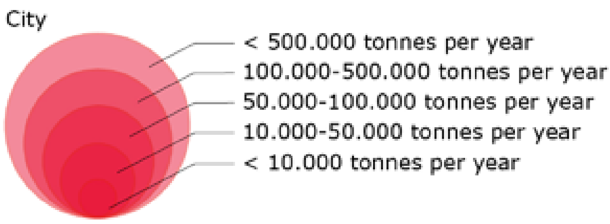


Figure 11. Quantities of waste cycling in Utrecht (Map based on AVU, 2012, pp. 8-10, 14; Hoogheemraadschap De Stichtse Rijnlanden, 2013)





waste water cycle in Utrecht, and we assume they have all available knowledge in this field available for their experts. At the RWZI's the water is treated and the clean water residue is pumped into the main water bodies. At the main installation in Overvecht dredge is filtered from the water and transported by a pipeline to the dredge fermentation installation at the RWZI Lage Weide (figure 10) (Hoogheemraadschap De Stichtse Rijnlanden, 2013).

Surface water pollution

The pollution of the surface waters is general in Utrecht, and is thus not shown as an entity in the map. The main pollutants in the surface water are phosphate and nitrogen. The norm for nitrogen levels set by the municipality of Utrecht is 2.8 mg/l, but in the current situation it is 3.0-3.5 mg/l. The norm for phosphate levels is 0.15 mg/l and in Utrecht it is 0.2-0.3 mg/l (Dienst Stadsontwikkeling, 2012b).

Groundwater pollution

The pollution of the groundwater in the city of Utrecht is quite extensive. The pollutions have been caused by industries over the past decennia and are now polluting not merely spots, but entire areas in the ground water zone. The areas that are marked on the map (figure 10) do no have a fixed edge and the entire pollution slowly moves towards the east-northeast by ten metres per year, transported by the groundwater flow (Arcadis, 2009). The pollutions are measured in the first aquifer (Watervoerend Pakket I – WVP I) at -5m NAP to -50m NAP. In this zone some of the existing TES systems have been used in a pilot to see if groundwater movement stimulates bacteria to break off pollutants and thus influence the pollution issue in a positive way. The outcomes of this process seem promising and the pilot is referred to as the 'bio washing machine' (Arcadis, 2009). Where the division between the first and second aquifer has been punctured by for example deep drilling activities, the pollution can slowly move into the second aquifer. This is quite a problem, as the water in the second aquifer is protected to secure the long-term drinking water supply (Provincie Utrecht, 2012). The punctures and extent of the dividing layer between the first and second aquifer are not known, thus the only measure by the government is at present to prohibit punctures by drilling deeper than -50m NAP (Provincie Utrecht, 2012).

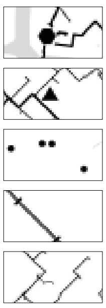
Soil pollution

The soil pollution in Utrecht is substantial, especially in former industrial areas like the Cartesius Triangle and Griftpark (figure 10). The areas marked on the map are to be cleaned or treated before they can be developed in the future. These pollutions are severe enough to prevent building developments without cleaning or treating the soil.

Spatial impact

The spatial impact of the waste cycles in Utrecht is most apparent in relation to mobility. The mobility is influenced by the daily use of the main roads and Amsterdam Rijnkanaal by waste trucks and ships for the transport of waste. The waste collection points and RWZI's are visible, but incorporated in industrial plots, blocks or buildings. The surface water pollution is spatially experienced mostly in summer, when the warmer temperatures of air and water together with the pollutants in the surface water cause an unpleasant smell. The sewage system, groundwater pollution, and soil pollution are underground. However, severe pollution can affect the future land use in relation to restrictions of functions for new developments.

Figure 12. Energy generation in Utrecht (Map based on Nuon, 2013; Harting, 2009, pp. 1-3; Wessels, 2013, pp. 42-43)



Energy plant

WOS/HWC

Thermal energy storage

Power lines

District heating

2.4 ENERGY GENERATION

To map the energy generation and distributing systems in Utrecht we used information on regular sources like production of electric- and thermal energy, power lines, and district-heating system, and information on renewable sources like dredge fermentation, and thermal energy storage (TES). There are investigations on the opportunities of solar energy, wind energy, thermal energy from sewage and a biomass plant in Utrecht, but as these are not yet exisitng systems they are not mapped in this research.

Energy production

The main energy production cluster for Utrecht is situated at the Lage Weide and Merwede crossing (figure 12). Here four major STEG (Steam and Gas Turbine) plants of the Nuon are producing a staggering 690 Megawatt electric energy per year, which provides electricity for 1.4 million households (Nuon, 2013). Nuon distributes the produced electricity by high voltage (150 kV) power lines throughout the Netherlands (TenneT, 2011). Besides electricity the four plants also produce a total of 570 Megawatt of thermal energy for 500.000 households in the region of Utrecht (Nuon, 2013). Nuon delivers the thermal energy produced by the plants by means of main heating transport pipes (figure 12) to the heating distributing stations (WOS - Warmte Overslag Stations) in Overvecht, Station district, Rijnsweerd, Leidsche Rijn and Merwede industrial area. From the heating distributing stations Eneco takes over from Nuon to distribute the thermal energy in the district-heating system (figure 12) to 35.000 households in the city of Utrecht. The system in Utrecht is most extensive in the Netherlands and the oldest, as it was built in 1923 (Harting, 2009). The district-heating only covers one third of the total heating demand in the city (Harting, 2009), as most buildings are still heated by means of gas. However, the district-heating system does offer a CO2 emission reduction of 90.000 tons per year (Harting, 2009). Please note that in the energy production of Utrecht the Uithof is excluded from all data, as this area has a separate power plant, set of thermal energy storages (TES's) and other sources of renewable energy.

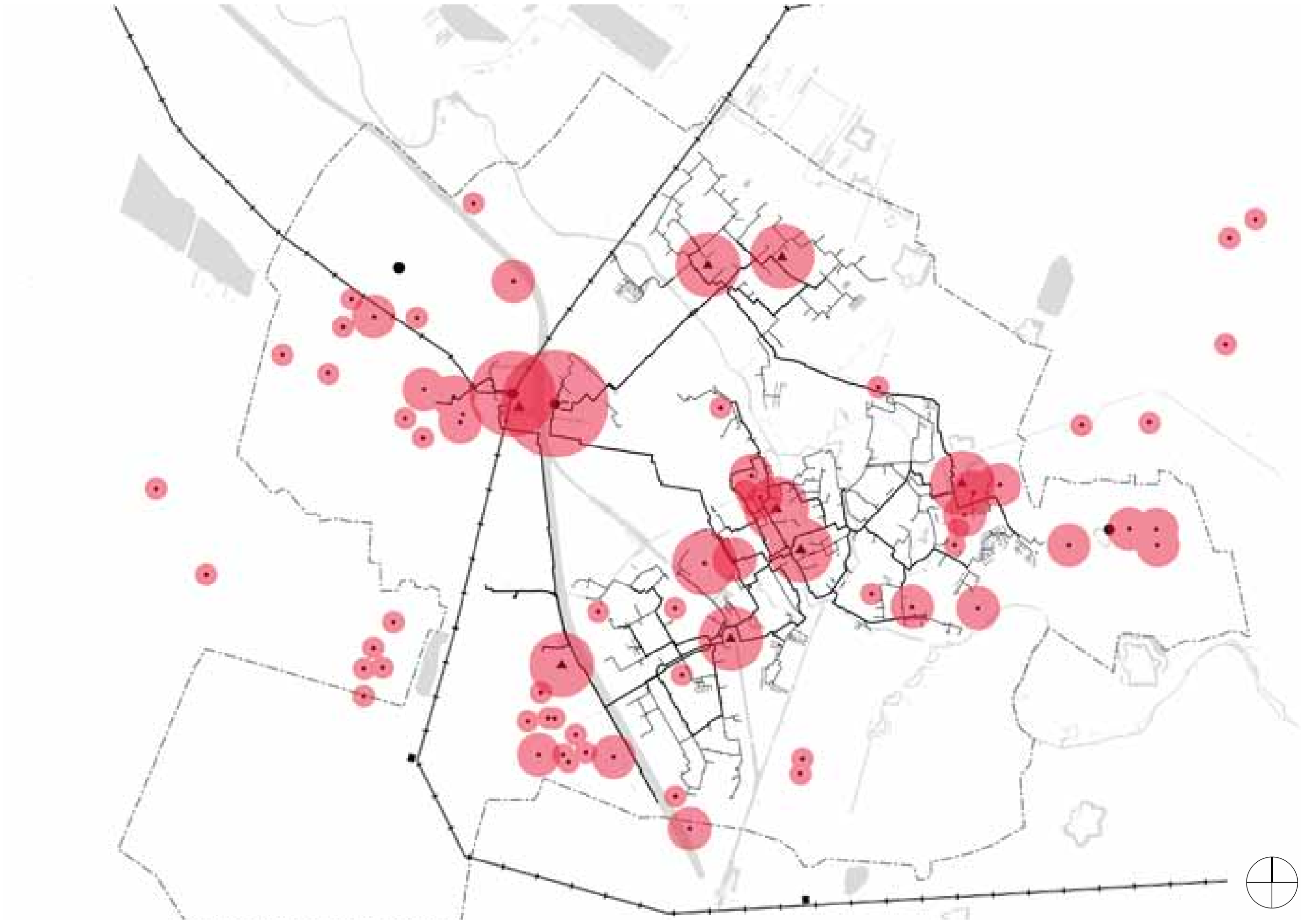
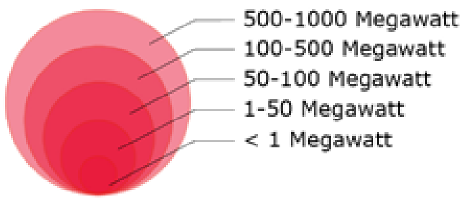


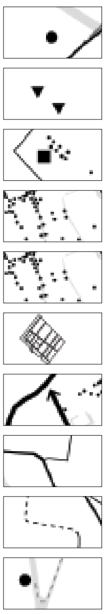
Figure 13. Quantities of energy generation in Utrecht (Map based on Nuon, 2013; Harting, 2009, pp. 1-3; Wessels, 2013, pp. 42-43)



Thermal energy storage
Thermal energy storage (TES) has seen a rapid growth in demand and application in Utrecht over the past five years. A TES system stores heating and cooling energy in the groundwater. Thus the heating energy can be used in winter to heat the building and the cooling energy can be used in summer to cool the building. In Utrecht this storage is only allowed in the first aquifer (Watervoerend Pakket I – WVP I) at -5m NAP to -50m NAP to secure the drinking water supply (paragraph 2.2). Important clusters of TES systems in Utrecht are the Station District, Rijnsweerd, Uithof, Papendorp, Leidsche Rijn, De Wetering, and Lage Weide. Companies that use thermal energy storage for the heating and cooling of their new office buildings mostly develop them individually. However, govenmental bodies now start to regulate the development of TES's, because the demand is increasing and many companies tend to develop an extraction range that exceeds their own plot footprint.

Spatial impact
The spatial impact of the energy systems is mostly found in the highly visible power lines and wind turbines in the landscape. The large power plants, future biomass plant, dredge fermentation installation, WOS buildings, TES systems, and solar panels are visible, but incorporated in blocks or buildings. District-heating pipes, gas pipes and electricity cables are underground and thus have only a spatial impact in relation to planning and construction of new developments.

Figure 14. Food production in Utrecht (Map based on Vleugel, 2003, p. 68; The Facility Group, 2008, p. 52-53)



Distribution centre

Urban distribution centre

Neighbourhood market

Supermarket

Restaurant

Allotment garden

Primary distribution routes

Secondary distribution routes

Planned distribution routes

Distribution bij ship

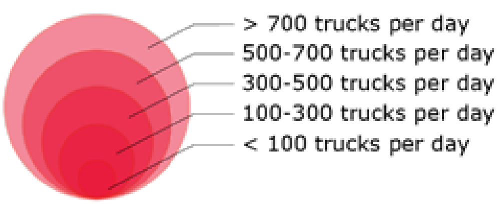
2.5 FOOD PRODUCTION

To map the food production and distributing systems in Utrecht we used information on distribution routes and centres, supply of supermarkets, restaurants, and markets, and locations of allotment gardens.

Food distribution network

An extensive distribution network covering large parts of the Netherlands serves the food consumption in Utrecht through supermarkets. Most of the supply is coming from the regions of Amsterdam and Breda from large distribution centres per individual chain of supermarkets (figure 14) (Vleugel, 2003, p. 61; The Facility Group, 2008, pp. 52-53). Trucks bring food by road to urban distribution centres, shops and wholesale stores. The routes used by trucks for distribution, which are specifically authorized by the municipality, are marked on the map (figure 14) (Vleugel, J.M. 2003, p. 68). One exception is the GEPU wholesale store that supplies parts of the inner city by ship via the Oudegracht. From the distribution centres and wholesale stores the food is transported to central Utrecht where most of the shops, supermarkets and restaurants are situated. The access to the inner city is increasingly under pressure from distribution by trucks. Though the time windows for deliveries in the pedestrian areas have been set at 6.00-11.00 and 18.00-19.00 from Monday to Saturday (Dienst Stadsontwikkeling, 2003).

Figure 15. Quantities of food distribution in Utrecht (Map based on Vleugel, 2003, p. 68; The Facility Group, 2008, p. 52-53)



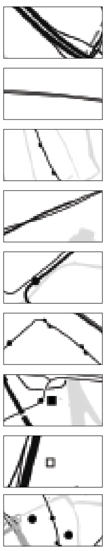
Local food production

Though the supermarkets are the main providers the local food production through allotment gardens (figure 14) and local farmers is increasing according to Lekker Utrechs. This tendency of people wanting to know where their food comes from has been growing steadily. The people living in the province of Utrecht annually spend an average of €42,60 on biologically produced food which is higher than the average of €36,10 in the Netherlands (Provincie Utrecht, 2010, p. 10).

Spatial impact

The spatial impact of the food related system in Utrecht is most evident in terms of mobility. The transport by distribution routes influences the mobility and the supply of supermarkets and restaurants require facilities like (un)loading points. The density of the facilities that need supplying in the inner city is such that the centre is often congested with trucks and window times are needed. Distribution centres, supermarkets, and restaurants are visible, but incorporated in blocks or buildings. Neighbourhood markets and allotment gardens contribute to the lively character and use of people of public or green spaces.

Figure 16. Fast traffic mobility in Utrecht (Map based on BOEI-Advies, 2009, pp. 70-71; HTM Consultancy, 2007, pp.14-15; GVU, 2009; Dienst Stadsontwikkeling, 2005, pp. 26-27; Binkhorst, et al, 2009)



Highway

Secondary road

Tertiary road

Railway

Tramway

Busroute

Park+Ride

Park+Ride planned

Parking

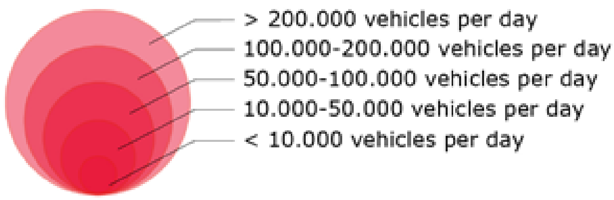
2.6 MASS MOBILITY

To map the mass mobility in Utrecht we used information on public transport (train, tram and bus), car movements, cycling and walking, and parking. As the maps were too complex to show all, we made a distinction in fast and slow traffic mobility.

Public transport systems

Utrecht is a main railway hub in the Netherlands, being situated roughly in the centre of the country it connects the western, eastern, northern and southern provinces. Daily an average of 164.000 travellers pass through Utrecht Central Station (Ministerie van Verkeer en Waterstaat, 2007). Between Utrecht and Amsterdam, The Haque and Rotterdam eight trains per hour move over the railway system (figure 16) (Ministerie van Verkeer en Waterstaat, 2007). The intensive use of the railway system of Utrecht is not only reflected in public transport, as the transport of goods is increasing rapidly. The weight of goods transported by train in 1995 was 20 million tons, compared to 2006 it increased to 41 million tons, which is more than double the amount (Ministerie van Verkeer en Waterstaat, 2007). It is even estimated to double again before 2020 (Ministerie van Verkeer en Waterstaat, 2007). Over the years the railways have developed, and sometimes diminished like the former Griftpark line, and the railway yard of the Cathesius Triangle and parts of the Oosterspoorbaan that are soon to become obsolete (figure 16) (BOEI-Advies, 2009, p. 70). Though some railways disappear, the intensity of use of the rest is increasing and new stations are being developed. The new stations are Zuilen, Leidsche Rijn, Vaartse Rijn and Houten Castellum. Renovation of stations happens at Utrecht Central Station, Vleuten, Terwijde, Lunetten and Houten. In the trams system the demise of the tracks is even more visible, as around 1950 the tram system was huge in Utrecht and now only a connection to Nieuwegein and the new line to the Uithof are to be used (figure 16) (HTM Consultancy, 2007). Besides the train and tram systems the city is mostly covered by bus transport (figure 16) (GVU, 2009).

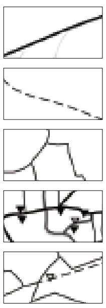
Figure 17. Quantities of fast traffic mobility in Utrecht (Map based on BOEI-Advies, 2009, pp. 70-71; HTM Consultancy, 2007, pp.14-15; GVU, 2009; Dienst Stadsontwikkeling, 2005, pp. 26-27; Binkhorst, et al, 2009)



Fast traffic mobility

The main car movement and transport occurs by means of the Ring Utrecht, consisting of the A27, A12, A2 and N230 (figure 16). This last will be upgraded in 2017 to a highway with overpasses that will connect the A2 and A27 (Dienst Stadsontwikkeling, 2005; Provincie Utrecht, 2008). The ring transports an average of 220.000 vehicles per day (Binkhorst, Kloppenborg, Korff de Gidts, 2012). The municipality stimulates a major access route from the A2 to the Jaarbeurs area for cars and trucks to reach the city centre (Dienst Stadsontwikkeling, 2012a). The ambition of the municipality is to make the secondary ring for cars (figure 16) less attractive for cars and upgrade the accessibility for slow traffic and the character of the public space around these roads (Dienst Stadsontwikkeling, 2012a). But still the other main roads and secondary roads in the city of Utrecht are quite under pressure from the amount of traffic and distribution. Many roads are used intensively, which leads to congestion, especially in the city centre. The parking of cars is quite a pressure on the urban space and is thus clustered in parking buildings in the inner city (figure 16). In Hogeweide, Papendorp, and Westraven park and rides with a connection to the city centre of Utrecht are situated near the highways (figure 16).

Figure 18. Slow traffic mobility in Utrecht (Map based on AGV Movares, 201, pp. 28-32; Dienst Stadsontwikkeling, 2005, pp. 46-47)



Cycling route

Cycling route planned

Walking route

Cycle parking

OV-Bike point

Slow traffic mobility

The slow traffic in Utrecht comprises of dense cycling and walking networks. These network sometimes follow roads, but are often separate as well (figure 18). Many cycling routes are used intensively, as there are 268.000 cycling movements inside the Ring Utrecht (AGV Movares. 2011). This leads to 'bike queues' near traffic lights, especially in the city centre. The Fietsersbond and municipality are currently working together to create an unimpeded cycling network in the city (figure 18). The many barriers created by water, roads and railways are a major threat to this fast network. Most of these barriers are oriented north to south, but the economic axis of the city (Leidsche Rijn, Centre, Uithof) is oriented west to east. The ambition of the municipality is not only to create a stronger network in which slow traffic has a priority position, but also to combine mobility with the development attractive and green public space (Dienst Stadsontwikkeling, 2012a, pp. 31-41).

Spatial impact

The spatial impact of the road and railway infrastructures in Utrecht is quite substantial. The railways and roads are in many places elevated to prevent dangers at same level crossings. The elevated infrastructures are quite a barrier between the inner city and the landscape, as only a few bottleneck underpasses allow cars and cyclists to pass. This makes it increasingly difficult for people to get out of the city and into the surrounding landscape. The public transport (train, tram and bus), roads, cycling paths and street parking are visible in the landscape and form a pressure the urban space. The parking in the centre of the city is visible, but incorporated in blocks or buildings, which somewhat relieves the pressure of parking in the city.

Figure 19. Quantities of slow traffic mobility in Utrecht (Map based on AGV Movares, 201, pp. 28-32; Dienst Stadsontwikkeling, 2005, pp. 46-47)

2.7 CONCLUSION MAPPING

The specific research question that was supposed to be answered by this chapter is: *'what are the existing infrastructures in the city of Utrecht in terms of water, waste, energy, food and mobility?'*

In the mapping phase we explored the current infrastructures in Utrecht. We mapped them according to the five biophysical systems of Bélanger: water resources, waste cycling, energy generation, food production, and mass mobility. The existing infrastructures in Utrecht that we mapped, and the information that we missed are shortly described below.

For 'water resources' we mapped the surface water system, the drinking water distribution network and drinking water extraction. The information that we missed on water resources was the detailed drinking water distribution network. For 'waste cycling' we mapped waste collection, distribution and processing systems for household waste, vegetal waste, glass and paper, the sewage system, surface water pollution, groundwater pollution, and soil pollution. For 'energy generation' we mapped the production of electric- and thermal energy, power lines, district-heating system, dredge fermentation, and thermal energy storage (TES). The information that we missed on energy generation was the detailed electricity distribution network and gas network. For 'food production' we mapped distribution routes and centres, supply of supermarkets, restaurants, and markets, and locations of allotment gardens. The information that we missed on food production was about the quantities of food production, consumption and distribution. For 'mass mobility' we mapped the public transport (train, tram and bus), car movements, cycling and walking, and parking.

The final result of the mapping phase was a thorough knowledge of the existing infrastructures in Utrecht. However, the information shown and described in the mapping is all that we found and that we could translate to maps, though the data was not collected, interpreted, integrated and evaluated in a structured way. We based the mapping phase on data and maps from mostly official organizations and used additional (unrecorded) interviews with experts for confirmation. The outcomes of this process made for the best possible data under the circumstances.

In this chapter the mapping of existing infrastructures was defined and described. In this final paragraph we will reflect on the process and outcomes of the mapping phase. A detailed description of the mapping methodology can be read in the introduction paragraph of this chapter (paragraph 2.1). As described in the preface and introduction our thesis process consisted of two phases: at first the thesis was unsatisfactory and needed additional work, and in the completion phase we added the necessary material to come to a passable product. The following reflection should be considered in this light.

Reflection on landscape infrastructures as compass

In the first phase of our thesis project we chose to literally apply the mapping method as described by Pierre Bélanger (Bélanger, 2013). The mapping phase was conducted, based on the idea that 'the merger of biophysical systems with contemporary infrastructure is rapidly becoming the dominant order for urban regions' (Bélanger, 2010). Our interpretation of this line of thought was that the biophysical systems are equivalent to infrastructures. So in our first thesis product we mapped the present situation of these infrastructural systems in terms of water, waste, energy, food, and mobility.

We did not question the work of Bélanger and accepted what we read from his work as the truth. By not being aware of this fact the work of Bélanger became our guideline instead of the compass it should have been. In the mapping phase this meant we thought we needed to map as broad and complete as possible. By taking the checklist of biophysical systems of Bélanger as an absolute guideline we mapped all the infrastructures that we could find. This lead to an irrelevant and over-elaborate mapping phase that quite missed the point.

In the second phase or completion phase of the thesis we addressed the problem described above by using the concept of landscape infrastructures and the idea of mapping only as a compass to guide our work in a relative way. The thing that did not satisfy is that the mapping of biophysical systems is not clearly described or defined in the writings of Pierre Bélanger. This gave difficulties when conducting the mapping phase, but we solved this by not seeing the mapping phase as absolute method. We learned from the mapping phase that a list of five points is not a method, as it still needs a description of how to use it, interrelating thoughts and a clear structure.

2.8 REFLECTION MAPPING

Reflection on the relevance to the topic

In the first phase of the thesis we learned that a mapping that is only an inventory of existing infrastructures does not lead to a design assignment as mentioned by Pierre Bélanger (Bélanger, 2013, p. 375). When looking back we can conclude the mapping phase was quite elaborate and time consuming, but with only few relevant outcomes. We spent several months gathering information, and mapping the existing infrastructures. Especially obtaining information from official organizations, like the Municipality of Utrecht, Vitens, or Eneco, took more time than we had anticipated. During the mapping phase we found out about the possible need for a district-cooling network, while interviewing Sieb van der Weide of the Municipality of Utrecht on cables and ducts in the underground. This information finally led us to the topic that formed the focus of the research. However, as the district-cooling network is not an existing system, it was not included in our mapping phase. Which had the implication that the mapping phase was very broad and not focused the topic, so after months of work we could only use a small part of the mapped information for the subsequent phases of the research.

In hindsight we realized it would have been better to remove the self-constructed bundling phase and focus the mapping phase on the topic of the research. To conduct a complete mapping that leads to a design assignment we thought we would have to conduct the mapping more like a SWOT analysis of strengths, weaknesses, opportunities and threats of the existing infrastructures, but this was only a hypothesis. This hypothesis of mapping in the form of a SWOT analysis would need to be tested in further research to develop the mapping as described by Pierre Bélanger beyond the research described in this thesis work.

In the completion phase of the thesis we changed our research questions to fit the phases better, and described the structure of the report as a story that is not continuous and in which the phases do not inevitably lead to the next. For the mapping phase this means the broad mapping of existing infrastructures answers the first specific research question in the final version of the thesis. This might render the abovementioned hypothesis irrelevant, because the mapping phase eventually fits our research structure. Also we made it clear in the final version that the phases do not connect directly, so the assumption that the mapping should lead to a design assignment might not necessarily be relevant. To conclude we learned to work more in an iterative and explicit way and not as we did at first by 'making it up as we go along'.

Reflection on data handling

The reflections and critiques on the mapping phase that were given during the green light presentation and colloquium presentation made us more aware of the intuitive and inexplicit choices concerning data use that we had made in the first phase of the thesis process. We based the mapping phase on data and maps from mostly official organizations and used additional (unrecorded) interviews with experts for confirmation. The outcomes of this process made for the best possible data under the circumstances. By reflecting on this process we learned a lot about the principles of handling data in scientific research.

We can conclude that the significance of the mapping phase is that the mapping creates a clear overview of the systems in Utrecht. However, the validity and reliability were not ensured, as we did not triangulate our data and did not transcribe the input from the experts, which made it impossible to estimate the value of our material and assess the conclusions drawn from the data. In the completion phase we added reflections on how we used data or maps, and the extra information we obtained from experts to confirm or add data.

3. BUNDLING

Relating the district-cooling network to infrastructures in Utrecht

In this paragraph we describe the coherence between the district-cooling network and the relevant existing infrastructures that we mapped in the previous phase: mobility, surface water, and thermal energy storage systems. We also describe here the problems and opportunities that arise when seeking this coherence. For this last point two layers of information that are relevant for the renewable energy sources of the system are surface- and groundwater pollution are included. We include these, because the renewable the sources for cooling can have a positive side effect on these two types of pollution. We found the other information layers from the mapping irrelevant in relation to the district-cooling network, as they are either unconnected with road infrastructure or with the production of cooling energy in any form. The specific research question we answer with the bundling phase is: *'What is the possible spatial and technical coherence between a district-cooling network and the current infrastructures in Utrecht?'*

We focused on two possible cooling energy sources: surface water and thermal energy storage systems. In our choice for the TES systems we considered the need for renewable cooling sources, the growing demand for TES systems in Utrecht, and their possibility to solve groundwater pollution. In making the choice for surface water sources we considered the need for renewable cooling sources and the suitability for Utrecht with its many canals and waterways. Also we were inspired by the Zuidas reference project in Amsterdam, where a district-cooling system was developed with surface water as the main source.

Table 2. Coherence between infrastructures and the district cooling network

Infrastructures	C1. Cooling production	C2. Accomodation pipeline	Possible coherence
Surface water system	+	+	Renewable source
Drinking water extraction	-	-	-
Drinking water distribution	-	-	-
Waste distribution systems	-	-	-
Sewage system	-	-	-
Surface water pollution	-	-	Related to source
Groundwater pollution	-	-	Related to source
Soil pollution	-	-	-
Electricity production	-	-	-
Power lines	-	-	-
District-heating system	-	-	-
Dredge fermentation	-	-	-
Thermal energy storage (TES)	+	-	Renewable source
Food distribution	-	-	-
Food sale	-	-	-
Allotment gardens	-	-	-
Public transport	-	+	Connecting demand
Fast traffic mobility	-	+	Connecting demand
Slow traffic mobility	-	+	Connecting demand
Parking	-	-	-

3.1 INTRODUCTION BUNDLING

We focused on these two cooling energy sources to keep the technical system close to its essence and leave out unnecessary complexity. As we had already spent too much effort in designing the technical system, we did not want to make it even more complicated. However, we did consider the other possibilities, like generating cooling energy through heat adsorption while designing the technical system. This option of adsorption would have made existing district-heating network, sewage system and drinking water system possible sources. Also we reasoned that the more indirect generation of cooling from heating energy would be less renewable as a source, because the adsorption process costs energy in itself.

Compass

Belanger mentions the idea of bundling as an integration of systems. 'The new design imperatives are found in the basic processes and essential services that support urbanization including the integrated ecologies of water, energy, food, mobility and waste, which have traditionally been treated as separate components or separate districts in municipal planning. Through the bundling of multiple ecological services, strategies can achieve greater economies and ecologies of scale' (Bélanger, 2013, p. 337). We interpreted that making the connection between biophysical systems with contemporary infrastructures leads to a landscape infrastructure. We used these views as a compass for this phase of the process.

Methods

The bundling phase was hard to structure, as it did not really have an underlying methodology. Bundling is the process of combining certain systems that can together come to an added value. We felt this bundling is needed as a step between the mapping and the design phases in order to come to our design assignment.

We searched for coherence between the existing infrastructures in Utrecht and the district-cooling network. We did this by means of a deduction of possible infrastructures from the mapping phase that can be combined with the district-cooling network, which we then discussed with experts.

The selection of the infrastructures was done by means of two criteria: (C1) an existing infrastructure should produce cooling energy, and (C2) an existing infrastructure should be able to accommodate the pipelines of the district-cooling network between the demand areas (table 2).

Based on the selection we contacted several specific experts (table 5 and expert profiles) to be able to link these systems to the district-cooling network. We asked the experts for their view on the possibilities of the infrastructures we deduced and selected with the district-cooling network. During these interviews we shortly described our project and context and discussed specific aspects of the bundling outcomes. The interviews were not recorded on tape or in writing, and are thus not useable as source material for our research.

Based on the outcomes of the bundling phase we formulated the design assignment by means of deduction. In this deduction process we kept our context of landscape architecture, the topic and focus of the research and our consequential search for a large-scale implementation in mind.

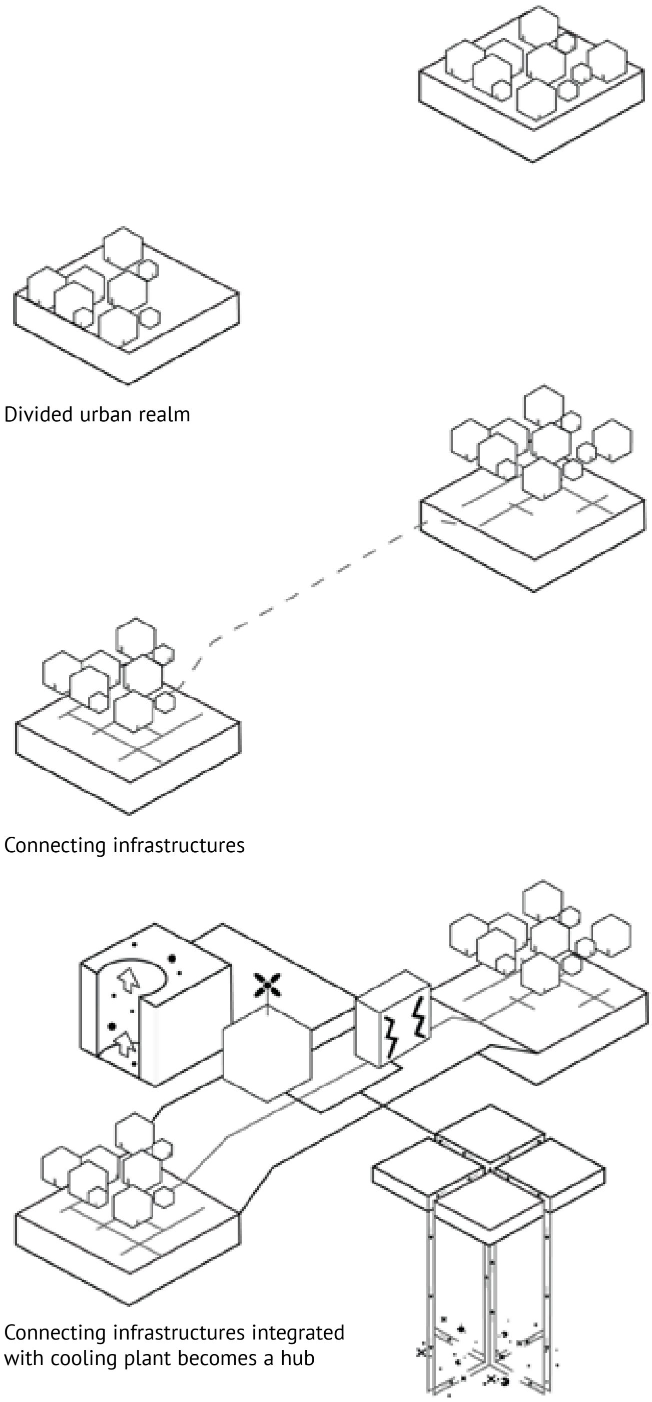
Figure 24. Missing links for slow traffic mobility (Map based on Fietsersbond, 2013; Degenkamp, 2013) can be solved by connecting hubs

3.2 DISTRICT-COOLING NETWORK IN RELATION TO INFRASTRUCTURE

District-cooling network and mobility

The first point in which the district-cooling network can be placed in relation to the existing infrastructure is fast and slow traffic mobility. As described in the mapping phase mobility in Utrecht is an issue, as there is much infrastructure in Utrecht that is under intense pressure. The development of a new underground system can have an added value for relieving this pressure, because the pipeline requires tunnelling or bridging when it meets a barrier, which is very similar to the barriers taken by traffic (figure 25). Also the roads used by buses, cars and cyclists offer a relatively easy access to the main distribution pipelines and often form quite a direct connection to all parts of the city.

Slow traffic, like cyclists and walkers, is in need of better connectivity in Utrecht (Fietsersbond, 2010). Where the underground network meets barriers, like waterways or railways, we want to connect the district-cooling network to missing links in the preferred fast cycling network: the Carthesius Triangle, Jaarbeurs and Oosterspoorbaan (figure 24) (Dienst Stadsontwikkeling, 2012a). This could contribute to a CO2 emission reduction, because it can stimulate environmental friendly modes of transport and thus reduce the CO2 emission by the use of cars for local mobility. Also the ambition of the municipality to create a stronger network in which slow traffic has a priority position and to combine mobility with the development attractive and green public space (Dienst Stadsontwikkeling, 2012a, pp. 31-41) as previously described in paragraph 2.6. These reasonings were at the base of the choice to connect district-cooling and fast- and slow traffic mobility.


Divided urban realm

Connecting infrastructures

Connecting infrastructures integrated with cooling plant becomes a hub

Figure 25. Connecting hubs principle

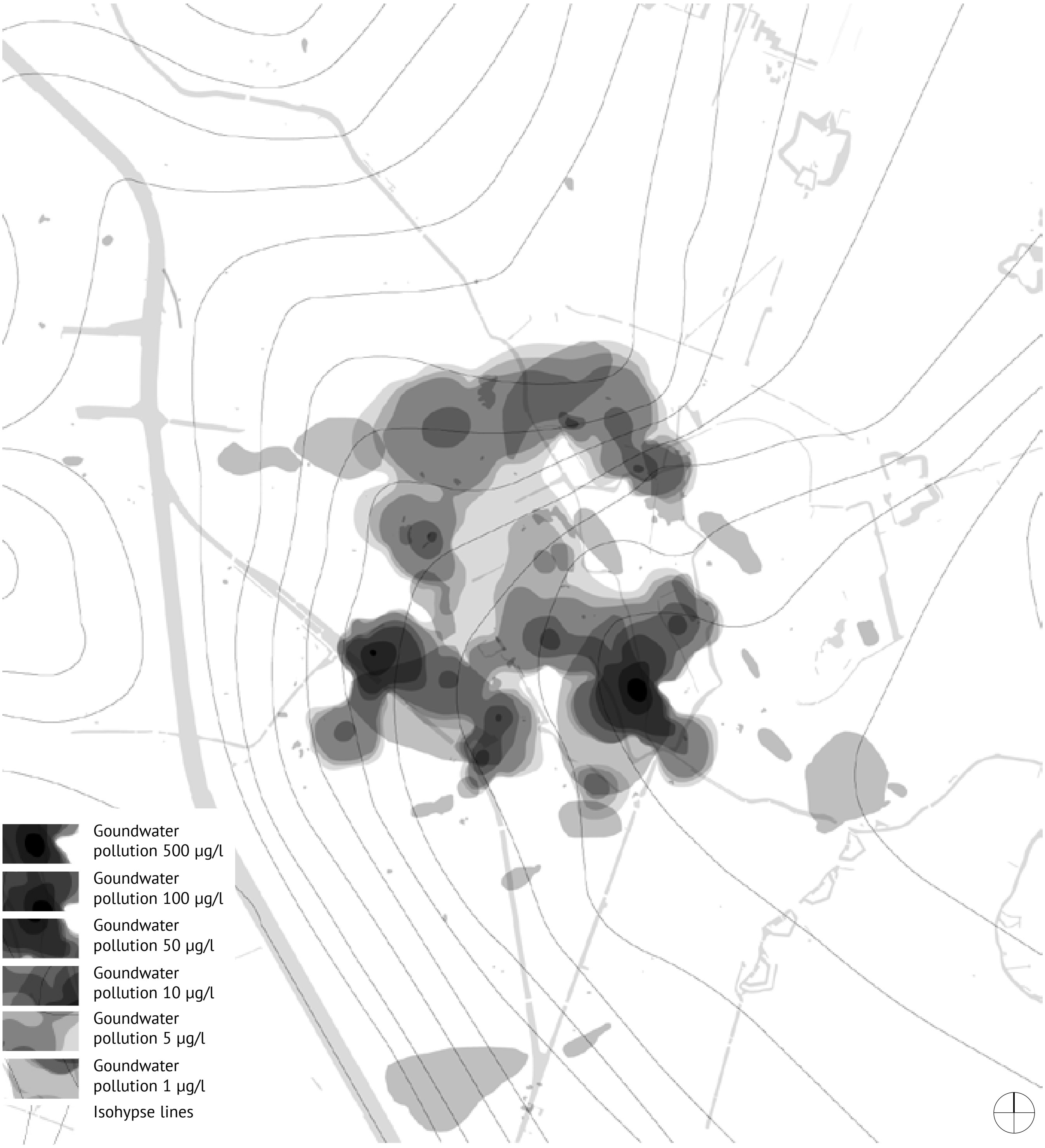


Figure 26. Groundwater pollution (Map based on GIS information of the Municipality of Utrecht and Arcadis, 2009, p. 95) can be solved by a 'bio-washing machine'

District-cooling network, energy production and groundwater pollution

The second point in which the district-cooling network can be placed in relation to the existing infrastructure is energy production and groundwater pollution. These two aspects are combined in the 'bio washing machine' principle. We reasoned that the 'bio washing machine' principle can be connected to the district-cooling network, because it involves the production of cooling energy by means of a renewable source.

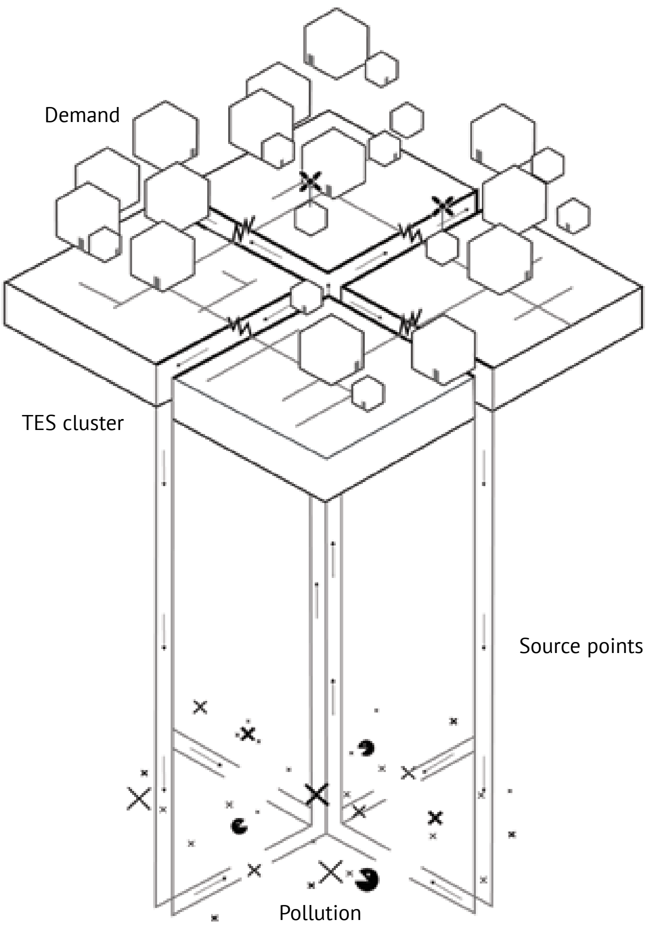


Figure 27. The 'bio-washing machine' principle

A thermal energy storage system supplies a building with heat in winter and cooling in summer by storing thermal energy in the groundwater (Arcadis, 2009). The groundwater is extracted by deep pipes and led through a thermal exchanger.

Many thermal energy storage systems have a cold source and a warm source, which are situated approximately 50-100 metres from each other depending on the thermal radius (Arcadis, 2009). The cold source pumps cold water up in summer to cool the building, and the warmer water residue after the extraction of the cooling is then stored in the warm source. In winter the heat from the water stored in the warm source is extracted and the colder residue is pumped back into the cold source (figure 27). It is legally required to keep the energetic value of the groundwater even when extracting water for thermal energy storage (Arcadis, 2009).

The growing demand for TES systems in Utrecht is an opportunity to address the groundwater pollution in the first aquifer (figure 26) as described in paragraph 2.3. We considered this, because the groundwater is quite polluted (figure 26) and the TES systems are the only systems in Utrecht that go deep into the first aquifer. Also the increase of TES systems could speed the cleaning process up considerably. The use of thermal energy storage systems to treat groundwater pollution has so far been tested in the 'bio washing machine' pilot in Utrecht. The TES systems generate groundwater movements that stimulate naturally existing bacteria to break the pollutants (figure 27). By adding nutrients this process is accelerated, but it is still a long-term solution (Arcadis, 2009).

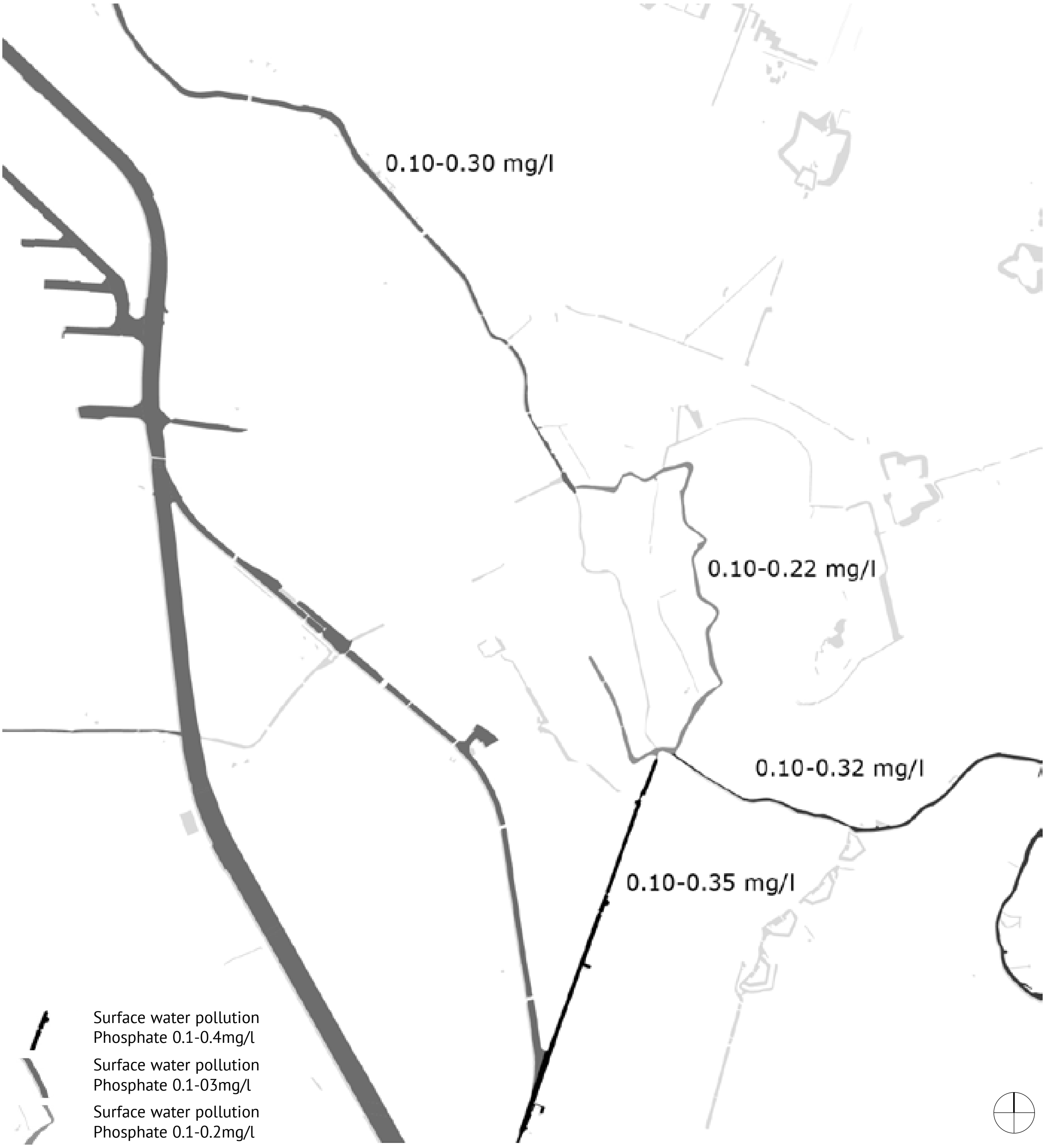


Figure 28. Surface water pollution (Map based on Rebergen, 2013) can be solved by a cooling water shaft with filter (Van der Hoek, 2013)

District-cooling network, surface water, and surface water pollution

The third point in which the district-cooling network can be placed in relation to the existing infrastructure is surface water. Cooling energy can be gained from surface water and this makes this infrastructure a possible source for the district-cooling network. This cooling energy generation is renewable and is thus interesting for CO2 reduction ambition as well. The principle of surface water sources came from a reference project in Amsterdam, where the Zuidas is supplied with cooling energy by means of cold water from a deep water body (Gemeente Amsterdam, 2011; Roelen, 2009).

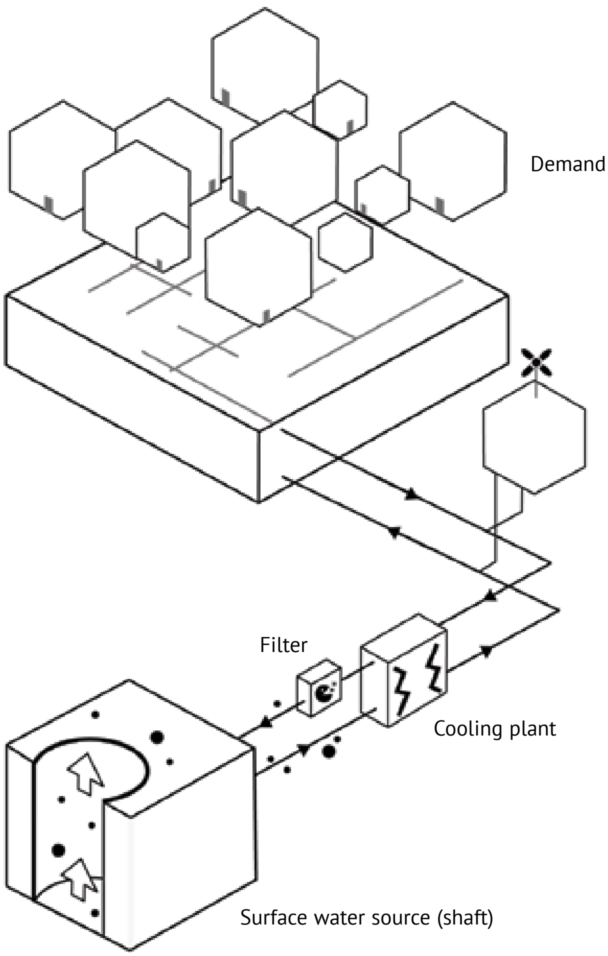


Figure 29. Cooling water shaft with filter principle

This project is currently the only pilot for a large-scale district-cooling network in the Netherlands. As Utrecht lacks the presence of deep water bodies we also considered the findings from a reference project of the University of Twente that studied the use of deep water shafts for cooling energy (Vermeer and Willems, 2006, pp. 22-24).

The principle of a surface water source is that a water body with sufficient depth can be used to pump cold water from the deepest point into a cooling plant (figure 29). In this plant the cold from the surface water is transferred to the water in the distribution network through a thermal exchanger. The distribution network then transports the cooling (6 degrees Celsius) to the connected buildings. The warmer water (16 degrees Celsius) coming back from the buildings is then treated and pumped back into the surface water source (Agentschap NL Energie en Klimaat, 2010; Roelen, 2009).

We deduced that the pumping and filtering of the surface water through a cooling plant could be an opportunity to filter the pollutants from the water. In Utrecht the most widespread pollutants are phosphates and nitrates. We considerd both, but we only needed an example, so in this case we focused on phosphate, as this causes the most urgent pollutant in the surface water of Utrecht (figure 28). This urgency was underlined in an unrecorded interview with Erwin Rebergen of the municipality of Utrecht.

In the case of the Zuidas, where cold surface water from the Nieuwe Meer and Ouderkerkerplas is used as a source for the district-cooling system, the phosphate level of the water is reduced by means of oxidation to stabilize the temperature of the water output and prevent algae growth (Agentschap NL Energie en Klimaat, 2010). We reasoned that this system could be used to filter more phosphates from the water than necessary to stabilize the temperature, and thus slowly contribute to solving the phosphate pollution issue. Jan Peter van der Hoek of Waternet confirmed this line of thought, based on his experience with the Zuidas reference project.

3.3 CONCLUSION BUNDLING

The specific research question that was supposed to be answered by this chapter is: *'what is the possible spatial and technical coherence between a district-cooling network and the current infrastructures in Utrecht?'*

In the bundling phase (chapter 3) we described the coherence between the district-cooling network and the relevant existing infrastructures in Utrecht. The infrastructures from the mapping phase that we thought could be connected to the district-cooling network are fast- and slow traffic mobility, surface water, and thermal energy storage systems. We also included the problems and opportunities that arise when seeking this coherence concerning surface- and groundwater pollution. We found the other information layers from the mapping irrelevant in relation to the district-cooling network, as they are either unconnected with road infrastructure or with the production of cooling energy in any form.

Fast and slow traffic mobility could spatially cohere with the district-cooling network, because the roads used by buses, cars and cyclists offer a relatively easy access to the main distribution pipelines and often form quite a direct connection to all parts of the city. Energy production and groundwater pollution could technically cohere with the district-cooling network, because thermal energy storage systems a renewable source for cooling energy, and they can be used to treat groundwater pollution. The surface water system could cohere with the district-cooling network, because cooling energy can be gained from surface water and this makes this infrastructure a possible source for the district-cooling network. Also we deduced that the pumping and filtering of the surface water through a cooling plant could be an opportunity to filter the pollutants, like phosphates, from the water.

3.4 REFLECTION BUNDLING

We thought the bundling was needed as a step between the mapping and the design phases in order to come to our design assignment as described previously in the reflection on the mapping phase (paragraph 2.8). A more detailed description of the use of methods in the bundling phase can be read in the introduction paragraph of this chapter (paragraph 3.1). As described in the preface and introduction our thesis process consisted of two phases: at first the thesis was unsatisfactory and needed additional work, and in the completion phase we added the necessary material to come to a passable product. The following reflection should be considered with this in mind.

Reflection on landscape infrastructures as compass

In his writings on landscape infrastructures Pierre Bélanger describes the integration of biophysical systems with contemporary infrastructures (Bélanger, 2013). We interpreted that making the connection between these two aspects leads to a landscape infrastructure. We used integration to create a phase in our thesis called bundling.

Reflecting critically on this phase we now see we used the bundling as a way to create a technically working district-cooling network by selecting possible source systems. The technical approach that we have chosen was too holistic and was incorporating aspects that are not part of our scope. We would have done better to look at what a landscape architect can contribute to bundling systems with a district-cooling network, as further described in the reflection on the designing phase (paragraph 4.8).

Reflection on the bundling phase

The bundling phase has no structure embedded in methodology or any critical reflection on the data that we used, therefore we got the critique after the colloquium presentation that the bundling phase is poorly developed and seems to be incidental. This last is a fact, as we kind of devised this phase ourselves and we did not build it properly in terms of methods. While going through the bundling phase, we found it quite difficult to make a connection with the mapping, and designing phases. We actually rewrote the complete bundling chapter as much as four times while trying to make this connection. This is no surprise, as we had created an unworkable situation for ourselves in this phase.

Without a focus or framework it became unclear why certain data was used and added to the concept of a district-cooling network. Besides that the data sources and the outcomes were not questioned or evaluated. Therefore the bundling phase does not offer any alternatives to prove the value of the choices for the infrastructures that we connected to the district-cooling network. By falling short on reasoning, description of data sources and critical reflection we cannot state that the bundling needs to be added between the mapping and designing or that the bundling phase could lead to a design assignment.

After several months of working without being critical on the paths that we chose we came to the understanding in the completion phase of the thesis on how we should have analysed the choices that we had made. Without reasoning or comparisons for choices it was not clear how different parts fitted into the whole. We realize now we should have compared, reasoned, examined, explained, and evaluated the data and the relationships between different data sets. In the completion phase the intention was not to redo the entire work, but to come to a passable result. So we decided to explain how the problems with the bundling phase occurred, what we learned from this, and what the value of the results is.

In the completion phase we concentrated on a creating a clearer structure, adding reasoning and making the process more transparent. We changed the research question to better fit the phases, which lead to removing the original paragraphs 3.1 and 3.2 from the chapter. As these paragraphs were focused on how to bundle underground and aboveground infrastructures they were no longer relevant to the changed topic of the research in the second phase of the thesis. We then focused the bundling phase on the coherence between the district-cooling network and existing infrastructures that were described in the mapping phase. In that sense the bundling phase is not sufficient or transferable, but it is connects better to the mapping phase by changing this focus.

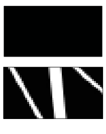
Looking back we conducted a mapping phase focused on existing infrastructures, so in order to connect the mapping and the designing phases we think the bundling phase should have been a study of strengths, weaknesses, opportunities, threats, precedents, and the concept of bundling itself. We assume that this would have given the opportunity to create and value several alternatives. By showing different alternatives the topic could have been questioned and a funded choice for a design assignment could have been made. This is a hypothesis that would need to be tested in further research to develop the bundling phase. That is, if one would even consider developing the idea of a bundling phase, because a different approach of the mapping or even other, unexplored methods might be better options for repetition or further development. Through the described experiences we became aware of the importance of a clear methodology and why this is important for a scientific research.

We can conclude that the significance, validity and reliability of the bundling phase are non-existent, as we did not manage to use a sound methodology to operationalize this phase and explore its value in research. The bundling phase had not been necessary if the mapping phase would have been coherent. Therefore the only significance of the bundling phase could be that it shows what the mapping phase was lacking in order to tell a coherent story and lead to a design assignment.

4. DESIGNING

Designing a district-cooling network in relation to infrastructure

Figure 30. Barriers are obstructing the west-east economical axis in Utrecht



Schematic view of economical axis

Infrastructures as barriers

4.1 INTRODUCTION DESIGNING

The mapping and bundling phases have lead to the choice to combine a district-cooling network with road infrastructures, slow traffic mobility, and renewable sources, like thermal energy storage, and cooling from surface water. The designing phase shows the spatial implementation of the district-cooling network in relation to the abovementioned infrastructures and sources. The specific research question we answer with the designing phase is: 'How can one possible spatial and technical solution for a district-cooling network be implemented in coherence with infrastructures in Utrecht?'

Compass

Within the context of this research we use the definition of designing by Pierre Bélanger as a compass. He described designing as 'a form of synthesis that often revels in complexity when dealing with diffuse, indeterminate, fluctuating processes or dynamics, most often found in biophysical processes, social networks, or urban conditions (Bélanger, 2013, p. 394). We were naïve to think that, as Bélanger states that design is a practical act, we did not have to add theoretical concepts on aesthetics in relation to the design of a landscape infrastructure and that were free to make an intuitive and implicit design.

Methods

The main method of this phase is designing based on research, because designing forms the core of landscape architecture (Creswell & Plano Clark, 2011, p. 47 in Lenzholzer, Duchhart, and Koh, 2013, p. 120).

We designed a possible implementation of the district-cooling network in coherence with existing infrastructures by means of spatial analysis, formulating the assignment and program, sketching, visualizing and deduction.

To link the assignment defined in the bundling phase to a spatial intervention we started by connecting the assignment to the demand of cooling in the city, spatial problems, and future developments. Based on this we formulated an indication of the program.

We sketched possible options on the scales of the city (1:15.000), the plan elements (1:5000), and details (1:500). These sketches formed the basis for visualizing the outcomes into plans and thus solving spatial issues and strengthening the proposed interventions.

Please note that as we are landscape architects our scope does not include technical detailing and detailed calculations. Thus these are not part of this research as explained further in paragraph 5.5.

4.2 DESIGN CHALLENGE

Design challenge
The design challenge we formulated is to explore how a district-cooling network supplied by renewable sources can be implemented in cohenrence with the existing infrastructures in the city of Utrecht. Infrasturctures are in this context focused on structures for fast- and slow traffic mobility, as explained in the bundling chapter.

In the bundling phase we described the infrastructures that can be related to the district-cooling network. In the designing phase we determine where and how the district-cooling network can be implemented and how it relates to existing infrastructures. We argue the choices we made during our creative and iterative design process. The possible desirable future we designed to answer the design challenge is only one possible way to deal with this challenge.

Spatial assignment
Besides the general design challenge there is a spatial assignment in Utrecht. Together they form the focus of the designing phase of our thesis. The many barriers created by water, roads and railways are a threat to the spatial connectivity in Utrecht. We chose this particular threat, because we reasoned it fits the focus on fast and slow traffic mobility that we chose for the designing phase.

Most of the barriers in Utrecht are oriented north to south, but the economic axis of the city is oriented west to east (figure 30). This economic axis connects the developments of Leidsche Rijn to the companies in the inner city and the knowledge cluster of the Uithof (figure 30). Barriers that hinder this economic axis are (from west to east) the A2 highway, Amsterdam Rijnkanaal, Merwedekanaal, Beneluxlaan, Vleutenseweg, Croeselaan, railway system, Station District, Singel, Oosterspoorbaan, Waterlinieweg, and A27 highway (figure 30).

Overcoming these barriers by means of connecting hubs (see also the previously described missing links in paragraph 3.2) and reconnecting the economic axis in terms of slow traffic mobility is our focus for the strategic plan and details.

4.3 DESIGN PROGRAM

To come to a design a program needed to be set. However, this thesis is purely academic and we do not have access to certain information that is necessary to calculate the input and output of the system.

The first program point is the development of a district-cooling network supplied by renewable sources as previously explained. The exact dimensions of this network depend on the current and future cooling demand of the city. This information depends on the organisations that together develop the district-cooling system, the amounts of built content that needs cooling, the state of the building's insulation, etcetera. As this kind of information has not yet been mapped by anyone and the future developments are not yet specified, we chose not to calculate the cooling demand within the context of this research. The quantity and dimensions of renewable sources that supply the cooling energy and the quantity of cooling plants that are needed for the proposed district-cooling network depend on the cooling demand as described above. As we are not able to calculate the cooling demand we could not determine the quantity and dimensions of the renewable sources and cooling plants. The situation, dimensions and quantities of the plan elements designed in this thesis must thus be considered to be indicative.

The second program point is the reduction of ground- and surface water pollution, which we learned from the mapping process. As previously described in paragraph 2.3 the surface water pollution with phosphates is an important issue for the surface water quality and temperature, which influences the urban liveability. Reduction of surface water phosphates with 0.2-0.7 mg/l is part of the program for the design, as this can be linked with the renewable sources for the district-cooling system. The ground water pollution in the first aquifer is an issue in Utrecht, which on the long-term threatens the drinking water supply for the city as described in paragraph 2.3. As this issue is related to the 'bio washing machine principle' and we intended to use this system as a source for de district-cooling network we make the reduction of groundwater pollution part of the program. However, we cannot specify the pollution's extent, because the composition of the ground water pollutions is very complex and the locations or intensities are not fixed (Arcadis, 2009).

The third program point is the optimization of slow traffic mobility. Concerning the slow traffic mobility issues that are central in the ambitions of the new mobility plan of the municipality (Dienst Stadsontwikkeling, 2012a) a certain specification of the program is possible. Three major connections in the city are of importance for the optimization of slow traffic mobility: the Carthesius Triangle point, the Link between the Station District and the Jaarbeurs area and the Oosterspoorbaan-Venuslaan connection. These connections between the inner city and the Carthesius Triangle, Jaarbeurs area and Kromme Rijn area are now missing links, but they are included in all mobility plans and policies for Utrecht (Dienst Stadsontwikkeling, 2005; Dienst Stadsontwikkeling, 2012a).

Figure 31. Strategic plan 1:15.000 for an indicative, possible development for 2030

Main distribution pipeline

Secodary distribution pipelines (indicative)

Surface water sources

Thermal energy storage (TES) clusters

Connecting hub

4.4 STRATEGIC PLAN

A district-cooling network as described in this paragraph could be developed on the long-term in several districts in Utrecht in order to optimally supply clusters of industrial buildings, office buildings or educational buildings with cooling energy. The scale of the conceptual plan (figure 31) is set at 1:15.000 to include the entire city of Utrecht. We chose to only show the functional or technical interventions on this scale, because the relation to the infrastrucutre is very different for every part of the city. We did make general principles per plan element (main distribution pipeline, thermal energy storage clusters, surface water sources, and connecting hubs) that show this relationship, as described in the next paragraphs.

District-cooling network

We designed a strategy for the development of a district-cooling network supplied by renewable cooling sources. This collective system serves the demand for cooling of office buildings, educational buildings, shops, and industries in the city of Utrecht. As the cooling energy is to be generated by renewable sources the system contributes to the ambition to become CO2 neutral in 2030. When looking at the Zuidas reference project we assume that we can contribute a 75% reduction of CO2 emissions (Roelen, 2009) in comparison to the emissions of current unsustainable and individual cooling systems. The development of this network shows coherence with the existing infrastructure as the pipelines will be situated under existing roads and paths and the cooling plants and pipelines are to be integrated in bridge-like elements that have a connective function.

We designed the main distribution network, the cooling sources and the connecting hubs, however the smaller branches of the network as shown in the strategic plan are only indicative.

Table 3. Dimensions of plan elements

Plan elements	Dimensions
Main distribution pipeline	- 60 cm in section (Gemeente Amsterdam, 2011, p. 23)
Cooling plant	- Size of several houses (Gemeente Amsterdam, 2011, p. 23)
Surface water source	- 15m depth and - 15-30m section (Vermeer and Willems, 2006, pp. 22-24)
Thermal energy storage	- 50 m depth max - distance depends on thermal radius

Table 4. Meters of main distribution pipeline
Metres of pipeline measured from the strategic plan

Plan area	Pipeline
Lage Weide	1648 m1
Cartesius Triangle	3308 m1
Leidsche Rijn Centre	1108 m1
Station/Jaarbeurs	1256 m1
Inner city	5125 m1
Galgenwaard	2772 m1
Total amount	*15.217 m1*

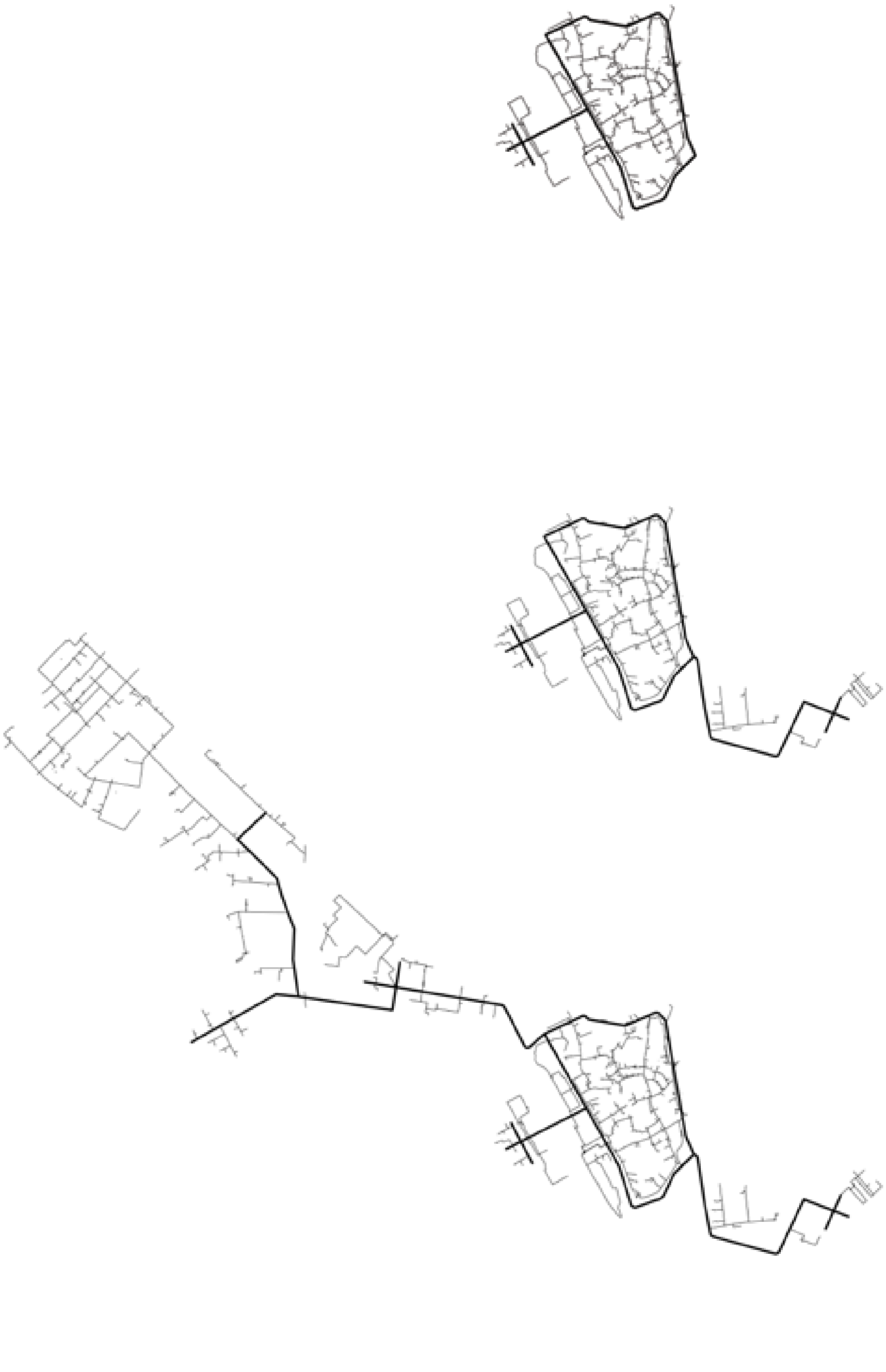


Figure 32. Indicative possibility of developing the district-cooling network over time - 2020 - 2025 - 2030

The development of underground infrastructures, like a district-cooling network, is more viable when developing them to give an added value to the aboveground urban systems (COB, 2012). To repeat the statement of Prof. Dr. Jaqueline Cramer: ‘the need and profit of underground building can best be discussed from the question what the use of the underground can contribute to quality of life, solving problems and creating opportunities above ground’ (COB, 2012, p. 25-26, 35). Thus the development of the district-cooling network depends on other developments that require underground works, as it is too expensive and inefficient to develop such a network on its own.

The developments that form the incentives for the development of the district-cooling system are for example large-scale building projects, infrastructural projects and the substituting of out-dated underground systems. We clustered the developments in Utrecht in relation to development of the district-cooling network in four indicative terms as described below and shown in figure 32.

2020 Singel, Jaarbeurs (2012-2020), Station District (2014-2018), inner city
2025 Oosterspoorbaan (2014-2025), Galgenwaard
2030 Cartesius Triangle (2026-2030), Leidsche Rijn Centre (2012-2030), Lage Weide

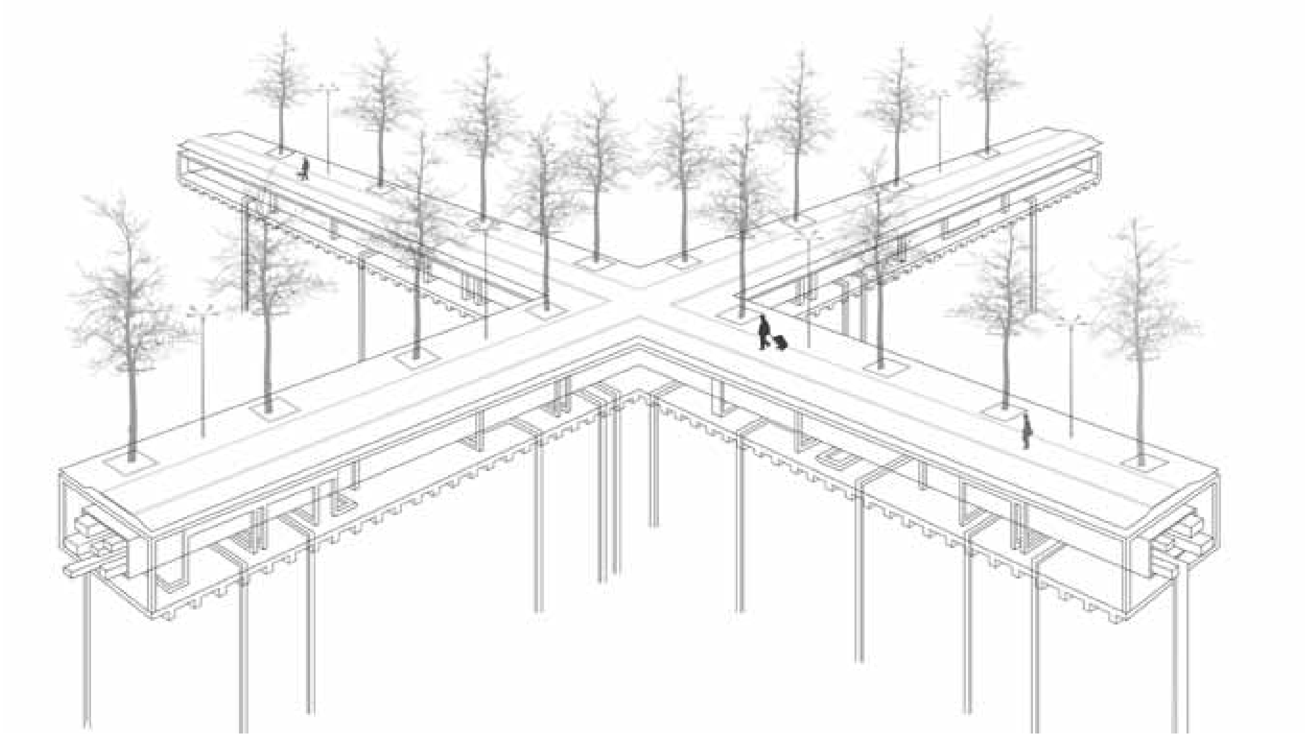


Figure 33. TES cluster designed as a road infrastructure

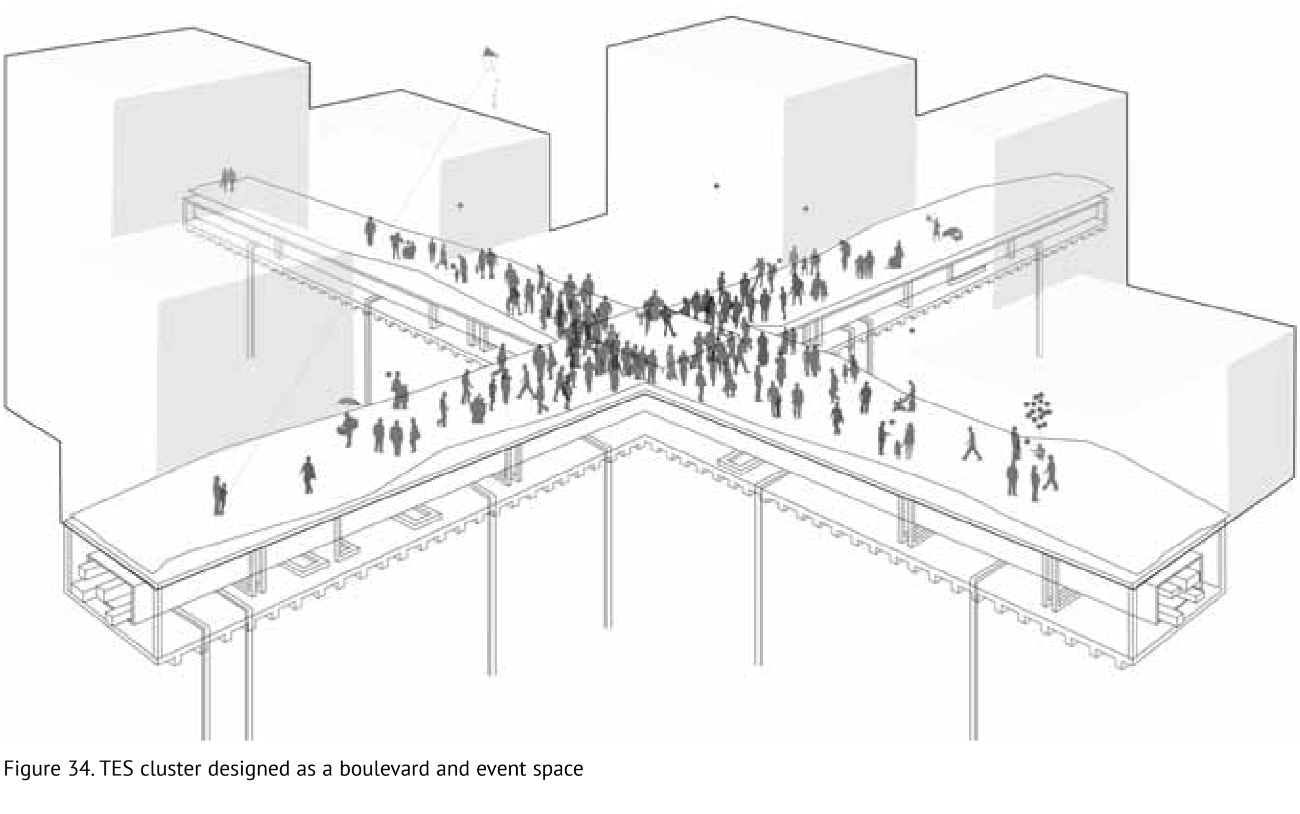


Figure 34. TES cluster designed as a boulevard and event space

Main distribution pipeline

The main distribution network is a pipeline that transports cooling water between 6-16 degrees Celsius (Gemeente Amsterdam, 2011, p. 25). As the development costs many kilometres of expensive pipeline (this can be €1000 per m1 for large pipes) the main distribution network is designed to be as direct as possible as it is very expensive.

The pipeline is situated in an underground duct that can be used flexibly for future systems like the extension of the district-heating network, data lines, hydrogen transport, etc. We also considered just developing the pipeline itself without a multifunctional duct, but we reasoned it would be more productive to build a structure that can contribute to developing other systems in the future. Of course this idea is only academic, as the duct would only be possible with well developed exploitation and investment plans.

The main distribution network (figure 31) is designed to connect the Singel with development areas or existing areas with a cooling demand. Development areas are the Jaarbeurs, Station District, Cartesius Triangle, Oosterspoorbaan, and Leidsche Rijn Centre. We deduced that existing areas with a cooling demand are the inner city (shops and university), Galgenwaard, Rijnsweerd, Lage Weide, Overvecht, Oudenrijn and Papendorp (figure 31). For the developments and existing areas we only considered clusters of utilitarian buildings (industries, offices, schools, shops, etc) as these have a cooling demand.

We considered including other areas, like housing and the Uithof, but for these areas the district-cooling network would be irrelevant. The Uithof is not included, because this area has a completely separate energy system, as described in paragraph 2.4 The housing areas and developments we did not take into account, as these are mostly not centrally air-conditioned, and if they do have a cooling demand, it is for a cooling temperature of 17-25 degrees Celsius (Gemeente Amsterdam, 2011, p. 25), which is not compatible with the utilitarian district-cooling system.

The district-cooling pipeline mostly follows existing structures, like waterways and roads to ensure a relatively easy construction and the accessibility of the pipeline for management. The future developments near the centre of Utrecht, like the Jaarbeurs, Station District, Oosterspoorbaan and Cartesius Triangle, will be structured by means of the main underground duct as the location of the duct can indicate the situation of the infrastructure to be developed in the future.

The distribution network connects the clusters of utilitarian buildings with the cooling supply. These supply points can be clusters of thermal energy storage systems that extract cooling from groundwater or deep water shafts that supply cooling from surface water. At the points where the district-cooling system meets a barrier the pipes are clustered in a tunnel or bridge-like element that connects the district-cooling network to infrastructures in the city and contributes to the accessibility for traffic. The implementation and possible typologies of the thermal energy storage clusters, the surface water sources and the connecting bridges and tunnels are explained below.

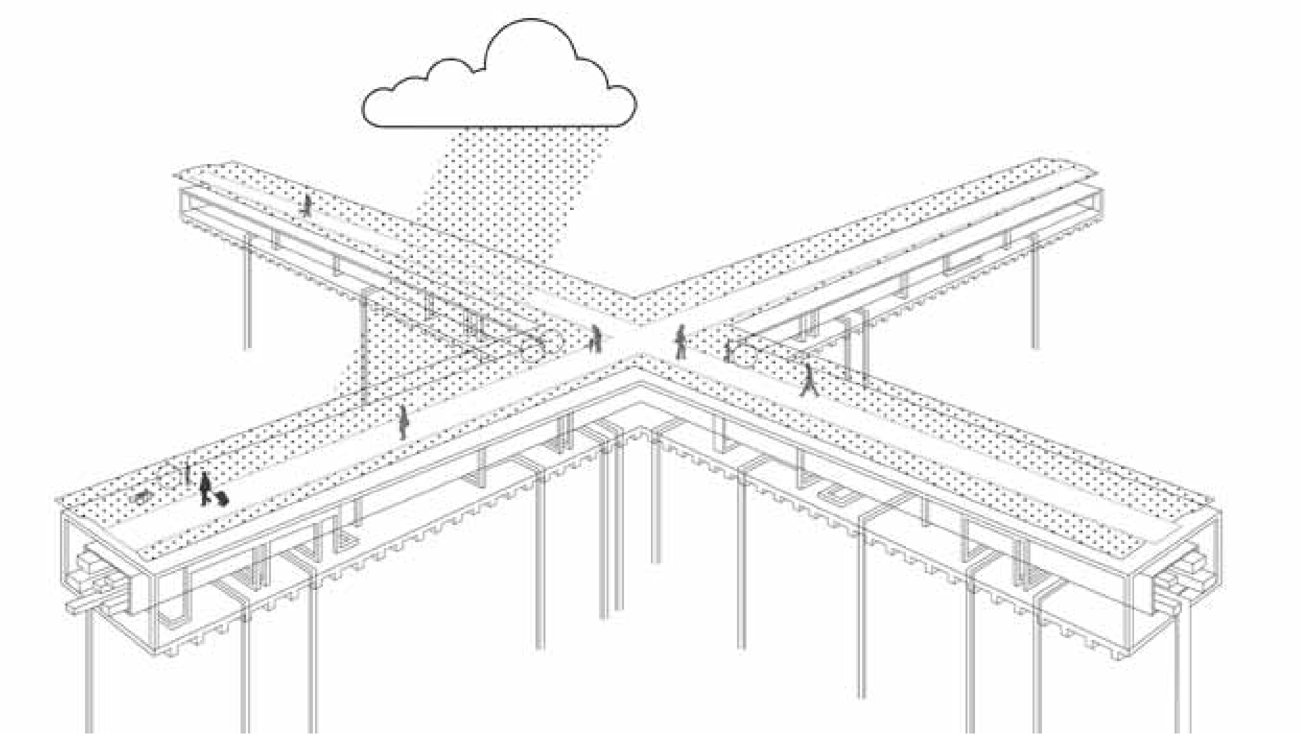


Figure 36. TES cluster designed as a walking- and cycling path

Thermal energy storage clusters

The first renewable source that we explored for the supply of the district-cooling system is cooling energy gained from groundwater by means of thermal energy storage systems. This energy generation is renewable and thus contributes to the CO2 emission reduction. The working of TES systems was previously discussed in paragraph 3.2. In this case we look at open systems, which can have a direct connection with the first aquifer at -5m NAP to -50m NAP. We did not consider working with closed TES systems, as they do not have the advantage of cleaning the groundwater pollution. As previously explained in paragraph 2.2 it is not possible in Utrecht to drill deeper than the first aquifer, because the second aquifer is protected for drinking water extraction.

As described in paragraph 2.4 many newly developed buildings are equipped with an individual thermal energy storage system, but there is not yet a collective supply that connects these systems. As the amount of individual TES systems in Utrecht increases in areas like the Station District new problems arise. Many TES systems are so close together that they cause a reciprocal thermal interference, which means that the sources start to influence each other and thus lose their efficiency (Arcadis, 2009). In Utrecht seven or eight out of ten TES systems are not functioning optimally due to thermal interference (A. Harting, Gemeente Utrecht, email communication, July 3, 2012). Because of these reasons we did not consider working with individual systems. The issues described above ask for a clustering of TES systems that are connected and managed collectively. A collective system could make it possible to fine-tune the management of the TES systems and thus lead to an optimisation of the sources (Wessels, 2013).

In the conceptual plan three thermal energy storage clusters are designed to supply the cooling network and contribute to cleaning groundwater pollution. The three locations for the clusters were selected based on pollution areas in the first aquifer: the Cartesius Triangle, Jaarbeurs and Galgenwaard. The areas have heavily polluted groundwater as they where sources of pollution in the past (Arcadis 2009). TES clusters have mostly been used in circles or grids to function as a ‘bio washing machine’, however we deduced a cross would have the same effect on the groundwater pollution.

During the design process we also considered using lines or circles, but these seemed less suitable to solve the groundwater pollution or less easy to fit in the urban fabric. A line would not cover the pollution centres sufficiently, though it would be fit well with other infrastructure. A circle would be difficult to implement in the urban fabric, and it would have to be complete in order to work, preferably with a distance of fifty metres between the TES’s, depending on the thermal radius (Arcadis 2009). A cross can more efficient in the amount of TES’s needed to develop and fits well in the urban fabric. The development could for example start at the four points of the cross and then continue inwards, thus flexibly responding to TES demand. Also a cross can be adapted to follow existing structures, with uneven angles and variable lengths of arms. By combining TES clusters with other sources of thermal energy, like energy from sewage or drinking water, the heat from these other sources can be used to stabilize the pressure of the TES systems and thus optimizing them further.

The bio washing machine’ slowly cleans the ground water below the city, thus contributing a clean underground to the urban environment. This offers new land uses for places that were previously too heavily polluted for uses like living. It also offers opportunities to shape the infrastructure of future aboveground developments on the locations of the underground TES clusters. In figures 33 to 36 we show some indicative and schematic drawings of possible opportunities, like roads, boulevards, or slow traffic routes.

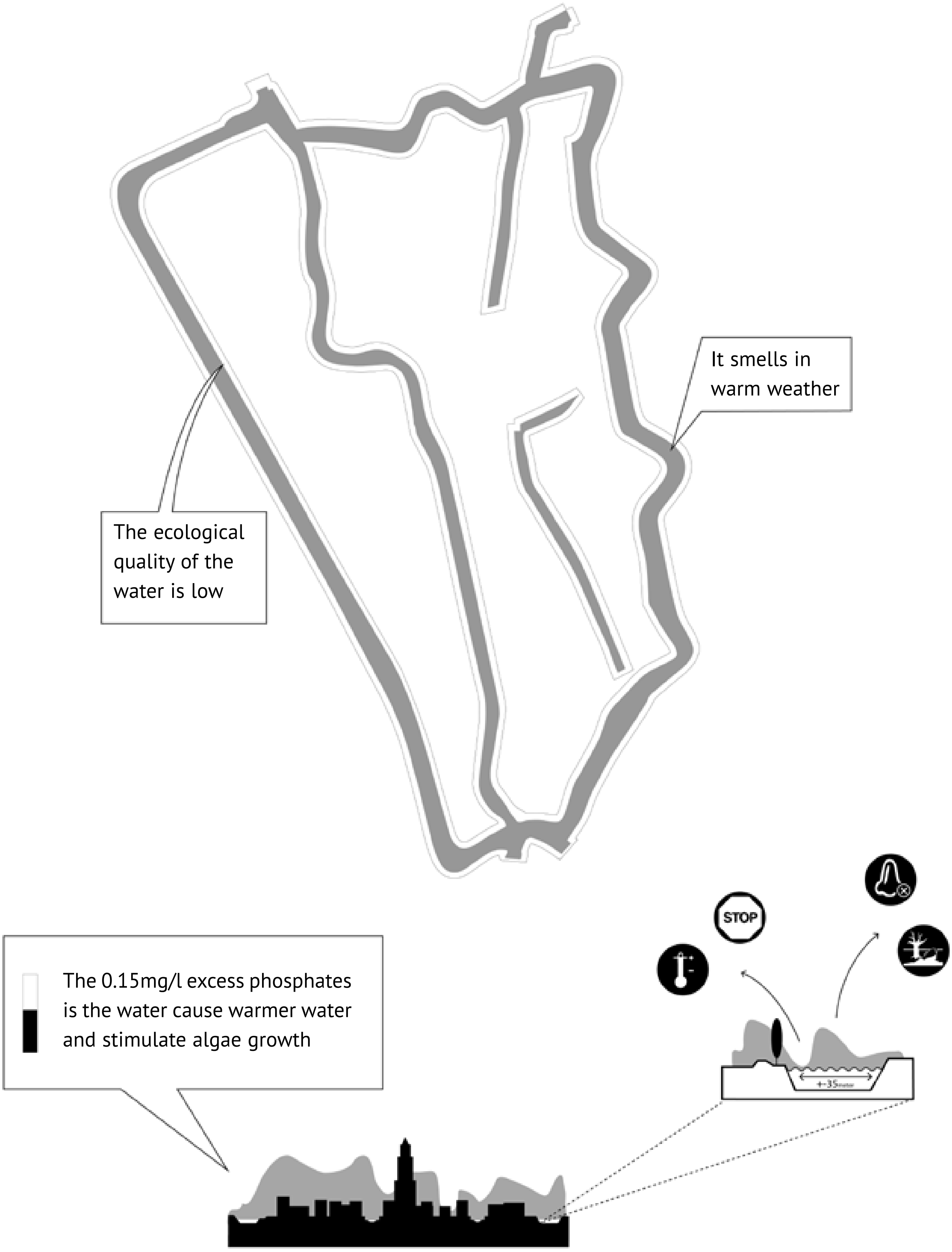


Figure 37. In the current situation the water quality of the Singel is not very good (Information from Rebergen, 2013)

Surface water sources

The surface water cooling sources could be situated in the Singel and Amsterdam Rijnkanaal, depending on the location of demand from utilitarian buildings and the situation of the main distribution network (figures 31 and 37). The sources are mostly designed in relation to planned or existing bridges, where the distribution pipeline crosses the water. This way the sources can be connected to a cooling plant built in the bridge that also supports the pipeline. The amount of surface water sources designed in the conceptual plan is only indicative, as the amount and size or sources depends on the demand and debit of cooling. As we did not have the means to calculate these aspects in the context of this thesis we can only give an indication of the system's dimensions.

The underwater shafts that hold deeper and thus cooler water in existing water bodies (Roelen, 2009) supply the cooling from surface water for the district-cooling system. The sources consist of a 15 metre deep shaft with a section width between 10 and 35 metres. These dimensions are based on the University of Twente reference project (Vermeer and Willems, 2006). As described before we cannot realistically specify the dimensions for the case of Utrecht.

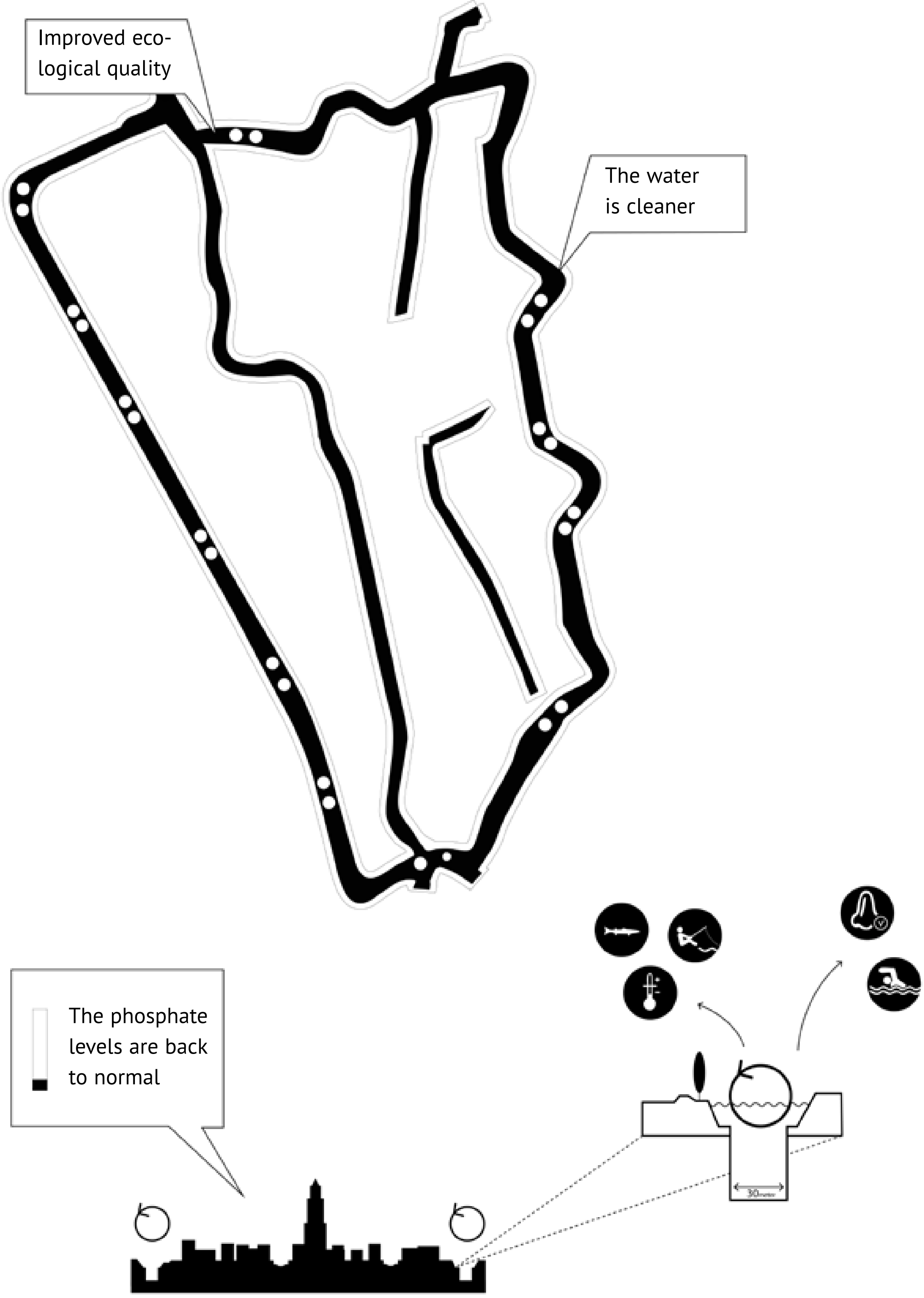


Figure 38. Surface water shafts in the Singel improve the quality of the water for the inner city

To ensure the accessibility of the Singel for recreational water use and the Amsterdam Rijnkanaal for shipping the shafts are not protruding above the floor of the water body. To ensure the safety of the shafts for boats, fish, and people the shafts are closed with a grid, as it is desirable to keep a direct connection between the water in the shaft and the surface water. We also considered designing the shafts to show above the water and make the cold water of the district-cooling network visible and tangible. However, we decided against this, because we found it too artificial and trick-like. Besides, this would make the water bodies partly inaccessible for boats, which would be a problem for the transport on the Amsterdam Rijnkanaal. Also we think protruding shafts would degrade the historical character of the Singel.

The long-term cleaning process of the phosphate excess in the surface water could be a positive side effect of the surface water sources (figure 38). The lower phosphate levels mean a lower water temperature, which means less algae growth, thus cleaner and clearer surface water for sluicing and recreation. Also the cooler surface water has more potential to cool the warm air in the inner city when wind blows over the water, which adds to a pleasant microclimate in the city in warm summer months.

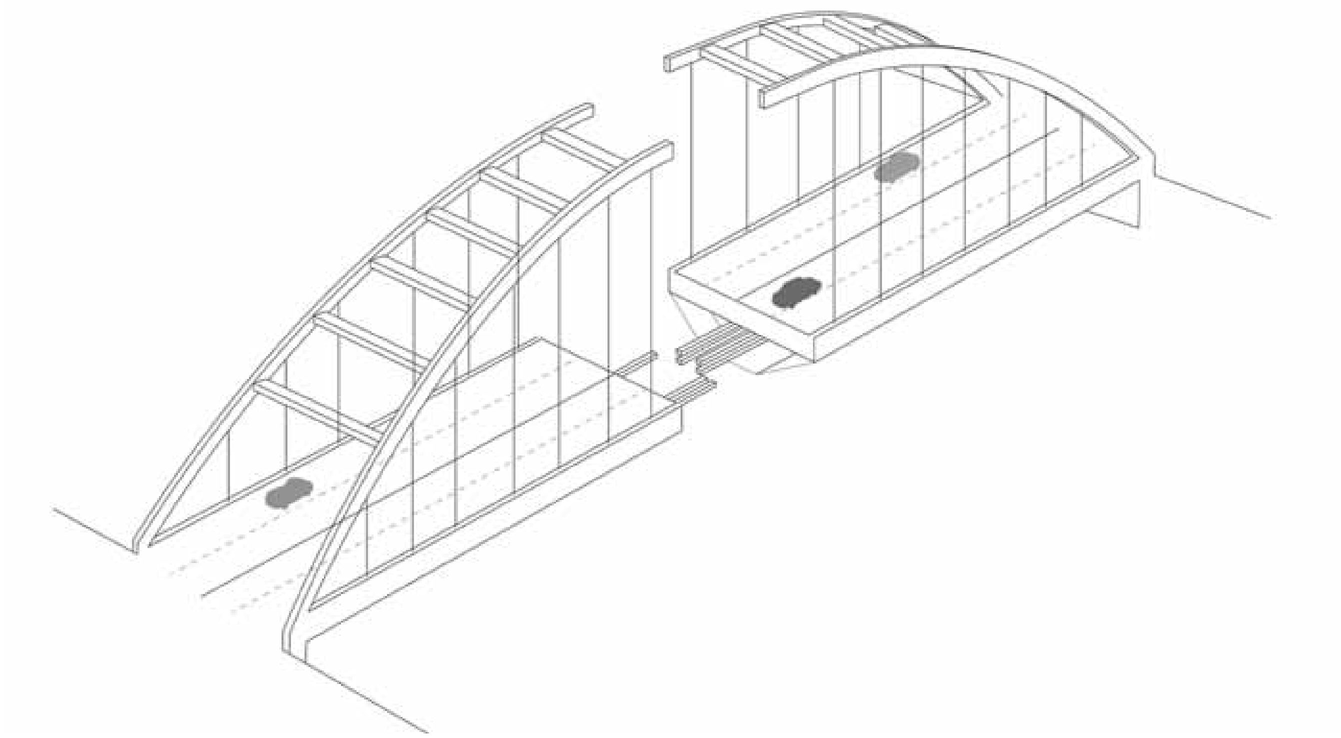


Figure 39. Existing bridges as connecting hubs

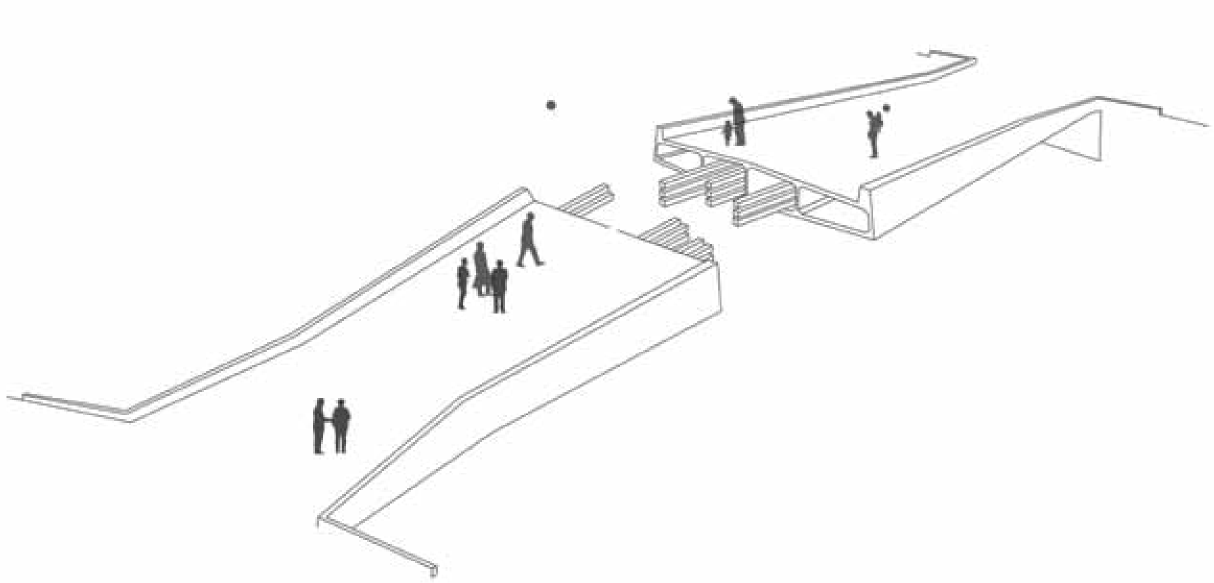


Figure 40. New bridges as connecting hubs

Connecting bridges and tunnels

As described before the district- cooling network and and mobility are both hindered by barriers, like waterways and railways. Thus we looked at some possible ways in which barriers can become opportunities to make the cooling plants accessible and at the same time optimize the mobility in the city. The barriers thus become the hubs where the underground system meets the surface to make the management of technical systems possible. These hubs are the ideal places to situate the cooling plants that regulate the pressure on the system, and distribute the cooling energy. Besides this added value from a technical point of view the hubs can have an added value for the spatial domain in terms of mobility.

As previously described in paragraph 2.6 the ambition of the Fietsersbond and municipality to create an unimpeded cycling network is threatened by the many barriers in the city. Barriers created by water, roads and railways are oriented north to south, and the economic axis of the city moves west to east. These barriers require over- or underpasses, depending on the character of the barrier. These barriers are also an issue for the development of the district-cooling network, so we chose to connect this to filling some of the missing links in the preferred fast cycling network: the Carthesius Triangle, Jaarbeurs and Oosterspoorbaan. We did not have enough information to consider other missing links, because did not thoroughly analyze the mobility issues in the city. However, the missing links described above serve as an example to show some of the possibilities.

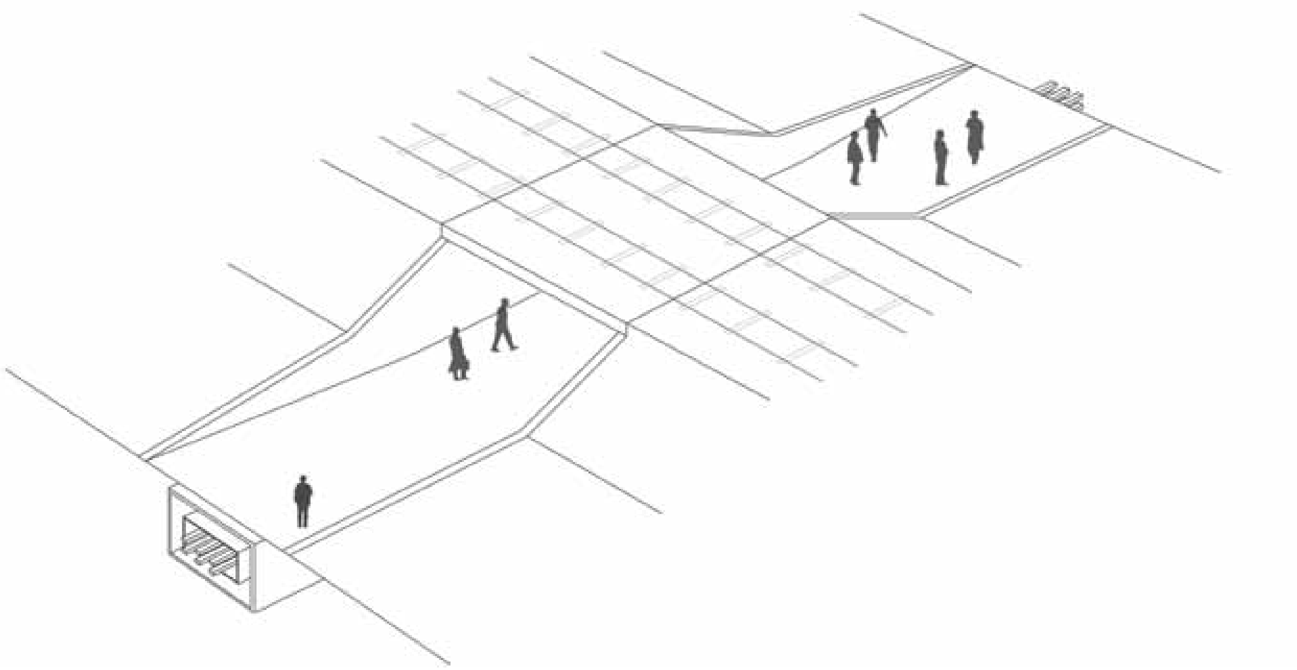


Figure 41. Tunnels as connecting hubs

Bridges or tunnels could be developed where cars and cyclists can make use of the passing of the district-cooling system aboveground where it meets barriers. These places are situated at three strategic locations near the inner city, that are examples for the optimisation of the mobility (figure 24). The locations of the bridge between the Jaarbeurs area and the Station District, the viaduct at the crossing of the Oosterspoorbaan and the Venuslaan, and the tunnel at the southeast corner of the Cartesius Triangle, are all mentioned in various mobility plans and policies for mobility in Utrecht (AGV Movares, 2011; Binkhorst, Kloppenborg, Korff de Gidts, 2012; BOEI-Advies, 2009; Dienst Stadsontwikkeling, 2005; Dienst Stadsontwikkeling, 2012a; Fietsersbond, 2010).

The tunnel at the Cartesius Triangle corner connects the inner city and the Cartesius Triangle. The tunnel crosses underneath the railway and connects the cycling routes near the inner city with the Cartesiusweg, which will be developed as a more accessible and green space in the future plans of the municipality (Dienst Stadsontwikkeling, 2012a). As the development of this area is still in the far future and the function is not entirely clear yet, we chose not to make a detailed elaboration of this area in the context of this thesis.

The bridge spanning the railway and thus connecting the Jaarbeurs area and Station District is already planned and will be built within the coming years. We only add to this bridge the bundling of a cooling plant with the pipeline and future other systems, which we propose for other existing bridges as well. Because of this line of reasoning, we chose not to make a detail plan for this area either.

The viaduct of the Oosterspoorbaan crossing the Venuslaan and Kromme Rijn is currently in an outdated state, and it will be developed over the coming years. As this development is just starting now we made a detail design for this bridge within its spatial context (paragraph 4.6). The choice for the detailing of the Oosterspoorbaan area also has some other arguments connected to it, that will be explained in paragrpag 4.5.

How the bridges and tunnels are to be designed and constructed depends on the detailed development of the surrounding areas that form the context of the bridges and tunnels. In this thesis we only detailed the bridge in the Oosterspoorbaan area as described before. However, we have developed some possible schematic options to give an idea of the possibilities for the bridges and tunnels that are shown in the strategic design (figures 39 to 41).

Most of the principles used in this thesis, like the cable ducts, connecting hubs, groundwater sources and surface water sources are existing principles. Our contribution is that we bring them together in a coherent system with existing infrastructures and the proposed district-cooling network.

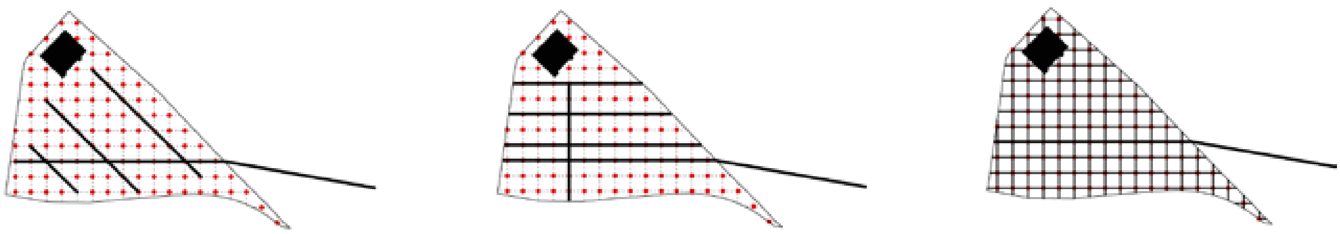
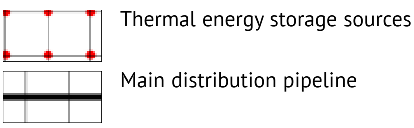


Figure 42. Options for the bandwidth of thermal energy storage clusters (large map scale 1:5000)



4.5 PLAN ELEMENTS

This paragraph describes the implementation of the previously described principles of the thermal energy storage clusters, surface water sources, and connecting hubs on exemple locations in Utrecht. We made this step to explore the possible bandwidths of the principles. However, de considered the programs and design challenges of these examples not to be available yet or not relevant, so it is only an indicative implementation.

Thermal energy storage clusters

For the implementation of the thermal energy storage (TES) clusters we chose the Cartesius Triangle as a location, because this area will be newly developed in the future and it is one of the larger areas in Utrecht that will yet be transformed. In this line of reasoning the Cathesius Triangle is the most logical example compared to the smaller Jaarbeurs and Galgenwaard areas. The size of a TES cluster depends on the cooling demand in the area and the program of the new development. As both are not yet available for the Cartesius Triangle the models (figure 42) show the maximum amount of TES points possible in the area. To the grid of points shown in the figure the indicative distance of 50 metres was used. This indication is based on the principle that sources should not have a thermal interference, but in order to calculate the true distance the structure of the soil and the size of the debit need to be known. The distance of 50 metres as a rough indication was confirmed by Rachelle Verburg of Arcadis. Also the total amount of TES systems is limited by the amount of available space in the area of development, in this case the Cartesius Triangle. As every TES system needs two sources (hot and cold) we can roughly estimate by menas of deduction that the Cartesius area could hold fifty TES systems. The actual amount would be dependant on the buildings that are to be connected to the system. However, a minimum of four TES systems is needed to make a collective system viable (Gemeente Amsterdam, 2011). The TES systems in the collective cluster are connected by cable ducts, as shown in the different models (figure 42) by means of the black lines. The sources themselves need four square metres of space for access and maintenance, so they are situated outside the cable ducts, and as close to the demand as possible.

The four options we explored for the implementation of the TES cluster on the Cartesius Triangle site are a crossed duct, ducts in diagonal lines, ducts in horizontal lines, and ducts that follow the underlying grid structure. The choice of an option would depend on the infrastructural layout and the urban design for the area. In the options of the crossed duct and the ducts in horizontal lines, the infrastructure would fit quite well in the urban fabric. In the options of diagonal lines or grid lines, the structure is quite complicated and requires the creation of a large amount of open space. These four options (figure 42) are only indicative and many other option are possible.

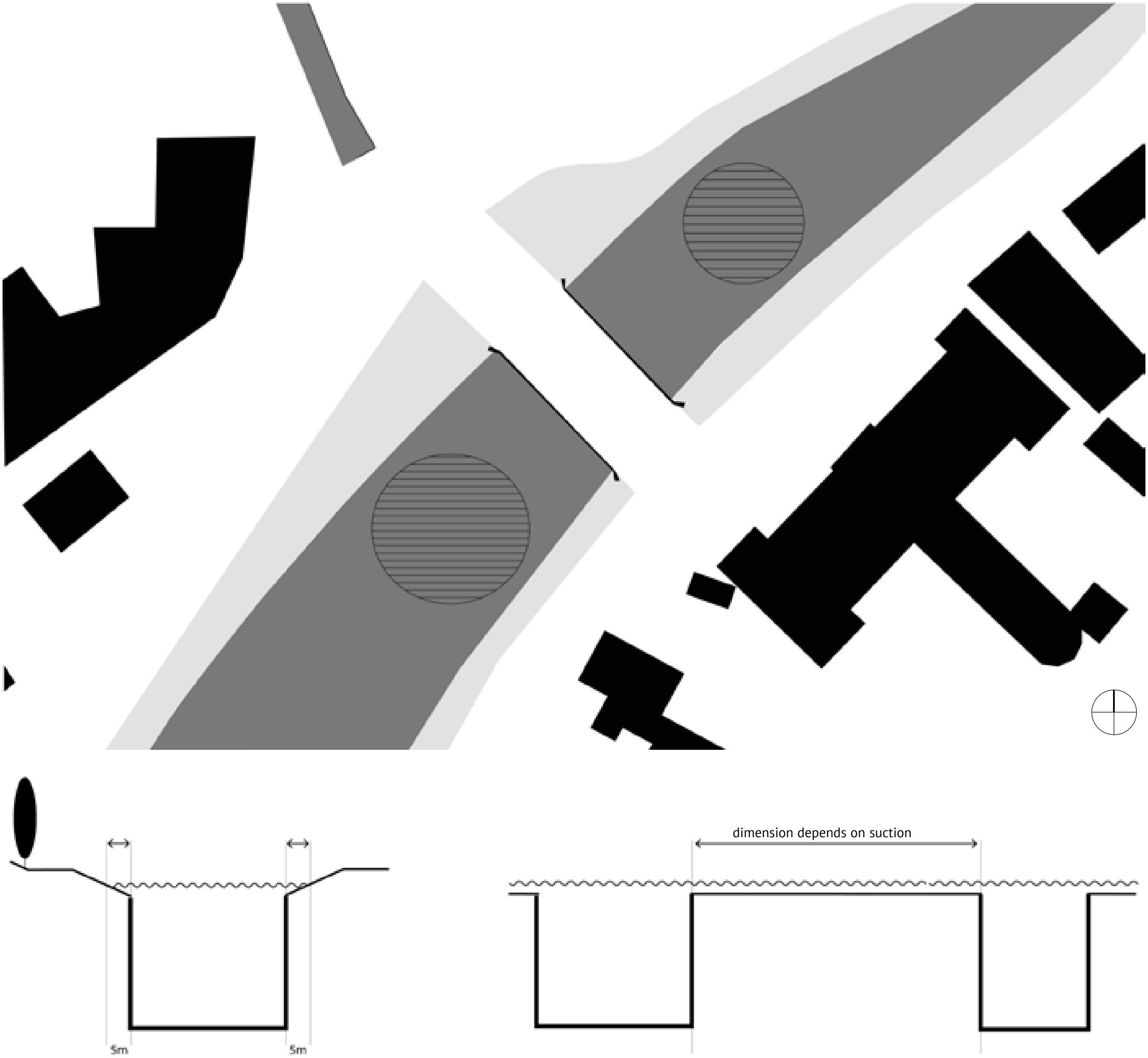
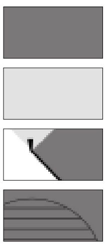


Figure 43. Options for the bandwidth of surface water sources (scale 1:500)



Surface water

Water edge

Bridge

Surface water source (shaft)

Surface water sources

For the implementation of the surface water sources we chose the Singel near the Abstederbrug as a location, because this area contains both broader and narrower parts of the water body (figure 43). The size of a surface water source depends on the required debit for the cooling demand. However, we deduced that the minimum size of a shaft is determined by the amount of water that is needed to pump the cold water to the thermal exchangers. Also we reasoned that the shaft should be deeper than it is wide, to ensure the supply of deeper, colder water for the system (figure 43). As it is not possible to dig deeper than the first aquifer (50m -NAP) in Utrecht, the maximum depth would be 50 metres and the maximum width <50 metres. This is only relevant for the shafts in the Amsterdam Rijnkanaal, as this water body is roughly one hundred metres wide. We think that the edges of the water body should be kept free for five metres (figure 43) for functions like recreation, mooring boats, ecological water edges, etc. This would mean that the broader areas in the Singel could hold shafts of roughly 25 metres in width, and the narrower areas in the Singel could hold shafts of for example 15 metres wide. The distance between the shafts depends on the suction and currents caused by the sources, as interference between the sources should be prevented.

Connecting hubs

For the implementation of the connecting hubs we chose the Gele Brug between the city and Lage Weide as a location (figures 44 and 45), because this existing bridge is the largest hub proposed in the strategic plan and because this location consists of two bridges next to each other. We considered using the existing Oosterspoorbaan viaduct, but we will also show this location in the detail plan and we want to seize the opportunity to show another example here. We reasoned the bridge connecting the Jaarbeurs and Station District is a less interesting example, because it is not yet existing like the Gele Brug.

We reasoned that the development of bridges and tunnels is quite expensive, and thus their development and dimensions should first of all serve mobility optimisation. The hub should be considered as an addition to this priority in a development. In the first option for the Gele Brug location (figure 44) we explored the use of one bridge as a hub, which leads to a massive structure underneath the bridge. In the second option (figure 45) we split the cables and technical elements under two bridges to make the hub more compact. However, as we described above the dimensions of the existing or planned bridge are leading in developing the hub.

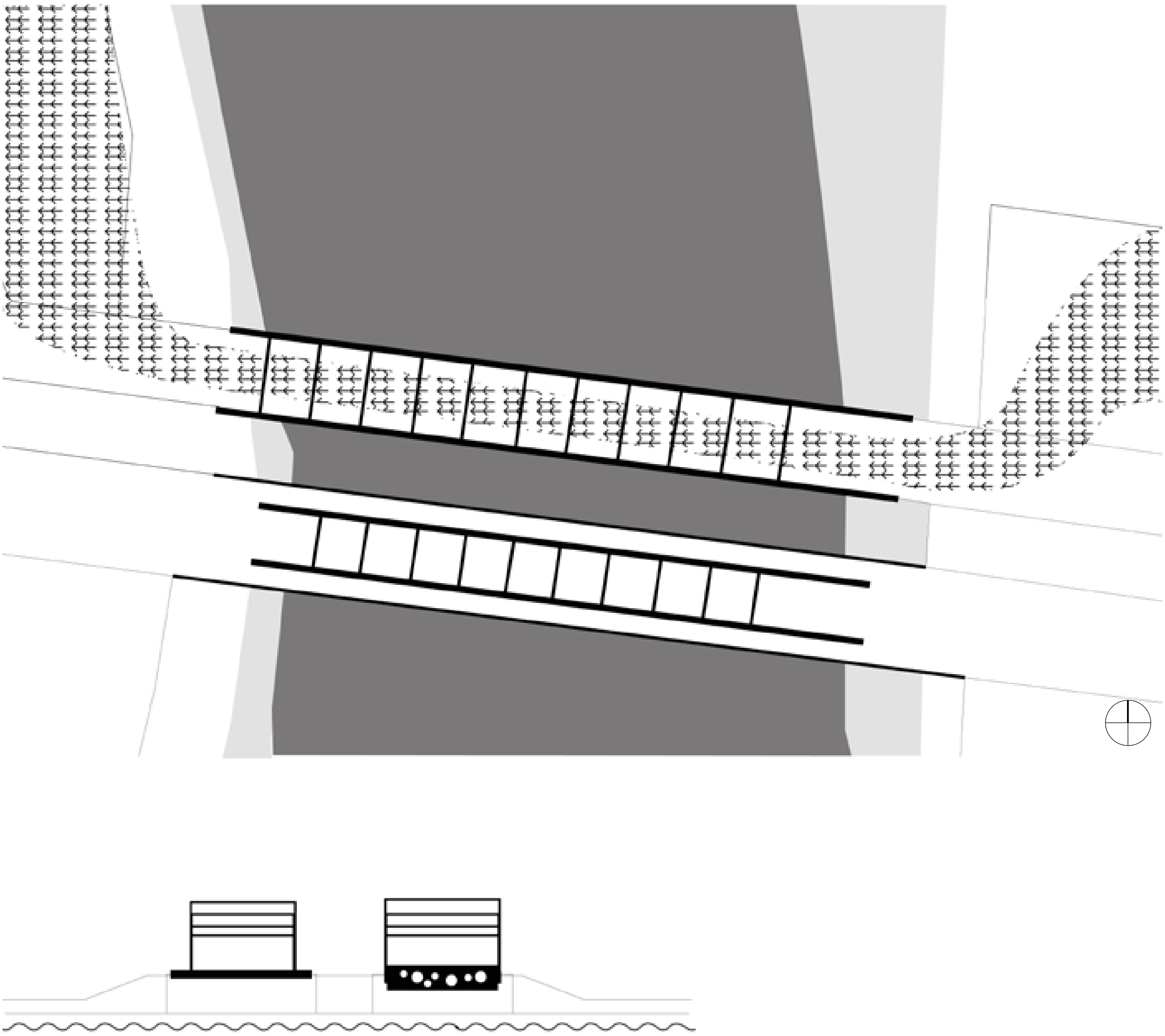
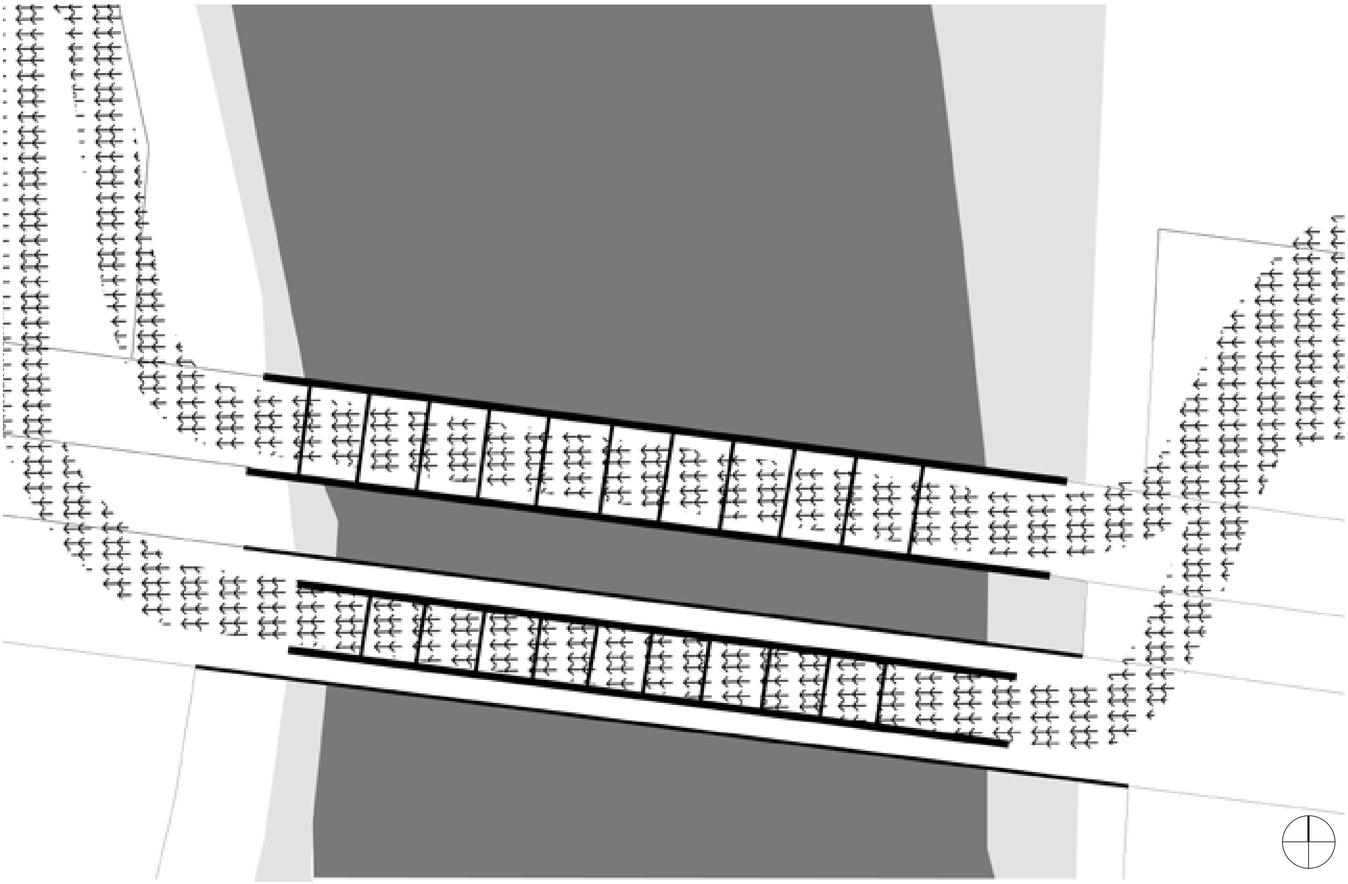


Figure 44. Option 1 for the bandwidth of connecting hubs (scale 1:500)

Surface water

Water edge

Bridge integrated with cable duct



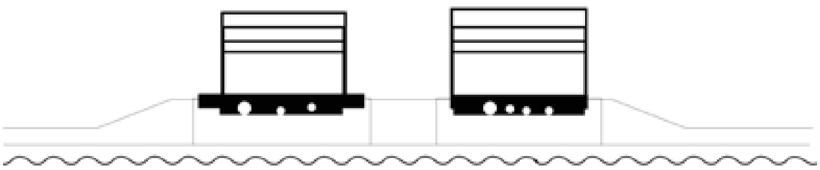
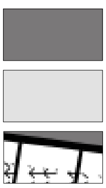


Figure 45. Option 2 for the bandwidth of connecting hubs (scale 1:500)



Surface water

Water edge

Bridge integrated with cable duct

Figure 46. The Oosterspoorbaan details in the context of the east side of Utrecht (Underlay map by Google Maps, 2013)

4.6 DETAILED PLANS

For the detail plan we chose the Oosterpoorbaan area between the Singel near the Zonstraat and the Koningsweg (figure 46). We chose this detail area, because it contains a bridge serving as a cooling plant, surface water sources in the Singel and a part of the main distribution pipeline. We reasoned that this detail area would thus show three out of four plan elements. One could argue that most other possible details would also meet this criterion, so our other reason for our choice is that this area is going to be developed as a new slow traffic route over the coming years and we saw this is an opportunity to explore how the district-cooling network can be connected to new infrastructures in Utrecht. We did not really consider other detail areas, which is one of the serious hiatus in our designing phase. We describe this problem more fully in the reflection on this phase (paragraph 4.8).

Historical analysis

Utrecht was founded on the banks of the Kromme Rijn, a river between Wijk bij Duurstede and Utrecht. The Kromme Rijn was the northern border (Limes) of the Roman Empire. The Kromme Rijn was the main course of the Rhine, until it was dammed in 1122. This event caused the river to become a smaller stream and Utrecht to obtain city rights.

The Kromme Rijn was the main supply route to Utrecht for food and goods. This was the reason that many horticulturists were situated on the fertile grounds near the Kromme Rijn. An example of an important area for horticulture is Abstede. The Abstederdijk is and old levee of the Kromme Rijn and its influent the Minstroom (figure 48). The moist and fertile soil was good for food production, and the people themselves lived on the sandy ridges. Abstede was called the 'Vegetable Garden of Utrecht' and supplied the city with food by means of the Minstroom (figure 50). The railway development as described in the next paragraph cut through the horticultural lands of Abstede. It was the catalyst for new commercial activities and housing developments, and the last horticulturist stopped in the seventies. A small part of the horticultural character of Abstede is still present in the allotment gardens along the Minstroom (figure 49).

In the nineteenth century the Nieuwe Hollandse Waterlinie was developed between the Markermeer and the Biesbosch, passing the city of Utrecht on the east side. This defence system consisted of forts and inundation fields, which could be used to inundate a several kilometres wide area with thirty to sixty centimetres of water. In the current situation the east of Utrecht still has the remains of Fort op de Ruigenhoekse Dijk, Fort Blauwkapel, Fort op de Biltstraat, Fort Hoofddijk, Fort Vossegat, Lunetten, Fort bij Rhijnauwen, Fort Vechten, and Fort bij het Hemeltje.

During the train track-building period the HSM (Hollandse Spoorwegmaatschappij) received concession to build a track Amsterdam-Hilversum-Amersfoort-Zuthpen with a branch towards Utrecht. The proposed track would run from the gas factory of Griftpark in a straight line to Lunetten. The people of Utrecht were firmly against the plan, as the result would be that a large part of the Singel would be closed. Their message was that this plan would not be beneficial for walking and would cause an obstacle for traffic. Under pressure from both the public as well as the council the HSM changed the plan, and from then on the railway was to be build east of the Maliebaan (figure 51) (Storm van Leeuwen, 2004, p. 231). The resulting new Oosterspoorbaan was finished in 1874 (Storm van Leeuwen, 2004, p. 229). In the mid-twentieth century the main station on the Oosterspoorbaan, the Maliebaan station, could no longer compete with the Rhine Railway and Biltstraat stations. This resulted in the Maliebaan station closing down for passengers in 1939. After an extensive renovation the Maliebaan station was opened as the Spoorwegmuseum in 1954 (Storm van Leeuwen, 2004, p. 232).

Figure 48. East side of Utrecht in 1868

Figure 49. Abstede in 1600 (HUA, 2013)

Figure 50. Horticulturist family (HUA, 2013)

Figure 51. East side of Utrecht in 1959

Figure 52. Oosterspoorbaan (Aardema, 1950)

Figure 53. Oosterspoorbaan (Pothuizen, 1973)

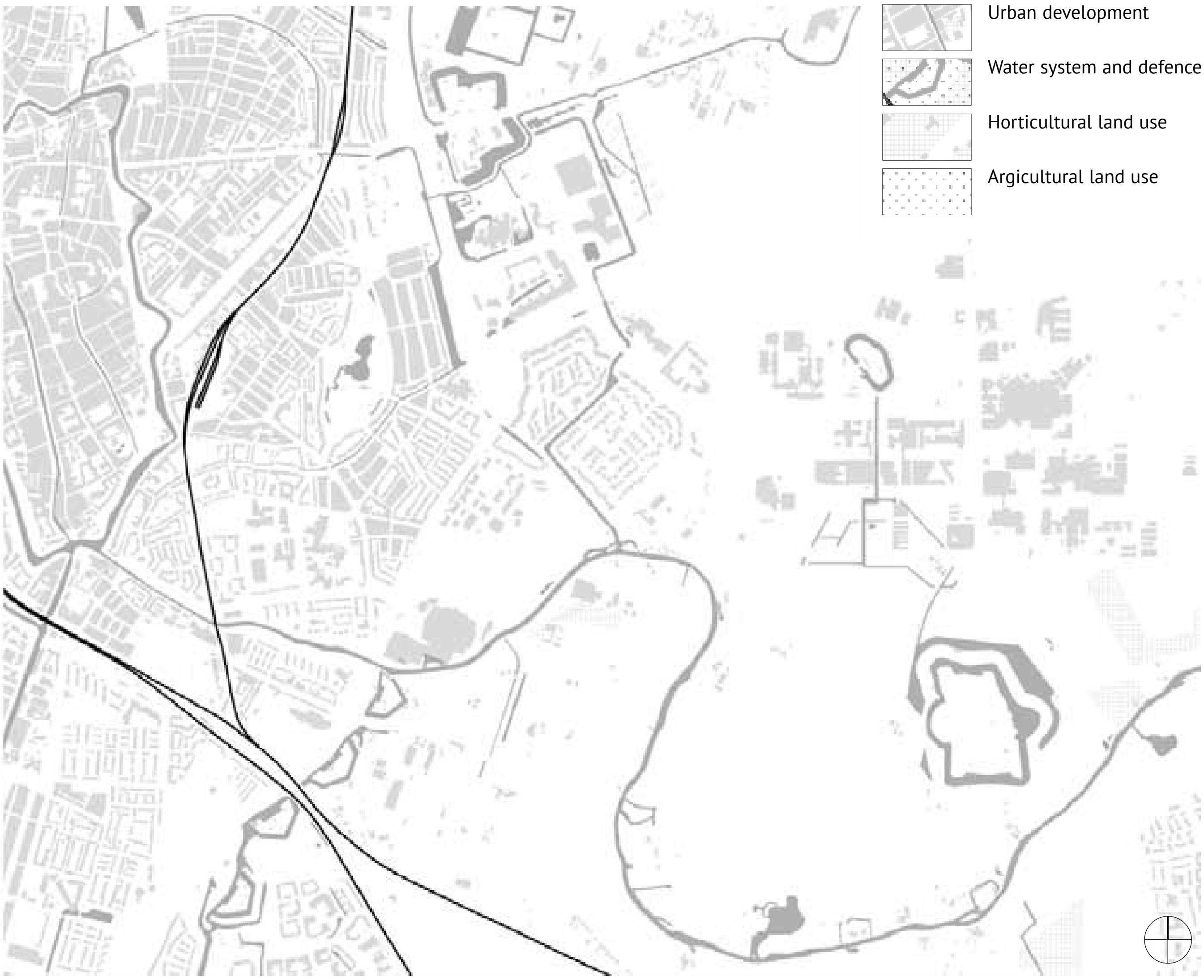


Figure 54. East side of Utrecht in 2013

Figure 55. Barrier (Happyland Collective, 2012)

Figure 56. Closing the railway (Happyland Collective, 2012)

After the Second World War Utrecht went through a major urban development, which meant the redefinition of the city's boundaries in 1954, doubling the surface of the Utrecht area (figure 54). In de seventies the Uithof was developed in the last agricultural corner of eastern Utrecht. Also in the seventies, after many years of noise and nuisance, local residents of Utrecht Oost started a major resistance against the transport of goods and chlorine over the Oosterspoorbaan. The 'Comité Stop de Chloortrein door Utrecht' protested from 1978 to 1981 and finally managed to stop the chlorine transports through the city in 1993 (Beukers, 2013). In 1972 the Venuslaan was developed to connect the inner city to the Uithof via the Rubenslaan. The crossing of the raised Oosterspoorbaan and de Venuslaan was solved by means of a tunnel.

The recent development of the Uithoflijn has caused a broadening of the railway Utrecht-Arnhem, which means that trains can no longer enter the southern part of the Oosterspoorbaan (figure 56) (Happyland Collective, 2013). The municipality of Utrecht has decided to buy the land from ProRail and create a green walking- and cycling route in correspondence with the ideas of the local inhabitants as explored by Happyland Collective in 2013.

Landscape analysis
The natural layer of the Oosterspoorbaan zone and its direct context consists by origin of the banks and levees of the Kromme Rijn. This moist and fertile soil was used for centuries to produce food for the city of Utrecht. The oldest buildings are situated on the sandy levees along for example the Zonstaat. The area is quite well drained, as Utrecht is situated on slightly higher grounds amidst different river systems. The soil in the detail plan area is mostly light river clay, unless levelled up by sand for housing (figure 57). The soil of the railway zone is slightly polluted by an old battery factory near the Koningsweg and the copper sharps, soot and heavy metals from the trains. The height in the plan area is mostly influenced by the adding of sand for housing developments, except for the lower areas near the Minstroom and Kromme Rijn. These can be said to be both naturally and culturally the most important water bodies in the plan area (figure 58), as previously described in the historical analysis.

The spatial mass in the Oosterspoorbaan zone mostly consists of the buildings at the edges of the railway. These differ from the monumental houses of two to four floors in the Abstede area, row housing with two floors in the Sterrenwijk area and the student flats of five floors of the Ina Boudier-Bakker (IBB) area. The functions of the buildings differ slightly for the three aforementioned neighbourhoods: expensive housing in Abstede, social housing in Sterrenwijk, and student housing in the IBB area. These differences also influence the social structure, as the highly educated and wealthy residents of Abstede are a world apart in relation to the working-class Sterrenwijk area. It has even been said by local stakeholders that the social and spatial barrier of the railway might not be undesirable (Happyland Collective, 2013). All housing along the railway zone faces the Oosterspoorbaan with the rear side. This can probably be considered typical for housing along railway infrastructures, and it can lessen the strength of social control in the area. However, this also means that the gardens are quite deep, flanking the railway zone with a green and enclosed edge.

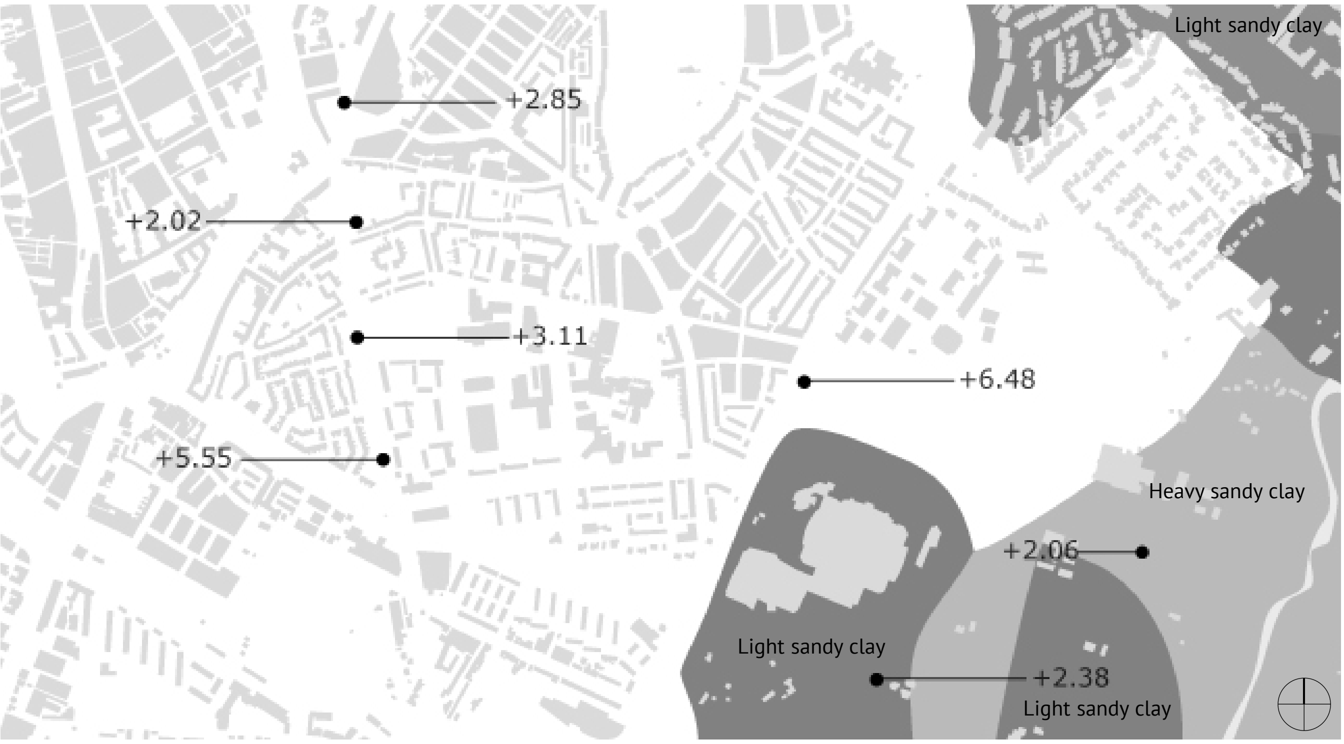


Figure 57. Soil types and heights

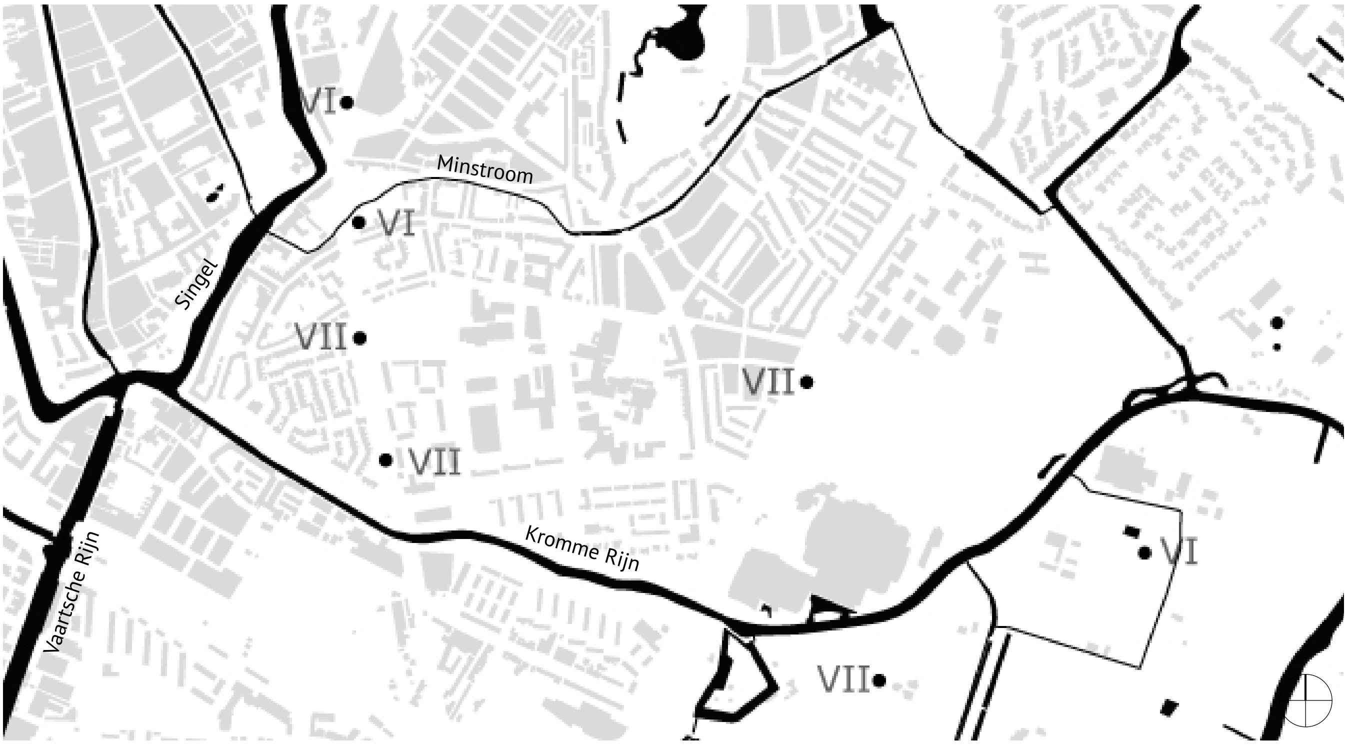


Figure 58. Surface water system and ground water levels

Figure 58.1. The vista of the railway

Figure 58.2. The Kromme Rijn crossing with the Oosterspoorbaan

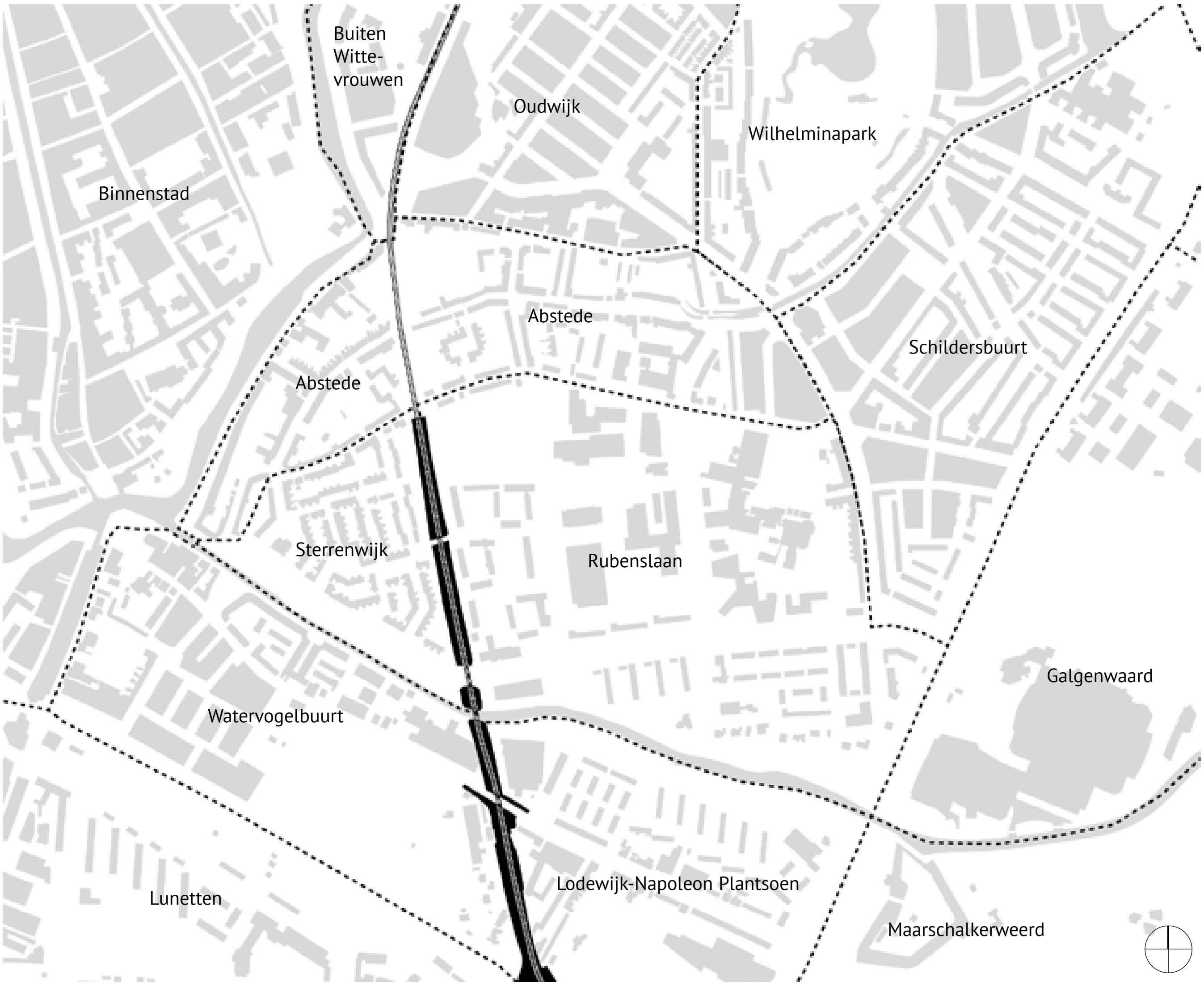


Figure 59. The Oosterspoorbaan as a barrier in the East side of Utrecht

The open (green) spaces along the railway zone are respectively from north to south the Minstroom area, the Beerthuizenplantsoen, the Schippersplantsoen and the Krommerijnpark (figures 60 and 61). The Minstroom area has a historical horticultural character with allotment gardens and pollard willows along the stream. The Beerthuizenplantsoen and Schippersplantsoen are public green spaces with little character and municipality planting. The Krommerijnpark can be described as quite lush and offers a nice vista into the Kromme Rijn landscape that crosses the Oosterspoorbaan.

The east side of Utrecht has several barriers, like the Waterlinieweg and the A27 highway that make it quite hard to get out of the city and into the surrounding landscape. The Koningsweg is basically the main route into Amelisweerd, but this road only offers an east-west connection. The Oosterspoorbaan is a barrier in the current situation (figures 55 and 59), but offers the opportunity to form a north-south connection between the Singel near the Zonstraat and the Koningsweg, thus creating a route from the east side of the inner city to the surrounding landscape.

Detail design program

The program for the detail design can partly be derived from the program of the strategic plan and from a research that was conducted by Happyland Collective (Happyland Collective, 2013) that was commissioned by the Stichting Oosterspoorbaan Utrecht.

The first program point is the district-cooling network as previously explained in the strategic plan (paragraph 4.4). In the detail plan area the network consist of surface water sources in the Singel, the main distribution pipeline under the Oosterpoorbaan and the cooling plant situated in the Venuslaan viaduct. As described in paragraph 4.3 we cannot calculate the cooling demand and thus specify the dimensions and quantities of surface water sources or the cooling plant.

The second program point is the wish of the Spoorwegmuseum for a new museum workplace in the Oosterspoorbaan area to check and fix monumental trains. “The workshop could be a simple building with a 19th century architectural style, with one track leading from the workplace to the museum” (Spoorwegmuseum in Happyland Collective, 2013, p. 27).

The third program point is that the Spoorwegmuseum wants to reconstructs it’s historical ‘eco bank’: an ecological railway bank that shows the ecological value of railways for unique flora and fauna. For the development and maintenance of this eco bank the museum even had an ecologist in service. The museum regards the development of the Oosterspoorbaan as a possibility to bring back this educational aspect to show the connection between railways and nature (Happyland Collective, 2013, p. 27).

Figure 60. Current green structure

Figure 61. Future green structure

Figure 61.1. The crossing with the Notebomenlaan and railway

Figure 61.2. The Venuslaan viaduct

Figure 62. Current routes connecting the city to the surrounding landscape

Figure 63. Future routes connecting the city to the surrounding landscape

The fourth program point is the connection between the Oosterspoorbaan, Venuslaan and Kromme Rijn that is considered a missing link for the slow traffic mobility. The Venuslaan will be developed as a part of the unimpeded cycling network in the city from the Vaartse Rijn to the Uithof. This is considered by the neighbourhood ambitions as a possible alternative route on the west-east economical axis in addition to the route past the Wilhelminapark (Wijkbureau Oost, 2013, p. 16). The connection of the Venuslaan and Oosterspoorbaan is part of the ambition of the municipality to combine mobility with the development attractive and green public space (Dienst Stadsontwikkeling, 2012a, pp. 31-41). This connection is also seen as an opportunity to create a green route from the inner city, via the Oosterspoorbaan to the Krommerijnpark and the surrounding landscape of Amelisweerd and Rhijnauwen (figures 62 and 63). The need for a cycling and walking route over the Oosterspoorbaan line has been underlined in the research of interests of stakeholders by more than fifty inhabitants and by organisations like the Utrechts Stedelijk Gymnasium, Fietsersbond, Bestuur Regio Utrecht, Stuurgroep Kromme Rijnstreek, Tuindersvereniging Abstede, Stichting Studentenhuisvesting, Stichting De Minstroom Erven, Stichting Het Boompje, Ludens Kinderopvang, and the Nederlandse Rode Kruis (Happyland Collective, 2013, p. 56).

The fifth and final program point is the desire of many inhabitants and the municipality to approach the Oosterspoorbaan as an open green space, a historical line in the city. This is an important point of the neighbourhood ambitions (Wijkbureau Oost, 2013, p. 16).

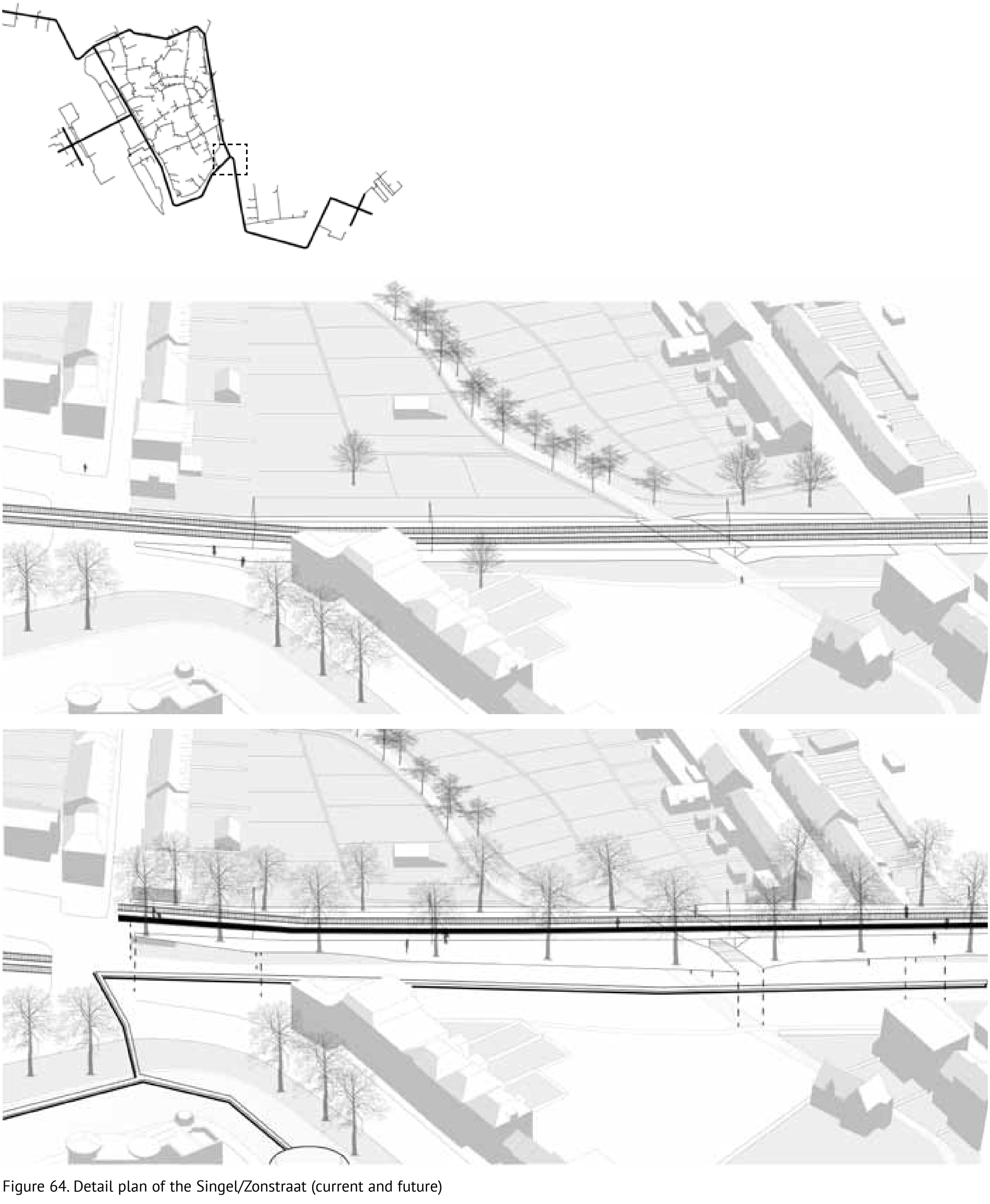


Figure 64. Detail plan of the Singel/Zonstraat (current and future)

Oosterspoorbaan detail design

From north to south the detail of the Oosterspoorbaan area consists of the surface water sources in the Singel, the main distribution pipeline under the Oosterspoorbaan between the Spoorwegmuseum and the Kromme Rijn, and the connecting hub formed by the existing viaduct of the Venuslaan.

The old railway zone between the Spoorwegmuseum and the Kromme Rijn will preserve its height of the railway dike, to ensure the connection to the viaduct. This is needed for the plan, as we intend to retain one of the tracks leading from the Spoorwegmuseum to the viaduct, which is described more elaborately later on in this paragraph. The other track will disappear, creating space on the one side of the railway zone for the slow traffic route (figures 64 to 71). The newly created space at the site of the banks of the railway zone are an ideal place to situate the main distribution pipeline of the district-cooling network (figure 64), because the construction of the pipeline is very expensive and it is most economical and convenient to use the available space. While making the choice to situate the pipeline in the railway bank we also considered situating it under the tracks, the cycle path or above the ground. However, the tracks and path make the access to the pipeline for maintenance more difficult. The situation above the ground does make for an easy access, but we reasoned it might be unsafe and also more interesting to use the open space on top of the pipeline for green and public functions.

The surface water sources in the Singel are designed indicatively to be 10 metres in section and 15 metres deep and are situated under water in order to keep the water accessible for recreational use. A grid covers the shaft to ensure the connection between the water in the shaft and the water in the Singel for redistribution of the clean water coming from the system. This grid also ensures the safety of people, boats, and water life to not get stuck in the shaft.

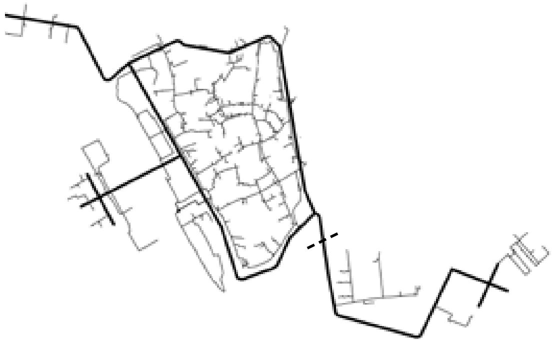
Composition of seeds

Based on information from Cruydthoeck, 2013

- Achillea millefolium
- Barbarea vulgaris
- Centaurea jacea
- Crepis biennis
- Daucus carota
- Echium vulgare
- Erodium cicutarium
- Galium mollugo
- Hieracium laevigatum
- Hieracium umbellatum
- Hypericum perforatum
- Hypochaeris radicata
- Jasione montana
- Leontodon autumnalis
- Leucanthemum vulgare
- Luzula campestris
- Malva moschata
- Oenothera biennis
- Plantago lanceolata
- Prunella vulgaris
- Ranunculus acris
- Rhinanthus minor
- Silene dioica
- Tragopogon pratensis
- Trifolium arvense

Figure 65. Wild flowers and grasses (Cruydthoeck, 2013)

Figure 66. Wild flower banks (Cruydthoeck, 2013)



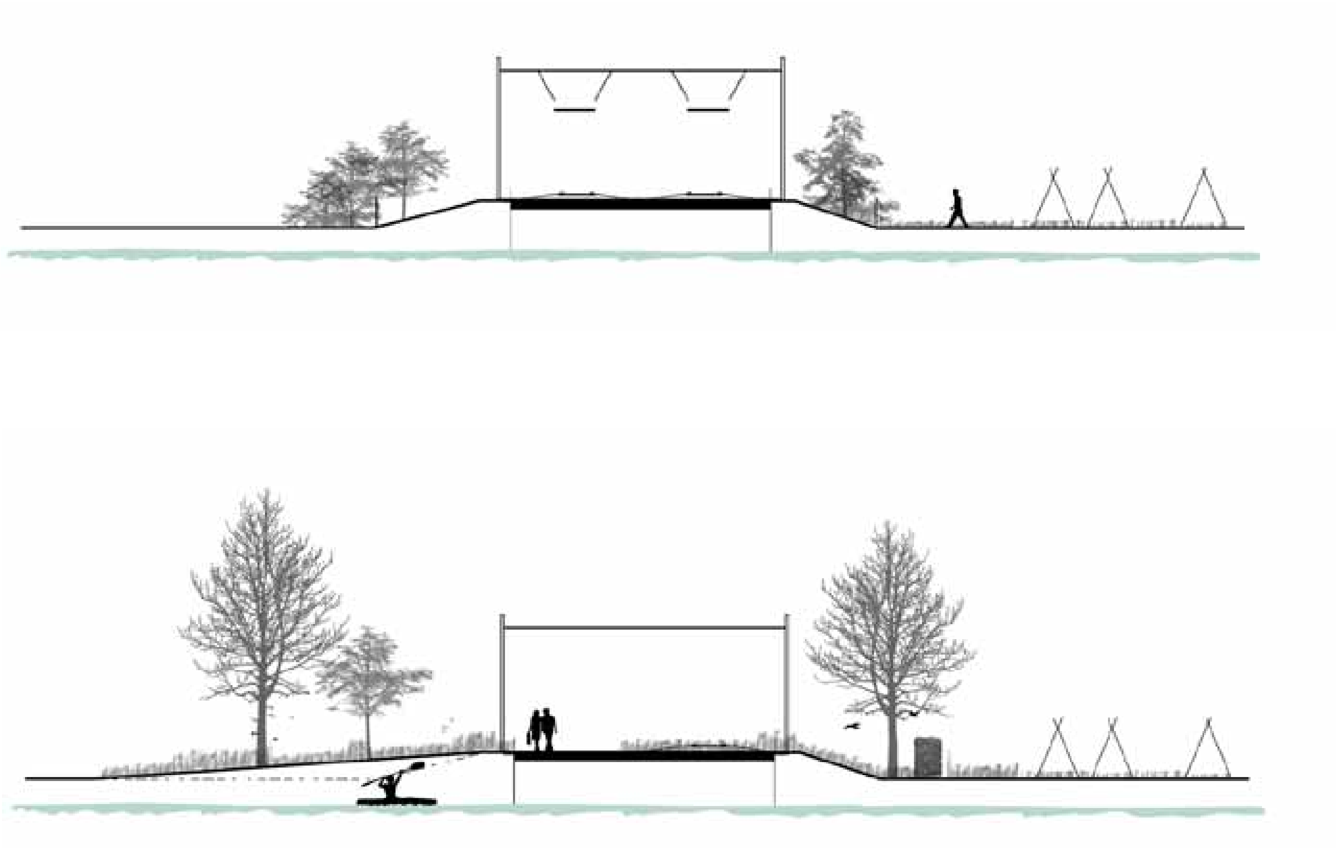
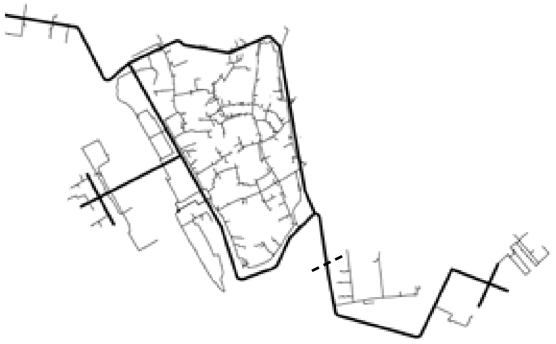


Figure 67. Sections of the Minstroom and allotment gardens of Abstede (current and future)

Figure 68. Juglans regia (Treesandhedging.co.uk, 2013)

Figure 69. Prunus avium (Biopix.nl, 2013)



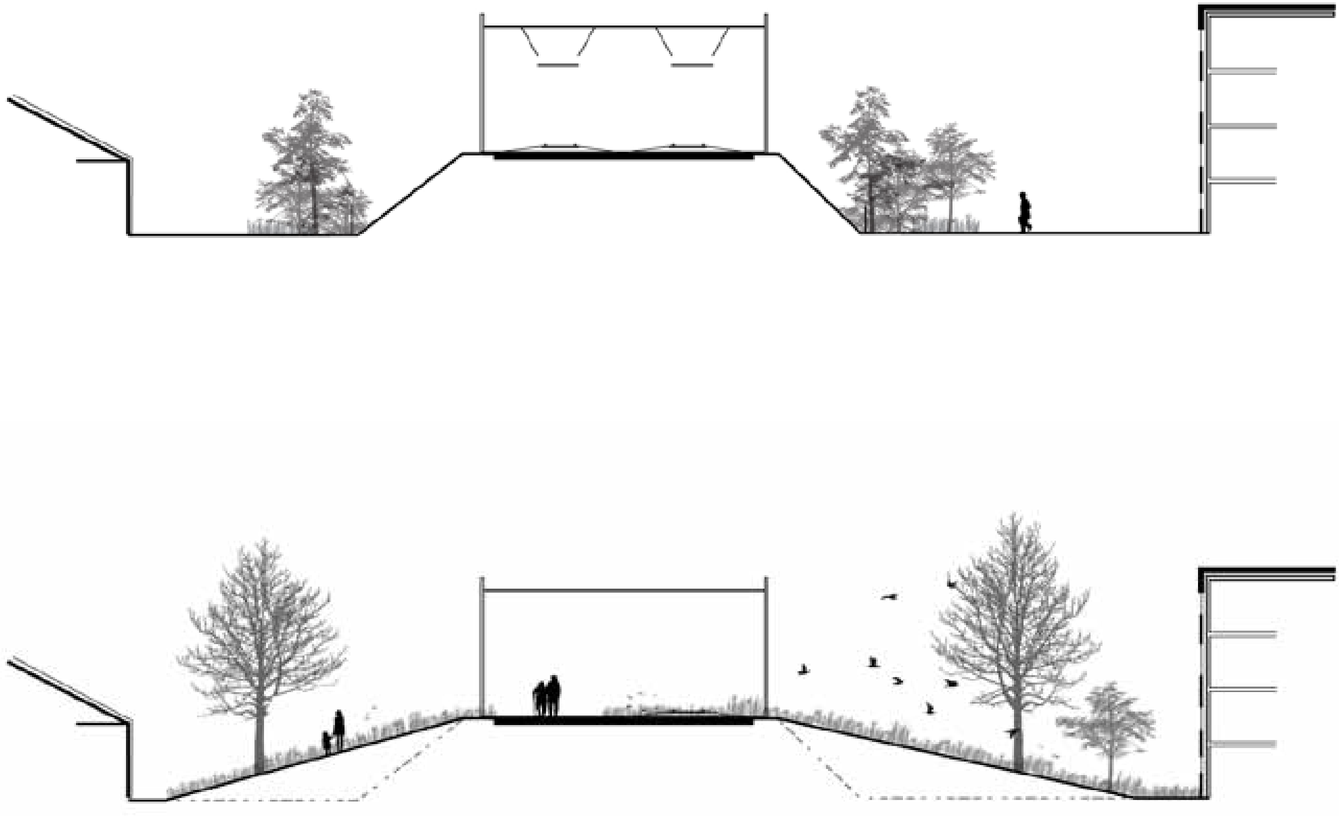


Figure 70. Sections of the railway bank near the IBB student housing (current and future)

We assume there will come a large amount of soil available when constructing the district-cooling network (pipeline, TES-clusters and surface water shafts). We do not know the amount of soil, but for the municipality it is compulsory to have a closed soil balance. Of course one could use this soil in many different areas in the city, but in the detail plan we want to show one of the possibilities. In the light of these assumptions we want to propose an indicative idea of re-using the soil in the Oosterspoorbaan area (figures 64, 67, 70, 72-75). We want to use it to change the steep railway dike into a gently sloping park-like area that connects the neighbourhoods that are currently divided by the railway.

The sloping landscape of the railway banks offers the opportunity to use trees, high grasses and wildflowers (figures 65 and 66) (Cruydthoeck, 2013) at the sides of the railway, creating a green park-like area that accents the vista of the railway itself. We also considered other options, like adding built program or a route for fast traffic and public transport, but from the research on the wishes of the inhabitants of the area it became clear that there is no support for these options. We also considered keeping it in its current state (unkempt greenery and old railway elements), but we chose to do more in order to add to the utility of the landscape. The last option we considered is making an enclosed park-like space with many trees and shrubs. However, this would compromise the historical Oosterspoorbaan vista and it is not possible to have the roots of trees too close to the main distribution pipeline of the district-cooling network.

Figure 71. Impression of the eco banks

The choice of trees for the Oosterspoorbaan area consists of Juglans regia and Prunus avium (figures 68 and 69). Our reasoning behind this choice was that these species refer to the history of horticulture in the area. These trees are of the fist and second size and carry nuts and flowers, which will create diversity in image throughout the seasons.

The openness of the railway preserves the vista of the Oosterspoorbaan (figure 71) and at the same time offers space to develop a slow traffic route for cyclists, walkers, skaters and joggers. This route connects the inner city and Singel with the Venuslaan, Kromme Rijn, Koningsweg and areas at the edges of the city, like Amelisweerd.

As previously explained in paragraph 2.6 it is now quite hard to get out of the city and into the surrounding landscape, and this new recreational route will make this fast, green and attractive slow traffic connection possible. The banks will be given a natural and open character, with high grasses and wildflowers (figures 65 and 66). The natural character of the banks should offer the opportunity for the Spoorwegmuseum to regain the educational aspect of the 'eco banks' as described before in the program. These banks will show the rich flora and fauna that prosper along railways to the visitors that walk along the railway banks towards the museum workplace.

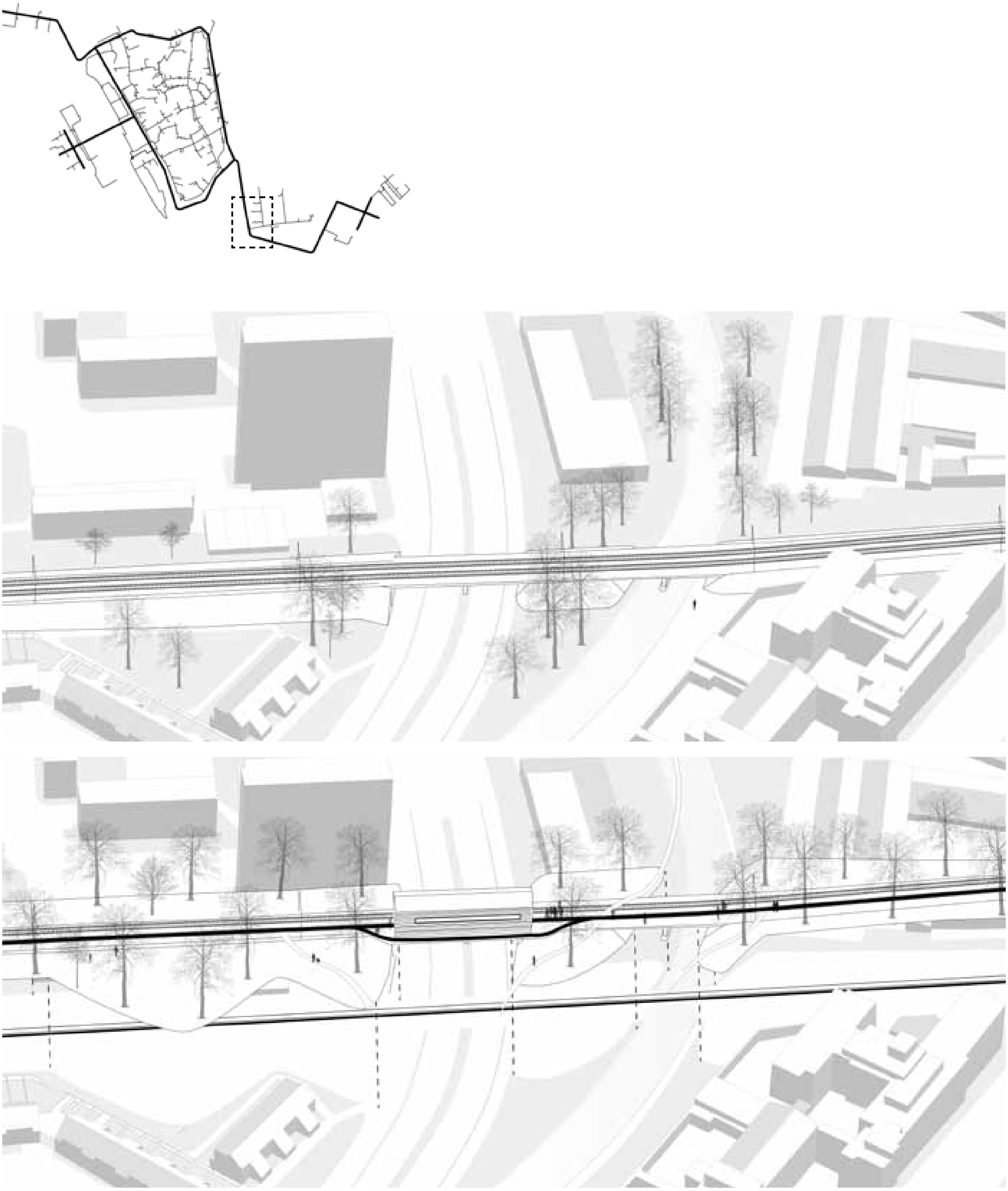
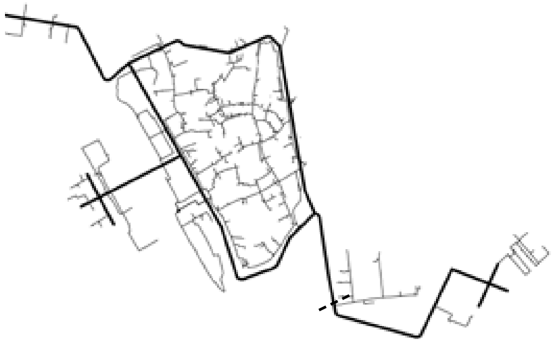


Figure 72. Detail plan of the Venuslaan/Kromme Rijn (current and future)



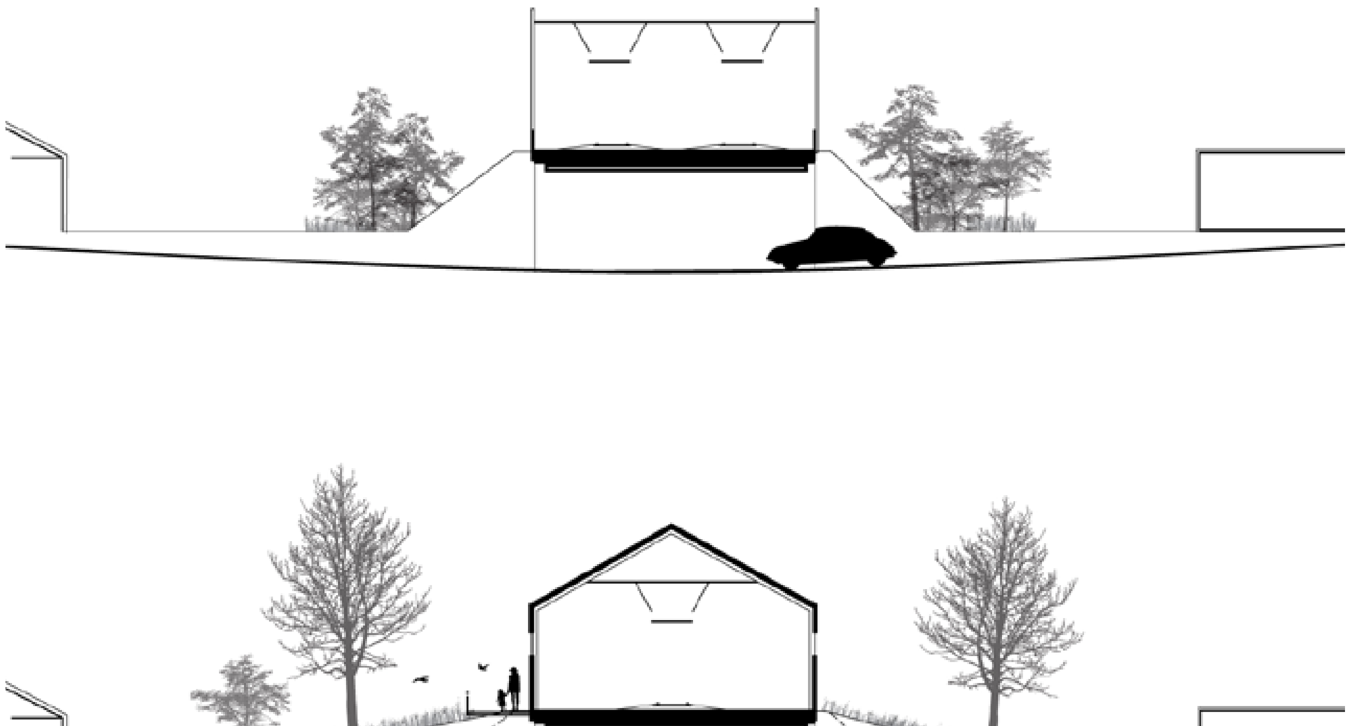
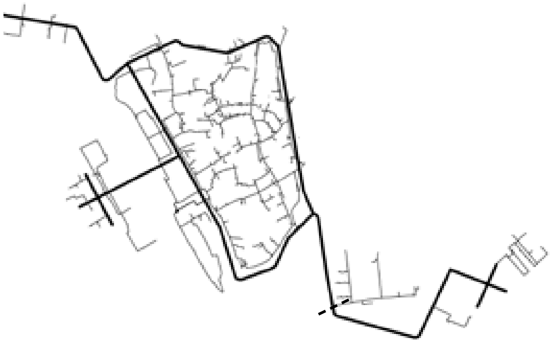


Figure 73. Sections of the Venuslaan viaduct with hub, museum workshop, and broadened banks (current and future)



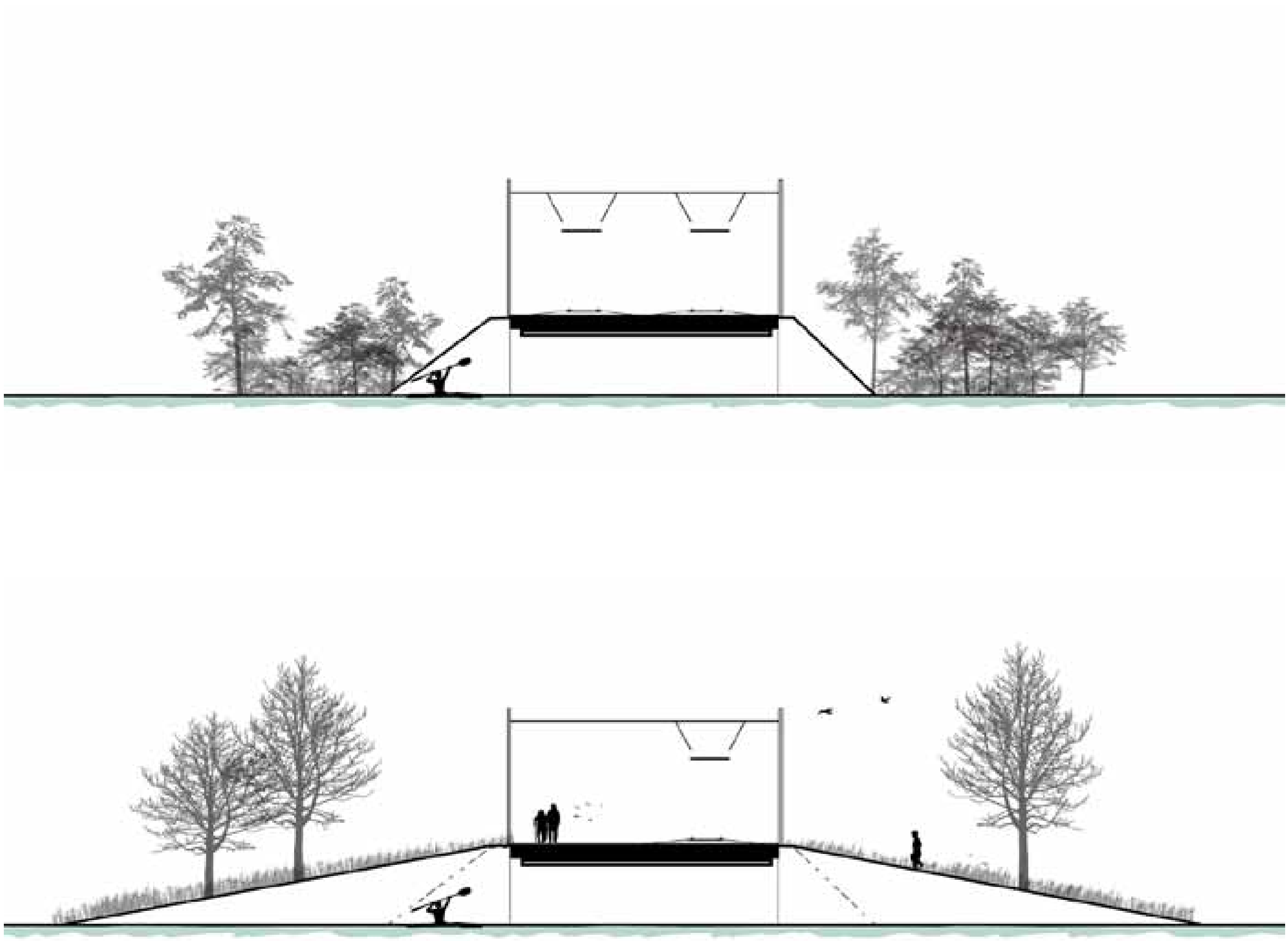


Figure 74. Sections of the Kromme Rijn and railway banks (current and future)

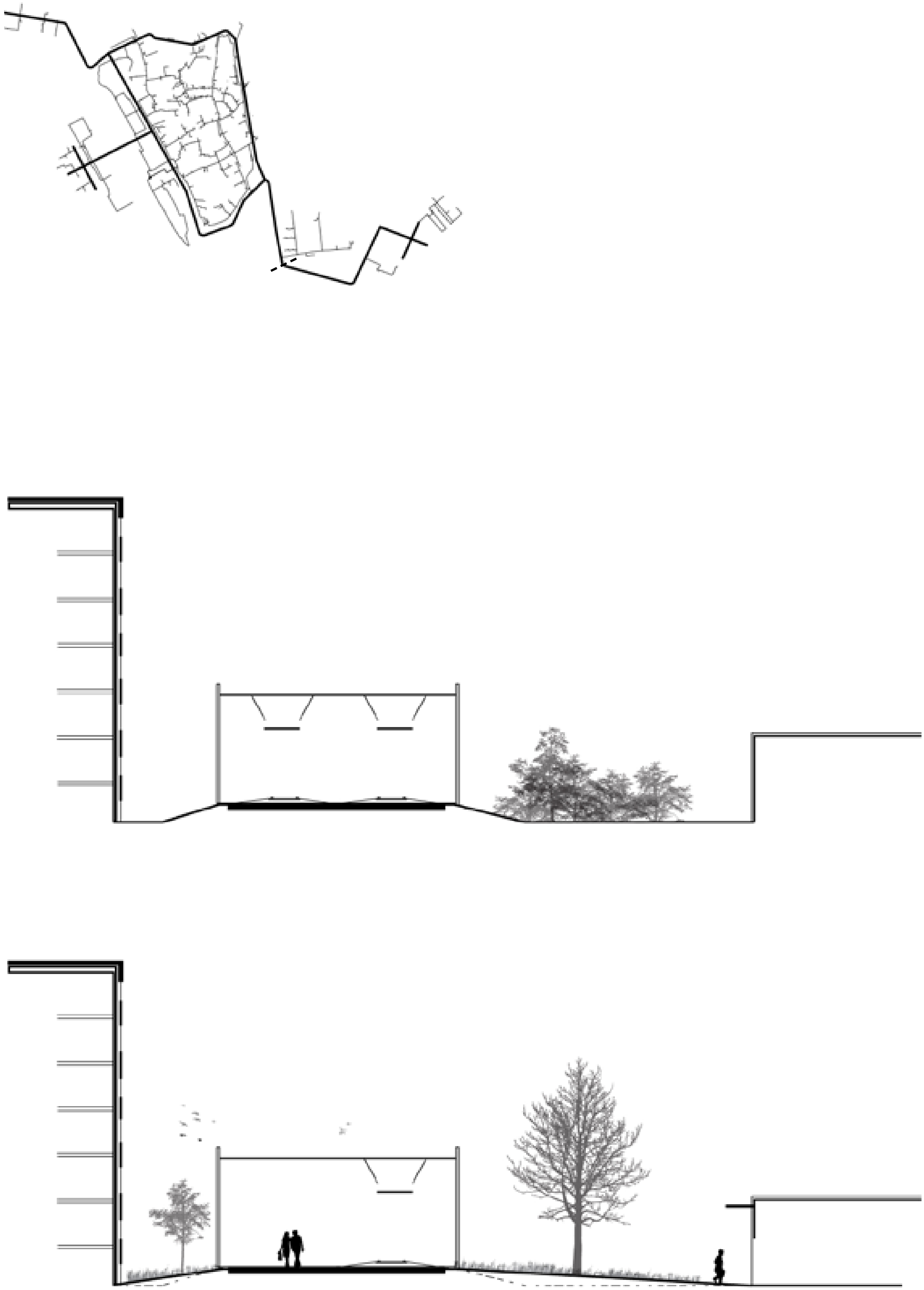


Figure 75. Sections of the area near the Koningsweg with broadened banks (current and future)

The southern part of the detail plan area contains the existing Venuslaan viaduct (figure 72). This viaduct needs maintenance in the near future and becomes an expensive element to manage in the Oosterspoorbaan zone now the railway has lost it function. To ensure the future development of the viaduct we propose to combine the bridge with new functions. The first new function we propose is the combination of a cooling plant and pipeline for the district-cooling network with the existing bridge (figures 73 to 75).

Figure 76. Impression of the Venuslaan hub

The second new function we propose is the connection with slow traffic mobility. The third new function is the combination of the existing structure with the required museum workplace (figures 72, 73 and 76). This workplace is situated on top of the viaduct to strengthen the construction and to create a linnear extension of the tracks coming from the museum. We also considered situating the workshop in other places that are a linnear extension of the tracks, but we chose the integration with viaduct to use the foundation of the workshop as a strengthening of the viaduct.

The new building could be added as a steel construction to the concrete viaduct with an outdoor hanging construction on the side of the viaduct to ensure the slow traffic route along the Oosterspoorbaan and a connection to the Venuslaan and Kromme Rijn. The workshop is connected to the museum by means of one remaining track and can be used to store or fix trains. The route that passes the workplace offers a nice view of the trains inside through a window along the entire length of the building. When the workplace is not in use for train maintenance or exhibitions the space can be used for events by third parties or neighbourhood gatherings.

4.7 CONCLUSION DESIGNING

The specific research question that was supposed to be answered by this chapter is: *'how can one possible spatial and technical solution for a district-cooling network be implemented in coherence with infrastructures in Utrecht?'*

The designing phase (chapter 4) explored the spatial and technical implementation of the district-cooling network in relation to road infrastructures, slow traffic mobility, and renewable sources, like thermal energy storage, and cooling from surface water. The results of the designing phase are a strategic plan, plan elements, and detail plan for the implementation of the district-cooling network in coherence with infrastructures in Utrecht.

We designed a strategy for the development of a district-cooling network supplied by renewable cooling sources. This collective system serves the demand for cooling of office buildings, educational buildings, shops, and industries in the city of Utrecht. The main distribution network is designed to connect the Singel with development areas or estimated existing areas with a cooling demand. The development of this network shows coherence with the existing infrastructure as the pipelines will be situated under existing roads and paths, and the cooling plants and pipelines are to be integrated in bridge-like elements that have a connective function. In the conceptual plan three thermal energy storage clusters are designed to supply the cooling network and contribute to cleaning groundwater pollution. The TES clusters also offer opportunities to shape the infrastructure of future aboveground developments on the locations of the underground clusters, like the Cartesius Triangle, Jaarbeurs and Galgenwaard. According to the design the surface water cooling sources could be situated in the Singel and Amsterdam Rijnkanaal. The long-term cleaning process of the phosphate excess in the surface water could be a positive side effect of the surface water sources in terms of ecology, microclimate and recreation. In the details plans of the Oosterspoorbaan area the surface water sources, connecting hubs and main distribution pipeline are shown. The sloping landscape of the railway banks offers the opportunity to create a slow traffic route in a green park-like area that accents the vista of the railway itself. This detail is only an example of the spatial opportunities of the district-cooling network.

4.8 REFLECTION DESIGNING

In the designing phase we tried to bring the assignment that we formulated to a spatial intervention. A more detailed description of the designing methodology can be read in the introduction paragraph of this chapter (paragraph 4.1). As described in the preface and introduction our thesis process consisted of two phases: at first the thesis was unsatisfactory and needed additional work, and in the completion phase we added the necessary material to come to a passable product. The following reflection should be considered in this context.

Reflection on landscape infrastructures as compass

In the first thesis product the design phase was built on the interpretation of the following description of Bélanger. He describes the need to design, which is by definition a practical act, and he states that research is only a precondition to come to a design (Bélanger, 2013, pp. 245, 394, 571). We were naïve to think that, as Bélanger states that design is a practical act, we did not have to add theoretical concepts on aesthetics in relation to the design of a landscape infrastructure and that were free to make an intuitive and implicit design.

By approaching the writings of Bélanger as absolute, and by lacking a theoretical context a critical and broad understanding on landscape infrastructures was missing in the first thesis product. We improved this by adding a theoretical context to our final thesis product, in which it became much clearer that landscape infrastructures is completely focused on planning, and that we needed to add a designerly way of knowing to the concept in order to make a landscape architecture design.

Reflection on lack of landscape architectural contribution

As described in the paragraph on the possible contribution of landscape architects (paragraph 1.1) we intended to integrate systems in order to come to an added spatial value in the first phase of the thesis process. However, in the designing phase we did not deliver this landscape architectural contribution, as we did not focus on the spatial analysis and design of the possible spatial value of a district-cooling network in Utrecht.

During the process we were focussing too much on making a clear technical story, therefore the design phase is more concentrated on a technical assignment than on a landscape design assignment. We did not answer our research question on spatial value by concentrating too much on making the technical story fit, and therefore we lacked a landscape approach in the designing phase of our research. Thus we could not answer to our own critique on the landscape infrastructures method that it is too technocratic. Also we were not able to answer our main research question from the first phase of the thesis on adding spatial value by bundling underground and aboveground systems.

In the first phase of the thesis we should have analysed references on the spatial value of bundling underground and aboveground systems. Also the spatial analysis of the urban realm of Utrecht and reference projects is largely lacking, which seriously hampers the development of improvements as well as specific Utrecht examples. We only tell something about the history and landscape of the detail plan area, but we should have done this about the entire city. It is partly because of this hiatus that we could not answer the original research question on how the design for a district-cooling network in Utrecht can contribute to exploring the spatial value of underground infrastructures.

In the completion phase of the project we chose not to address this hiatus by changing the design itself, as we strove only to come to a passable thesis in a relatively short time. However, we did describe our considerations and reasoning for the choices that we made in the design. Also we added a specific research question and devised more focused research framework in order to make the phases connect better to one another. This has lead to a more transparent and explicit designing phase that answers a research question. However, it remains that from the envisioned contribution of us as landscape architect only the integrative aspect has been addressed and the spatial aspect has remained insufficient, also in the completion phase of the thesis process. By reflecting on the spatial aspect we learned that the distinctiveness of a landscape architect towards other disciplines concerning civil engineering projects like infrastructures is the aspect of aesthetics.

Reflection on our designer's bias

From the point that we started working on our design phase our thesis was not a coherent story and was not supported by critical reasoning or alternatives to decisions that we made. This continued in the designing phase, as 'we make it up as we go along' or working in an inexplicit, intuitive and designerly way was still our unintended and unconscious credo in the first thesis process. The result of this is that designing phase is not convincing, transparent or reliable.

A strong designer's bias from us as researchers resulted in a designing phase in which no explanations are given about what is already known, and what considerations and reasoning lies behind our choices. The designing phase shows one possible solution to implement the district-cooling network. Because we did not investigate alternative options well argued choices could not be made, and we could not test whether the strategy, principles and detail design are the best possible solutions.

As described before we addressed our designer's bias partly in the completion phase by describing our considerations and reasoning for the choices that we made in the design. The hiatus of the missing alternatives remains so we did not make the design free of our bias, but we did try to be more explicit in order to make this phase more transparent. In making the designing phase more transparent we learned how to define the steps and describe the steps in our thoughts that we had made.

Reflection on choice of detail plan area

In the first version of the thesis the arguments for the choice for the Oosterspoorbaan detail were weak, as openness created by the pipeline as a perfect fit for the historical line of the Oosterspoorbaan is not a valid reasoning. The former ambition of ProRail to build houses there, which was still relevant at the time of writing the first version, could for example also have been the starting point for the detail design.

The true reason for choosing the Oosterspoorbaan as our detail plan area was that we had affinity with the location as we were working on a voluntary project there. We were asked to investigate the wishes of the inhabitants of the area, and thought we might be able to use the thesis as a preparation for a possible future design project. So it was not the case that we used the thesis to produce material for a current or paid assignment.

The detail design for the Oosterspoorbaan does not serve to improve the principles into more specific design characteristics, which means that the detail plan is not a further detailing of the principles in the report. All we did is that we designed an example of a contribution to open space and then stated 'bundling underground and aboveground contribute to open space'.

In order to relate the district-cooling network to the urban fabric in the first phase of the thesis we should have shown how the city and systems in the city developed. We think this would have formed a framework for developing a new system and connecting this to existing infrastructures, such as the Oosterspoorbaan railway area. If we had looked at it like this we could have argued the choice for the Oosterspoorbaan detail plan area.

Besides reflecting on this point and describing our considerations and reasoning for the choices that we made in the detail design we did not change the detail design in the completion phase. We learned that you should not lose yourself in a technical story or other details that are not part of your profession. Stick to what a landscape architect is good at; make a proper landscape design.

Eventually the critical reflection that we had to make through describing, analysing and evaluating the design process gave us more insight in what went wrong. It became clear what kind of structure, data, reasoning, and spatial contribution the design phase was lacking and what we should have done to come closer to a sound scientific product. We have created one district-cooling network implementation in relation to infrastructures in Utrecht. But the design process that we constructed is largely intuitive and iterative, so the research we conducted has no external validity.

5. CONCLUSION

Explaining and reviewing the outcomes of this research

The objective of this research was to explore in what way a landscape design can contribute to the implementation of a district-cooling network in relation to the infrastructures in the city of Utrecht. Based on this objective we formulated the following general research question and specific research questions as the main focus of the research:

To what extent and in what way can a landscape design contribute to the implementation of a district-cooling network in relation to the infrastructures in the city of Utrecht?

1. What are the existing infrastructures in the city of Utrecht in terms of water, waste, energy, food and mobility?
2. What is the possible spatial and technical coherence between a district-cooling network and the current infrastructures in Utrecht?
3. How can one possible spatial and technical solution for a district-cooling network be implemented in coherence with infrastructures in Utrecht?

In the following paragraphs we will answer the specific research questions first and then finally we will answer the general research question.

Answer to specific research question 1
What are the existing infrastructures in the city of Utrecht in terms of water, waste, energy, food and mobility?

In the mapping phase (chapter 2) we explored the current infrastructures in Utrecht. We mapped them according to the five biophysical systems of Bélanger: water resources, waste cycling, energy generation, food production, and mass mobility. The existing infrastructures in Utrecht that we mapped, and the information that we missed are shortly described below.

For 'water resources' we mapped the surface water system, the drinking water distribution network and drinking water extraction. The information that we missed on water resources was the detailed drinking water distribution network. For 'waste cycling' we mapped waste collection, distribution and processing systems for household waste, vegetal waste, glass and paper, the sewage system, surface water pollution, groundwater pollution, and soil pollution. For 'energy generation' we mapped the production of electric- and thermal energy, power lines, district-heating system, dredge fermentation, and thermal energy storage (TES). The information that we missed on energy generation was the detailed electricity distribution network and gas network. For 'food production' we mapped distribution routes and centres, supply of supermarkets, restaurants, and markets, and locations of allotment gardens. The information that we missed on food production was about the quantities of food production, consumption and distribution. For 'mass mobility' we mapped the public transport (train, tram and bus), car movements, cycling and walking, and parking.

The final result of the mapping phase was a thorough knowledge of the existing infrastructures in Utrecht. However, the information shown and described in the mapping is all that we found and that we could translate to maps, though the data was not collected, interpreted, integrated and evaluated in a structured way. We based the mapping phase on data and maps from mostly official organizations and used additional (unrecorded) interviews with experts for confirmation. The outcomes of this process made for the best possible data under the circumstances.

5.1 ANSWERS TO THE RESEARCH QUESTIONS

Answer to specific research question 2
What is the possible spatial and technical coherence between a district-cooling network and the current infrastructures in Utrecht?

In the bundling phase (chapter 3) we described the coherence between the district-cooling network and the relevant existing infrastructures in Utrecht. The infrastructures from the mapping phase that we thought could be connected to the district-cooling network are fast- and slow traffic mobility, surface water, and thermal energy storage systems. We also included the problems and opportunities that arise when seeking this coherence concerning surface- and groundwater pollution. We found the other information layers from the mapping irrelevant in relation to the district-cooling network, as they are either unconnected with road infrastructure or with the production of cooling energy in any form.

Fast and slow traffic mobility could spatially cohere with the district-cooling network, because the roads used by buses, cars and cyclists offer a relatively easy access to the main distribution pipelines and often form quite a direct connection to all parts of the city. Energy production and groundwater pollution could technically cohere with the district-cooling network, because thermal energy storage systems a renewable source for cooling energy, and they can be used to treat groundwater pollution. The surface water system could cohere with the district-cooling network, because cooling energy can be gained from surface water and this makes this infrastructure a possible source for the district-cooling network. Also we deduced that the pumping and filtering of the surface water through a cooling plant could be an opportunity to filter the pollutants, like phosphates, from the water.

Answer to specific research question 3
How can one possible spatial and technical solution for a district-cooling network be implemented in coherence with infrastructures in Utrecht?

The designing phase (chapter 4) explored the spatial and technical implementation of the district-cooling network in relation to road infrastructures, slow traffic mobility, and renewable sources, like thermal energy storage, and cooling from surface water. The results of the designing phase are a strategic plan, plan elements, and detail plan for the implementation of the district-cooling network in coherence with infrastructures in Utrecht.

We designed a strategy for the development of a district-cooling network supplied by renewable cooling sources. This collective system serves the demand for cooling of office buildings, educational buildings, shops, and industries in the city of Utrecht. The main distribution network is designed to connect the Singel with development areas or estimated existing areas with a cooling demand. The development of this network shows coherence with the existing infrastructure as the pipelines will be situated under existing roads and paths, and the cooling plants and pipelines are to be integrated in bridge-like elements that have a connective function. In the conceptual plan three thermal energy storage clusters are designed to supply the cooling network and contribute to cleaning groundwater pollution. The TES clusters also offer opportunities to shape the infrastructure of future aboveground developments on the locations of the underground clusters, like the Cartesius Triangle, Jaarbeurs and Galgenwaard. According to the design the surface water cooling sources could be situated in the Singel and Amsterdam Rijnkanaal. The long-term cleaning process of the phosphate excess in the surface water could be a positive side effect of the surface water sources in terms of ecology, microclimate and recreation. In the details plans of the Oosterspoorbaan area the surface water sources, connecting hubs and main distribution pipeline are shown. The sloping landscape of the railway banks offers the opportunity to create a slow traffic route in a green park-like area that accents the vista of the railway itself. This detail is only an example of the spatial opportunities of the district-cooling network.

Answer to the general research question

In what way can a landscape design contribute to the implementation of a district-cooling network in relation to the infrastructures in the city of Utrecht?

A landscape design can contribute to the implementation of a district-cooling network in relation to the infrastructures in the city of Utrecht by spatially integrating these systems. For example the main distribution pipeline of the district-cooling network can be spatial integrated with road infrastructures (paragraph 3.2). This spatial integration can be used to solve other problems as well, such as fixing missing links in the slow traffic mobility network or optimizing the surface water quality in the inner city (chapter 4).

While working on the landscape design we focused too much on the design of the technical system, the district-cooling network, itself instead of its spatial implementation. This had lead to a questionable design, which is dominated by technical information. In light of answering the general research question we can say we did answer the question, though with a (low quality) design, but we also generated excess material about the technical system that did not necessarily contribute to the design. The fact that we got lost in the technical story also meant that we did not fully address our knowledge gap, because we wanted to research the topic from a landscape architectural point of view, but we did not work with a consequent, structured, explicit, and strong landscape architectural approach.

5.2 DISCUSSION OF THE RESEARCH OUTCOMES

Significance

In this paragraph we shortly describe the actual significance our thesis results (paragraph 5.1) have in terms of academic, societal and landscape architectural values. The described values that we had envisioned for the thesis project (paragraph 1.2) have partly been realized.

Academic value

Wanted to contribute a reflection on the use of research-based-design as a research strategy. We did not contribute to this aspect, because we did not apply research-based-design in a consequent way. We did do research and based (parts of) our designing phase on this, but the research was not valid or reliable and the designing phase lacked a proper structure and was inexplicit as described in the next part of this paragraph and the final reflection.

A second envisioned significance was that we intended to use the landscape infrastructures concept (paragraph 3.1) as a compass for our research and our contribution will be a reflection on this use of the compass. In every phase of the project we described the use of landscape infrastructures as our compass, and we reflected on this in every chapter. Also we reflected on the overall use of the compass in the final reflection (paragraph 5.3), and we presume that our reflections were thorough and honest, so we can tentatively state that we have contributed this aspect.

Societal value

In terms of societal value we wanted to contribute one possible solution for the implementation of a district-cooling network in relation to infrastructures in Utrecht as an inspiration. As described in the answer to the third research question (paragraph 5.1) we have provided one possible solution for the implementation of a district-cooling network in relation to infrastructures in Utrecht. However, the designing phase was lacking analysis, proper argumentation, and sound methodology, so the possible solution might be supposed to have a doubtful quality. This makes for a lesser significance of the inspiration the design could have for local stakeholders as we originally envisioned.

Landscape architectural value

We thought value of our work for the landscape architectural field could be to show an example of the integration of a large-scale system in an existing urban context. Looking back our landscape architectural approach of the implementation of a district-cooling network in relation to infrastructures in Utrecht (which was our knowledge gap) was not very strong. We did not focus on the spatial analysis and design of the possible spatial value of a district-cooling network in Utrecht. The design phase was more concentrated on a technical assignment than on a landscape design assignment. So we conclude we did make an example of the integration of a large-scale system in an existing urban context, but its value was not high enough to be a significant contribution to the landscape architectural field.

Validity and reliability

In this paragraph we explain the actual validity and reliability of the results our thesis work. The envisioned validity and reliability as described in the introduction chapter (paragraph 1.2) have for a large part not been realized during the first phase of the thesis process. The first version of the thesis was unsatisfactory and had to be improved during a completion phase, thus in this paragraph the validity and reliability of the first version of the thesis and the final version of the thesis are both discussed.

In terms of internal validity we did not triangulate our data, which made it impossible to estimate the value of our material and assess the conclusions drawn from the data. During the process we did involve external experts in the research and design process as much as possible. These participants were able to confirm, validate and approve very specific parts of the project and thus judge the validity of these parts. However, we did not involve experts to confirm, validate and approve the total of material, results and process. Also we did not record the input from the experts in any way, so the internal validity is not ensured. In the completion phase we added reflections on the ways in which we used data or maps, and the extra information we obtained from experts to confirm or add data.

The research we conducted has no external validity, because we did not keep any record of our process. In the completion phase we added reflections and descriptions of our considerations and reasoning to make it possible for others to understand the process. However, the process would still not be replicable. A design process is largely intuitive and iterative, so this part of the thesis would be almost impossible to be repeated by others.

In order to ensure the reliability of the thesis we should give a detailed description of the process of collection, interpretation, integration and evaluation of the data. Looking back we did not give these detailed descriptions in the first version of the thesis, so we did not ensure the reliability of this research. In the completion phase we added reflections on the use of data, process and results in order to make the material of the thesis assessable. These reflections give a detailed and honest evaluation of the reliability of our material, which in short is poor, but at least the reflections offer transparency about the shortcomings.

5.3 REFLECTION ON THE PROCESS AND PRODUCTS

Reflection on landscape infrastructures as a compass
In the beginning of the thesis we started with a fascination for the landscape infrastructures, and we were accepting what we read or heard without question. By not being aware of this fact the work of Bélanger became our absolute guideline instead of being our compass.

In our first thesis product the use of the work of Bélanger was absolute, out of his work we reduced a directive from mapping towards design. We missed a theoretical context, which could have given us information on positive and also critical points on the concept of landscape infrastructures. If we would have done this in the beginning of the thesis we could have formulated how we as landscape architects could contribute to the landscape infrastructures method. These contributions then should have been compared with other literature during the process and later on in the final conclusion.

Reflecting on this process of using landscape infrastructures as compass we can state that it was hard to reduce a directive out of the work of Bélanger. It does not give any description on the relations between the steps that need to be taken to come towards a landscape infrastructure. It is clear that mapping biophysical systems is important, but it is not clear how to come from an inventory of systems to an analysis, and how you can generate information to come from the mapping to a design assignment. With a critical view on our work, we now see we should have figured out how to do make these connections. This point is further elaborates in the reflection on the process in this paragraph.

The point that we want to make here is that landscape infrastructure is not a concept that can be used as a plug-and-play method. Bélanger is not explicit on what kind of information the mapping needs to contain and how the maps can be made and read. So it became hard for us to compare it with work of others or to use it as a tool to communicate with fellow students and other researchers. The mapping of biophysical systems needs to be part of education concerning its themes and making the maps, before it can become a workable tool for landscape architectural research. We learned that the tool of Bélanger is not something for which we posses the right education, because making the maps in itself is not so difficult, but handling information on 'flow' is something that is the scope of ecologists or geo data analysts.

Reflection on our contribution as landscape architects
We were not able to answer our main research question in the first thesis report on adding spatial value by bundling underground and aboveground systems. This was partly caused by our lacking a landscape approach in the designing phase of our research. By missing information on aesthetics we could not answer to our own critique on the landscape infrastructures method, saying that it is too technocratic. So in the final thesis product, made in the completion phase, only the integrative aspect has been addressed and the spatial aspect has remained insufficient. With the information on integrating systems the question remains how a landscape architect can integrate a new system in an existing context on a human scale? To give an answer to this question we reviewed information on aesthetics to get an idea on how it would have contributed to our research.

Landscape is not only a phenomenon of construal and construction (Corner, 1992, in Swaffield 2002, p. 144) the actual landscape is landscape plus people (Koh, 2012). This hybrid form is called 'ecological and environmental aesthetics' and deals with human ecology and the ecological aesthetic of our landscape (Koh, 2012). Human ecology finds its basis in understanding how people experience the landscape and derive meaning from landscapes. Merleau Ponty observed that the world is not laid out before us, but it's all around us and we are emerged in it (Smith, 2002, p.p. 368-370). The ideas of Martin Heidegger add to this that 'to build is to dwell and to dwell is to live poetically with the sense of the holy' (Heidegger, 1951, in Thompson, 2009, p. 213). So by relating landscape to people one can create a strong relation between the character of a person and that of a place. When making places that fit human purposes we need to understand the nature of the site, how its users will act in it, will value it and feel responsible towards co-creation and stewardship of the end result (Lynch, 1987).

By looking at aesthetics and the human scale, we came to understand what the importance of landscape architecture could be in engineering projects. Before this research we positioned the landscape architect at the centre of a project, but we now realize that the contribution of a landscape architect is quite modest. Economists, planners, and ecologists create possible technocratic strategies. The understanding of a landscape architect on the 'multi-layered knowledge of the landscape its spatial structure, visual landscape, history, context, and the underlying the ecological, economic and social processes (Nijhuis, et al, 2012)' can contribute to these strategies by integrating the landscape infrastructure in its context on a human scale.

Reflection on the major thesis process

Looking back we had a difficult process, and we spent much time working on an insufficient product. In the final phase of the process our ambition was not to make the thesis completely sufficient, but learn from the mistakes we had made and make additions to the product in order to achieve a positive end result.

In retrospect we can conclude that the starting point of the problems we had during the thesis process was our lack of academic mentality. This resulted in us not being critical on the concept of landscape infrastructures, and having problems on handling methodology, structure and data. By analysing the critiques from our green light presentation, and colloquium presentation, and by reflecting on the process we learned what we did and why we went wrong and what we should have done differently. With this steep learning curve we are now better grounded in understanding on handling academic writing, structure, data, and critical reflection.

Academic mentality

Our lack of an academic mentality at the beginning of the thesis process originated from our background, and our personal attitudes. We started the master at Wageningen University after our professional bachelor degree and two years of experience in the field of landscape architecture. This gave us a certain attitude and ideas on how to practice landscape architecture. We were trained in making a product that sells, and we were constantly focused on the end result. This resulted in being uncritical and intuitive regarding the choices that we made during our process in the first phase of the thesis.

After the colloquium presentation we were confronted with failure and our self-centred way of knowing. To overcome and learn from this failure we took some time to reflect on our selves. In this period the aspect of modesty became important for both of us; Marie found this through coaching and Marijn through classes in meditation. These periods of personal development helped us to a get a better perspective on how our own thinking processes work. Therefore it helped us to write the critical reflections in becoming more modest regarding the process.

Eventually the critical reflection that we had to make through describing, analysing and evaluating the process gave us more insight about what went wrong. It became clear what kind of structure, methodology, data handling, and reasoning our thesis was lacking and what we should have done to make it a proper scientific product. From an academic point of view it gave us more understanding on how to look for evidence, good reasoning, and deal with structure and data.

Research structure

By focusing on landscape infrastructures as a framework and main method, and by having formulated one general research question and no specific research questions there was no clear structure in the first thesis product. Though the lack of a valid and coherent scientific framework we generated excess information, and we did not produce the information that we needed.

By changing the research questions and removing parts that were not consistent we made a story that is more credible and coherent. The questions are now more related to the information that we really produced and needed. The general research question has changed as follows:

General research question of the first thesis product: '*how can the design for a district-cooling network in Utrecht contribute to exploring the spatial value of underground infrastructures?'*

General research question of the final thesis product: '*in what way can a landscape design contribute to the implementation of a district-cooling network in relation to the infrastructures in the city of Utrecht?'*

We added the contribution of landscape architecture, because this aspect was missing (see previous reflections). We removed the aspect of 'spatial value' from our first product, because in our completion phase we had to admit we did not research his aspect well enough. The structure is now more logical; the new questions (see paragraph 1.2 for the specific research questions) follow each other better, while shaping the information that we produced during our thesis into a coherent story. In that way the new questions offer a better coherence between the different phases of the thesis, which results in a more interwoven topic and method.

What we learned is how important it is to make a good proposal with a clear topic, structure, knowledge gap, and research questions. Working without a good starting point causes problems for the further process.

In the first phase of the thesis we 'made it up as we went along', but this is not the right approach when handling a thesis process. It is important that, before you take a step, think what, who, where, when, how, and why you take a certain direction and make this explicit. We learned how to organize and describe thoughts and material, and to ask and answer questions in a coherent and credible way to make a storyline that can be followed.

Data handling

Besides not having a clear structure also a proper data use, reasoning and critical reflection were lacking in the first thesis product. By making such mistakes on data and structure, the first thesis product was neither transparent nor transferable, and the entire work was stuck together through hypotheses.

In the reflection on the phases (paragraphs 2.8, 3.4, and 4.8) we already described what went wrong concerning the data. In both the first and final versions of the thesis we did not describe the collection, selection, interpretation, integration and evaluation of the data in a structured way during the mapping process. Also we did not triangulate the data. We did not record and evaluate the data from the interviews with experts, causing the interviews to become useless as a valid data source. Besides these facts we did not put the thesis in a methodological context by comparing it with relevant literature. Therefore the data that we used and produced in the thesis phase is neither valid nor reliable.

Through the completion process we learned how to handle data in a scientific way, and what it requires in terms of description, analysis and evaluation. This critical thinking process was useful for generating new reflective material, but it also gave us a better understanding on assessing sources. We came to this understanding by using the critiques from our green light presentation, and colloquium presentation. In that sense we can say we learned and became aware in our completion process of the thesis.

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The experts that we approached for this thesis were selected based on their expertise or publications. The methodology of the interviewing process is described in the introduction. As we did not record the interviews, we only used the information of the experts to confirm data. The experts, their backgrounds and the reasons for interviewing them are shortly described below (table 5).

Table 5. Experts contacted during the research process

Expert	Organization
A. Bruinsma	Eneco
Ir. M. Degenkamp	Gemeente Utrecht
Prof. Dr. Ir. A.A.J.F. van den Dobbelsteen	TU Delft
Drs. M.E. Elzerman	Vitens
R. Glas	Fietsersbond Utrecht
Ing. A. Harting	Gemeente Utrecht
Prof. Dr. Ir. J.P. van der Hoek MBA	Waternet/TU Delft
L. de Jel	Lekker Utrechs
M. van Langen – van der Meer	AVU
N. van Pagee	LSNed
Ir. E.W. Rebergen	Gemeente Utrecht
Msc. T. Simon	Arcadis
Ir. R. Verburg	Arcadis
C. van der Vliet	Gemeente Utrecht
Drs. S.F. van der Weide	Gemeente Utrecht
J.A.C. Wiegers	Gemeente Utrecht

A. Bruinsma
Eneco
Auke Bruinsma is Account Manager Heating and Cooling at Eneco. We were advised to contact him by Arno Harting of the municipality of Utrecht, because we needed more information about the development and capacity of the district-heating network in Utrecht.

Ir. M. Degenkamp
Gemeente Utrecht
Mark Degenkamp is Senior Advisor Mobility Policy at Gemeente Utrecht. We contacted him, because he is currently working on the new mobility policy for Utrecht and knows al the issues concerning mobility in the city.

Prof. Dr. Ir. A.A.J.F. van den Dobbelsteen
TU Delft
Andy van den Dobbelsteen is Head of the Department of Architectural Engineering and Technology, and Professor of Climate Design and Sustainability at TU Delft. We were advised to contact him by Cees van der Vliet of the municipality of Utrecht, because we needed more information about energy usage of utilitarian buildings in the Netherlands and Utrecht.

Drs. M.E. Elzerman
Vitens
Mark Elzerman is Environmental Manager at Vitens. We contacted him through Hanneke Wiegers of the municipality of Utrecht. He knows all about the drinking water system in Utrecht, because Vitens is the supplier for the entire region.

R. Glas
Fietsersbond
Ria Glas is an active member of the Fietsersbond Utrecht and works as an accountant for Administer. We interviewed Ria Glas as she knows the system for slow traffic in Utrecht very well and is active within the Fietsersbond organisation as a representative towards politics and working on optimisations of the cycling network.

Ing. A. Harting
Gemeente Utrecht
Arno Harting is Environmental Advisor Sustainable Building and Energy at Gemeente Utrecht. We contacted him through the website of the municipality of Utrecht. He is specialized in energy systems and in particular the district-heating network in Utrecht.

Prof. Dr. Ir. J.P. van der Hoek MBA
Waternet/TU Delft
Jan Peter van der Hoek is Head of the Strategic Centre of Waternet and Professor at the Chair on Drinking Water Engineering at TU Delft. We contacted him after reading an article of him on energy from surface water (Hoek, 2012). We interviewed Jan Peter van der Hoek to find out how surface water can be used as energy source, and how a surface water energy system can solve surface water pollution.

EXPERT PROFILES

L. de Jel
Lekker Utrechs
Louis de Jel is the chairman of Stichting Aarde and one of the Project Managers at Lekker Utrechs. We approached him through Happyland Collective, for which we had contact with him previously for the Koningshof project. He knows much about food production and distribution in Utrecht, and especially about sustainable and local production.

M. van Langen – van der Meer
AVU
Monique van Langen – van der Meer is Senior Policy Advisor at AVU (Afval Verwijdering Utrecht). We contacted her through the AVU website. She knows all about the waste cycles in the province and city of Utrecht.

N. van Pagee
LSNed
Niels van Pagee is Projectmanager at LSNed (Leidingenstraat Nederland). We contacted him through the LSNed website in order to find out how cable ducts are developed and what dimensions they can have.

Ir. E.W. Rebergen
Gemeente Utrecht
Erwin Rebergen is Manager Ground and Surface Water at Gemeente Utrecht. We contacted him through the website of the municipality of Utrecht. He is specialized in the ground- and surface water systems and policies in Utrecht.

Msc. T. Simon
Arcadis
Tristan Simon is Energy and Climate Consultant at Arcadis. Rachelle Verburg suggested including him in the interview . We interviewed them to explore ways to cluster TES systems and use this to contribute to solving ground water pollution.

Ir. R. Verburg
Arcadis
Rachelle Verburg is Senior Consultant at Arcadis, specialized in ground water pollution and thermal energy storage. We contacted her through a publication on this topic (Verburg, 2010). We interviewed Rachelle Verburg to explore ways to cluster TES systems and use this to contribute to solving ground water pollution.

C. van der Vliet
Gemeente Utrecht
Cees van der Vliet is Environmental Advisor Development and Energy at Gemeente Utrecht. We contacted him through his collegue Arno Harting. He is specialized in energy systems and in particular the sustainable energy systems, like TES systems, in Utrecht.

Drs. S.F. van der Weide
Gemeente Utrecht
Sieb van der Weide is the Coordinator of Underground Infrastructures at Gemeente Utrecht. He is also the secretary of the Gemeentelijk Platform Kabels en Leidingen (GPKL). We found him through the Dienst Stadswerken website when looking for the expert on underground infrastructures in Utrecht. We interviewed Sieb van der Weide to discover the policy of the municipality of Utrecht on underground infrastructures, and discuss the necessity, possibilities, and challenges of a district-cooling system for Utrecht.

J.A.C. Wiegers
Gemeente Utrecht
Hanneke Wiegers is Environmental Advisor Soil at Gemeente Utrecht. We contacted her through the website of the municipality of Utrecht. She is specialized in soil- and groundwater pollution in Utrecht.

EMAIL CORRESPONDENCES

During the thesis we had email correspondences with some of the experts (see expert profiles). We show the most pivotal correspondences here, as they have formed the foundation for our topic as described in the introduction chapter. We want to show the emails in their original form, so we chose not to translate them from Dutch to English.

Email from Andy van den Dobbelsteen
October 6, 2013

Head of the Department of Architectural Engineering and Technology, and Professor of Climate Design and Sustainability at TU Delft.

“Er zijn geen officiële registraties van het aandeel van elektriciteit in koeling van kantoren. Er wordt alleen elektriciteit afgenomen bij het energiegebruik, dus het moet een beetje ingeschat worden (is ook sterk afhankelijk van de leeftijd en kwaliteit van het kantoor: oud en slecht geïsoleerd verlies makkelijk interne warmte maar warmt ook snel op bij hoge buitentemperaturen; bij moderne, goed geïsoleerde kantoren is het aandeel interne warmteproductie van personen en apparaten bepalend voor wanneer de airco aan moet). Mijn benadering: van alle energie in een kantoor gaat ongeveer 30% naar verwarming en koeling (nog 30% naar verlichting en 30% naar apparatuur, 10% naar pompen en ventilatie). Bij een redelijk modern kantoor zijn koeling en verwarming gelijk; bij oudere kantoren gaat het om 20-50% koeling. Dus als je totale energiegebruik kent van kantoren (zie CBS of ‘Cijfers en Tabellen’ van SenterNovem/Agentschap NL) kun je het dan uitrekenen. Andere benadering: een Nederlands kantoor gebruikt ongeveer 140 kWh/m2 BVO (check even bij CBS en Agentschap NL). Ik schat dat een kwart daarvan voor koeling is, dus ongeveer 35 kWh/m2 BVO”.

Email from Sieb van der Weide
May 12, 2014

Coordinator of Underground Infrastructures at Gemeente Utrecht.

“Wat ik vaker hoor is dat bij locaties met veel kantoren de koudevraag de warmtevraag gaat overstijgen, zo al niet op dit moment overstijgt. Hier in Utrecht kun je dan denken aan locaties zoals Papendorp, de Uithof, Rijnsweerd, en stationsgebied. Stationsgebied heeft groot aantal individuele WKO’s, Papendorp ook. Bij Rijnsweerd is planontwikkeling om gezamenlijke WKO’s aan te leggen in het kader van face lift van het hele gebied”.

Email from Arno Harting
May 12, 2014

Environmental Advisor Sustainable Building and Energy at Gemeente Utrecht.

“Er is een koudevraag in Utrecht, die zal toenemen in de toekomst. Er is een koudevraag in Utrecht. Diverse functies als kantoren, supermarkten, zorgcentra, onderwijsinstellingen, ziekenhuizen blazen tussen de 1½ en 3 miljoen GJ aan warmte de lucht in. Dat kan de temperatuur in de (binnen)stad verhogen. Maar het is ook verspilling om die warmte niet op te slaan voor gebruik op een later (= lees winter) moment. En met een dergelijke hoeveelheid is het ook de moeite waard daar eens goed over na te denken. Een collectief koudenet zou deze vraag kunnen voldoen. Teneinde de uitgeblazen warmte te ‘verzamelen’ en gereed te maken voor een vorm van centrale/geconcentreerde opslag is een koudenet bij gebleken (maatschappelijke financiële) haalbaarheid verstandig”.

Biophysical systems
Bélanger describes biophysical systems as hydrology, geology, biomass, and climate. His checklist of biophysical systems consists of water resources, waste cycling, energy generation, food production, and mass mobility (Bélanger, 2013)

'Bio washing machine' principle
The use of thermal energy storage systems to treat groundwater pollution has so far been tested in the 'bio washing machine' pilot in Utrecht. The TES systems generate groundwater movements that stimulate naturally existing bacteria to break the pollutants. By adding nutrients this process is accelerated, but it is still a long-term solution (Arcadis, 2009).

Bundling
Bundling is the process of combining certain systems that can together come to an added value. 'The new design imperatives are found in the basic processes and essential services that support urbanization including the integrated ecologies of water, energy, food, mobility and waste, which have traditionally been treated as separate components or separate districts in municipal planning. Through the bundling of multiple ecological services, strategies can achieve greater economies and ecologies of scale. Forming a geographic field, these urban- regional strategies can be considered synergistic, self-perpetuating and self-maintaining. It is at this precise moment that the region becomes infrastructural' (Bélanger, 2013, p. 337).

Design(ing)
Design is a form of synthesis that often revels in complexity when dealing with diffuse, indeterminate, fluctuating processes or dynamics, most often found in biophysical processes, social networks, or urban conditions (Bélanger, 2013, p. 394). 'Designing is the process of giving form to objects or space on diverse levels of scale and when we speak about design, we mean the results of a design process' (Lenzholzer, Duchhart, and Koh, 2013, p. 121).

District-cooling system
A district-cooling network is very similar to the existing district-heating system in Utrecht: one or more sources produce thermal energy that is distributed throughout the city by means of pipes. In case of a district-cooling network the buildings connected to the system are supplied with air-conditioning.

Evidence-based design
Evidence-based design (or research-based design) is 'a process for the conscientious explicit, and judicious use of current best evidence from research and practice in the making of critical decisions about the design of each individual and unique project' (Hamilton and Watkins, 2009 in Deming and Swaffield, 2011, p. 239).

Infrastructures
An infrastructure is 'the basic system of essential services that support a city, a region or a nation' (Bélanger, 2013, p. 69). 'Mature technological systems - cars, roads, municipal water supplies, sewers, telephones, railroads, weather forecasting, buildings, even computers in the majority of their uses - reside in a naturalized background, as ordinary and unremarkable to us as trees, daylight, and dirt. They are the connective tissues and the circulatory systems of modernity. In short, these systems have become infrastructures' (Edwards, 2003, in Bélanger, 2013, p. 67)

Landscape Infrastructures
'Landscape infrastructures is an analytical tool and a design strategy' (P. Bélanger, lecture TU Delft, May 21, 2013). According to Bélanger 'The merger of biophysical systems with contemporary infrastructure is now rapidly becoming the dominant order for urban regions' (Bélanger, 2010). We deduce that this merger of biophysical systems with contemporary infrastructure can be described as landscape infrastructures.

GLOSSARY

Mapping
Mapping is the process of researching and visualizing systems by means of the checklist of biophysical systems: water resources, waste cycling, energy generation, food production, and mass mobility. 'As a projective method, representation through the mapping of complex levels of information is instrumental to the design of infrastructure and ecology. Whether by diagrams or maps, composite imaging provides an important alternative to the conventional orthographic methods of visualization inherited from engineers and architects' (Bélanger, 2013, p. 371). Mapping is conducted in order to understand the workings of systems as well as possible.

Renewable sources
Renewable sources are sources of energy that do not compromise the environment and prospects of future generations.

Surface water source
A surface water source is a water body with sufficient depth that can be used to pump cold water from the deepest point into a cooling plant. In this plant the cold from the surface water is transferred to the water in the distribution network through a thermal exchanger. The distribution network then transports the cooling to the connected buildings. The warmer water coming back from the buildings is then treated and pumped back into the surface water source (Agentschap NL Energie en Klimaat, 2010; Roelen, 2009).

Thermal energy storage (TES) system
A thermal energy storage system supplies a building with heat in winter and cooling in summer by storing thermal energy in the groundwater. The groundwater is extracted by deep pipes and led through a thermal exchanger. Many thermal energy storage systems have a cold source and a warm source, that are situated approximately 100 metres from each other. The cold source pumps cold water up in summer to cool the building, and the warmer water residue after the extraction of the cooling is then stored in the warm source. In winter the heat from the water stored in the warm source is extracted and the colder residue is pumped back into the cold source.