Strijp-S revived:

A landscape design for public green space that integrates wastewater treatment

Vera Hetem
MSc Thesis Landscape Architecture
Wageningen University

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Acknowledgement

This MSc Thesis is completed as part of my MSc Landscape Architecture at Wageningen University. In cooperation with the landscape architecture chairgroup, the environmental technology chairgroup and Waterboard de Dommel, this resulted in the completion of this research.

I would like to take the opportunity to thank the people who played an important role in the completion of this thesis. Firstly, I would like to thank my supervisor dipl. ing. Wiebke Klemm for her supervision, feedback and support during the process. Due to her supervision I was able to complete this thesis appropriately. I would also like to thank my second supervisor dr. Katarzyna Kujawa-Roeleveld for her supervision from the environmental technology perspective. This resulted in new insights and made it possible to complete this thesis with a transdisciplinary approach.

This research topic was initiated by ing. István Koller and drs. Jack Crielaard from waterboard de Dommel, together with the Wageningen University. I would like to thank them for the possibility to conduct this thesis in cooperation with waterboard the Dommel. I am especially grateful for their support in organizing a workshop with a group of stakeholders and experts on Strijp-S and for bringing me in contact with these stakeholders.

I would also like to thank Loek de Bonth, MSc student from the Wageningen University with whom I cooperated during this thesis. The cooperation resulted in many new insights that would otherwise not have been possible. Organizing a workshop with him was a pleasure and I would like to thank him for that as well.

Lastly, I would like to thank the other people that contributed to this research as an attendee of the workshop, as an interviewee or by any other kind of personal communication.

Wageningen, 12-09-2016
Vera Hetem

Abstract

Urbanization causes two problems that are addressed in this study. On the one hand it results in a reduction of public green spaces in cities although the demand for public green spaces keeps increasing and cities depend on green spaces to maintain long-term conditions for life.
On the other hand urbanization results in an unsustainable wastewater infrastructure in the city. Generally wastewater is treated in centralized wastewater treatment plants, yet there are alternative sustainable decentralized treatment solutions available that could increase the sustainability of the wastewater infrastructure in the city. This research aims on addressing both problems by finding a design solution for the integration of a decentralized wastewater treatment plant in public green space.

A model study for the research area Strijp-S in Eindhoven resulted in different design options for the integration of a wastewater treatment plant in public green space. Three different treatment types are tested in models to find the most suitable treatment technique to be integrated in public green space. These models are evaluated according to their ability to enhance the benefits of public green space, also known as ecosystem services. For a comprehensive evaluation, a group of stakeholders with expert knowledge were asked to fill in a survey on the most suitable wastewater treatment type. Moreover they were asked to evaluate the enhancement of ecosystem services during a workshop with a participatory approach.

The result is a stakeholder supported landscape design for Strijp-S that integrates a wastewater treatment plant in public green space. The main finding is that ecosystem services can be enhanced by reusing the purified water in bioswales, retention areas, infiltration areas and fountains.

Keywords: public green space · ecosystem services · wastewater treatment · Strijp-S · Eindhoven · landscape architecture.

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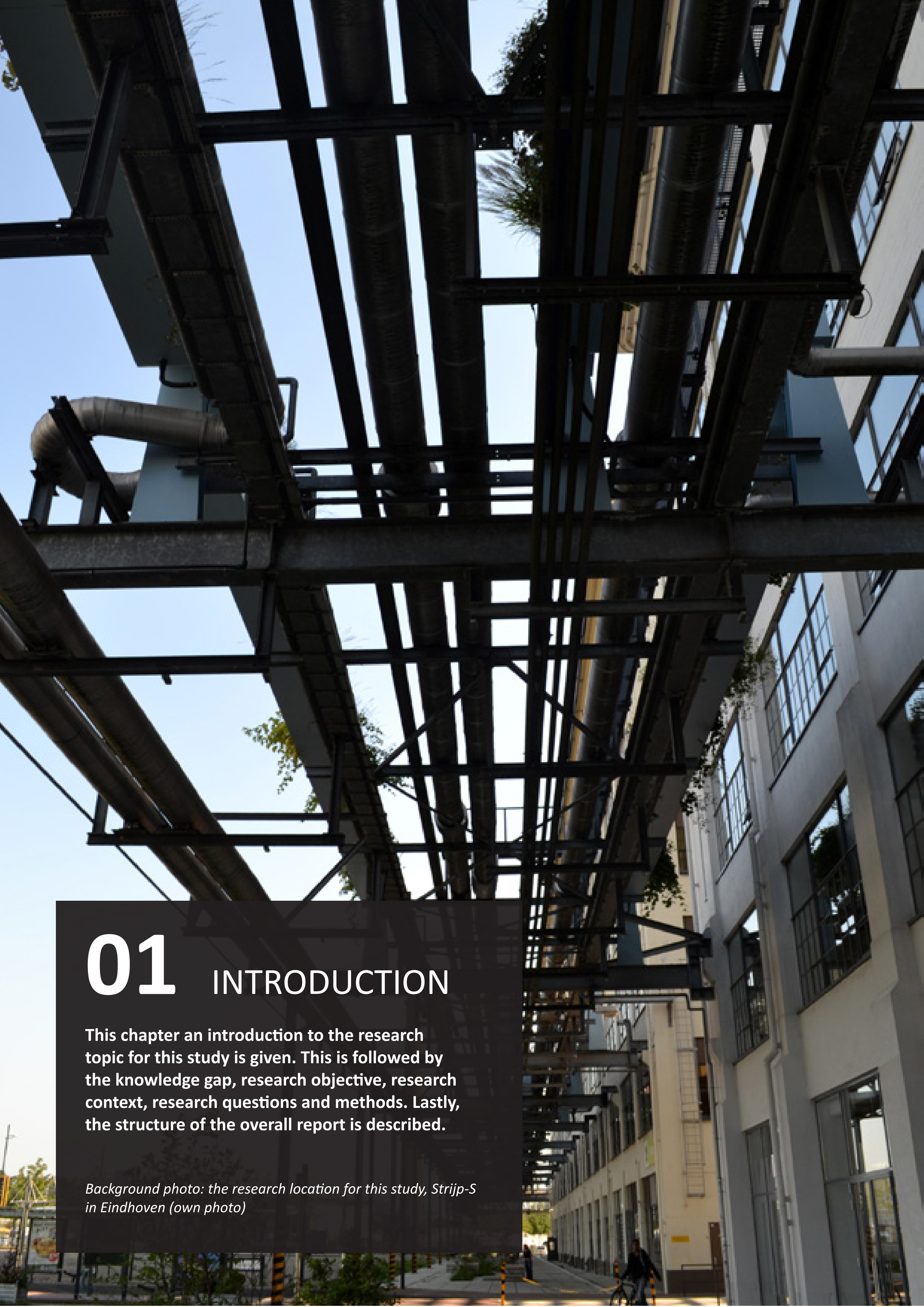

01 INTRODUCTION

This chapter an introduction to the research topic for this study is given. This is followed by the knowledge gap, research objective, research context, research questions and methods. Lastly, the structure of the overall report is described.

Background photo: the research location for this study, Strijp-S in Eindhoven (own photo)

Introduction

Urbanization is happening worldwide (United Nations, 2015). Nowadays, more than half of the world's population lives in urban areas. The growth of the population in urban areas is expected to increase from 3.9 billion in 2014 up to 6.3 billion in 2050. Predictions say that this trend will continue in the future with 66% of the world population living in urban areas (United Nations, 2015). This trend also applies to the Netherlands, one of the most urbanized countries of Europe. The Netherlands has a rate of 90% urban area, with 'urban' defined as municipalities over 20.000 inhabitants (United Nations, 2015). It is becoming more and more clear that sustainable development is a crucial task in urban planning (Agudelo-Vera, Mels, Keesman, & Rijnaarts, 2011).
Understanding how urban metabolic systems function is a challenge to tackle our environmental issue. Developing sustainable cities is dependent on strategic management of resources. Isolated technical solutions are not sufficient enough to deal with the environmental problems that we are facing today (Agudelo-Vera et al., 2011). The current urban metabolism is mostly linear, cities depend on the import of water, goods, energy, and the export of waste. They use the resources inefficiently and valuable remains are thrown away, see figure 1.1 (Girardet, 1996). The dependency and inefficiency makes these cities vulnerable (Agudelo-Vera, Leduc, Mels, & Rijnaarts, 2012). Therefore cities demand a metabolism that resembles metabolism of natural ecosystems, with less impact on other cities and surrounding landscapes (Agudelo-Vera et al., 2012).

Ecosystems in the city can be found in public green spaces (PGS). Urbanization reduces the quantity and quality of PGS in cities although the demand for PGS and their benefits keeps increasing in the urbanized world (Ayres & van den Bergh, 2004). Cities depend on green spaces to maintain long-term conditions for life (Odum, 1989), health (Maas, 2006; Tzoulas et al., 2007), social relations (MEA, 2005), security (Costanza, Mitsch, & Day Jr, 2006) and many other aspects regarding the well-being of humans (TEEB, 2010). PGS are part of a larger network in the city, usually described as green infrastructure. This is the overarching concept that defines an interconnected network of green features and spaces that bring added benefits to people and the surrounding environment (European Environment Agency, 2011). It addresses the connectivity and protection of ecosystems and the provisioning of ecosystem services, while it also addresses aspects such as adaptation to climate change (TEEB, 2010). It is important to understand green infrastructure as more than just the sum of its parts. Functional connectivity brings more benefits than solely the single functions. Therefore it is not only about connecting ecosystems, but also about strengthening them (European Environment Agency, 2011).
Ecosystems can be defined as *"a set on interacting species and their local, non-biological environment functioning together to sustain life"* (Moll & Petit,

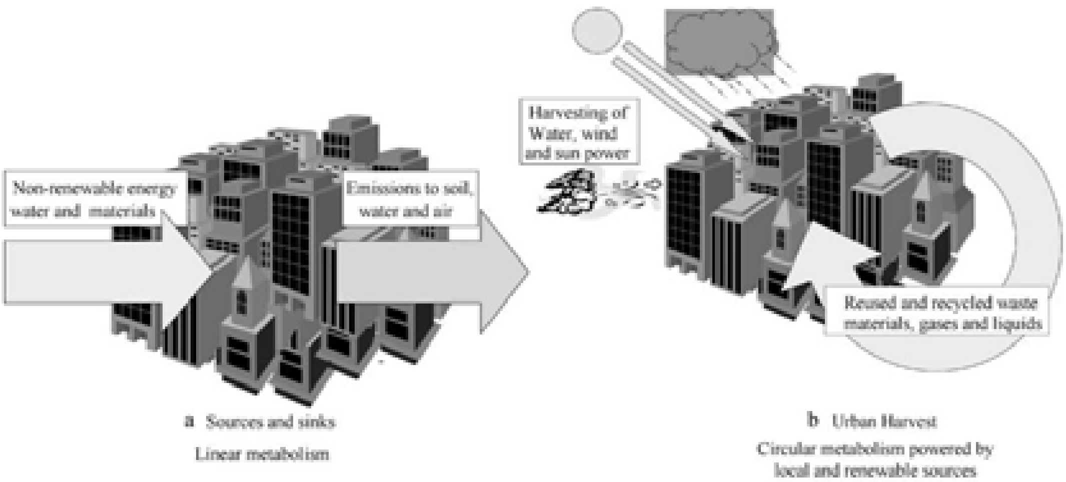

Figure 1.1 Linear metabolism vs. circular metabolism (Agudelo-Vera et al., 2012)

1994). Yet it is not always clear where the borders of an ecosystem are and they might be diffused. For instance, a city can be seen as one ecosystem, but it could also be seen as a composition of multiple individual ecosystems. The different urban landscapes that can function as an ecosystem can be categorized in several types, such as lawns and parks, street trees, urban forests, cultivated land, lakes and sea, wetlands and streams (Bolund & Hunhammar, 1999). The benefits that people derive from ecosystems are the ecosystem services (Costanza et al., 1997).
The benefits of PGS can be found on multiple levels, ranging from local to neighborhood, city and regional level. It supports human well-being by creating more cohesive places to live, recreate and work. It can also function as a way for people to engage with rural landscapes by providing the link between urban environment and rural landscape and by connecting cultural, psychological and ecological linkages (Lafortezza, Davies, Sanesi, & Konijnendijk, 2013). The potential health benefits are increased life expectancy, reduced health inequality, improvements in physical activity and health, and a promotion of psychological health and mental well-being (Lafortezza et al., 2013). It is thefore important to foster and enhance PGS in the future, to adapt to urbanization and enhance these benefits for the residents and the environment.

Secondly urbanization influences the urban water infrastructure (MEA, 2005). Many aspects of the hydrological cycle are regulated through natural and geophysical processes and the human impact on these processes is large (MEA, 2005). If urbanization progresses in the coming decades, the urban water infrastructure will become even more complex than it already is (McDonald et al., 2014). The increasing water consumption and the demand for services like sanitation place strains on the water infrastructure and resources (Tjandraatmadja, Burn, McLaughlin, & Biswas, 2005). Growing urban areas require expensive networks and wastewater treatment plant capacities, as a result of city densification and urban sprawl (Tjandraatmadja et al., 2005). The wastewater industry demands high investment and maintenance costs for the collection of sewerage, transport and treatment, while it provides a low return (Wilderer, 2005). As cities expand, treatment at a wastewater treatment plant (WWTP) also is compromised, because the infrastructure becomes incapable in dealing with the increasing amount of wastewater. The growing pressures on water resources and the growing interest in better wastewater management asks for alternative approaches. Alternatives based on decentralization, value recovery (product and energy recovery) and social acceptance are needed to develop a sustainable wastewater infrastructure (Tjandraatmadja et al., 2005). Decentralized WWTP's encompass local wastewater treatment from one district rather than the treatment of wastewater from a whole city or region. Until now it remains difficult to integrate an alternative WWTP based on decentralization into the urban context. The lack of social acceptance, the high ground prices and the limited space availability make it a challenge to switch from centralized treatment to decentralized treatment (Waterschap de Dommel, 2016). Due to this difficulty the already constructed WWTP's are usually implemented as isolated technical solutions, without seeking connections to the surrounding environment. These isolated solutions are not sufficient enough to deal with the environmental problems that we are facing today (Agudelo-Vera et al., 2011).

Both the need for PGS in the city and the need for a sustainable wastewater infrastructure are addressed in this study. The hypothesis for this research study therefore is that the integration of a wastewater treatment plant in public green space brings added benefits for the environment; these benefits are the ecosystem services. The integration of a WWTP in PGS would not only be a solution for the increasing pressure on the wastewater infrastructure in cities, but it would also provide a solution for the limited availability of space and could potentially increase the quality of PGS in cities.

A discription of the term green infrastructure, ecosystem services and decentralized treatment can be found in appendix 1, page 99.

1.1 Knowledge gap

There are no research studies available yet that provide design solutions for the integration of a WWTP in PGS. However, as a starting point, there is literature available on the benefits of PGS, known as ecosystem services, and there is knowledge available about different WWTP types and their spatial requirements.

Urban ecosystems and its services are still in the early phases of research (Gómez-Baggethun & Barton, 2013). Since the article of Bolund & Hunhammar (1999) was published, more literature has strived to advance the understanding of urban ecosystem services, for example in their socio-cultural dimensions (Chiesura, 2004; Elmqvist et al., 2004). In major initiatives, like the Economics of Ecosystems and biodiversity (TEEB, 2010) and the Millennium Ecosystem Assessment (MEA, 2005) the urban ecosystem that could be provided in urban areas received increasing attention, especially as part of the debate on green infrastructure. Still, in comparison to ecosystems in the natural environment, such as forests and wetlands, the attention given to the urban ecosystems is modest. Moreover, most studies focus on single ecosystems or values, rather than the whole spectrum (Gómez-Baggethun & Barton, 2013). In order to get an overview of the most relevant ecosystem services in the urban environment, a selection required that can provide design criteria for enhancing those services in PGS.

The current availability of knowledge about integrating a WWTP in PGS is very limited. Therefore, a cooperation with MSc student Loek de Bonth from the Environmetal Technology chair group of Wageningen University is required to obtain the required knowledge to develop design criteria for integration a WWTP in PGS. In his MSc thesis report, he compared three WWTP types on their performance in an urban context based on an evaluation of different criteria. The evaluation of the WWTP's in his research resulted in the design criteria required for the integration of a WWTP in PGS.

To close the knowledge gap the feedback of a group of stakeholders on this topic is required. This group of stakeholders with expert knowledge on wastewater treatment and landscape architecture provide feedback on the design process for integrating a WWTP in PGS. In this way, the design solutions are not only evaluated by myself, but also by a group of experts. By using existing literature on ecosystem services, the knowledge from the Environmental Technology chairgroup and the evaluation of stakeholders, the knowledge gap can be closed, which means that stakeholder supported design solutions for the integration of a WWTP in PGS can be found.

1.2 Objective

The objective of this master thesis is to provide a design solution for the integration of a wastewater treatment plant (WWTP) in public green space (PGS) that is supported by stakeholders. This can be broken down into four sub objectives: (1) developing design criteria for the enhancement of ecosystem services in PGS and the integration of a WWTP in PGS, (2) integrating these criteria in a real-life context through a model study, (3) evaluating the integration of these design criteria in the models with the support of a group of stakeholders and lastly (4) developing an integral landscape design for the integration of a WWTP in PGS based on the outcome of the model study.

1.3 Research context

To investigate how design criteria for the enhancement of ecostem services and design criteria for the integration of a WWTP can be implemented in PGS, a research location is required. This research location is initiated by Waterboard 'de Dommel'. Waterboard de Dommel takes care of the water supply, water safety and purification of water in the area Midden-Brabant (Waterschap de Dommel, 2016). Waterboard de Dommel is involved in the development of so-called 'living labs', which are research locations where companies, educational institutions, authorities and civilians together work on business ideas, new services, markets or technologies in a real-life context (Waterschap de Dommel, 2015). Sometimes this is initiated by a university, sometimes by a university commissioned by an enterprise, or just by the enterprise itself. The aim is to create a shared platform where new ideas can be tested with representatives of the users in a real-life context (Waterschap de Dommel, 2015). Waterboard De Dommel is the initiator of a living lab on Strijp-S in Eindhoven where new ideas for the integration of a of a WWTP can be tested (Waterschap de Dommel, 2015). Figure 1.2 indicates the location of Strijp-S in Eindhoven.

Strijp-S is an urban district close to the city center of Eindhoven. It is a former business area of around 30 hectares that was owned by the company Philips. Nowadays it is a place for innovation and experiments in urban development, technology, design and knowledge. It contains some culturally valuable structures, buildings and objects, mostly formed during the industrial time. The transformation of Strijp-S that is currently going on will result in an urban district with a high density, containing all the elements of a city center. The monumental buildings have been renovated and contain shops, cafés, restaurant and design or technological companies. New residential housing is constructed or will be constructed in the future, which will result in n even more urban district (Park Strijp Beheer BV, 2015). Therefore the existence of PGS that contains multiple benefits is crucial for a healthy and liveable Strijp-S.

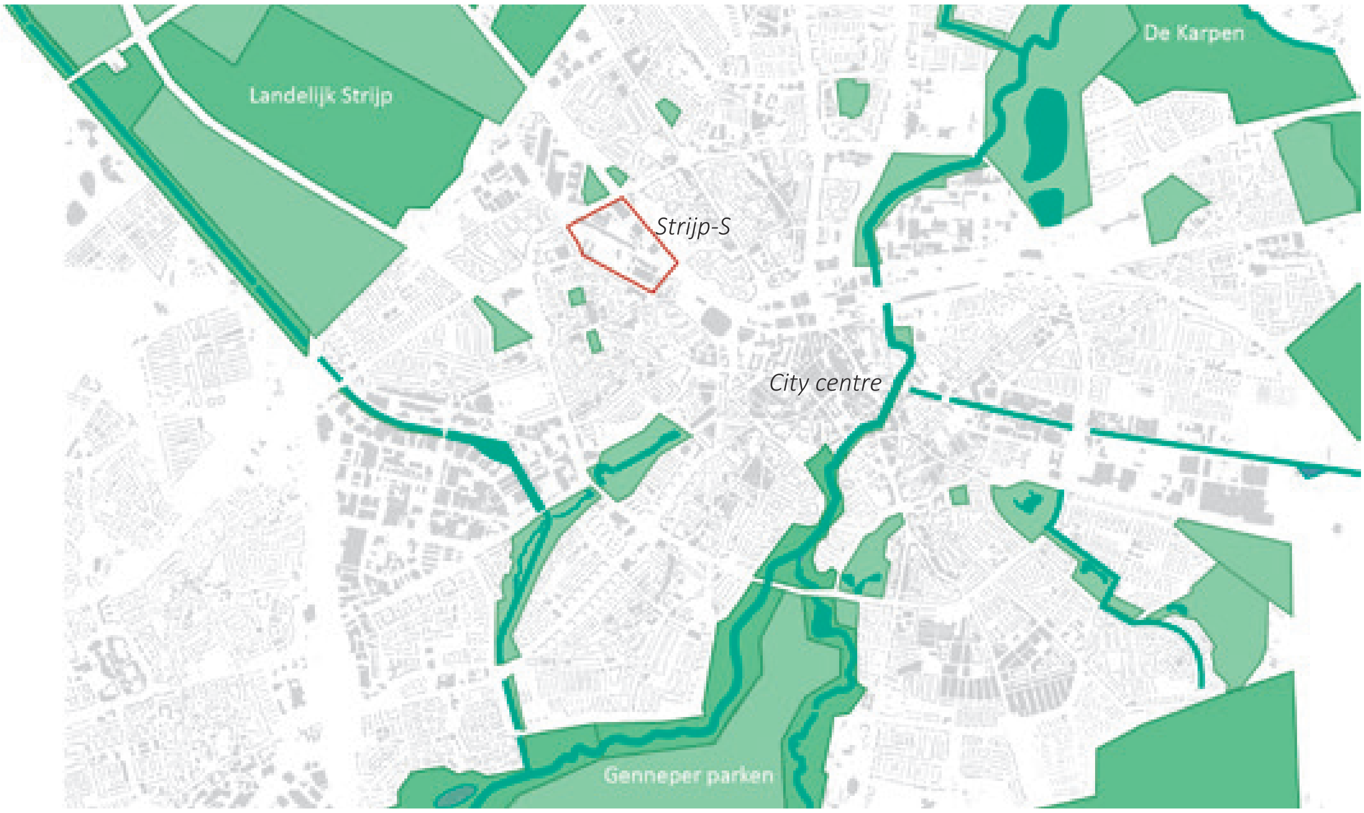

Figure 1.2 Location of Strijp-S in Eindhoven

1.4 Research questions

The objective for this study is translated into a main research question. This research question is then broken down into four specific questions, of which one design question:

Main research question:

What is a stakeholder supported design solution to integrate a wastewater treatment plant (WWTP) in public green space (PGS)?

Specific research questions:

1. *What are design criteria for enhancing ecosystem services and for integrating a wastewater treatment plant in public green spaces in cities?*
2. *Which ecosystem services can be enhanced through the integration of a wastewater treatment plant in public green space; Which wastewater treatment type has the most potential to enhance ecosystem services?*
3. *To which extent does the integration of a wastewater treatment plant in public green space respond to the stakeholders requirements?*

Design question:

4. *What is a stakeholder supported design solution to integrate a wastewater treatment plant on Strijp-S in Eindhoven?*

1.5 Methods

This study is based on evidence-based design (Nutley & Davies, 2000). Evidence-based design is a research method were practitioners, public officials or clients seek credible sources of knowledge about landscape and social processes, upon which design proposals and policy recommendations can be based (Nutley & Davies, 2000). In order to answer the main question: *'What is a stakeholder supported design solution to integrate a wastewater treatment plant (WWTP) in public green space (PGS)?',* four methods are used: (1) a literature review, (2) research through design (models), (3) a workshop including a survey, and (4) an integral landscape design.

1.5.1 Literature review

What are design criteria for enhancing ecosystem services and for integrating a wastewater treatment plant in public green spaces in cities?

Literature reviews are typically used to establish a baseline for the available knowledge on a given topic (Deming & Swaffield, 2011). This literature review is used to define the design criteria for enhancing ecosystem services in PGS and to define the design criteria for integrating a WWTP in PGS.
A selection of 84 articles are read as a baseline on PGS and their benefits. These articles are found by using the search database Scopus and Google Scholar. The following keywords are used: '(public) green space', '(urban) green infrastructure', '(urban) ecosystem services', 'urban parks' and 'urban green'. Of this number of articles, 14 are about the overarching concept of green infrastructure who sometimes also mention the role of ecosystem services. Another 7 articles are about 'public green space', sometimes also referred to as 'urban parks' or just 'green space'. 21 articles are about ecosystem services, of which 12 had a more general character and 9 were focused on specifically 'urban ecosystem services'. Another 42 items were scanned and read about one specific

ecosystem service, for example the benefit ‘health’ in public green space.

To define the design criteria for integrating a WWTP in PGS, the MSc thesis report of de Bonth (2016) ‘*A wastewater treatment plant for a shift towards sustainable development a research for the urban environment of Strijp-S’* provided the main information. This report describes the functioning of three WWTP types when integrated on Strijp-S in Eindhoven, the activated-sludge WWTP, the Nereda® WWTP and the Biomakery WWTP. In combination with an additional 10 articles on urban wastewater treatment sufficient information was collected.

1.5.2 Models

Which ecosystem services can be enhanced through the integration of a wastewater treatment plant in public green space; Which wastewater treatement type has the most potential to enhance ecosystem services?

Developing models is a research strategy based on simplification (Deming & Swaffield, 2011). The common feature of developing models is that it is the process of abstracting aspects of reality and the incorporation of empirical data into the abstraction. They are idealized simplifications of a system or phenomenon and for landscapes they take the form of external representation (Perry, 2009). It is a physical construct or a graphic representation of the landscape (Deming & Swaffield, 2011). Modeling can be used for multiple purposes. For this research it is used for synthesizing the descriptive information from the literature review in a spatial context. Each model shows a simplified landscape design indicating the location of the location of the WWTP and the ways in which urban ecosystem services can be enhanced in PGS. These models are evaluated on how the design criteria for enhancing ecosystem services and the design criteria for integrating a WWTP are implemented in each model.

1.5.3 Workshop and survey

To which extent does the integration of a wastewater treatment plant in public green space respond to the stakeholders requirements?

To evaluate the models, the opinion of a group of stakeholders was required. On 02-02-2016 a workshop afternoon was organized together with Loek de Bonth. In cooperation with Waterboard de Dommel, a group of 10 stakeholders were invited to this workshop. This included people from Hydreco (drinkingwater consultancy firm), Brabant Water (responsible for the provisioning of drinking water in the region of Noord-Brabant), Park Strijp Beheer (responsible for the urban development on Strijp-S), MJ Oomen (construction, inspection and renovation of sewers and roads) and my MSc thesis supervisor from the Wageningen University. For a full list of the participants, see appendix 4. p 102. The workshop consisted of two parts, the presentation of the models in the first half of the afternoon and an interactive part during the second half of the afternoon (see program flyer in appendix 2, p. 100). In the first part the concept ecosystem services was explained, followed by an analysis of the research area Strijp-S and an explanation of the different WWTP types. During the second half of the workshop the landscape models were presented and the stakeholders were divided into two groups to evaluate the presented models. The workshop turned out to be a reality check on how to integrate a WWTP in PGS and provided specific feedback that could not be gained through another method.

Before the workshop, the stakeholders were asked to fill in a survey on the WWTP in urban context. A survey is a suitable research method when the answer on the research question cannot directly be found from secondary sources (Deming & Swaffield, 2011). The survey delivers information that can only be found by asking people what they prefer. Through the survey the stakeholders were asked to give their opinion on which criteria they value most for the implementation of a WWTP on Strijp-S. These criteria were divided into five groups: environmental, technical, landscape, social and economic criteria. They scored statements in each group and this score gave feedback on which WWTP type is most suitable to be integrated in PGS.

1.5.4 Integral landscape design

What is a stakeholder supported design solution to integrate a wastewater treatment plant on Strijp-S in Eindhoven?

The findings of the models, workshop and survey are used for the landscape design of Strijp-S. The workshop provided information about the preferred implementation of the design criteria by stakeholders and the survey provided information about which WWTP was preferred by stakeholders to be integrated in PGS. Ultimately, the masterplan with sections and visualizations illustrates how a WWTP can be integrated on Strijp-S in a way that it enhances ecosystem services in PGS.

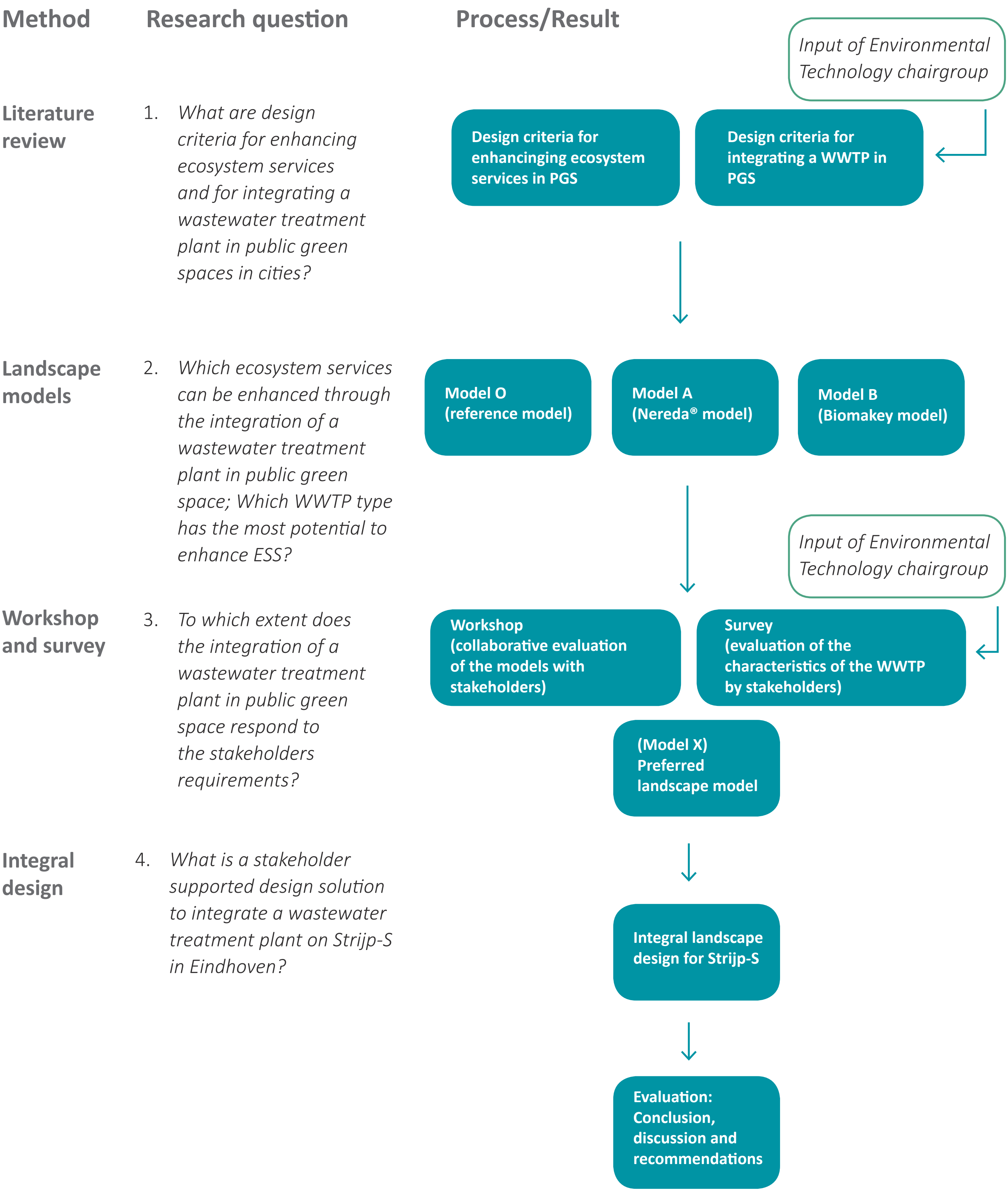

Figure 2.1 Schematic overview of the research and design process

1.6 Structure of the report

Chapter 1 describes the knowledge gap and objective for this research, the research questions, research context and methods.

Chapter 2 describes the design criteria to enhance ecosystem services in PGS and describes the design criteria for integrating a WWTP in PGS.

In the third chapter a landscape analysis of the ecosystem functioning of Eindhoven and more specifically Strijp-S is presented, which is used for the development of the models in the next chapter.

In chapter 4 models are described that combine the design criteria for the enhancement of ecosystem services and the design criteria for the integration of a WWTP in PGS. These models are then evaluated according to their potential to enhance ecosystem services.

Chapter 5 describes the workshop and survey that are conducted to get the stakeholders evaluation on the models developed in the previous chapter.

In chapter 6 the preferred model is further carried out in an integral landscape design for Strijp-S in Eindhoven.

Lastly a conclusion of the entire study is given, including a discussion and recommendations for further research studies.

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02 DESIGN CRITERIA

In this chapter, the design criteria for enhancing ecosystem services in PGS and the design criteria for integrating a WWTP in PGS are explained. First, an introduction is given about ecosystem services. This is followed by a description of each relevant service including their design criteria. Secondly, a description of three WWTP types is given, including their design criteria.

Background photo: the existing greenery on Strijp-S (own photo)

Design criteria

2.1 Design criteria for enhancing ecosystem services in PGS

The benefits that people derive from ecosystems are the ecosystem services (Costanza et al., 1997). Costanza et al. is one of the pioneers of ecosystem services thinking and identified 17 major categories of ecosystem services. Some of these services are necessary to sustain other ecosystems services and are not directly consumed by humans, such as pollination and nutrient cycling (Costanza et al., 1997). The services can be available on several scales, from local to global scale, depending on the scope of the problem, where it is connected to and the possibility of transferring the service from where it is produced to where humans benefit from it (Bolund & Hunhammar, 1999). Transfer can take place by human organized transport or by natural means, for example by atmospheric transport. There are also services that are impossible to transfer, such as noise reduction (Bolund & Hunhammar, 1999).

The Millennium Ecosystem Assessment (MEA) (2005) popularized the term ecosystem services and assessed the effect of human activity on the environment. They defined an ecosystem services framework that is now commonly used. It devides the services into four groups: the provisioning, the regulating, the supporting and the cultural services, see figure 3.1 (MEA, 2005). This framework of the Millennium Ecosystem Assessment is intended for all landscapes types and is not specifically envisioned for the urban context. There are also studies available on urban ecosystem services (Ahern, Cilliers, & Niemelä, 2014; Gómez-Baggethun & Barton, 2013). Urban ecosystem services are services that are relevant for people in an urban context; for example, the production of wood as ecosystem service is less relevant in the urban context than the benefit obtained from the regulation of the climate in cities.

The selection of ecosystem services or the urban context used in this study are presented in figure 3.2 and 3.3. They are sorted into the four groups of ecosystem services defined by the Millennium Ecosystem Assessment (MEA, 2005). In the following subchapters their design criteria are described.

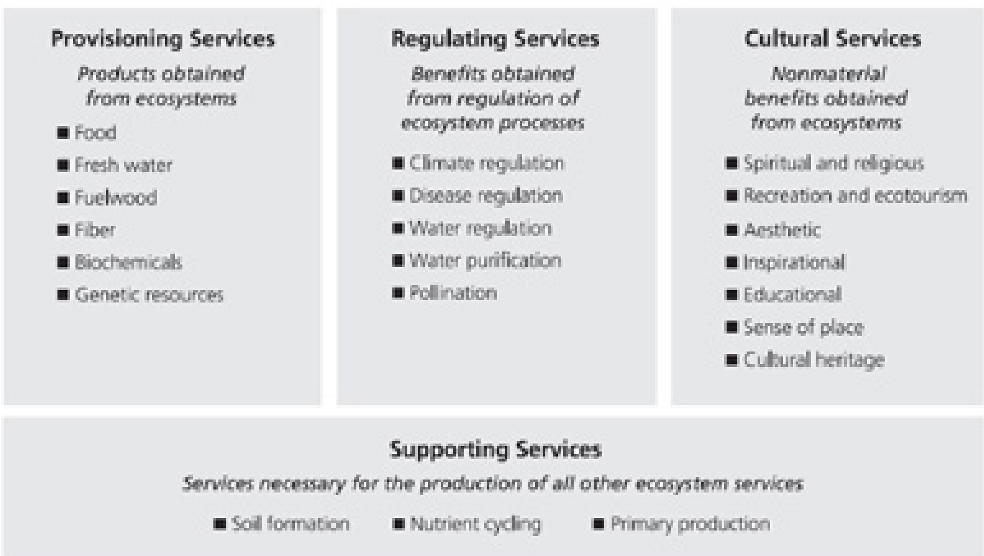

Figure 3.1 The four groups of ecosystem services, defined in the Millenium Ecosystem Assessment (MEA, 2005; p. 57)

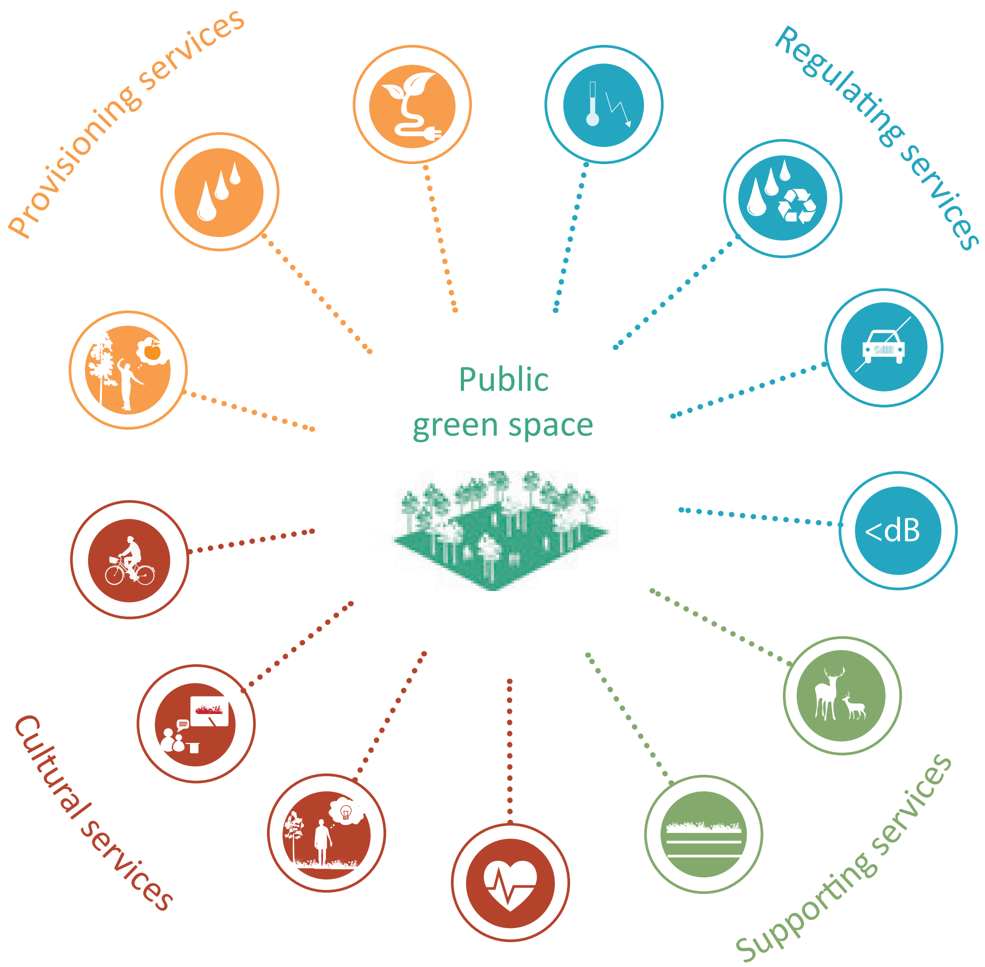

Figure 3.2 The selection of ecosystem services relevant to be enhanced in public green space

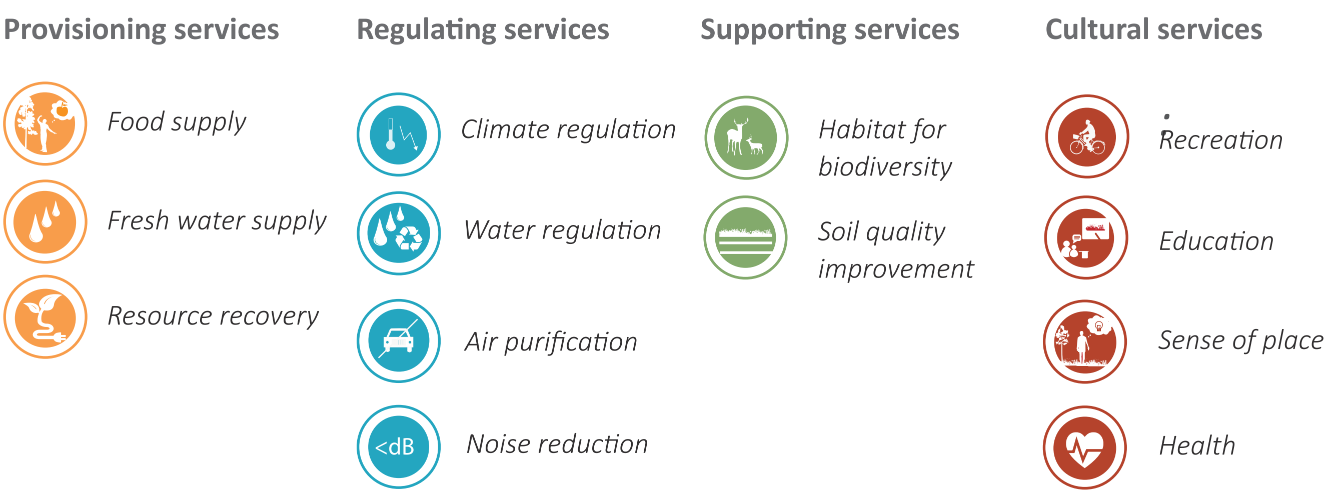

Figure 3.3 The meaning of each icon representing an ecosystem service

2.1.1 Provisioning services

The first group of ecosystem services are the provisioning services. Provisioning services are the products obtained from ecosystems such as food, fresh water, fiber, wood, genetic resources and medicines (MEA, 2005). For the urban context, three of them are particularly relevant. These are food supply, fresh water supply and resource recovery since those services are most likely to contribute to the living conditions of the residents (Gómez-Baggethun & Barton, 2013; UACDC, 2011).

Food supply

The growing trend towards urbanization and the increase of human population makes that we have to expand our food production (Deutsch, Dyball, & Steffen, 2013). By 2050 the population is projected to grow 20%, while the food production will have to grow by 50%. The reason for this is directly related to urbanization; for people who are moving from rural to urban areas income and consumption will tend to rise (Deutsch et al., 2013). Food production in cities is only a small share of the food citizens consume. However, urban agriculture could play an important role for food security (Gómez-Baggethun & Barton, 2013). Everything that contributes to the food supply that is produced in a city and everything that brings city dwellers in contact with food production can be considered as urban agriculture. Nowadays 15% of the worlds food is produced in cities and in the coming 20 years this amount will probably double. (Pötz & Bleuzé, 2012).

Urban agriculture makes material flows efficient (Pötz & Bleuzé, 2012). Organic household waste can be used as compost and transport distances are shorter and more energy efficient. It also alleviates heat stress and small scale or organic agriculture increases biodiversity. Many urban agriculture companies in cities have other functions besides agriculture. These other functions complement the opportunities for city dwellers and enrich the city. Urban gardening contrasts with the over-active life in the city and by working with your hands in the earth pulls people away from this hectic life (Müller, 2011). Contact with the earth is one of the reasons for people to do urban gardening and it helps people to relax, reduce stress and can accelerate a healing process (Müller, 2011).

Design criteria:

- The presence of areas for food production, such as community gardens (Gómez-Baggethun & Barton, 2013)

Freshwater supply

A diverse range of water sources is accessible for cities (Wong & Brown, 2009). Some of the alternative water sources include urban storm water, groundwater and recycled wastewater and many of these water sources are within the city boundaries. When cities are built around a diversity of water sources together with a diversity of water infrastructure, it will allow cities flexibility to access water sources at low cost and low impact. Each water source has its own reliability, environmental risk and costs. Access to these water sources can be realized by developing water infrastructure associated with treatment, storage, harvesting and delivery of the water sources. This also includes centralized and decentralized water supply schemes (Wong & Brown, 2009). This is more elaborately explained in chapter 2.2 where the design criteria for WWTP's are described.

Design criteria:

- WWTP's (see chapter 2.2) (Wong & Brown, 2009)
- Retention areas to temporary store water (Wong & Brown, 2009)

Resource recovery

Renewable biotic resources can be taken into account for example wood and fibers, bio-chemicals and biodynamic compounds that could be used for many industrial purposes (de Groot et al., 2010). Nature can also provide energy resources, such as organic matter, fuelwood bio-chemicals or animal feed (e.g. grass). Abiotic resources are usually not considered since they usually are non-renewable and therefore cannot be attributed to specific ecosystems. Examples of non-renewable resources are fossil fuels, minerals, wind and solar energy (de Groot et al., 2010).

Design criteria:

- Presence of fuelwood, organic matter to be reused in e.g. urban farms, or animal feed (de Groot et al., 2010)

2.1.2 Regulating services

Regulating services can be defined as the benefits that are obtained from regulation of ecosystem processes (MEA, 2005). Climate regulation, water regulation, noise reduction, and air purification are examples of regulating services which could be present in the urban environment.

Climate regulation

Both urban fabric and global climate change influence the climate in the city. Climate change causes an increase of global mean surface temperature (IPCC, 2013). The climate scenario of the KNMI (2014) indicates that temperature will keep increasing, which will result in more mild winters and warmer summers. Precipitation and extreme precipitation events will keep increasing in winter, and the intensity of extreme precipitation in will increase in summer with more intense hail and thunder. Change in wind patterns will be small with less days of fog and the amount of solar radiation at surface area increases slightly (KNMI, 2014).

Often the urban climate is forgotten although it is proven that cities have their own urban climate (Lenzholzer, 2013). The impact of buildings and pavement in cities results in an increase of at least 1°C but could increase up to 10°C at night. It also results in up to 10% less humidity and reduced wind speeds of 30-50%, although on specific places the wind speeds can be much stronger. Extension and densification of the urban areas can increase the effect of the changing climate, but the implementation of urban green has a positive influence on the urban climate (Lenzholzer, 2013).

Design criteria:

- For shade: parktrees and-shrubs, squares with trees, streettrees (Lenzholzer, 2013).
- For solar reflection: materials with high albedo, pavement with low density (Lenzholzer, 2013).

- For evapotranspiration: green waterbodies, fountains, waterfalls, no impervious surfaces (Lenzholzer, 2013).
- Wind: urban shelterbelts, streettrees, windoptimised squares (Lenzholzer, 2013).

Water regulation

There are three separate water systems in the urban environment, the potable water supply that consists of a piped system to deliver the drinking water, the sewage system which consists of a piped system that collects and transports wastewater to treatment plants, and the stormwater drainage system, which consists of various elements, such as constructed channels and natural waterways (Wong, 2007). Water as a regulating services is mainly dealing with the thirds aspect, stormwater. The 'urban stream syndrome' is a major problem in cities (UACDC, 2011). This is the unhealthy stream flow regime that results in ecological degradation. It is marked by flash flooding, higher contaminant and nutrient levels, excessive sedimentation, changed stream morphologies, loss of species diversity and higher water temperatures (UACDC, 2011).

Design criteria:

- Retention areas to (temporary) store runoff (Pötz & Bleuzé, 2012)
- Infiltration areas to infiltrate runoff (Pötz & Bleuzé, 2012)
- Pervious materials for infiltration (Pötz & Bleuzé, 2012)

Air purification

Bad air quality in cities is mainly caused by heavy traffic (Hiemstra, Schoenmaker-van der Bijl, & Tonneijck, 2008). This is a mix of substances consisting of particulate matter, nitrogen oxides and volatile organic compounds. The majority of the pollution is caused by human actions. Policies try to tackle this by reducing emissions on the source, for example by requiring diesel particulate filters and putting restrictions on industry and livestock sectors (Pötz & Bleuzé, 2012). Plants can capture particulate matter, trees in particular are interesting because of their larger amount of leaves and the fact that they can form a wind block for polluted air (Hiemstra et al., 2008). All green contributes to the improvement of air quality even though it might not directly be measurable, yet studies have shown that optimized green can capture around 20% of the present particulate matter (Gemeente Amsterdam, 2012). As mentioned before, trees can also reduce air pollution when they are placed as a physical object to reduce wind speeds. In this way they influence the local wind climate (Hiemstra et al., 2008). However a reverse effect can happen resulting in higher pollution levels. When trees with a high canopy density are placed next to a road, wind speeds are reduced and this can eventually effect in higher concentrations. In these situations, it can be useful to reduce the tree canopy density or use alternative green structures, such as green roofs or green walls (Hiemstra et al., 2008). These green structures reduce pollution but do not reduce wind speed. When selecting vegetation, multiple species should be selected to be able to address the multiple types of pollution (Hiemstra et al., 2008). Unfortunately the air pollution problem cannot be solved solely with green, it is only a measure that helps to reduce the problem (Gemeente Amsterdam, 2012).

Design criteria:

- Vegetation to capture particulate matter, preferably deciduous trees or needle trees (Hiemstra et al., 2008).

- Trees as physical object to influence local wind climate, e.g. next to road (Hiemstra et al., 2008).

Noise reduction

Noise from traffic, construction and other human activities cause major problems in cities and affects the health through stress (Gómez-Baggethun & Barton, 2013). Society is prepared to pay for lowered noise levels for solutions such as walls that can reduce noise with 10-15 dB (Bolund & Hunhammar, 1999). However, the visual landscape in the urban environment will be destroyed if noise walls were built in large quantities. Plants and urban soil can attenuate sources of noise through deviation, absorption, reflection and refraction of the sound waves (Fang & Ling, 2003). Trees planted in a row can reflect and refract sound wavers, diffusing the sound energy through the trees and branches. Different species however mitigate noise differently, important factors are density, height, width and length of the tree rows, but also branching characteristics and leaf sizes result in differences.

Design criteria:

- A wide vegetation belt with high density, branches and foliage for noise reduction (Fang & Ling, 2003).

2.1.3 Supporting services

The supporting services are the services that are necessary for the production of other ecosystem services (MEA, 2005). Two of those ecosystem services apply especially for the urban environment, those are soil quality and habitat for biodiversity.

Soil quality

Soils are formed through disintegration of rock and gradually become fertile through accretion of plant and animal organic matter and the release of minerals (de Groot et al., 2010). This is a slow process. Improvement of soil quality is a service necessary for the integrity and functioning of other ecosystem services, for example for maintenance of food production or water regulation through infiltration. The pores and fractures of which the soil structure consist, act as conduits to carry the water from the surface to groundwater below. The structure of the soil is formed when organic matter and soil biota physically and chemically bind mineral particles into aggregates. 15 to 30 centimeters of soil, depending on the location, form the topsoil that lays on top of the substrate. The texture and structure determine the pore space that is available for water and air circulation, plant root penetration and erosion resistance. Clay offers the least infiltration potential while sand offers the most (UACDC, 2011). Depending on the structure and soil type (see figure X) 10 to 40 percent of the annual precipitation can be infiltrated to replenish the groundwater level (UACDC, 2011). Soil retention mainly dependent on the soil type and the structure aspects such as vegetation cover and root systems. Native soils play a critical role in the conveyance, storage and treatment of water (UACDC, 2011).

Design criteria:

- Infiltration areas for precipitation (UACDC, 2011).

Habitat for biodiversity

In the Netherlands, biodiversity has diminished to about 15% of the original situation (BPL, 2015). This loss is higher than in other countries in Europe. In Europe as a whole, around half of the original biodiversity is left, and worldwide this is around 70%. Fortunately the the speed of reduction is decreasing now in the Netherlands (BPL, 2015). There is more biodiversity in cities then most people expect and cities are more diverse than most cultivated rural areas. They have become islands of diversity, which are surrounded by agricultural landscapes. It turns out that cities create a diversity of microclimates, which facilitates for corresponding diversity of flora and fauna. Higher temperatures and more sheltered places support also support biodiversity. Buildings with varying density, trees and tree groups, lawns, city parks, city forests, gardens and bodies of water form a variety of living areas (Pötz & Bleuzé, 2012). Aspects that promote a loss of biodiversity in the city are the large expanse of impervious surfaces, that fragment and reduce the available area for animals and plants. In most central urban areas, around 80% of the areas are covered by pavement and buildings (Blair & Launer, 1997). A second impact on biodiversity is the structural simplification of vegetation that is happening in many urban areas. Gardening and maintenance of residential or commercial areas often involves removing shrubs and dead wood, while there is an increase of grasses and herbs This has a negative impact on the diversity of animals, which correlates with the vegetative complexity (Marzluff, 2001). Some aspects of urbanization promote an increasing level of biodiversity, usually for the non-native species, that replace native species faster than the loss of the native species (McKinney, 2008). The high spatial heterogeneity of the city produced by many different land uses at small spatial scales result in high levels of biodiversity and higher species diversity than the surrounding rural areas, especially when the groups require a small area to support their populations (McKinney, 2008).
The importation of water, fertilizers and other factors and other factors also limits the species diversity in the suburban areas. The increasing amount of biodiversity, and especially non-native species, in urban settlements is also higher because of the human activities such as accidental importation by traffic, but also the intentional importation of species for pets, cultivation or other uses (Mack & Lonsdale, 2001).

Design criteria:

- Pervious surfaces (Blair & Launer, 1997)
- Diverse vegetation with high complexity, e.g. both wet and dry vegetation (Marzluff, 2001)

2.1.4 Cultural services

Cultural services are the non-material benefits that people obtain from ecosystems, through recreation, education, experiencing the sense of place and the benefits for citizens health (MEA, 2005).

Recreation

Recreational areas are threatened by construction in growing urban regions. The loss of public green spaces makes people travel further to get to other recreational areas and generally travel by car if the recreational area is further away (Niemelä et al., 2010). Yet, recreational ecosystem services are important for a high quality living environment (MEA, 2005; Tzoulas et al., 2007). Therefore it is important to foster the green areas in the urban regions to provide possibilities for outdoor recreation. Not only larger urban green areas as parks are significant for recreation, also small green areas can be important (Niemelä et al., 2010). Good accessibility of these recreational areas is important. Recreational environments that have good accessibility, more easily attracts children, the aging population and disabled people to recreate in green areas (Tzoulas et al., 2007). Public green spaces within the built environment offer opportunities for beneficial 'green exercise', such as cycling and walking. Several articles suggest that the built environment can constrain or facilitate physical activity and that there may be other physical benefits, although the mechanisms for this are not always clear (Lee & Maheswaran, 2010). There is a strong link between physical activity levels and their health benefits, but the evidence for the link between physical activity and green space availability is not as strong (Lee & Maheswaran, 2010). According to Pincetl & Gearin (2005), citizens do not simply desire recreation or leisure destinations, but rather naturalized environments in the city, such as tree-lined streets, pedestrian corridors for people on 'necessary journeys' to a bus or metro stop, store or school. Unofficial green areas are very important for people. In urban areas even small green areas are significant for human recreation (Pincetl & Gearin, 2005).

Design criteria:

- Good accessibility of public green spaces (Tzoulas et al., 2007).
- Areas for 'green exercise', such as cycling and walking (Lee & Maheswaran, 2010).
- Naturalized environments in the city, such as tree-lined streets for people on their necessary journeys (Pincetl & Gearin, 2005).
- Unofficial green areas or small green areas (Pincetl & Gearin, 2005).

Sense of place

The sense of place is the major driver for environmental stewardship. Environmental stewardship is concerned with the attachment to public green spaces and can increase social cohesion, neighborhood participation and promotion of shared interests (Andersson, Barthel, & Ahrné, 2007). Environmental agencies of the European Union have emphasized the importance of urban green spaces for interaction between groups and individuals, which could reduce criminality and increase social cohesion (European Environment Agency, 2011). According to Peters, Elands, & Buijs (2010) urban green space can promote social cohesion more than non-urban green areas. They are places where people from different ethnic groups mingle and where brief and informal interactions can stimulate social cohesion. The design of the place, its image and the location in combination with the characteristics of the groups visiting results in the opportunities for interaction (Peters et al., 2010). Also meeting places contribute to the social ties in a neighborhood, which improves social interaction and enhances social and personal communication skills (Lee & Maheswaran, 2010). Especially youth, elderly and secondary educated people in large cities benefit more from the presence of green spaces in the urban environment (Maas, 2006).

Design criteria:

- Meeting places in public green space (Lee & Maheswaran, 2010)

Education

Exposure to green spaces and nature provides opportunities for cognitive development, which can increase the potential stewardship of the environment and can result in a stronger recognition of ecosystem services (Krasny & Tidball, 2009). Studies show positive impacts of urban environmental education on environmental attitudes, science understanding, awareness of urban nature and self-efficacy, which has greater effect with a higher degree of involvement in field-based and hand-on experiences (Krasny, Lundholm, Shava, Lee, & Kobori, 2013). Urban forests and community gardens are suitable environments for environmental education. The heterogeneous environment of a community garden provides a context for learning by integrating community activism, cultural expressions, social interactions and environmental restoration and food security. Also city parks can play a role in urban environmental education as well by including people in activities such as hiking, ecology awareness activities like birdwatching, and workshops (Krasny et al., 2013). Public green spaces are locations to learn about ecosystem services and urban biodiversity. When ecology education programs are developed around environmental practices, it can contribute to the social-ecological resilience. These natural learning environments also demonstrate that people are part of ecosystems and can contribute to other living organisms in these urban systems (Krasny & Tidball, 2009).

Design criteria:

- Urban forests and community gardens (Krasny et al., 2013)
- PGS with high ecological value (Krasny et al., 2013)

Health

Urban ecosystems are providers of aesthetic and psychological benefits which enrich human life (Kaplan & Kaplan, 1989). These aesthetic benefits are associated with reduced stress and increased physical and mental health. Kaplan & Kaplan (1989) found that the proximity of individuals to green spaces are correlated with fewer stress-related health problems. Other research conducted in the Netherlands showed positive correlation between the quantity of urban green space and perception of general health (Maas, 2006). This relation was present at all degrees of urbanization, and is somewhat stronger for lower socioeconomic groups.

It has been recognized that greenery in public areas provides pleasant and comfortable living environments the residents in the urban environment (Takano, Nakamura, & Watanabe, 2002). Epidemiological studies have provided evidence for the positive relationship between green space and citizens' longevity (Takano et al., 2002). It is important that public green areas are easy to walk and nearby (Takano et al., 2002). Payne, Orsega-Smith, Roy, & Godbey (2005) found that users of urban parks reported better perceived health, the ability to relax faster and higher levels of activity. Only since the last 15 years it has been park use has been related to health and health policies. Often visits are thought of as recreation but increasing evidence suggests parks visits have significant consequences for health. The study of (Payne et al., 2005) indicated that local parks should be thought of as part of a strategy for disease prevention and health promotion. Especially amongst older residents the physical activities such as walking during a visit are beneficial for their health and wellbeing. In addition, people who live within walking distance of a park use it more significantly than people without walking distance to a park (Payne et al., 2005).

Survey studies have shown that people visit particular natural places for regulation of their feelings (Korpela, Hartig, Kaiser, & Fuhrer, 2001). Often natural places are chosen as favorite places, because they offer emotional release and restorative experiences. Some examples are clearing away random thoughts, forgetting worries, recovering focus, relaxation and facing matters on one's mind. Also, people with higher negative mood scores and more health complaints more likely choose a place dominated by natural vegetation as their favorite place than other places such as community, sport or commercial settings (Korpela et al., 2001).

Design criteria:

- High quantity of PGS in urban areas (Maas, 2006)
- PGS nearby residential housing (Payne et al., 2005)
- PGS easy to walk for residents (Payne et al., 2005)

2.2 Design criteria for integrating a WWTP in PGS

It is questionable whether the centralized wastewater treatment plants are still preferred. The continuing growth of cities will require an enlargement of the expensive wastewater infrastructure. It requires high maintenance and investment costs to collect, transport and treat the water. This also influences the treatment process at the treatment plants, resulting in an increased risk of infiltration, diluted wastewater streams, higher pressures on wastewater treatment capacities and thus reducing the efficiency of the treatment plant (de Bonth, 2016). Mass treatment can be harmful for ecological value of waterbodies, since treatment on this scale results in mass displacement of water (Tjandraatmadja, Burn, McLaughlin, & Biswas, 2005).

Our current centralized wastewater treatment system is mainly the result of the small capacity of early on-site systems in the 19th century. They were inefficient and contributed to major disease outbreaks (de Bonth, 2016). Decentralized systems have been adopted by remote communities that are located too far from a central treatment plant, when the terrain did not allow for the construction of sewerage or when infrastructure costs were too high. Many failures with these decentralized treatment systems were caused by inadequate design, inadequate maintenance or improper installation. Recently the reliability of decentralized systems has improved through technological development, however, these systems still need to be tailored to the specific location preferred for the integration (de Bonth, 2016).

In the following subchapters three WWTP types are described. The first type is a centralized WWTP; this type is described as a reference type, in order to understand what it would mean if such a treatment plant would be integrated in public green space. The second treatment type is the Nereda® WWTP, a decentralized treatment system and the third WWTP type is the Biomakery WWTP, another decentralized treatment system. The design criteria that are formulated for each treatment type are calclulated for the case of integration on Strijp-S in Eindhoven (de Bonth, 2016). Each WWTP has different footprint and bufferzone requirements. The footprint is dependent on the water purifying capacity that is required for the area and the size of the bufferzone is dependent on the type of purification (de Bonth, 2016). For example, an enclosed system requires a smaller bufferzone than an open water system. Therefore not every WWTP is as suitable as the others to be integrated in public green space.

2.2.1 Activated-sludge wastewater treatment

The current commonly used centralized WWTP type is called the activated-sludge WWTP. In the Netherlands this water treatment process is commonly used for municipal wastewater, using a biological treatment technology (Tchobanoglous, Burton, & Stensel, 2003). It is called the activated-sludge process because it involves the production of an activated mass of microorganisms that are able to aerobically stabilize organic materials in wastewater (Tchobanoglous et al., 2003). Over time various activated-sludge processes and designs have evolved, caused by innovations in engineering, technological advances, increased understanding of the microbial processes and the need to reduce operational costs and capital (Tchobanoglous et al., 2003). Nowadays, the activated-sludge model incorporates processes as nitrification, biological nitrogen removal and phosphorus removal. Its design of the treatment facility employs a series of reactors, but still most configurations are based on the same principle of biological wastewater treatment (Tchobanoglous et al., 2003). The process in an activated-sludge water treatment plant depends on a dense population of microorganisms which are mixed in suspension with wastewater under aerobic conditions. There is an unlimited availability of food and oxygen for the microorganisms, resulting in the utilization of organic matter to oxidized end-products and the growth of new microorganisms (Gray, 2010).
Figure 3.4 indicates the footprint of the activated-sludge treatment plant and the size of the bufferzone for Strijp-S (de Bonth, 2016). Figure 3.5 gives an indication of the activated-sludge WWTP in Eindhoven.

Design criteria:

Footprint of WWTP	400 m^2
Size of bufferzone	200 m
Accessibility of WWTP	WWTP inaccessible for the public
Water management in PGS	Only detention possible
Spatial integration in PGS	High impact on environment
Recreational and educational value	No recreational functions possible in WWTP
Visibility of the water	Water not visible for public
Enhancing greenness with WWTP	Minimally contributes to public greenery

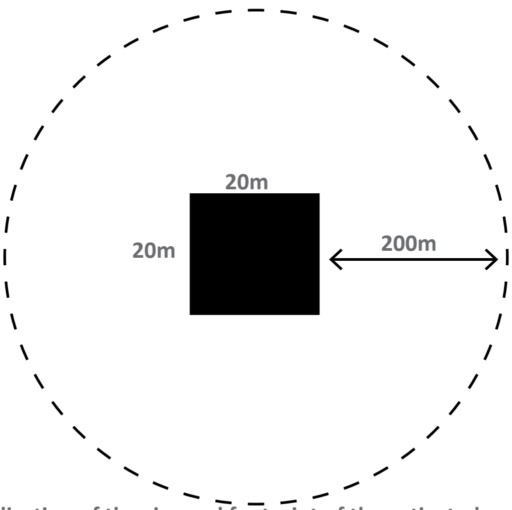

Figure 3.4 Indication of the size and footprint of the activated-sludge WWTP

Figure 3.5 A typical activated-sludge WWTP, in this case the WWTP of Eindhoven (Photo retrieved from www.duurzaamvastgoed.com)

2.2.2 Nereda® wastewater treatment

There are alternatives available for the activated-sludge treatment system that have a smaller footprint and bufferzone. An alternative WWTP type that takes up significantly less space is the Nereda®, which can be implement in areas where there is less space available, such as in dense urban areas. The Nereda® wastewater treatment technology is relatively new. In 1993, research and development of aerobic granules started at the university of Delft and from 2002 pilot scale research took place and pilot plants started operating. To develop the technology a partnership was set up to aim on scaling-up and implementing the technology for municipal applications. The technology is now being used more and more for treatment of domestic and industrial water (Giesen, Loosdrecht, Bruin, Roest, & Pronk, 2012). It is based on the characteristics of aerobic granular biomass and relies on microorganisms growing in the granules instead of in the activated-sludge flocs (Pronk et al., 2015). The treatment facilities are very compact compared to the activated-sludge treatment system. Figure 3.6 shows the footsprint and bufferzone requierments of the Nereda® treatment system for Strijp-S (de Bonth, 2016). Figure 3.7 gives an impression of a Nereda® WWTP.

Design criteria:

Footprint of WWTP	294 m^2
Size of bufferzone	10 meters or less
Accessibility of WWTP	WWTP not accessible for public
Water management in PGS	Additional watermanagement possible
Spatial integration in PGS	Moderate impact on environment
Recreational and educational value	No recreational functions in WWTP possible
Visibility of the water	Water can be made visible in PGS
Enhancing greenness with WWTP	Can contribute enhancement of greenness

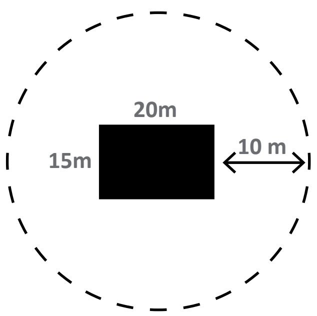

Figure 3.6 Indication of the size and footprint of the Nereda® WWTP

Figure 3.7 Indication of the building type of a Nereda® WWTP (photo retrieved from www.google.nl/maps)

2.2.3 Biomakery wastewater treatment

The Biomakery WWTP also requires less space and is more suited to be implemented in the urban environment. The Biomakery technology of Biopolus is also relatively new and its technology is designed for high-density urban environments (Biopolus Technologies Inc., 2015). It resembles a greenhouse with aquatic tropical plants, using the root system to purify the water. The technology contains a submerged fixed-film biological wastewater treatment technology, that is characterized by a large amount of biomass attached to the submerged carriers. The microbial biofilm can develop on the roots of the aquatic plants in the treatment center. Besides plants, also synthetic carriers consisting of microfiber are used to form larger structures, see figure 3.8. The building itself is heated to sustain the tropical plants in the greenhouse, with a minimum temperature of 10°C. These plants can easily adjust to the permanent water level (Biopolus Technologies Inc., 2015). Figure 3.9 indicates the footprint of the WWTP in case of implementation on Strijp-S. Figure 3.10 gives an impression of the indoor environment in the Biomakery WWTP.

Design criteria:

Footprint of WWTP	210 m^2
Size of bufferzone	0 m
Accessibility of WWTP	Partly accessible (50% or more)
Water management in PGS	Additional watermanagement possible
Spatial integration in PGS	Low impact on environment
Recreational and educational value	Recreation and education can be integrated in WWTP and PGS
Visibility of the water	Visibility of water in WWTP and PGS
Enhancing greenness with WWTP	WWTP can enhance greenness in WWTP and PGS

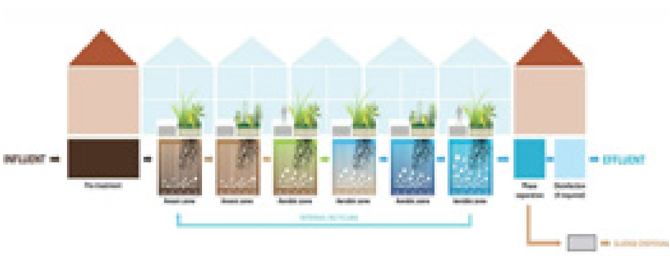

Figure 3.8 System of the Biomakery WWTP (Biopolus Technologies Inc, 2015)

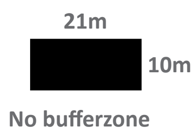

Figure 3.9 Indication of the size and footprint of the Biomakery WWTP

Figure 3.10 A typical Biomakery WWTP (own photo)

2.3 Summary of design criteria

	Service	*Design criteria*	*Reference*
Design criteria per ecosysetm service		The presence of areas for food production	(Gómez-Baggethun & Barton, 2013)
		WWTP's, retention areas to temporary store water	(Wong & Brown, 2009)
		Presence of fuelwood, organic matter to be reused	(de Groot et al., 2010)
		Parktrees and –shrubs, streettrees, materials with high albedo, pavement with low density, green waterbodies, fountains, waterfalls, no impervious surfaces, urban shelterbelts etc.	(Lenzholzer, 2013)
		Retention areas, infiltration areas, pervious materials	(Pötz & Bleuzé, 2012).
		Vegetation to capture particulate matter, trees as physical object	(Hiemstra et al., 2008).
	<dB	A wide vegetation belt with high density, branches and foliage	(Fang & Ling, 2003)
		Infiltration areas for precipitation to infiltrate in the soil	(UACDC, 2011)
		Impervious surfaces and a diverse vegetation with high complexity	(Blair & Launer, 1997) (Marzluff, 2001) (Mack & Lonsdale, 2001)
		Public green spaces with good accessibility, areas for 'green exercise', naturalized environments in the city, unofficial green areas or small green areas	(Tzoulas et al., 2007) (Lee & Maheswaran, 2010) (Pincetl & Gearin, 2005).
		Urban forests and community gardens, naturalized environments	(Krasny et al., 2013)
		Meeting places in public green space	(Lee & Maheswaran, 2010)
		Urban forests and community gardens, public green spaces with high ecological value	(Krasny et al., 2013)
Design criteria per WWTP type		Activated-sludge WWTP: large footprint and bufferzone, high impact on the environment, no recreational functions in WWTP	(de Bonth, 2016)
		The Nereda® WWTP: small footprint and bufferzone, moderate impact on the environment, no recreational function in WWTP	(de Bonth, 2016)
		The Biomakery WWTP: small footprint and no bufferzone, low impact on the environment, recreational functions possible in WWTP	(de Bonth, 2016)

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03 LANDSCAPE ANALYSIS

In this chapter the ecosystem functioning of Eindhoven and specifically Strijp-S is analyzed. For each ecosystem service it is analyzed what their strenghts and weaknesses are in order to get an understanding of which services are most important to be enhanced in public green space

Background photo: the industrial character of Strijp-S that defines the experience for visitors and residents (own photo)

Landscape analysis

3.1 The research location in Eindhoven

Eindhoven is currently the fifth biggest city in the Netherlands. It is expected that the growth of inhabitants in Eindhoven will increase with 7 percent until 2030. In 2014, Eindhoven counted 220.895 inhabitants, while the province expects this to be up to 250.000 in 2030 (ED, 2015). In the second half of the 19th century Eindhoven drastically changed as a result of industrial development (Vakblad Groen, 2013). Because Eindhoven was growing so fast, expansion was only possible by connecting to the surrounding villages. The planned expansion of Eindhoven was very similar to the garden city model of that Ebenezer Howard described, see figure 3.1 (Vakblad Groen, 2013). Ebenezer Howard (1850-1928) introduced the garden city concept in his book Garden Cities of Tomorrow (1898). The aim of a garden city was to give employees of industrial cities better living conditions by developing neighborhoods plenty of public green space (Vakblad Groen, 2013). Philipsdorp was the first planned residential district that was developed according to the garden city idea. Eventually this model was applied within the development of the several Philips neighborhoods. The old villages that used to surround Eindhoven are still visible as the cores of the different neighborhoods (Vakblad Groen, 2013). Due to the development according to the garden city model, Eindhoven is connected to the three large nature areas: De Karpen, Genneper Parken and Landelijk Strijp, see figure 3.2. They reach into the city and provide natural areas that are easily accessible from the city.

3.2 Strijp-S as living lab

Waterboard De Dommel is the initiator of a living lab on Strijp-S to test new ideas for the integration of a WWTP in the area. The basis for this living lab is a new type of treatment for the production of clean water, resources and energy, with the aim to combine multiple functionalities such as recreation, agriculture and the production of new materials (Waterschap de Dommel, 2015). The development of a living lab on Strijp-S is in line with the future scenario for Eindhoven: 'Safe and pleasant living in Eindhoven 2050', developed by the municipality of Eindhoven, see figure 3.3 (Gemeente Eindhoven, 2016). This future scenario contains three main goals:

- Creating a safe and living environment which is resilient to climate change through smart solutions
- Creating a healthy living environment with extensive blue and green areas that support a healthy lifestyle and social activities
- Creating a circular water system that provides a sustainable use of water, energy and materials (Gemeente Eindhoven, 2016).

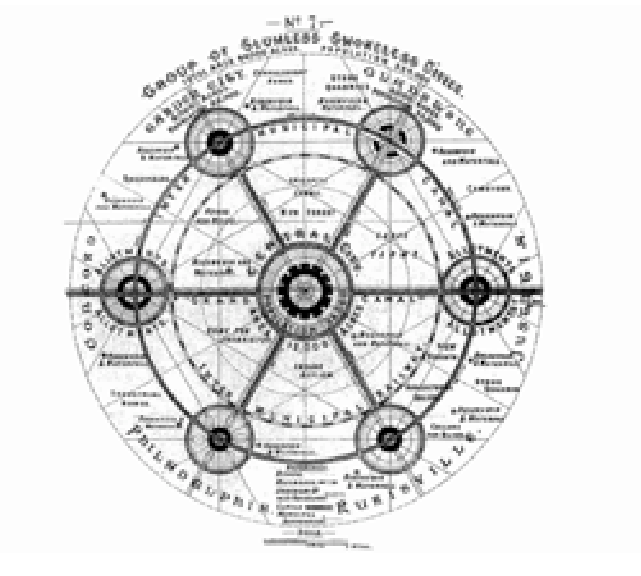


Fig. 3.1 The garden city model by Ebenezer Howard (scodpub. wordpress.com)

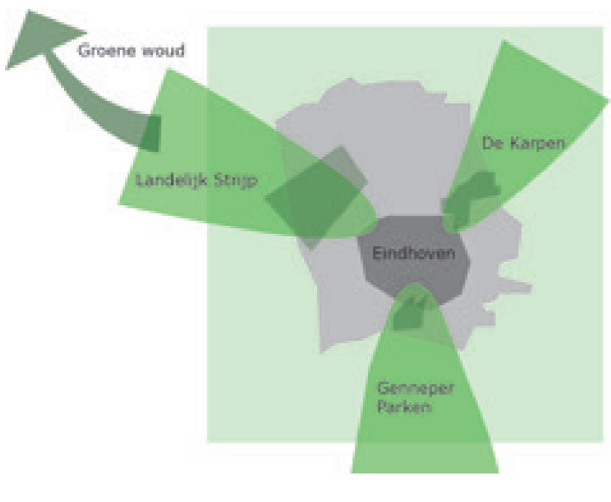


Fig. 3.2 The three large nature areas in Eindhoven

Strijp-S is initiated as a living lab location due to the innovativeness of the area. It is a location where experiments in urban development, technology, design and knowledge come together. This urban district close to the city centre of Eindhoven is a former business area of approximately 30 hectares that was owned by the company Philips. This company origates from 1892, when Anton Philips started a small factory for the production of lightbulbs. The production quickly increased and after ten years Philips had already produced around 1.5 million lightbulbs. After the realisation of Strijp-S, Philips became completely self-sufficient (Park Strijp Beheer, 2015). Radio technologies, televisions, shavers, cd and DVDs are examples of products that are developed at Strijp-S. In the 70s the company had its peak with around 10.000 employees on Strijp-S. The area got the name 'the Forbidden City', because it was surrounded by fences and barriers, and was only accessible for employees (Park Strijp Beheer, 2015). From 2000 onwards the idea of Philips to leave Eindhoven emerged and in 2004 Strijp-S is sold to Park Strijp Beheer. From 2006 redevelopment of Strijp-S starts; buildings are demolished and new companies settle, mainly in the creative industry. Nowadays it is a place for innovation and experiments in urban development, technology, design and knowledge. It contains some culturally valuable structures, buildings and objects, mostly connected to the industrial history of the area. The transformation of Strijp-S that is still in progress will result in an highly urban district that contains all the elements of a city centre, see figure 3.4 (Park Strijp Beheer BV, 2015).

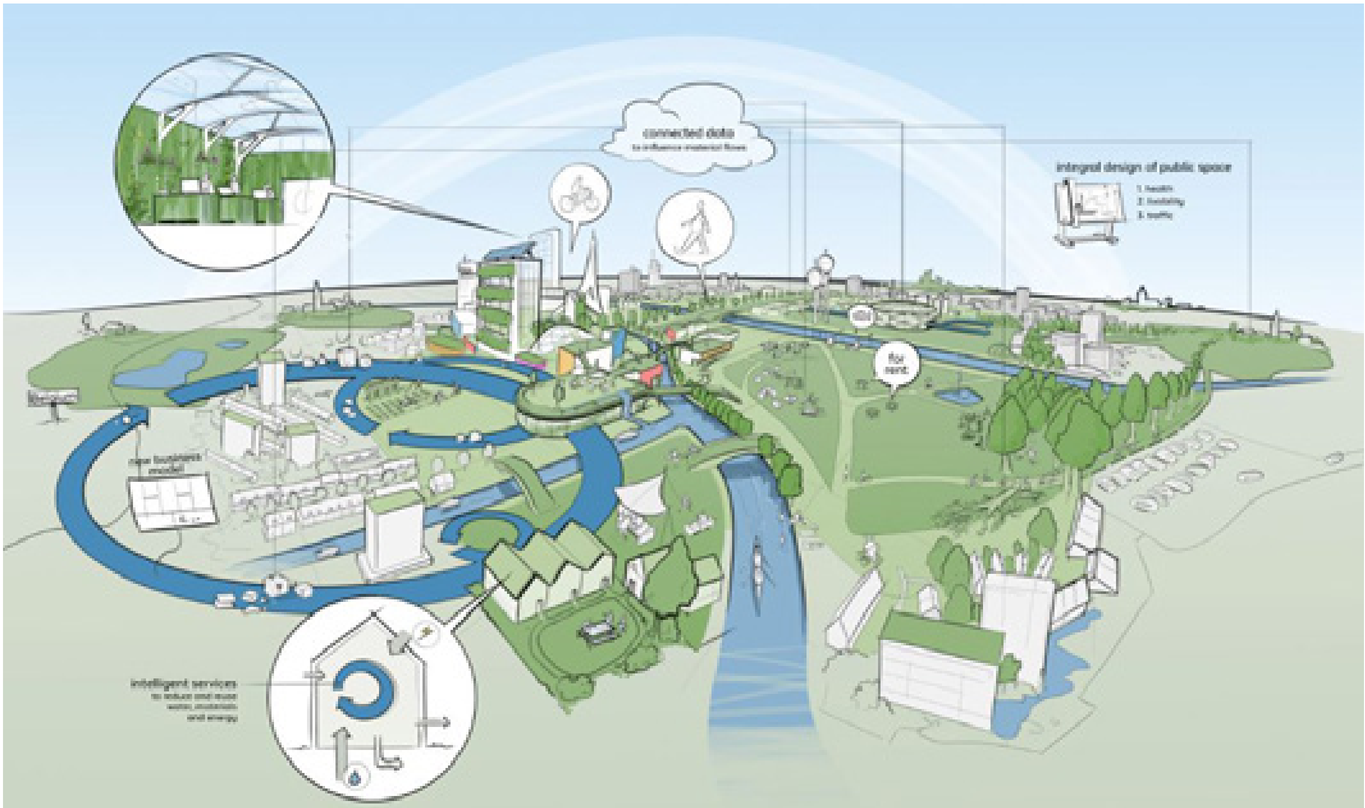


Fig. 3.3 Future water scenario for Eindhoven, 'Safe and pleasant living in Eindhoven 2050' (Gemeente Eindhoven, 2016)

Fig. 3.4 The industrial character of Strijp-S (own photos)

Figure 3.5 The presence of provisioning services in Eindhoven

3.3 Ecosystem services in Eindhoven

3.3.1 Provisioning services

3.3.1.1 Food supply

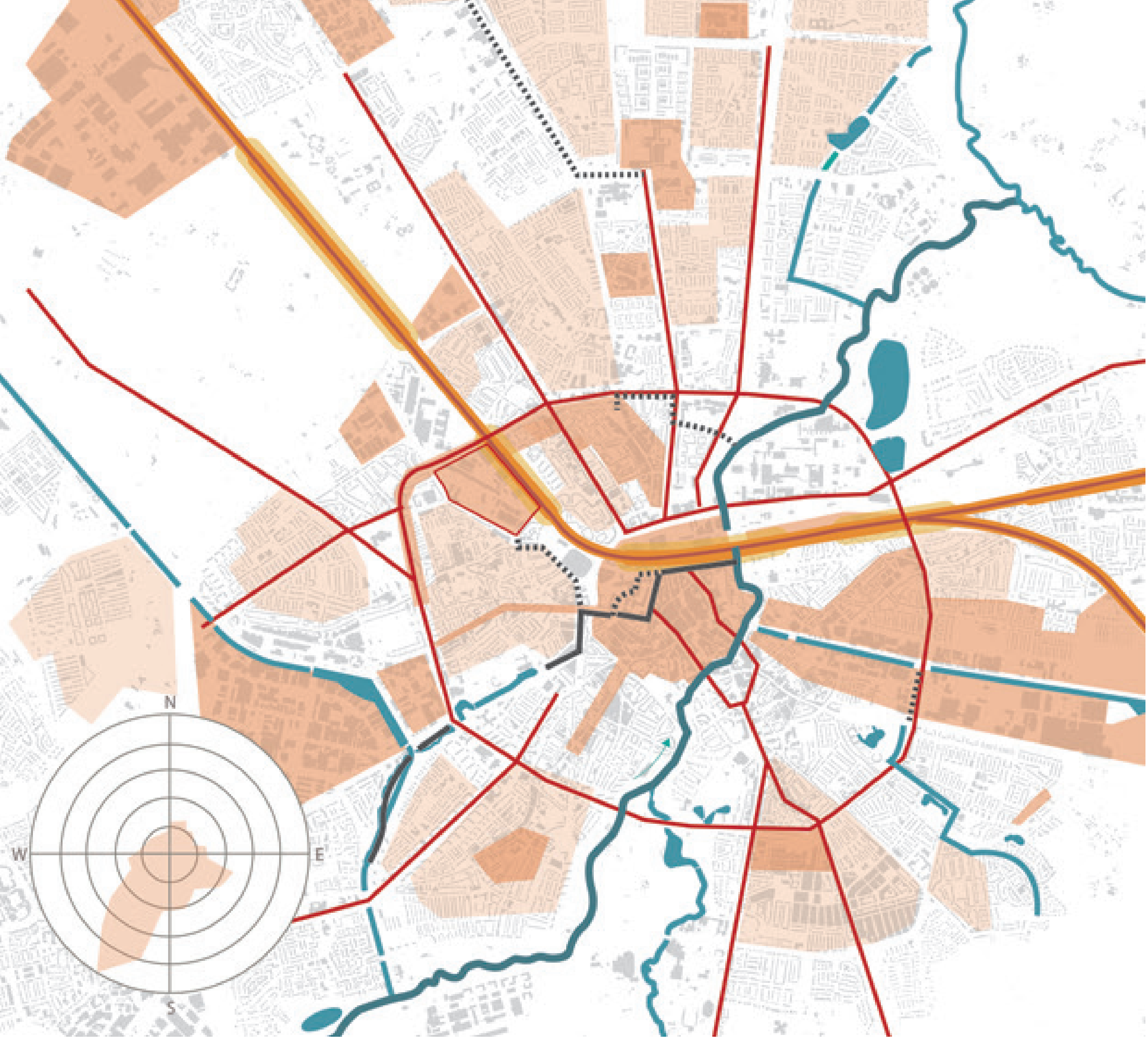
The current urban food supply in Eindhoven is represented by urban farming practices with different scales and ambitions. Some urban farming practices are developed and maintained through citizen participation and do not aim on profits besides the food products they harvest whereas other urban farms are profit making organizations. Eindhoven contains many urban farming practices compared to other cities, with 38 existing urban farms at this moment (Proeftuin040, 2016). This implies that there is ambition by the residents to grow local products in the area and that new urban farming projects will likely get support. In figure 3.5 these existing urban farming practices are marked.

3.3.1.2 Fresh water supply

Fresh water in Eindhoven is supplied with water from water catchment areas in the province Noord-Brabant (Brabant Water, 2016). In the city itself, the river 'de Dommel' is an important source of water for ecological- and recreational value. The wastewater of Eindhoven is treated in a centralized WWTP north-east of Eindhoven, located in the rural area 'de Karpen', see figure 3.5. This wastewater treatment plant is based on the conventional activated-sludge treatment technique and requires a relatively large space.

3.3.1.3 Resource recovery

The municipality of Eindhoven has ambitions to change its energy production and usage to become a self-sufficient energy producing city by 2045 (den Ouden & Gal, 2014). The municipality intents on reducing the non-sustainable energy demand and increasing the provisioning of sustainable energy within the boundaries of the city Eindhoven. This can be done by means of different energy supply types such as wind energy, solar energy, geothermal energy and biomass power plants. Biomass is collective term for organically biodegradable fractions of organic material such as wood, organic waste and manure (den Ouden & Gal, 2014). In the city there are already biomass power plants constructed which use loppings or bio-oil for the process. There are also other sources available that could be used in the future for the production of biomass energy in Eindhoven like organic waste, manure and sludge from wastewater treatment plants (den Ouden & Gal, 2014). Figure 3.5 indicates the location of the (potential) biomass plants.



Areas highly affected by heatwaves

Areas affected by heatwaves

Rivers and streams

Rivers and streams

Main roads as source of pollution

<dB

Main roads as source of noise

Train noise (56-69 dB)

Train noise (55-64 dB)

Figure 3.6 The presence of regulating services in Eindhoven

3.3.2 Regulating services

3.3.2.1 Climate regulation

Climate regulation is influenced by the building density, the amount of greenery and spatial organization of the area. One aspect that influences the thermal comfort for citizens is the vulnerability of districts for heatwaves (Touw, 2013). Areas with a higher vulnerability for heatwaves have higher temperatures in case of a heatwave. This could be the result of for example a high amount of paved surface or a low amount of greenery in the area. Figure 3.6 shows the areas in Eindhoven that are more vulnerable for heatwaves. Areas like the city center, but also Strijp-S, with its high urban density and large amount of paved areas are also part of these more vulnerable areas (Touw, 2013). The three green areas Landelijk Strijp, Genneper Parken and de Karpen, are areas where the temperature is generally lower compared to the urban districts during a heatwave.

3.3.2.2 Water regulation

Water regulation in Eindhoven is organized around the river 'de Dommel'. This river originates in Belgium and flows partly through old convolutions in the sandy grounds via Eindhoven towards 's-Hertogenbosch. Another stream in Eindhoven is 'De Gender', a stream of approximately 15 kilometers, originating in marshy meadows outside the city and ending up in Eindhoven. This stream used to flow though the city center towards the Dommel but during the construction of the large scale residential districts in in 20th century the stream changed by channeling the last part of the stream and creating a shortcut to avoid the city center. The municipality has decided to bring back the Gender where it used to be in Eindhoven. This will partly be constructed above ground and partly underground (Gemeente Eindhoven, 2014). The main reason to bring back de Gender to its original location is for the discharge of rainwater. At this moment most of the rainwater goes towards the sewage system and from there to the wastewater treatment plant of Eindhoven. This has negative consequences for the capacity of the sewage system (Gemeente Eindhoven, 2014). In case of heavy rainfall, the sewage system cannot handle this amounts of water, resulting that part of the water will end up on the streets and tunnels will flood, or it will end up in the surface waters together with wastewater (Gemeente Eindhoven, 2014). By separating the wastewater and rainwater, the WWTP can function more efficiently and the pressure on the sewage system will be reduced. Figure 3.6 shows the planned rainwater system connected to the Gender. Currently the Gender ends up in the pond 'Gendervijver', a dead-end with algae growth where waste accumulates. By creating a flow through the 'Gendervijver' with the supply of clean water, the quality of the pond will increase (Gemeente Eindhoven, 2014).

3.3.2.4 Air purification

The air pollution is also largely a result of the ring road around the city, but also the smaller streets and the highway A2 and Eindhoven airport are sources of pollution that to a reduction of air quality in the city. Figure 3.6 indicates the main sources of air pollution.

<dB

3.3.2.3 Noise reduction

Noise nuisance in Eindhoven is a problem due to the relatively high car usage in the city. The ring road in Eindhoven is the main problem in the city center, see figure 3.6. This road is a four lane road that contains some viaducts and tunnels. It passes several highly urban districts in close distance, which affects people negatively.

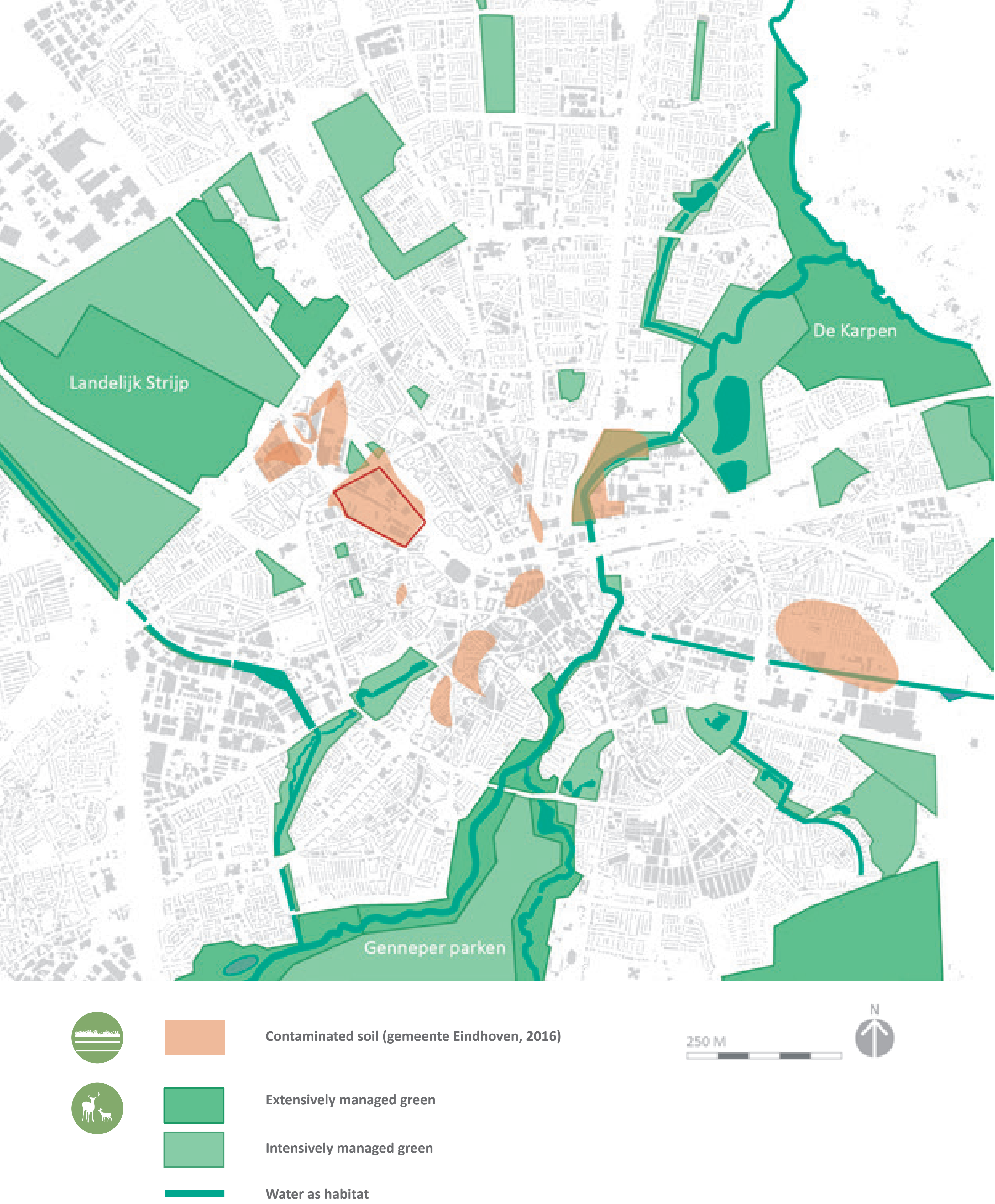


Figure 3.7 The presence of supporting services in Eindhoven

3.3.3 Supporting services

3.3.3.1 Soil quality improvement
Eindhoven's soil type is mainly sand with a stream valley where the river Dommel flows, see figure 3.7. (Gemeente Eindhoven, 2016). The sand consists of sand plains and ridges. Due to Eindhoven's industrial history, some districts, especially around Strijp-S, have severe contamination of the soil which could give risks for the health of people and could damage ecological values (Gemeente Eindhoven, 2016).

3.3.3.2 Habitat for biodiversity
The three green areas that reach into the city are important to provide habitats for biodiversity, see figure 3.7. De Karpen is a green area that starts in the surrounding rural area and extends into the city center. The park is constructed in 1963 and was inspired by the surrounding forests of Eindhoven. It therefore includes many native tree species such as oaks, poplars and birches. It contains a larger waterbody that was caused by sand mining. Genneper parken is an area that was spared from urban developments in the industrial period. Gennep used to be agricultural land located between two rivers, de Dommel and de Tongelreep. Landelijk Strijp is a green area that is connected with the rural land outside the city, Groene Woud. Within the city itself there are smaller parks that form habitats for biodiversity but also the river Dommel is also an important habitat for water loving species.

Figure 3.8 The presence of cultural services in Eindhoven

3.3.4 Cultural services


3.3.4.1 Recreation and education

Eindhoven contains many recreational facilities, such as parks, museums, shops and historic features (Top10 Eindhoven, 2016). Most of these recreational activities are located in the city center of Eindhoven. The city parks are also popular recreational destinations. For example the Philips de Jonghpark, just north of Strijp-S is an historical park from the industrial time of Eindhoven that gets many visitors. Figure 3.8 shows the main cultural facilities. What is noticeable is that many of the recreational spots are located along a line, from the city center towards Landelijk Strijp, along the developing 'Groene Corridor', a car-free bicycle route going towards Oirschot. This 13 km long Green Corridor is being developed by the municipality of Eindhoven and the municipality of Oirschot. In the coming years this route should be further developed by enhancing the greenness and enriching the experiences and recreation on this route (Groene Corridor, 2016). Part of the plan is already constructed, such as the part on Strijp-S and part of the Oischotse dijk, which is nowadays a car-free road towards Oisschot. Yet there are still many physical barriers that compromise the strength of the route for cyclists and pedestrians, such as crossings.


3.3.4.2 Sense of place and health

A healthy city for the inhabitants can be realized with the presence of PGS in the city that takes into account people's needs for outdoor activities. Eindhoven has a cycling networking with fast bike routes leading towards to rural areas around the city, see figure 3.8. These bike routes make it more attractive for people to go out of the city and explore the natural environments. With the high amount of green in Eindhoven and the many parks, Eindhoven is a relatively 'healthy' city. Nevertheless, with the increasing amount of inhabitants and the increasing densification of the city that is currently going on, high quality PGS in the city becomes increasingly important.

3.4 Ecosystem services in Strijp-S

3.4.1 Provisioning services

3.4.1.1 Food supply

Even though there would be sufficient support for urban farming practices in Strijp-S, the area is unsuitable for farming practices directly in the soil of the area, due to high levels of contamination in the soil as a result of the industrial period of the area. Yet there are alternatives possible that do not depend on the soil quality of the area such as aquaponics. Aquaponics is an example of an urban farming practice that does not require soil but water to grow crops. In symbiosis with fish these crops are grown in tanks of water. The food hall 'het Veem' could potentially sell locally generated products, see figure 3.9. This building contains an indoor food market that sells locally produced food and other products. Aquaponics could be a good alternative for urban farming, however, it does not contribute to the enhancement of ecosystem services in PGS and is therefore less relevant to be enhanced as a service on Strijp-S.

Figure 3.9 Food supply on Strijp-S

3.4.1.2 Fresh water supply

There are no retention areas present on Strijp-S to store water on site for future reuse. In the case of Strijp-S, the stormwater is directly discharged towards the sewers. Yet there is space available in the area for the storage of water in retention areas in PGS, which could provide a second source of reusable water, for example to be reused as firewater or for infiltration in the soil to purify the contaminated soil in Strijp-S.

3.4.1.3 Resource recovery

On Strijp-T, a destrict next to Strijp-S, there is a biomass power plant located, see figure 3.10. This power plant produces energy from organic waste. When a WWTP would be integrated in Strijp-S, the by-product from the treatment process, sludge, could be reused in the power plant to generate energy. In this way the generated energy could be used for the treatment process of the WWTP, ultimately reducing the required energy for the treatment process.

Figure 3.10 Resource recovery on Strijp-S

3.4.2 Regulating services

3.4.2.1 Climate regulation

The urban density of Strijp-S influences its local climate. The lack of green and the high amount of paved surfaces influence the temperature and thermal comfort since paved areas heat up more easily than areas with vegetation, also indicated in figure 3.11. The area also suffers from strong winds; the usually southwestern winds get channeled between the high buildings of the Hoge Rug, resulting in corner streams. These winds are uncomfortable for people and could be reduced with the enhancement of greenery in PGS.

Figure 3.11 Climate regulation on Strijp-S

3.4.2.2 Water regulation

Strijp-S has a low groundwater level that can rise strongly in wet periods. In summer time the water level is around 4 to 5 meters under surface level, in winter time around 2 meters under surface level. In the current situation there is limited rainwater infiltration in the terrain possible, indicated in figure 3.12 (Park Strijp Beheer BV, 2007). The many parking lots and paved squares for events reduce the infiltration capacity of the area. Improvement of the infiltration of clean rainwater into the surface area is recommended, as it could contribute to the quality of the groundwater and reduce the current level of pollution (Park Strijp Beheer BV, 2007). Besides improvement of infiltration, water storage within the area is recommended to reduce the risk of flooding. Strijp-S should be able to store at least 5.5 thousand m³ of water of which 3000 m³ in the new planned buildings (Park Strijp Beheer BV, 2007). This means that 2.500m³ is needed for storage in PGS.

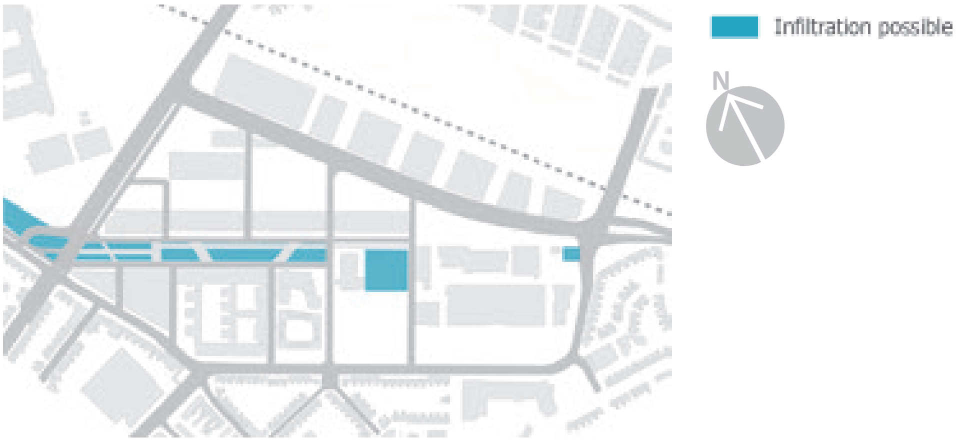


Figure 3.12 Air purification on Strijp-S

3.4.2.3 Air purification

Air quality reduction on Strijp-S is not only a result of reduction on the site itself but it is a part of the air quality reduction on a scale of the city. A large source of pollution is the ring road Beukenlaan that passes Strijp-S on the north-west side of the area, see figure 3.13. This four lane road is widely used by car owners to get to the other side of the city. Due to a minimal amount of green besides the road, there is also almost no absorption of particles by vegetation possible. More greenery would contribute to a better air quality on Strijp- S.

Figure 3.13 Air purification on Strijp-S

<dB

3.4.2.4 Noise reduction

The Beukenlaan and the train tracks are the main sources of noise on Strijp-S. A natural noise barrier with vegetation could reduce the noise from the Beukenlaan and the trains passing by. Figure 3.14 indication the main sources of noise.

Figure 3.14 Noise reduction on Strijp-S

3.4.3 Supporting services

3.4.3.1 Habitat for biodiversity

Strijp-S is defined as an urban that contains mostly culture-species (Park Strijp Beheer BV, 2007). The area is not located is close distance to protected nature areas and the area itself has almost no ecological relation to the surrounding environment, partly because of the many barriers for existent in the area and because most the area is paved and no surface water is present, see figure 3.15. During an inventory of protected species in 2005, no protected plant or animal species were found, neither are they expected in the area. The development of greenery on Strijp-S could result in an increase of biodiversity in the area.

Figure 3.15 Habitat for biodiversity on Strijp-S

3.4.3.2 Soil quality improvement

Strijp-S as a whole can be considered as a case of severe soil contamination, see figure 3.16. The first layer of soil up to 3 meters contains moderate levels of contamination, mostly heavy metals, PAK and mineral oils. There some areas in this layer with higher concentrations, especially where former business activities used to be. These areas contain volatile chlorinated hydrocarbons, volatile aromatic hydrocarbons and mineral oil. In the second layer, from 7 until 12 meters under surface level, increased amounts of volatile chlorinated hydrocarbons and other substances are existent. Here, also the groundwater is strongly contaminated with arsenic and cadmium (Park Strijp Beheer BV, 2007). In the deep groundwater also increased contamination levels where found, depending on which location on Strijp-S. When not acting on these problems, the risk of spreading of the pollutants will increase, however, at this moment there is no case of actual risk for humans or ecology (Park Strijp Beheer BV, 2007).

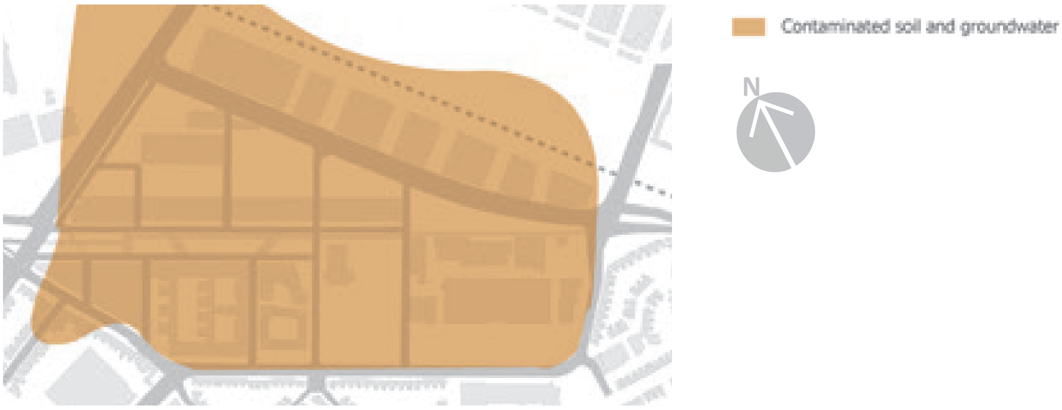


Figure 3.16 Soil quality improvement on Strijp-S

3.4.4 Cultural services

3.4.4.1 Recreation and education

Strijp-S is an area that is rich in recreational facilitates, with many restaurants and cafés present, indicated in figure 3.17. Vershal 'Het Veem' is one of the larger recreational facilities in the area. This market place inside the Veem building is part of the Hoge Rug, a line of buildings that contain shops, restaurants and companies in the creative sector. Strijp-S also hosts many events of which the Dutch design week is the largest and most known. This event attracts over 275.000 people a year, with 2500 designers in the area on 99 locations (Park Strijp Beheer, 2015). The existing recreational facilities are all linked to buildings and cultural activities, yet there are limited possibilities for outdoor recreation in PGS. Educational facilities such as learning children about the importance of water and biodiversity are not yet existent in the area. Interesting collaborations could be made were for example 'de Ontdekfabriek', a place for children to experiment inventing and playing, also takes part in making children aware of the benefits of urban green.

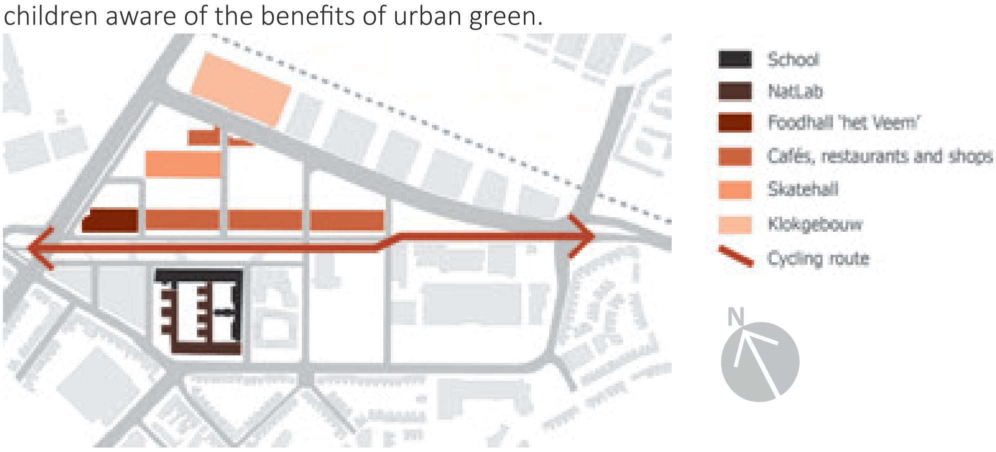


Figure 3.17 Recreation and education on Strijp-S

3.4.4.3 Sense of place

The clear urban structure on Strijp-S defines the sense of place in the area, see figure 3.18. This orthogonal and functionalistic structure was designed in 1913 by A. de Boekert (Park Strijp Beheer, 2015). The basis for this structure was the train tracks and the pipelines used by company Phillips. The roads are derived from that structure. The design of the buildings was influenced by the building techniques of that time with new materials techniques, such as concrete, steel and glass, and ornamental features were omitted. During demolition in 1975 many of the original buildings disappeared (Park Strijp Beheer, 2015). These buildings could be embedded in a visitor friendly PGS, that contributes to the sense of place of this location with its industrial history.

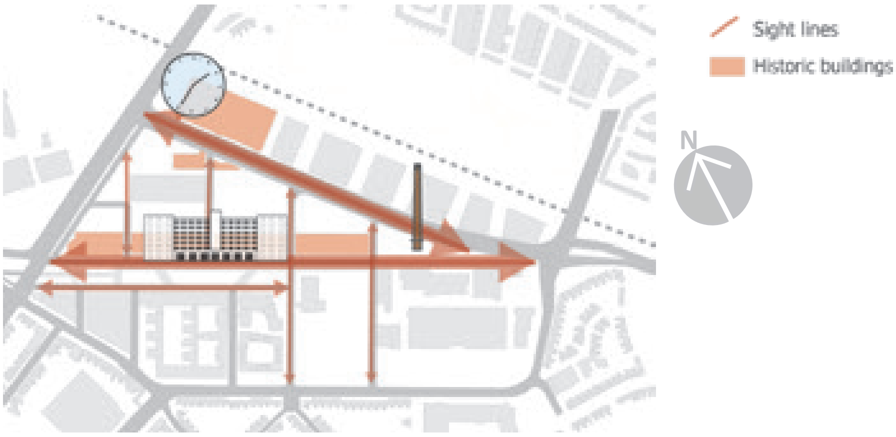


Figure 3.18 Sense of place on Strijp-S

3.4.4.4 Health

It is important that people have the ability to take a step back from the hectic life in the city in a greener environment, though on Strijp-S the health benefits of the existing green are negligible, except for a green cycling route that passes the area, also indicated in figure 3.19. The many paved areas and the lack of green do not contribute to a healthy living environment for its inhabitants and visitors. Particularly when the planned residential buildings are constructed, the existence of PGS becomes even more important.

Figure 3.19 Health benefits on Strijp-S

3.5 Conclusion of landscape analysis

Ecosystem service	*Problem*	*Design criteria to solve problem*
	Soil contamination due to industrial history	Areas for food production but unrelated to soil, such as urban farming in planters
	No water catchment areas or water treatment	Integration of WWTP, retention areas in public green space of Strijp-S
	Need to close resource cycles on Strijp-S	Reusing the resources of the WWTP on Strijp-S
	Lack of greenery on Strijp-S, imperviousness	Parktrees and –shrubs, streettrees, pervious paving, green waterbodies and fountains on Strijp-S
	Limited infiltration possible, no retention areas	Retention areas, infiltration areas, pervious materials on Strijp-S
	Noise of cars	A wide vegetation belt with high density, branches and foliage along roads on Strijp-S
	Particulate matter as a result of cars	Vegetation to capture particulate matter, trees as physical object along roads on Strijp-S
	Lack of vegetation and water as habitat	Pervious materials, a diverse vegetation with high complexity on Strijp-S
	Contaminated soil and groundwater	Infiltration areas on Strijp-S
	Lack of green with recreational function	Strijp-S with good accessbile public green space, with areas for 'green exercise'
	Maintaining industrial character	Meeting places in public green space
	Lack of healthy green environment	Public green space with high ecological value on Strijp-S

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04 LANDSCAPE MODELS

In this chapter the descriptive information from the literature review and the landscape analysis of the area are used for the development of landscape models, to find out which spatial configuration has the most potential to enhance ecosystem services and to integrate a wastewater treatment plant.

Background photo: location on Strijp-S used for the development of the models (own photo)

Landscape models

The landscape models are idealized simplifications that represent the ideal way of enhancing ecosystem services with the integration of a WWTP. In total three landscape models are visualized, one model for the integration of the activated-sludge WWTP, one model for the integration of the Nereda® WWTP and one model for the integration of the Biomakery WWTP. For the Biomakery WWTP some additional sketches are made that explore other design options. The Biomakery WWTP type has the most possibilities for variations in the design, due to its small footprint and the absence of bufferzone requirements.

The location for the models is the triangular square in the middle of Strijp-S, see figure 4.1. From the landscape analysis it is concluded that this area is the most suitable to integrate a WWTP since it contains sufficient space and there are much potential to enhance ecosystem services there due to the current absence of greenery.

4.1 Integrating design criteria on Strijp-S

The overall idea for the models is that the WWTP is the starting point for the design, located on the north side of the area. Here wastewater is collected and will be treated in the specific WWTP type. After the treatment process the water will be reused for the enhancement of ecosystem services where after it is transported to the south side of the area. Here the water leaves the area and will be transported to the Genderpark and will end up in the river Dommel eventually. The following design criteria that resulted from chapter 2 are integrated in the designs:

Figure 4.1 Design location for the models, based on the outcome of the analysis

1. A decentralized WWTP (Wong & Brown, 2009), figure 4.2.

Depending on the spatial requirements of the WWTP, the WWTP has to be located away from the buildings of Strijp-S when it has large bufferzone requirements, or it can be located in close distance to the buildings of Strijp-S when it has no bufferzone requirements. Preferably the WWTP is located next to a road for the transport of waste.

2. The presence of areas for food production, such as community gardens (de Groot et al., 2010; Gómez-Baggethun & Barton, 2013), figure 4.3.

On Strijp-S there is sufficient public support for urban farming practices. Urban farming is not possible directly in the ground due to soil pollution, but planting in trays or aquaponics would is a solution. This design criteria enhances the ecosystem services food supply and resource recovery.

3. Retention areas (Wong & Brown, 2009; Pötz & Bleuzé, 2012), figure 4.4.

There are no retention areas on Strijp-S yet, but policy documents advise retention area of approximately 2500m² in PGS of Strijp-S to prevent flooding and have stored water available. This enhances the ecosystem services water regulation, climate regulation, soil quality improvement, habitat for biodiversity and recreation.

4. Stormwater infiltration areas/pervious materials (Pötz & Bleuzé, 2012, UACDC, 2011; Blair & Launer, 1997), figure 4.4.

Strijp-S has no stormwater infiltration areas yet, stormwater is directly transported to the sewage system

Figure 4.2 Design criteria: a decentralized WWTP that is integrated in its spatial context (1). This is an example of how the WWTP coul look like in its urban context (www.patryst.com)

Figure 4.3 Design criteria: the presence of areas for food production, such as community gardens (2) (www.pbl.nl)

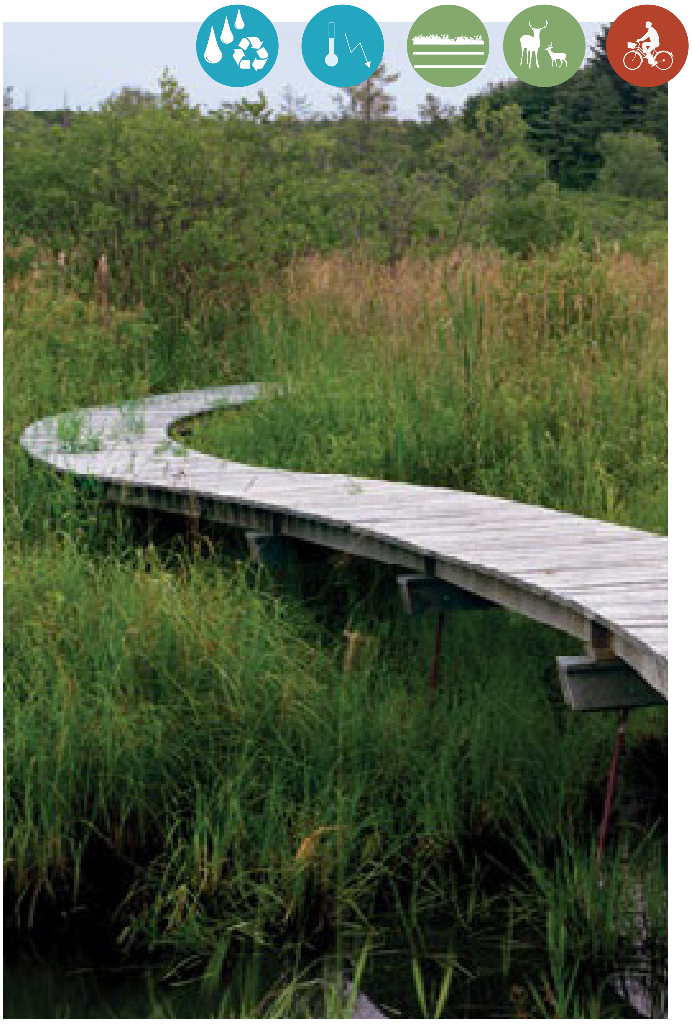


Figure 4.4 Design criteria: the presence of retention/infiltration areas (3 & 4) (dirt.asla.org)

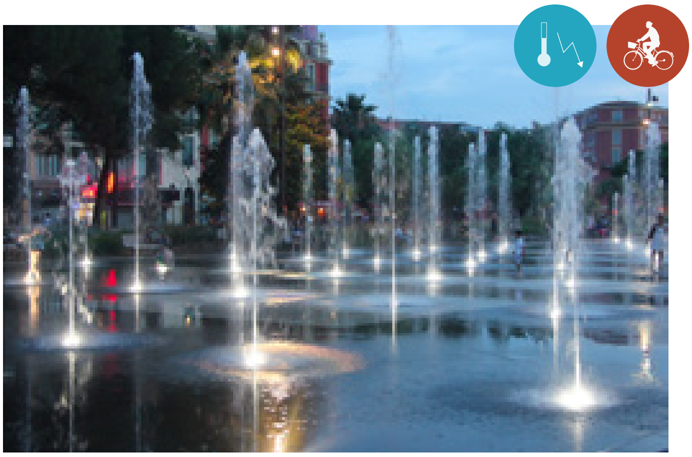


Figure 4.5 Design criteria: Fountains (6) This example is in Nice (www.loumessugo.com)

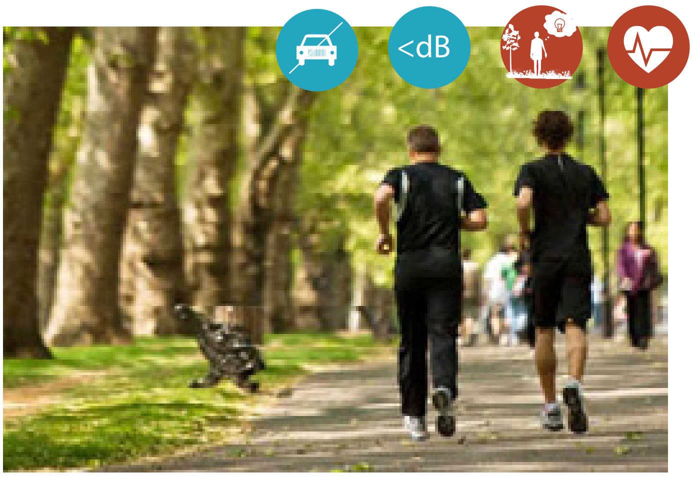


Figure 4.6 Design criteria: Naturalized green areas with good accesibilty and areas for 'green exercise' (parquesalegres.org)

and the area contains mostly impervious surfaces. This enhances the ecosystem services water regulation, climate regulation, soil quality improvement and habitat for biodiversity.

5. Fountains or green waterbodies (Lenzholzer, 2013), figure 4.5.

There are no water elements present on Strijp-S at the moment, but with the integration of a WWTP this could be implemented by using the purified water from the WWTP. This enhances the ecosystem services climate regulation and recreation.

6. In general the overall enhancement of greenery is important, including naturalized green areas with good accessibility and areas for 'green exercise' and also includes parktrees and –shrubs, squares with trees, streettrees (Lenzholzer, 2013; Hiemstra et al., 2008; Tzoulas et al., 2007; Pincetl & Gearin, 2005), figure 4.6.

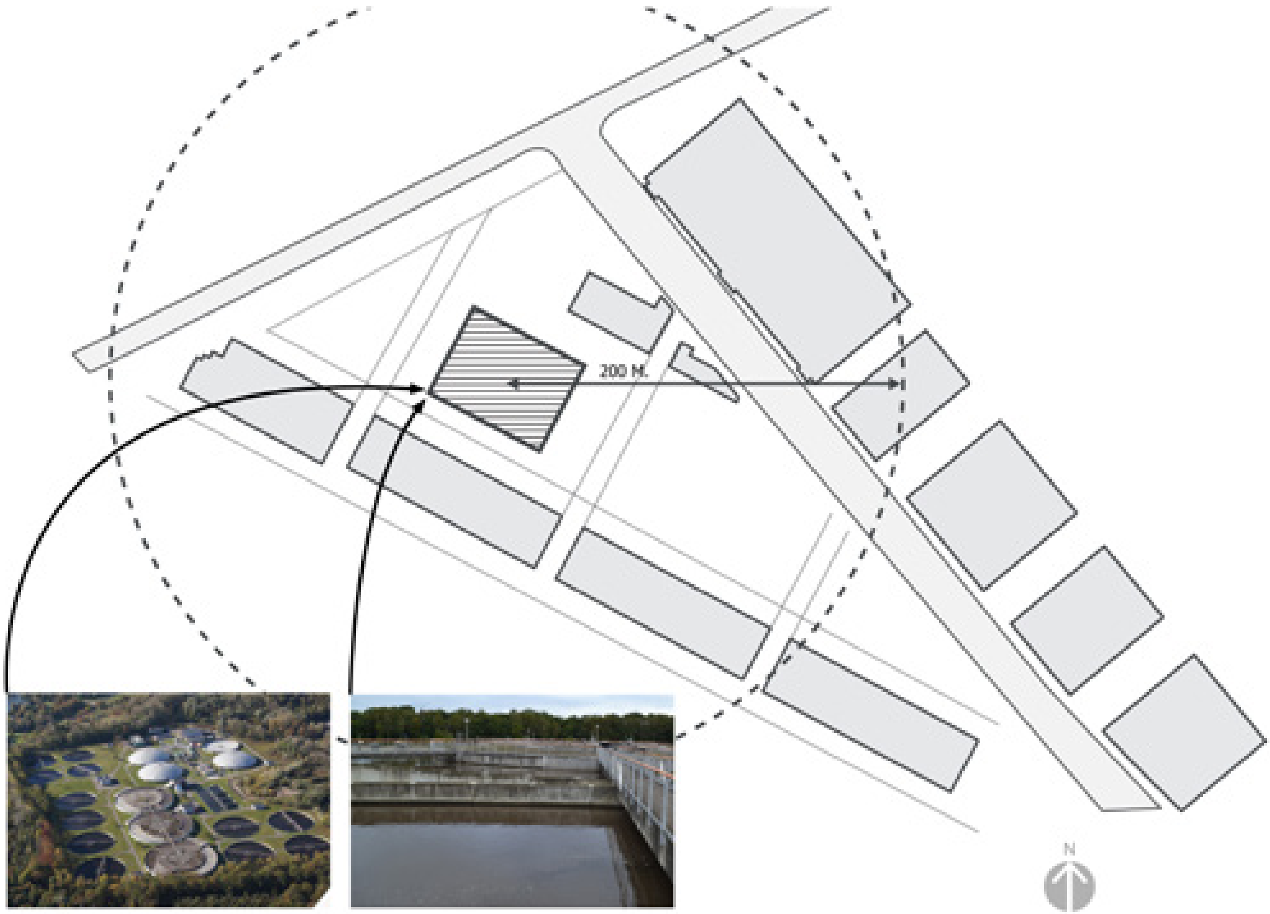
Currently the amount of greenery on Strijp-S is very minimal, but there is sufficient space available to enhance the greenness of the area. This would enhance the ecosystem services climate regulation, noise reduction, air quality improvement, sense of place and health.

4.2 The landscape models

The first model to be implemented in this area is the activated-sludge model. This model is used as a reference model (model 0) and shows what the impact on PGS would be if a conventional treatment type would be integrated in the urban context. Beforehand it was already clear that this WWTP type would not be the ideal type to integrate in PGS and therefore not seen as a realistic option for the design. Rather this model is used to argument why alternative decentralized WWTPs are required for the integration in PGS. The model for Nereda® (model A) and the model for Biomakery (model B) are carried out in more detail than the reference model, because there are more design possibilities for the integration in PGS.

4.2.1 The activated-sludge WWTP model (model 0)

The activated-sludge WWTP model is the reference model, shown in figure 4.7. This model shows the physical footprint of the WWTP and its bufferzone when integrated in Strijp-S. The physical footprint of 400m² and the bufferzone of 200 meters are inaccessible for the public. The exterior of the WWTP consists mainly of building materials such as concrete and steel, which therefore have a relatively high impact on the environment (de Bonth, 2016). The purified water would not be visible for the public within the design of the WWTP or the bufferzone. Moreover, the WWTP would not be able to contribute to the greenness of the area since the footprint of the WWTP would take up a large part of public space (de Bonth, 2016). Due to the size of the WWTP, there is no space available to implement the design criteria for the enhancement of ecosystem services. Therefore it can be concluded that the activated-sludge is not suitable for the integration in PGS of Strijp-S.



The activated-sludge WWTP

Figure 4.7 The activated-sludge model (model 0)

4.2.2 The Nereda® WWTP model (model A)

The Nereda® WWTP model shows how the Nereda® WWTP and the design criteria for enhancing ecosystem services can be integrated on Strijp-S, see figure 4.8. The Nereda® WWTP is a WWTP with a smaller physical footprint of 294 m² and a bufferzone of 10 meters or less (de Bonth, 2016). The exterior of the WWTP consists mainly of building materials such as concrete and steel. Yet, all elements of the treatment process can be incorporated in one compact building, which results in a moderate impact on the environment. The WWTP itself could not be used for the enhancement of green, however the bufferzone and surroundings could contribute to the greenness of the area (de Bonth, 2016). The treatment process takes place in an enclosed building, which makes the WWTP inaccessible for the public. Still the bufferzone can be accessible for the public. This leaves sufficient space for the integration of the design criteria for enhancing ecosystem services. The WWTP is located on a spot were the distance to the buildings is relatively large, to maintain the bufferzone requirements. On this location the WWTP is easily accessible for transport vehicles.

The model includes:

1. A decentralized Nereda WWTP, inaccessible for the public
2. A community garden for urban farming
3. A retention areas supplied with water from the WWTP
4. Stormwater infiltration areas
5. Fountains
6. Overall enhancement of greenery

Figure 4.8 The Nereda® model (model A)

4.2.3 The 'Biomakery' model (model B)

The Biomakery model indicates how the landscape of Strijp-S would be affected if a Biomakery WWTP would be implemented on Strijp-S, see figure 4.9. The Biomakery has a small physical footprint of 210 m^2 with no bufferzone requirements (de Bonth, 2016). The building itself is partly accessible for the public with a minimum of 50% of the footprint. The appearance of the WWTP is similar to a botanical greenhouse, in which all elements of the WWTP are enclosed in a glass building. The high transparency of the building makes its impact on the landscape relatively low. Recreational and educational functions can be incorporated in the building of the WWTP and its surroundings, especially due to the fact that the water is visible for the public, this could very well be combined with recreational and educational functions. Urban greenness can be enhanced within the WWTP since tropical plants are used for the purification process. The surrounding environment is also available for enhancement of greenness while there are no bufferzone requirements (de Bonth, 2016).

The model includes:

1. A decentralized Biomakery WWTP, accessible for the public
2. A community garden for urban farming
3. A retention areas supplied with water from the WWTP
4. Stormwater infiltration areas
5. Fountains
6. Overall enhancement of greenery

In appendix 3 the sketches can be found of two alternative models for the integration of the Biomakery WWTP. During the sketching process it showed that there were multiple options for the integration of a

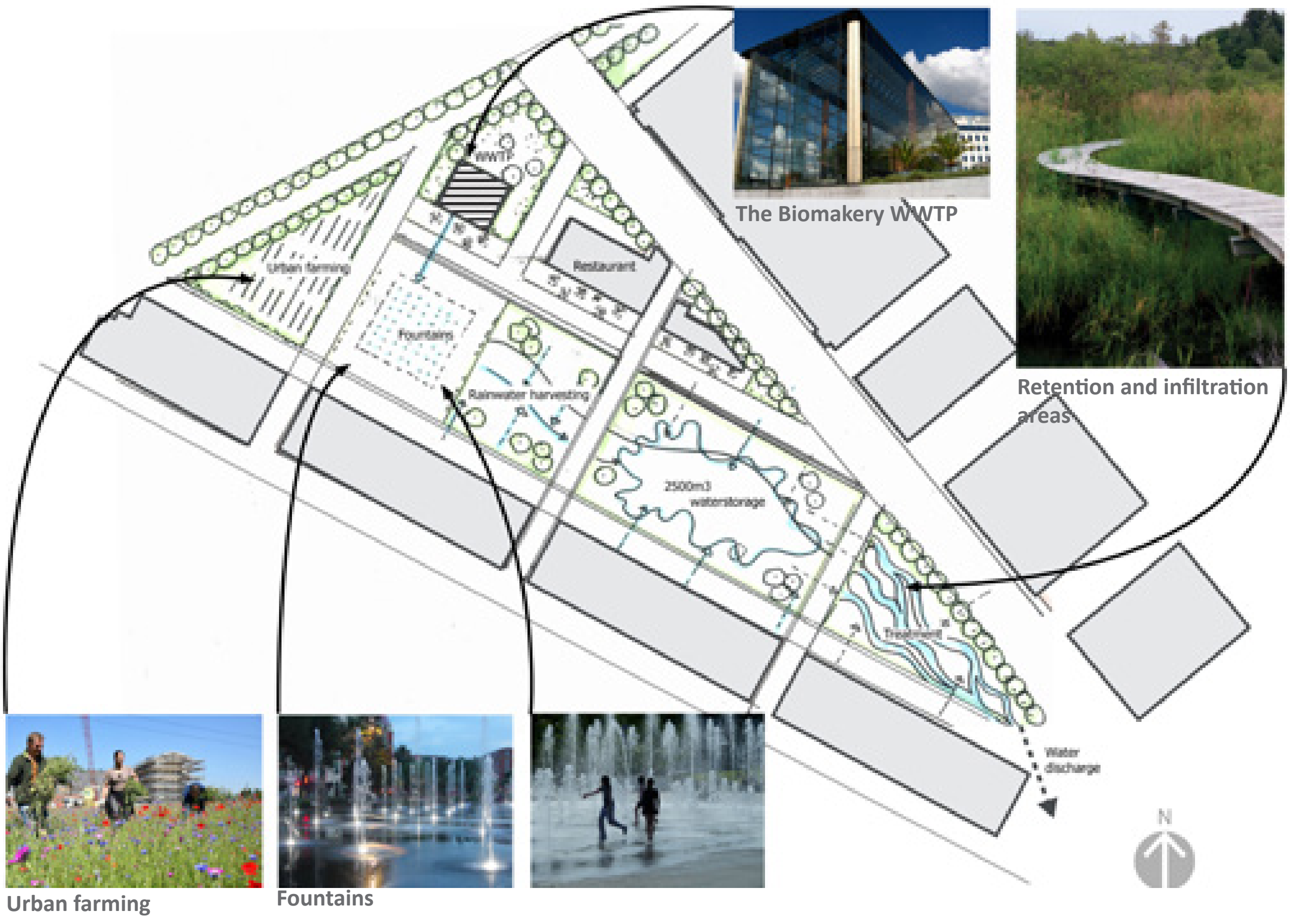


Figure 4.9 The Biomakery model, model B

Biomakery WWTP in the PGS of Strijp-S. In one of the models the WWTP is connected to an existing restaurant on Strijp-S. In this way, the public can enjoy a sight on the botanical character of the WWTP while having dinner. This is possible with the Biomakery WWTP due to the good accessibility for the public. The second alternative model for the Biomakery WWTP shows an alternative location where the WWTP is not located on the north side of the area but next to the retention area in the middle of the area. In this way the WWTP can contain recreational functions such as a terrace that overlooks the water.

4.3 Conclusion

The performance of the models in terms of ecosystem service enhancement is evaluated in figure 4.10. For each model it is evaluated how they can enhance ecosystem services through the integration of the design criteria. This shows that the WWTP in model 0 is unsuitable to be integrated in PGS since there is no space to integrate design criteria for the enhancement of ecosystem services. The Nereda WWTP in model A and the Biomakery WWTP in model B are both suitable to be integrated in PGS of Strijp-S, although the Biomakery WWTP has more potential to enhance ecosystem services. Therefore, according to the performance on ecosystem services, model B (Biomakery) is chosen as most suitable for Strijp-S.

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Model 0: Activated-sludge

Enhancement of ESS through integration of an activated-sludge WWTP possible?

The presence of areas for food production	--	(Insufficient space available)
WWTP's and retention areas to temporary store water	+/-	(Yes, however bufferzone requirements do not fit in urban context)
Presence of fuelwood, organic matter to be reused	--	(No, insufficient space available)
Parktrees and –shrubs, streettrees, materials with high albedo, pavement with low density, green waterbodies, fountains, waterfalls, no impervious surfaces, urban shelterbelts etc.	+/-	(Yes, within bufferzone of the WWTP)
Retention areas, infiltration areas, pervious materials	--	(No, insufficient space available)
Vegetation to capture particulate matter, trees as physical object	+/-	(Yes, but within bufferzone of the WWTP)
A wide vegetation belt with high density, branches and foliage	+/-	(Yes, but within bufferzone of the WWTP)
Infiltration areas for precipitation	--	(No, insufficient space available)
Impervious surfaces, diverse vegetation with high complexity	--	(No, insufficient space available)
Public green spaces with good accessibility, areas for 'green exercise', naturalized environments in the city, unofficial green areas or small green areas	--	(No, insufficient space available)
Urban forests and community gardens, naturalized environments	--	(No, insufficient space available)
Meeting places in public green space	--	(No, insufficient space available)
Urban forests and community gardens, public green spaces with high ecological value	--	(No, insufficient space available)

WWTP type unsuitable to be integrated in PGS in order to enhance ecosystem services.

Figure 4.10 Evaluation of the potential to enhance ecosystem services in public green space for each model

Model A: Nereda® *Enhancement of ESS through integration of Nereda WWTP possible?*		Model B: Biomakery *Enhancement of ESS through integration of Biomakery WWTP possible?*	
++	(Yes, WWTP can provide water for urban farming practices)	++	(Yes, WWTP can provide water for urban farming practices)
++	(Yes, sufficient space for the integration of a Nereda WWTP)	++	(Yes, sufficient space for the integration of a Biomakery WWTP)
++	(Yes, through urban farming practices)	++	(Yes, through urban farming practices)
++	(Yes, sufficient space available)	++	(Yes, sufficient space available)
++	(Yes, WWTP can supply water for retention areas etc.)	++	(Yes, WWTP can supply water for retention a reas etc.)
++	(Yes, sufficient space available)	++	(Yes, sufficient space available)
++	(Yes, sufficient space available)	++	(Yes, sufficient space available)
++	(Yes, sufficient space available)	++	(Yes, sufficient space available)
++	(Yes, sufficient space available)	++	(Yes, sufficient space available)
+/-	(WWTP inaccessible for the public, but PGS accessible)	++	(Yes, also WWTP accessible for the public)
+/-	(WWTP inaccessible for the public, but PGS accessible)	++	(Yes, also WWTP accessible for the public)
+/-	(WWTP inaccessible for the public, but PGS accessible)	++	(Yes, also WWTP accessible for the public)
++	(Yes, sufficient space available)	++	(Yes, sufficient space available)
WWTP type suitable to be integrated in PGS in order to enhance ecosystem services, but due to bufferzone requirements and inaccessibility of the WWTP this is limited.		*WWTP type suitable to be integrated in PGS in order to enhance ecosystem services, also in and around the WWTP.*	

05 WORKSHOP & SURVEY

In this chapter the results of the workshop and survey are described. During the workshop the stakeholders evaluated the integration of the WWTP and the enhancement of ecosystem services. The survey among the same stakeholders provided information on the most suitable WWTP type.

Background photo: the botanical character of the WWTP that is evaluated as most suitable for public green space (own photo, Biomakery WWTP in Budapest)

Workshop and survey

5.1 The workshop

In the previous chapter the models were evaluated from a landscape architects perspective. In this chapter the models are evaluated from the perspective of water treatment and management experts and experts on Strijp-S in order to get an evaluation on the integration of the WWTP's in the models. The list of participants of the workshop is described in appendix 4. Since this project combines both knowledge from the landscape architecture field and knowledge from the field of water management, the challenge is to combine these two fields to generate new knowledge. This co-production of knowledge by different proffessionals is known as a transdisciplinary approach (Ahern, Cilliers, & Niemelä, 2014).

To bring these stakeholders with expert knowledge together, a workshop with a transdisciplinary approach is organized, as described in the methods in chapter 1. Figure 5.1 shows the invitation for the workshop on Strijp-S and figure 5.2 an impression of the workshop. The aim for the workshop was to get an evaluation from the stakeholders on the integration of a WWTP in public green space. This consisted of an evaluation on the enhancement of ecosystem services through the integration of a WWTP, the actual location of the WWTP and the preferred treatment type for Strijp-S.

5.2 Evaluation of the workshop

In general the stakeholders were positive about the concept of integrating a WWTP with the aim to enhance ecosystem services. The concept 'ecosystem services' required an explanation since most of the stakeholders were not familiar with this term, but once this was clear they provided several remarks related to the services.

5.2.1 Remarks on ecosystem services

Urban farming
Urban farming practices are included in both model A and B, which is can be established by urban farming in planters due to the contamination levels in the soil. An alternative proposed by the stakeholders is to use the building 'Vershal het Veem' for the production of food by developing an aquaponics system as an urban farming practice. Aquaponics is a method to grow food which uses a conventional aquaculture, a water culture with snails, fish and shellfish, in a symbiotic way with a hydroculture, a water culture with plants, see figure

Figure 5.1 Invitation for the workshop

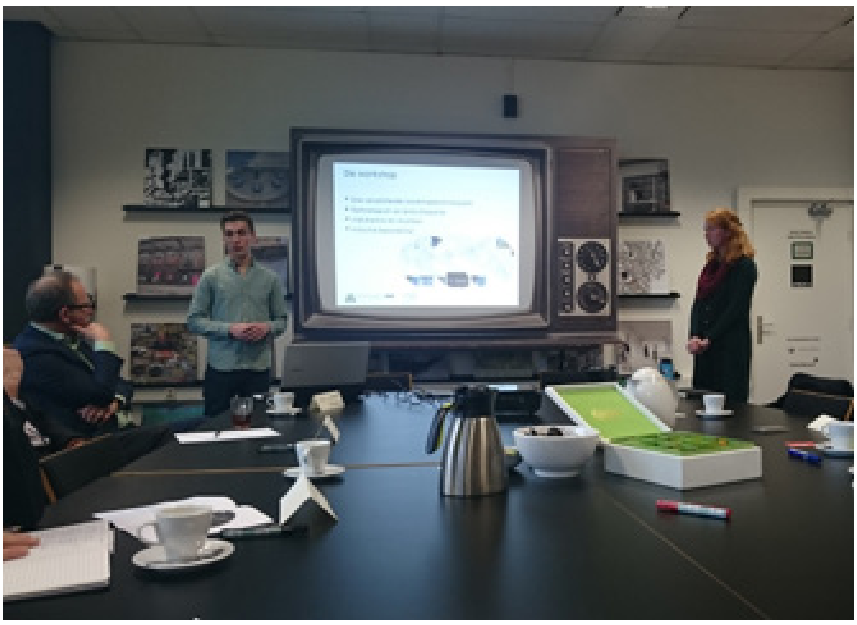

Figure 5.2 Impression of the workshop (photo by W. Klemm)

5.3 (Fox, Howerton, & Tamaru, 2010). Rather than using part of the PGS for urban farming practices in planters, this would be a more suitable solution as the purified water of the WWTP can be reused for the aquaponics system.

Resource recovery

Resource recovery is a difficult ecosystem service to directly enhance in PGS because this service is often dependent on other ecosystem services such as food supply. According to the stakeholders this ecosystem service is essential when integrating a WWTP, since the 'waste' from the treatment process can be used to generate energy. More specifically, the waste product sludge can be transported to a biomass power plant on Strijp-T (north of Strijp-S), to generate energy that can be used for the purification process in the WWTP. In this way the service will not directly be enhanced on Strijp-S, but will eventually provide benefits in the area through energy supply.

Water regulation

Water regulation is an important ecosystem service to be enhanced when the aim is to make people aware what the qualities of the water in the urban context are. People often take the availability of freshwater for granted, however to have access to fresh water requires a whole process. According to the stakeholders, design criteria like retention areas and bioswales are therefore increasingly important to make people aware of the quality of water. What was also noted is the importance of bringing back the river Gender in Eindhoven. This river used to flow through the city centre, but has been removed. Bringing back water on Strijp-S, could therefore be combined with bringing back the river Gender in the city. This means that the purified water can be used to create a new stream towards the Genderpark.

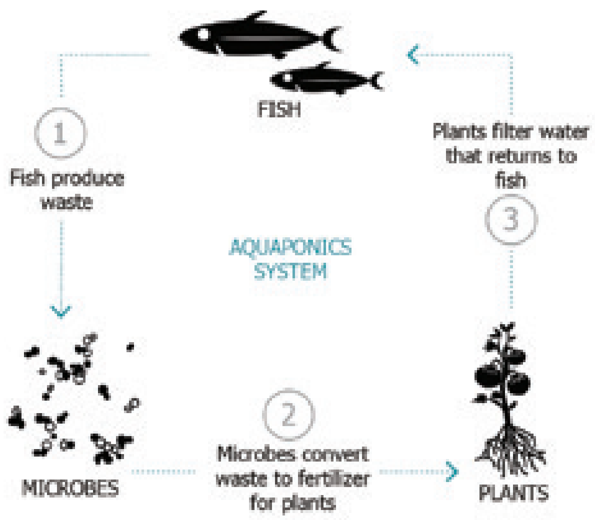

Figure 5.3 Aquaponics system as suitable solution for urban farming

Recreation

To enhance recreation as an ecosystem service, events on Strijp-S could be taken into account. Strijp-S is famous for its large events in the area, such as the Dutch design week. This is an annual event with over 275.000 visitors. Therefore the area requires good accessibility and space to hold events like this.

Other

The WWTP provides a source of water which contributes to the ecosystem service fresh water supply. Besides reusing the purified water for ecosystem services such as creating a habitat for biodiversity or enhancing soil quality, the purified water could get an additional purpose by being used as firewater in case of emergency.

5.2.2 Remarks on the location of the WWTP

The landscape models 0, A and B are located at the triangular open space between Klokgebouw and Hoge Rug. Currently this is still an open space, but building plans have already been made for this area. This means that this space will not be available for the integration of a WWTP in PGS. Therefore, the stakeholders recommended using an alternative location for the design that does not contain building plans. This location is the Torenallee that crosses the area, and has potential to include a WWTP (see figure 5.4). In this way, the Torenallee could become a so-called 'water experience trail' through Strijp-S, where visitors are able to see all the treatment steps from purification to eventually reuse of the water in the area. Moreover, on this location the water could be reused more easily for purposes such as aquaponics in the buildings such as Vershal 'het Veem' and the other buildings along the Torenallee.

5.3 The survey

Amongst the same group of stakeholders a survey is conducted to decide which of the three WWTP types is most suitable to be integrated on Strijp-S. The survey is a tool to analyse which statements about the WWTP the group of people most value, by enabling them to score these statements (de Bonth, 2016). The survey was executed in cooperation with de Bonth and contains therefore both criteria on the technical aspect of the WWTP and criteria related to the integration in the landscape. For the full survey, see appendix 5. To decide which WWTP is most suitable for the integration in the landscape the landscape criteria specifically are used to come to conclusions.
The survey consisted of five criteria groups: environment, technique, landscape, social and economy. Each criteria group contains statements that can be scored. Figure 5.5 indicates the topic of the statements in each criteria group. The highest score that could be given for a statement is a 5 (completely agree) and the lowest score that could be given is a 1 (not agree). This figure also indicates the average score for each criteria group that was given by the stakeholders and implies that economic criteria are thought of as less important than the environmental, technique, landscape and social criteria. For this research study the landscape criteria are particularly relevant, since this group of statements indicate the how important the stakeholders think the spatial characteristics of the WWTP are. The outcome of the survey on the landscape criteria is used to conclude which WWTP type is most suitable to be integrated in PGS of Strijp-S.

5.4 Evaluation of the survey

The landscape criteria groups contains statements about the physical footprint, the bufferzone requirements, the accessibility, water management, aesthetic appearance, recreational and educational values, urban water and urban green in relation to the WWTP. Figure 5.6 gives these criteria in relation to the three WWTP types. For each WWTP a description is given on how this criteria is present in at that particular treatment type. The score of the stakeholders is compared to the score of each WWTP type for each criteria. This resulted in a conclusion on the most suitable WWTP type for Strijp-S. The following paragraphs explain the criteria, their scores and ultimately the most appropriate WWTP to meet the criteria:

1. Physical footprint: the first statement was described as *'a small footprint of the WWTP is important of the development of a WWTP in PGS'.* This statement was scored with a 4 by the stakeholders and indicates that most of the stakeholders think the physical footprint of the WWTP should preferably be small. Comparing this to the footprints the three WWTP types, it can be concluded that the Biomakery WWTP is most suitable in terms of the

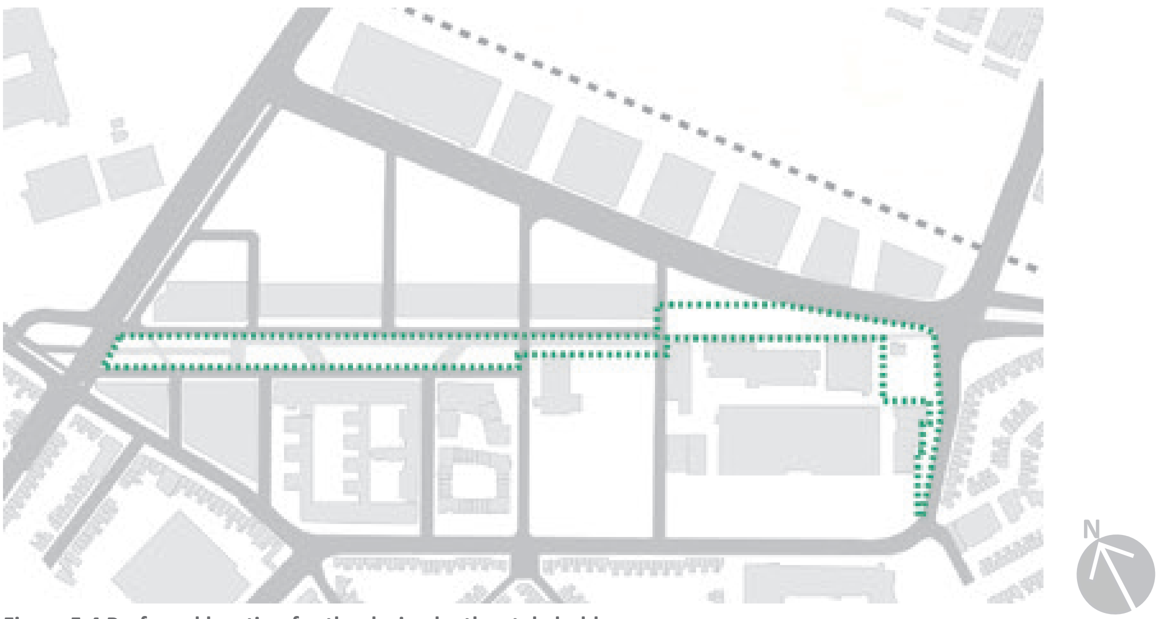

Figure 5.4 Preferred location for the design by the stakeholders

physical footprint.

2. Bufferzone requirements: this statement is described as *'the distance between the WWTP and the closest public functions is important due to safety regulations (i.e. noise, smell, etc.)'.* This statement got a modest score of 3 and is not very important in the opinion of the stakeholders. Comparing this to the bufferzone requirements of the WWTP types, this implies that both Nereda® and Biomakery are suitable with both a small or no bufferzone.

3. Accessibility: this statement was described as '*the bufferzone of the WWTP should be accessible for the inhabitants and visitors of Strijp-S'* and got a score of 4 by the stakeholders. This corresponds with the good accessibility of the Biomakery WWTP due to the fact that it does not contain a bufferzone and the building itself can be accessible for the public.

4. Water management: this is described as *'the urban context around the WWTP should include aspects such as rainwater discharge and rainwater buffer capacity'.* This statement was scored with a 4 by the stakeholders and indicates that the Biomakery WWT is most suitable since there is sufficient space available around this WWTP type for the integration of design criteria for water management.

5. Aesthetic appearance: this statement is described as *'integration of a WWTP including the bufferzone is of added value for the surrounding environment of Strijp-S and enhances the appearance of the landscape'.* This statement got scored with a 4, which mostly suits with the integration of a Biomakery WWTP. The appearance of this WWTP is comparable to a botanical garden or green house and could potentially contribute to the aesthetic value of the landscape.

6. Recreational and educational values: this is described as *'the WWTP including bufferzone should include new recreational and educational possibilities for inhabitants and visitors'*. This was scored with a 4 and can also be realized best with a Biomakery WWTP since the Nereda® WWTP is inaccessible for the public.

7. Urban water: this statement is described as *'the purified water of the wastewater treatment plant should be visible in the landscape, for example by above-ground water discharge and fountains'.* This was scored with a 4 and fits best with the Biomakery WWTP, due to the visibility of the water in the WWTP.

Criteria group	*Statements about*	*Score (1-5)*
Environment	The quality of the treated water, how much energy the purification process takes, how much chemicals are used in the process, how much polymers are used, the amount of sludge produced, the reuse possibility of resources and wastewater and closing cycles.	*4.0*
Technique	Adaptability, flexibility and stability of the wastewater treatment plant.	*4.2*
Landscape	The footprint and bufferzone of the WWTP, the accessibility of the WWTP, water management in the landscape, spatial integration of the WWTP, Recreational and educational values, visibility of the water in the landscape and enhancing the greenness of the area through water.	*4.1*
Social	Enhancing local development, awareness of the value of water, and responsibility for the WWTP by for example residents.	*4.4*
Economy	Investment costs, operational costs and social costs.	*3.2*

Figure 5.5 Criteria groups and the statements that they include, with an indication of the average score given to each group by the stakeholders

Statement	Stake-holders score	Activated-sludge (model 0)	Nereda® (model A)	Biomakery (model B)	Score according to de Bonth (2016) AS	Nereda	Biomakery
1. Physical footprint	4	400 m²	294 m²	210 m²	1	3	5
2. Bufferzone requirements		200 m	10 m[1] or less	0 m	2	5	5
3. Accessibility	3	The WWTP nor the buffer zone is accessible for the public.	The WWTP is not accessible for the public, the buffer zone is partly (50% or more) accessible for the public.	The WWTP is partly accessible (50% or more) for the public, the buffer zone is completely accessible for the public.	1	2	4
4. Water management	4	Water management can only take place via detention, due to the large footprint and buffer zone of the WWTP.	Water management can take place via detention, retention, filtration, infiltration and treatment, due to the small footprint and buffer zone of the WWTP.	Water management can take place via detention, retention, filtration, infiltration and treatment, due to the small footprint and buffer zone of the WWTP.	1	2	5
5. Aesthetic appearance	4	Large footprint of WWTP. Exterior of WWTP consists mainly of building materials (e.g. concrete, steel, etc.). So, a relatively high impact on the environment	Small footprint of WWTP. Exterior of WWTP consists mainly of building materials (e.g. concrete, steel, etc.). All elements can be enclosed within one building. So, a moderate impact on the environment.	Small footprint of WWTP. Appearance of WWTP is comparable to a botanical garden. All elements can be enclosed within a greenhouse. So, a low impact on the environment.	1	3	5
6. Recreational and educational values	4	The large footprint and buffer zone of the WWTP make it not possible to integrate recreational or educational functions within the WWTP nor the buffer zone.	Recreational or educational functions cannot be integrated within the WWTP. Only, the unexploited area could be used for development of recreational and educational functions.	Educational functions and public spaces (recreational function) can be integrated within the WWTP. The unexploited area could be used for development of additional recreational and educational functions.	1	3	5
7. Urban water	4	Urban water is not visible within the WWTP design nor the buffer zone or the unexploited area of the WWTP could be used.	Water is not visible within the WWTP design. The unexploited area of the WWTP could be used for increasing the visibility of water on Strijp-S.	Water is visible within the WWTP design. The unexploited area of the WWTP could be used for increasing the visibility of water on Strijp-S.	1	3	5
8. Urban green	5	Urban green is not visible within the WWTP design nor the buffer zone or the unexploited area of the WWTP could be	Urban green is not visible within the WWTP design. The unexploited area of the WWTP could be used for increasing the visibility of	Urban green is visible within the WWTP design. The unexploited area of the WWTP could be used for increasing the visibility of water on Strijp-S.	1	3	5

Figure 5.6 Landscape criteria of the survey, scored by the stakeholders, full survery results available in appendix 6

8. The last statement, urban green, is described as *'The wastewater treatment plant in the urban environment of Strijp-S should contribute to greening of the city'*. This statement was scored the highest with a 5, meaning that all stakeholders gave this statement the highest score. The integration of the Biomakery WWTP has the most potential since urban green is visible within the WWTP design and the unexploited area of the WWTP can be used to enhance the presence of urban green.

Based on the landscape criteria it can be concluded that the Biomakery WWTP has the most potential to be integrated in PGS and Nereda® WWTP would a suitable second option. The Nereda® scores higher in other criteria groups such as the ecological and social domain, but the Biomakery WWTP puts more emphasis on the landscape and social domain. The reason for this is that the Biomakery WWTP has a pleasing appearance, comparable to a botanical garden that can include recreational and educational functions within the WWTP design. Moreover, it does not require a bufferzone and therefore the surrounding environment can be exploited to enhance ecosystem services (de Bonth, 2016). Nevertheless it should be taken into account that Nereda® is a reliable and proven technology, whereas the Biomakery technique is still in an experimental stage. Besides that, Nereda® uses less resources in terms of energy and materials, while Biomakery uses less space (de Bonth, 2016).

5.5 Adjusted landscape model

Based on the outcomes of the evaluation of the models, an adjusted landscape model is made that brought together the design criteria, the requirements of the stakeholders and the outcome of the survey to choose for the Biomakery WWTP. This is also the vision for the integral landscape design. In figure 5.7 the Biomakery WWTP is located at the west side of the Torenallee. Here the influent from the neighbourhood enters the WWTP. The Biomakery WWTP becomes a centre for recreation and education for visitors, where people can experience the treatment steps to purify the water and can enjoy the botanical character of the WWTP. After the treatment process the purified water will be used

Figure 5.7 Vision based on the evaluation of the models and the survey

for several purposes to enhance ecosystem services. Firstly, the water follows the Torenallee towards the east where it supplies retention areas, infiltrates and can be used for fountains. It can also be used for domestic purposes in the buildings, and aquaponics in 'het Veemgebouw'. Eventually the water is transported towards the river 'Gender', leaving the area in the most southern point of Strijp-S. In this way the Torenallee becomes a 'showlane' for the reuse of water on Strijp-S.

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06 THE INTEGRAL DESIGN

In this chapter the outcome of the models, workshop and survey are translated into a landscape design for Strijp-S. This is visualized with details, sections and visuals.

Background photo: visualisation of part of the design, the infiltration area on Strijp-S

The integral design

In this chapter the outcomes of the models, workshop and survey are used to develop an integral landscape design for Strijp-S. The overall process from treatment to enhancement of ecosystem services in PGS that is the foundation for the design is indicated in figure 6.1. The key points for each step are:

1. The wastewater treatment process takes place in a Biomakery WWTP. This has the most potential to be adapted into the landscape and has the most opportunities to enhance the recreational value of the area.

2. Resources provided by the WWTP, of which most evidently purified water, are being reused in PGS to bring added benefits. The available resources and their connection to Strijp-S are described in chapter 6.1.

3. The purified water is used for the enhancement of ecosystem services. There are four principles to implement in PGS when integrating a WWTP. These principles are bioswales, a retention area, fountains and infiltration areas. All of them are described through in a detailed landscape plan and visualization in chapter 6.2.

4. The design provides sufficient greenery such as parktrees and -shrubs, squares with trees, streettrees and strengthens the green infrastructure within the city Eindhoven, see chapter 6.2 for the integral design.

6.1 Resource recovery

The stakeholders already mentioned the importance of reusing the resources from the water treatment process.
In figure 6.2 the various ways of reusing these resources are described including which ecoystem services are enhanced. Figure 6.3 gives a quantitative indication of the available resources from the treatment process of the WWTP connected to their reuse purpose on Strijp-S. This indication is based on calculations specifically for an area with a high urban density such as Strijp-S.

In terms of water recovery, the purified wastewater of the treatment process can be reused in several ways. In a conventional treatment system, the purified water is directly discharged towards a nearby river, whereas through the integration of a WWTP in PGS the treated water can get alternative purposes. Around 34% of the purified water can be reused for non-potable domestic use, such as toilet flushing, as indicated in figure 6.3 (de Bonth, 2016). Toilet flushing is chosen as a reuse function because it largely contributes to the daily wastewater production on Strijp-S and reuse of water for toilet flushing is relatively safe because direct contact with the water is avoided. Treated wastewater can be reticulated to households for non-potable use and can be supplemented by harvested roof water. Transportation of the water to the households and back to the WWTP can be realized through a secondary supply pipeline for non-potable water (Wong & Brown, 2009). Approximately 1% of the treated water can be used for urban farming practices such as aquaponics. This leaves around 64% of the purified water for the enhancement of ecosystem services in PGS through the

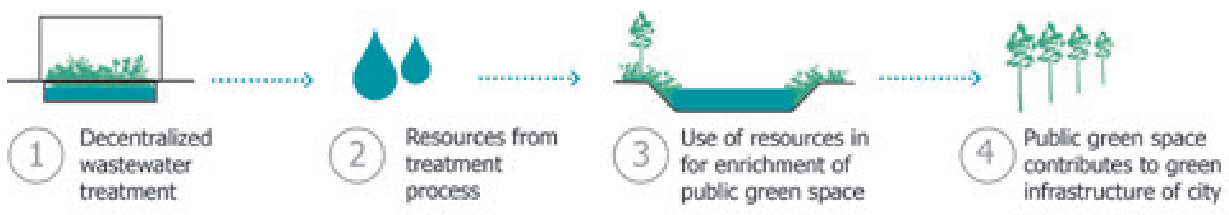


Figure 6.1 The process of reusing resources of the treatment process in PGS

integration of several principles, described in chapter 6.3 (de Bonth, 2016).

In terms of energy recovery, the WWTP requires approximately 1,305,788 MJ/year for treatment of water (de Bonth, 2016). To increase energy recovery, it is interesting to look at treatment of excess sludge. Sewage sludge is one of the less savory byproducts of the wastewater treatment process. It takes up space, it reeks and may contain pathogens, heavy metals or pharmaceutical residues. Treatment and transport of sludge is an expensive part of the treatment process. Via fermentation of excess sludge, a reduction in volume can be achieved that results not only in lower costs but can also produce biogas (van Nieuwenhuijzen, 2011). On Strijp-S the excess sludge can be transported to an already existing biogas factory on Strijp-T. The gained energy from producing biogas can then be used to provide energy for the treatment process, which can reduce the energy consumption of the WWTP by 1,177,467 MJ/year. This is the amount of energy that 13 residential houses consume per year (de Bonth, 2016). For further details on energy recovery out of sludge, see the MSc. thesis report of de Bonth (2016).

Lastly, the purified water can be reused in a thermal storage system to generate energy and to purify the soil. However, it is unclear how much water this requires and how large the actual benefits are. The thermal storage system is a sustainable technique to gain energy from the ground, by using the heat that is naturally available in the ground and groundwater (den Ouden & Gal, 2014). This can then be used to heat and cool buildings or residential housing. Underground storage of heat

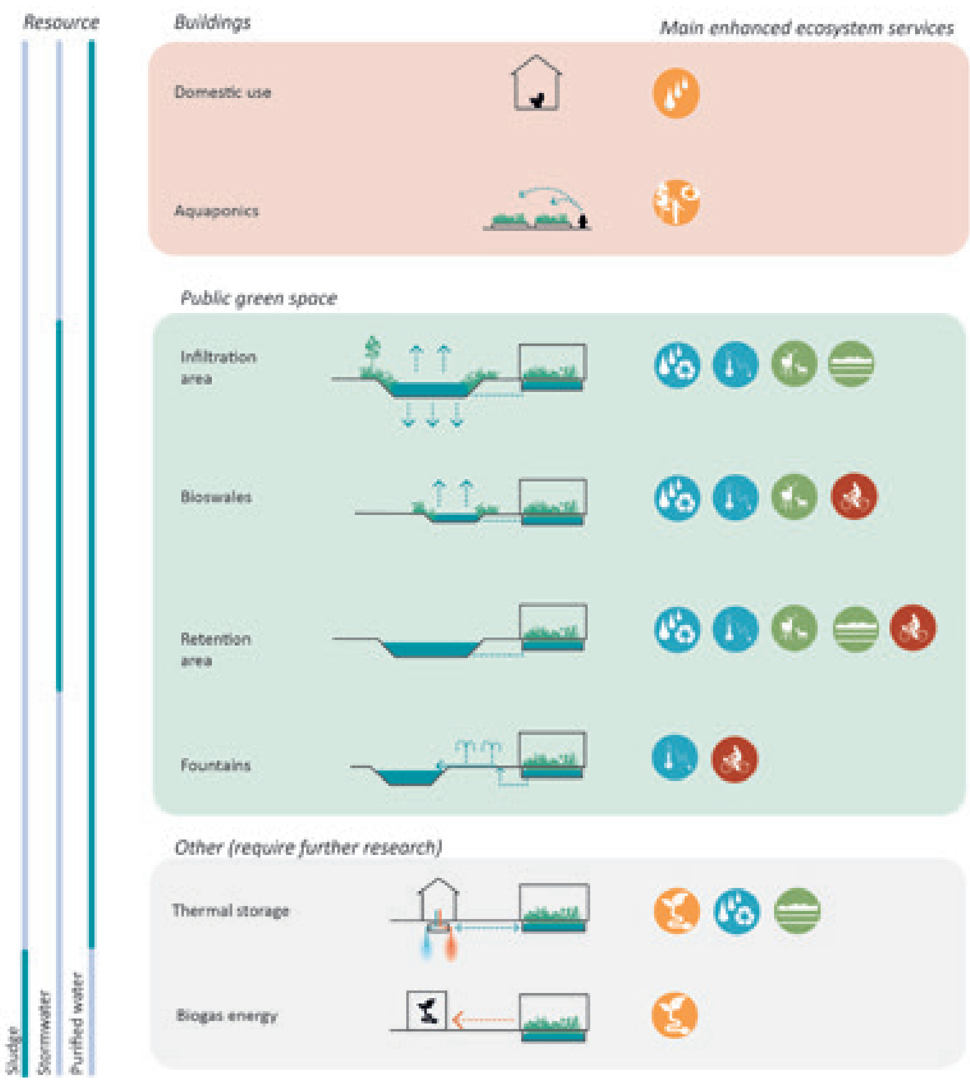


Figure 6.2 Overview of the ways to reuse the resources of the WWTP, indicating which ecosystem services are enhanced per reuse purpose

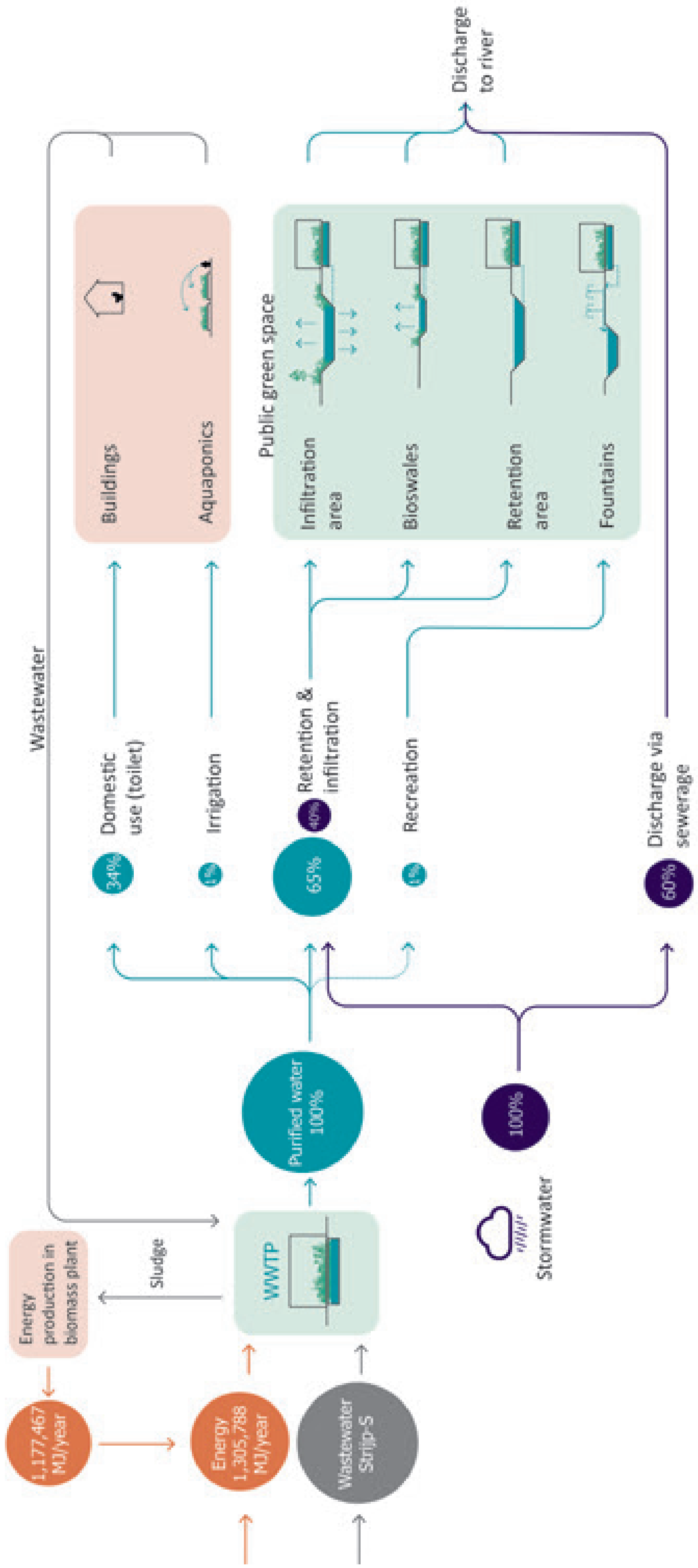


Figure 6.3 Schematic visualisation of the resource flow potentials on Strijp-S. Orange lines indicate energy fows, grey lines indicate waste products, blue lines indicate purified water and purple lines indicate stormwater. The reuse purposes are divided into reuse in buildings and reuse in public green space.

and cold takes place in the aquifers in the ground. In summer, when cooling is preferred, cold water is pumped towards the surface. Via a heat exchanger, the heat from the buildings will be withdrawn from the buildings and this will be transferred back to the groundwater layer. During winter this system works the other way around (den Ouden & Gal, 2014).

In figure 6.4 the resource recovery is translated to the context of Strijp-S. For each resource type it is shown how it can be transported to a specific location on Strijp-S and which purpose it has. The orange lines indicate energy as resource, the grey indicates the wastewater and the blue lines indicate the purified water. The dashed blue lines show the transportation of water through underground culverts, while the non-dashed lines show the above ground transportation of water. The purple lines indicate the transportation of stormwater from the buildings on Strijp-S to the main axis in the design.

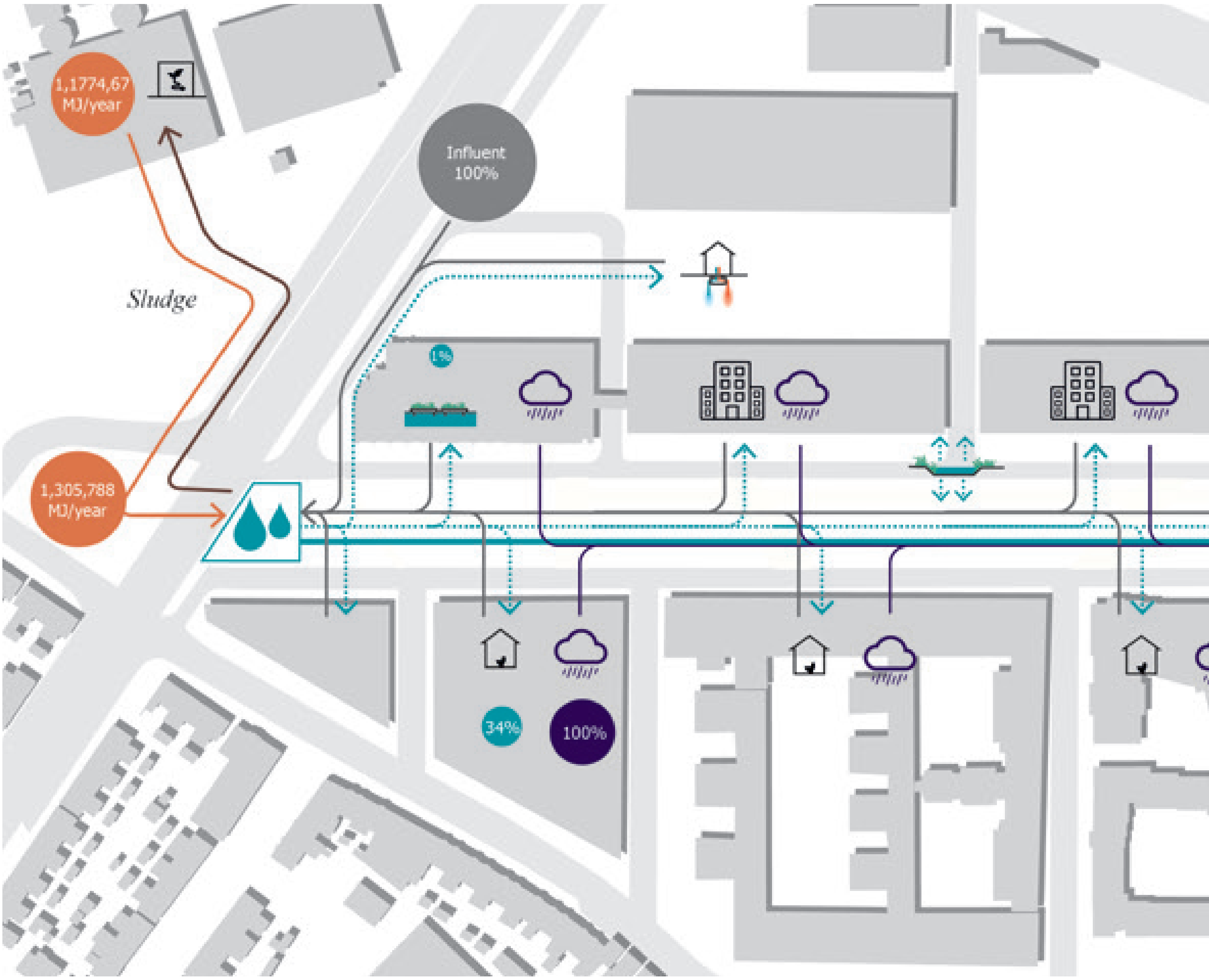
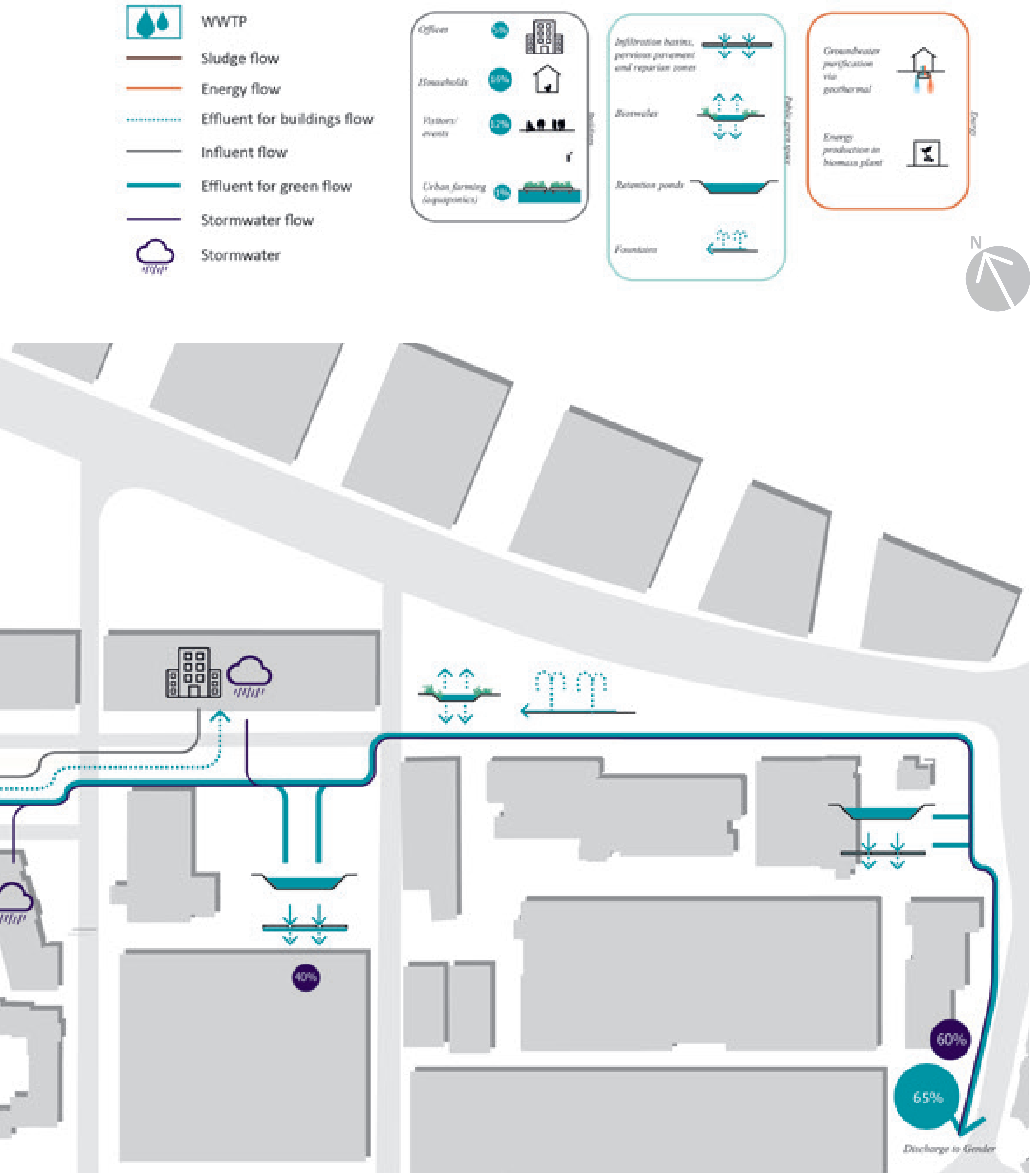


Figure 6.4 Resource flows visualized in on Strijp-S.


WWTP
Sludge flow
Energy flow
Effluent for buildings flow
Influent flow
Effluent for green flow
Stormwater flow
Stormwater
Offices
Households
Visitors/ events
Urban farming (aquaponics)
1%
Infiltration basins, pervious pavement and reparian zones
Bioswales
Retention ponds
Fountains
Groundwater purification via geothermal
Energy production in biomass plant
N
40%
60%
65%
Discharge to Gender

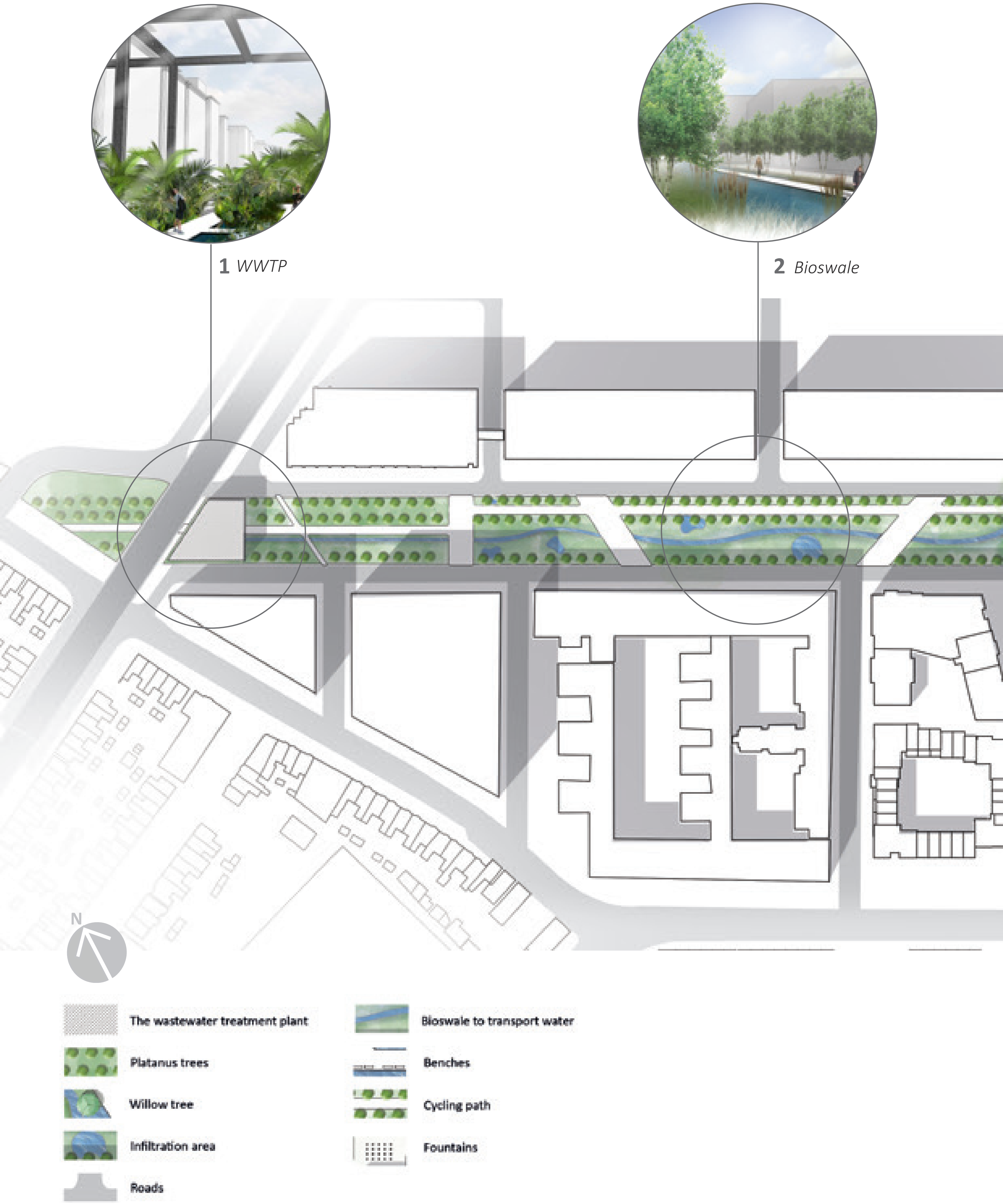
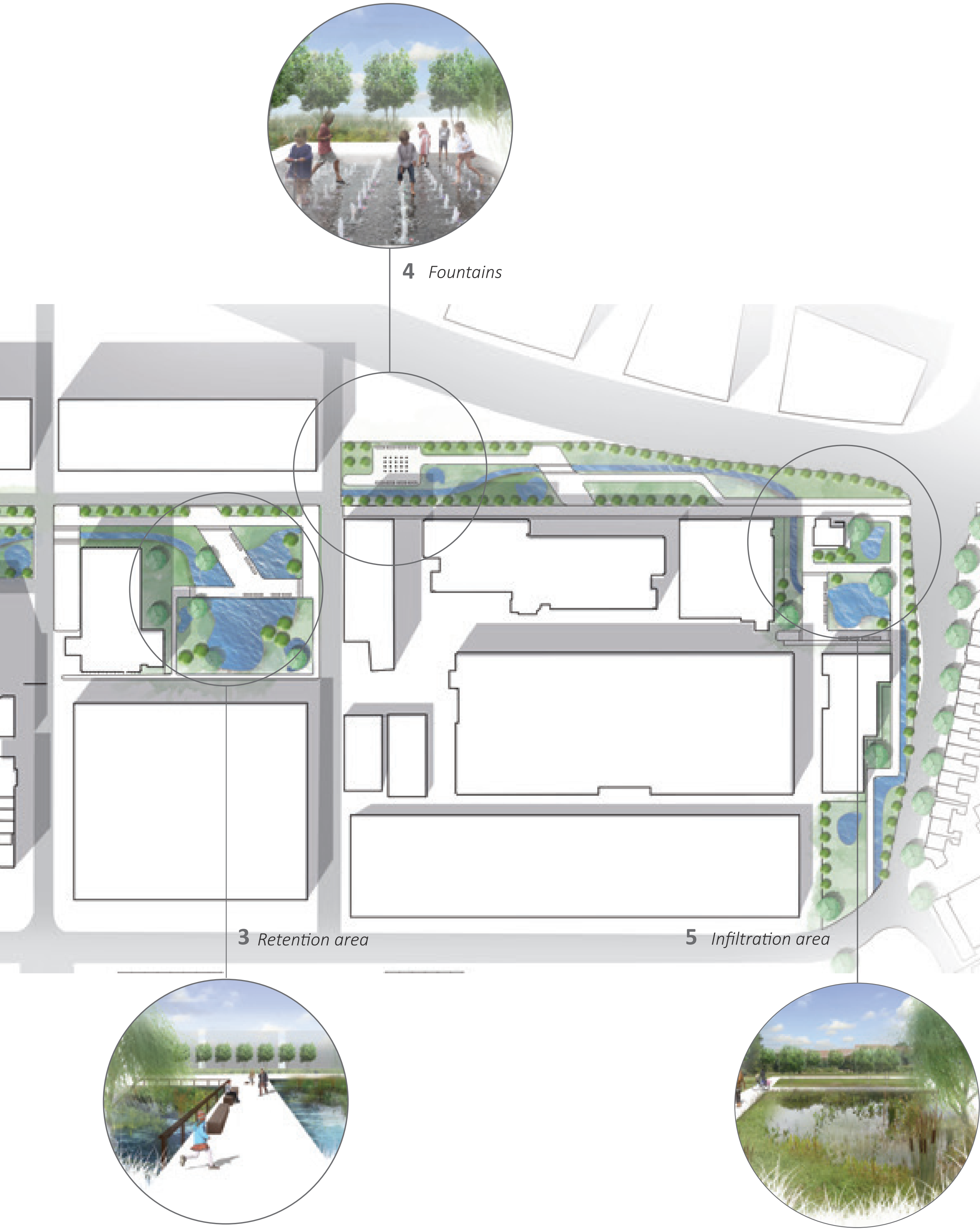


Figure 6.5 Masterplan for Strijp-S


4 Fountains
3 Retention area
5 Infiltration area

6.2 The integral design

Figure 6.5 shows the masterplan for Strijp-S. While Strijp-S was first an urban district with minimal greenness, it now becomes an area with an important green infrastructural connection. Not only the greenness is enhanced but the presence of water provides many benefits for the surroundings and its inhabitants and visitors. The WWTP becomes the visitor center for information about sustainable water management and information about the importance of ecosystem services in the city, while the rest of the area provides many opportunities to experience the water and these ecosystem services in the area. Aim is that the design does not only contribute to the ecosystem functioning on local scale, but that it becomes part of a larger network of ecosystem services in the city, which makes its existence even more important. Five parts of the design are elaborated through detailed landscape plans, sections and visuals. These five locations are the locations where the design measures to enhance UESS are implemented. These are a bioswale system, retention area, fountains, infiltration basins and the WWTP itself. The design is adapted to the existing realized design for the Torenallee. The typical two stemmed Platanus trees planted in lines are maintained in the design to further strengthen these long sightlines that were intended with this design.

6.2.1 The Biomakery WWTP

The Biomakery WWTP is the starting point for the design. This building functions as a recreational and educational center for visitors, but also contains a unique indoor habitat for tropical plant species. The spatial configuration of the WWTP on Strijp-S is indicated in figure 6.7. The building contains two separated parts; the part on the north side is private and contains the operator area, machine room and pre-treatment of the wastewater. The other part contains a treatment location in which the wastewater is already good enough quality to be safely accessible for the public. In this area people can learn about wastewater treatment process and enjoy the presence of the tropical plants in a greenhouse environment. The WWTP is a transparent building constructed of a steel frame and closed with glass, see figure 6.8. This makes its appearance blend into its green environment. To minimize that the building becomes a barrier, the existing bicycle path on the Torenallee passes through the WWTP; in this way the WWTP becomes an experience for both pedestrians and cyclists. The WWTP itself contributes to the ecosystem services: fresh water supply, recreation and education.

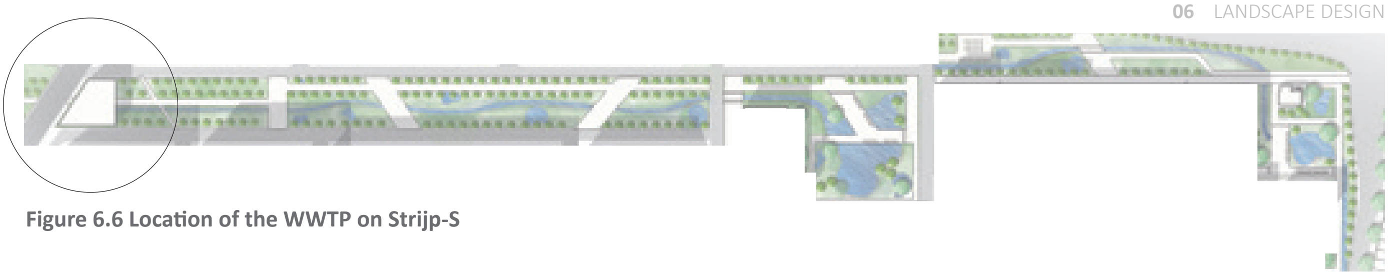


Figure 6.6 Location of the WWTP on Strijp-S

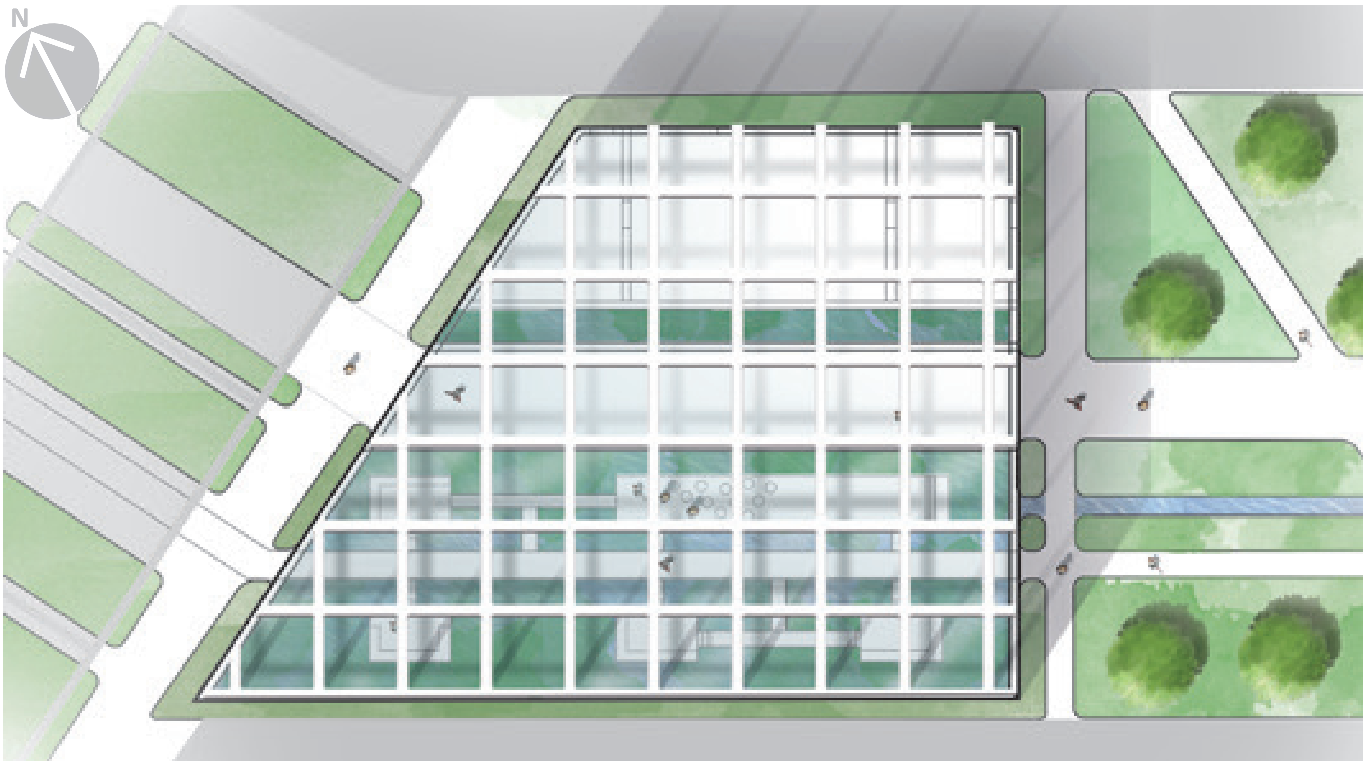


Figure 6.7 Detail of the WWTP, consisting of a steel frame with glass, a cycling path crossing the WWTP and an area for visitors

Figure 6.8 Visualisation of the Biomakery WWTP on Strijp-S. The building is highly transparant and includes tropical plants for the purification process.

6.2.2 The bioswale

Bioswale systems can be used to transport water in a natural way (UACDC, 2011). A bioswale system transports the water from the WWTP and collects the runoff from roofs and roads via an above ground gutter to an open and gently sloped channel with vegetation, which is designed for treatment and conveyance of storm water runoff, also indicated in figure 6.9 (UACDC, 2011). The top layer consists of enhanced soil with plants; The layer beneath consists of gravel, baked clay or scoria, that is packed in geotextile (UACDC, 2011). This is porous material that allows the water to infiltrate. Under this second layer there is a drain pipe. In case of heavy rainfall, overflow of the banks is prevented by connecting the edge to the drainpipe. Overflow should only happen occasionally, which means the bioswale should be a sufficient size to contain the water.

The integration of the bioswale system on Strijp-S is illustrated in figure 6.12. Its main function is to transport the purified water towards the retention area, but also to collect stormwater. Next to the bioswale there is an elevated walkway for pedestrians, to enhance the recreational value of the bioswale. The main ecosystem services that are enhanced in the bioswale are water regulation, climate regulation, habitat for biodiversity, soil quality improvement and recreation, as indicated in figure 6.13. For an impression of the bioswale on Strijp-S, see figure 6.10.

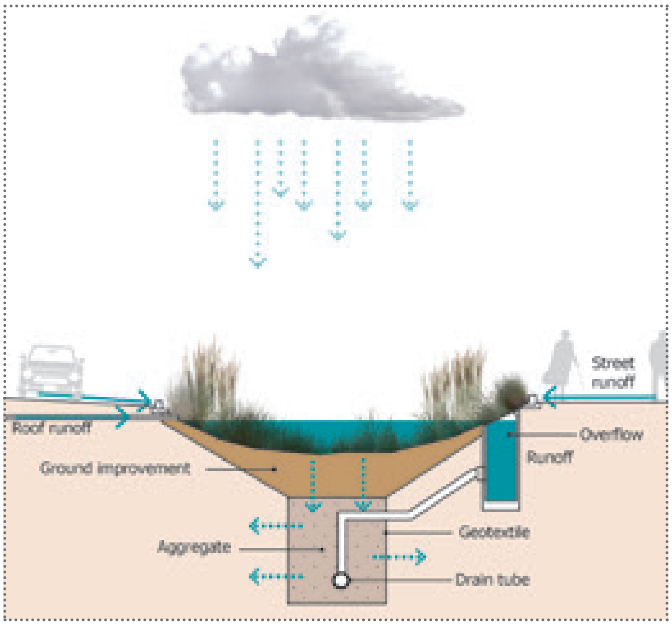


Figure 6.9 The functioning of a bioswale (adapted from UACDC, 2011)

Figure 6.10 Visualization of the bioswale. The long axis of the Torenallee is accentuated with the two-stemmed platanus trees and the long walkway also accentuates this axis.

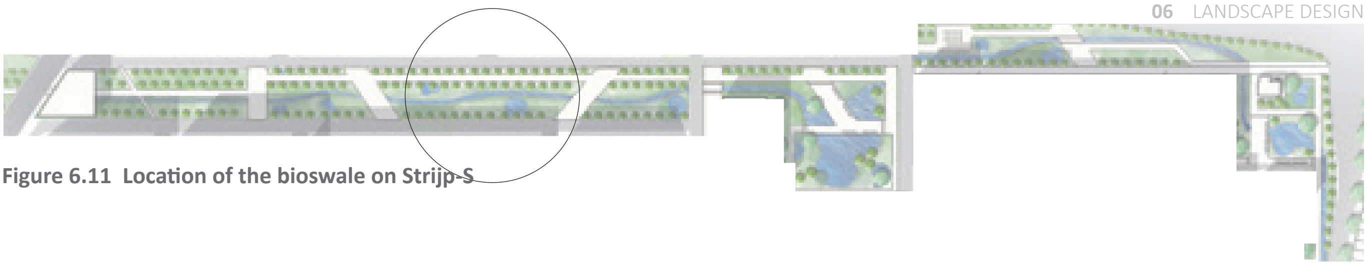
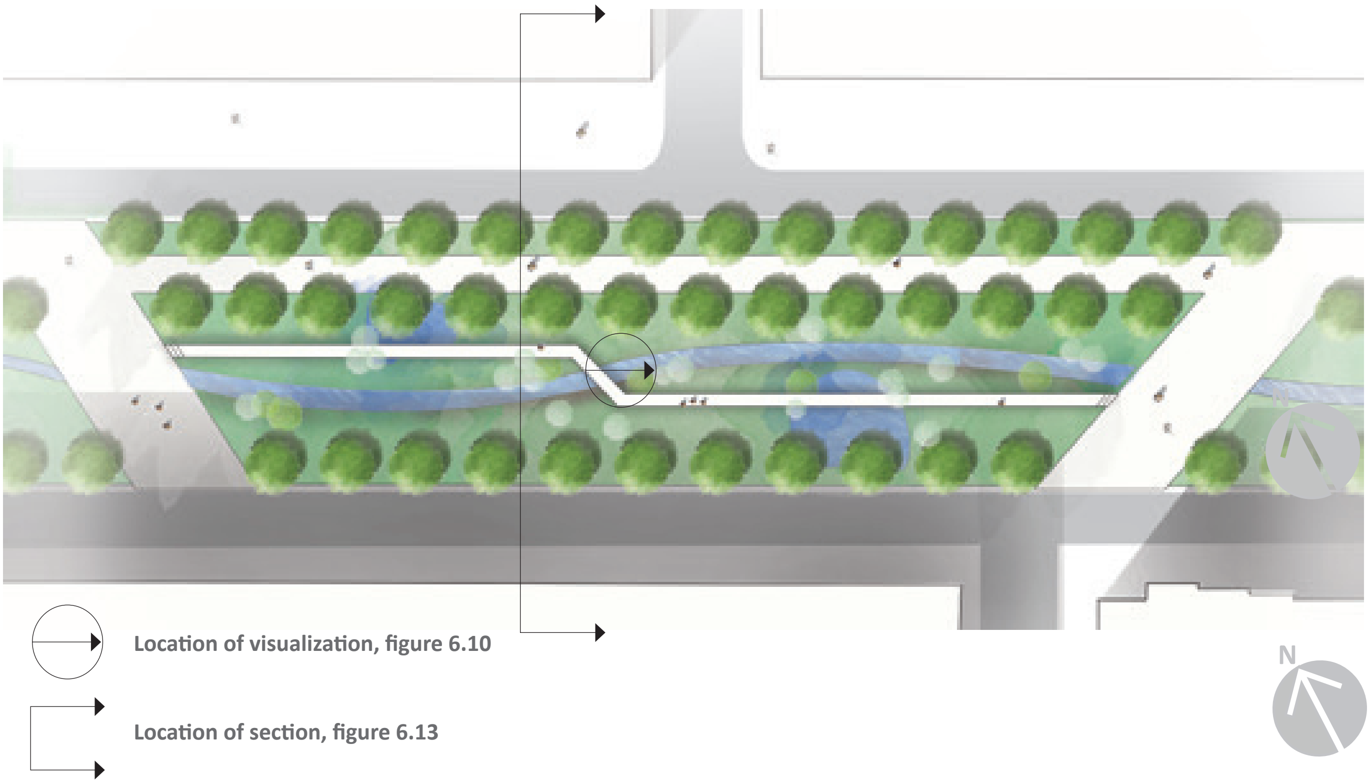


Figure 6.11 Location of the bioswale on Strijp-S



Location of visualization, figure 6.10

Location of section, figure 6.13

Figure 6.12 Detail of the bioswale on Strijp-S. The water is transported from the left side (WWTP) towards the right side (retention area). Along the way rainwater is collected and people there is an ability to walk along the water

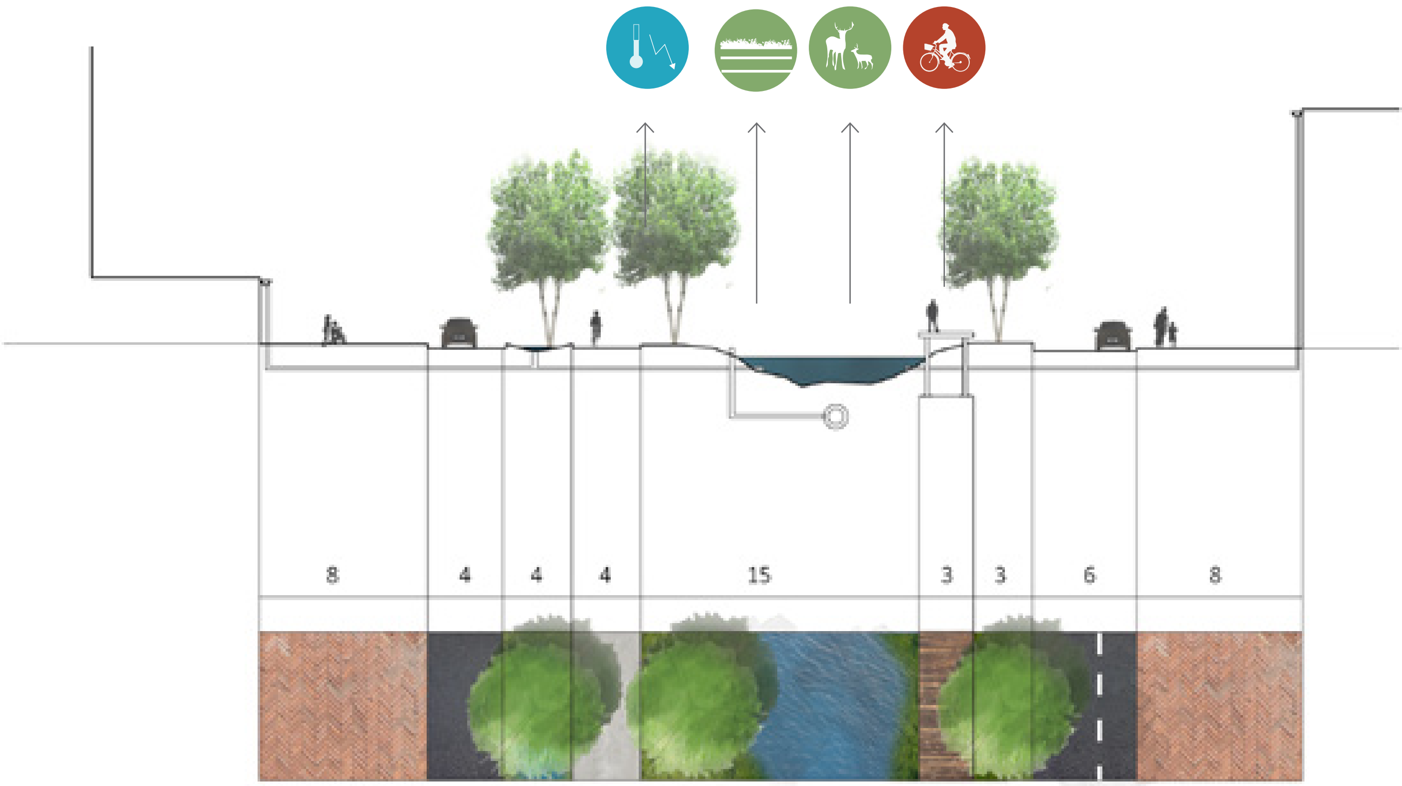


Figure 6.13 Section of the bioswale and its enhanced ecosystem services (widths indicated in meters)

6.2.3 The retention area

To temporarily store the purified water on site, a retention pond is required. This is a constructed stormwater pond that retains a permanent pool of water, see figure 6.14 (UACDC, 2011). Retention ponds remove pollutants through a process of biological uptake and sedimentation. Since they permanently contain a pool of water, they cannot be constructed on locations with a highly permeable soil or areas with low precipitation. Generally, continual drainage input is required for the maintenance of a permanent water level. The purified water from the WWTP can provide a permanent water level. The advantage of a retention pond is that it provides an aquatic habitat for biodiversity (UACDC, 2011). The riparian zones form good living areas for many plants, birds, insects, amphibians, mammals and fish. Moreover the reeds and rushes can absorb nutrients and can improve the water quality and water clarity (BPL, 2015). By developing curved lines in a riparian zone more variations of sun and wind conditions are created, which also enhances species diversity (BPL, 2015).
A retention pond can enhance many ecosystem services, such as water regulation, climate regulation, habitat for biodiversity, soil quality improvement and recreation, see figure 6.18. Generally waterbodies are not very effective for the reduction of air temperature, but when they are provided with dense vegetation more water is being evaporated and the waterbody will be more beneficial for thermal comfort of the area. Hydrous soils also have a higher evaporation that contributes to the thermal comfort. Figure 6.17 shows the detailed landscape plan for the retention area. There are elevated walkways with benches for people to enjoy the view on the water. Besides its recreational function, it also provides a habitat for biodiversity and will improve the soil conditions in the area.
For an impression of the retention area on Strijp-S, see figure 6.15.

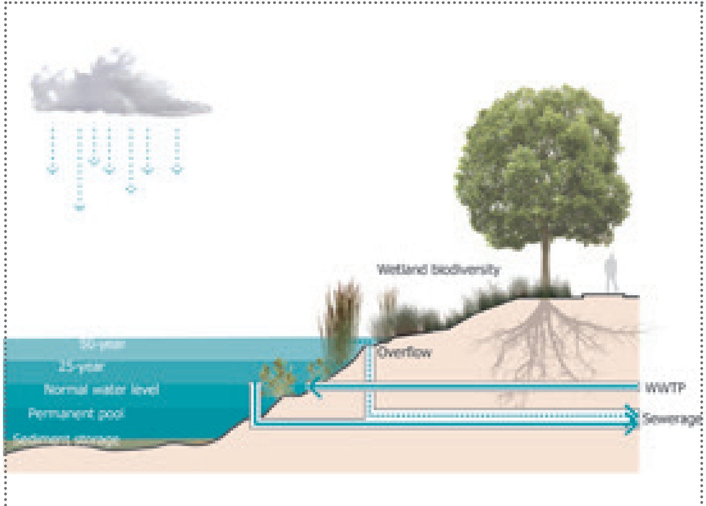


Figure 6.14 Functioning of a retention pond (adapted from UACDC, 2011)

Figure 6.15 Visualization of the retention pond

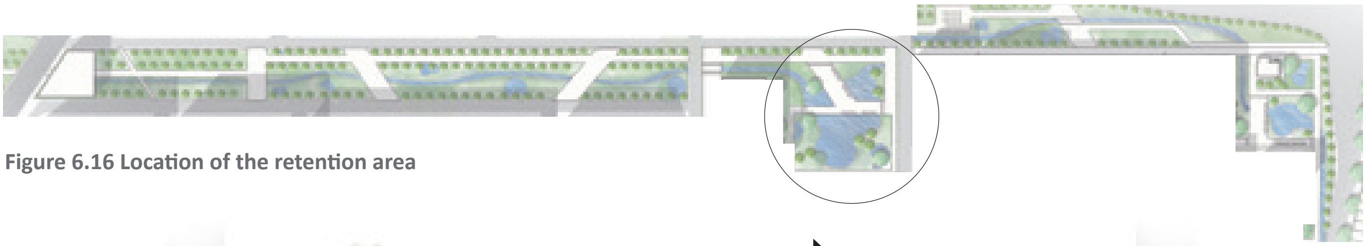


Figure 6.16 Location of the retention area

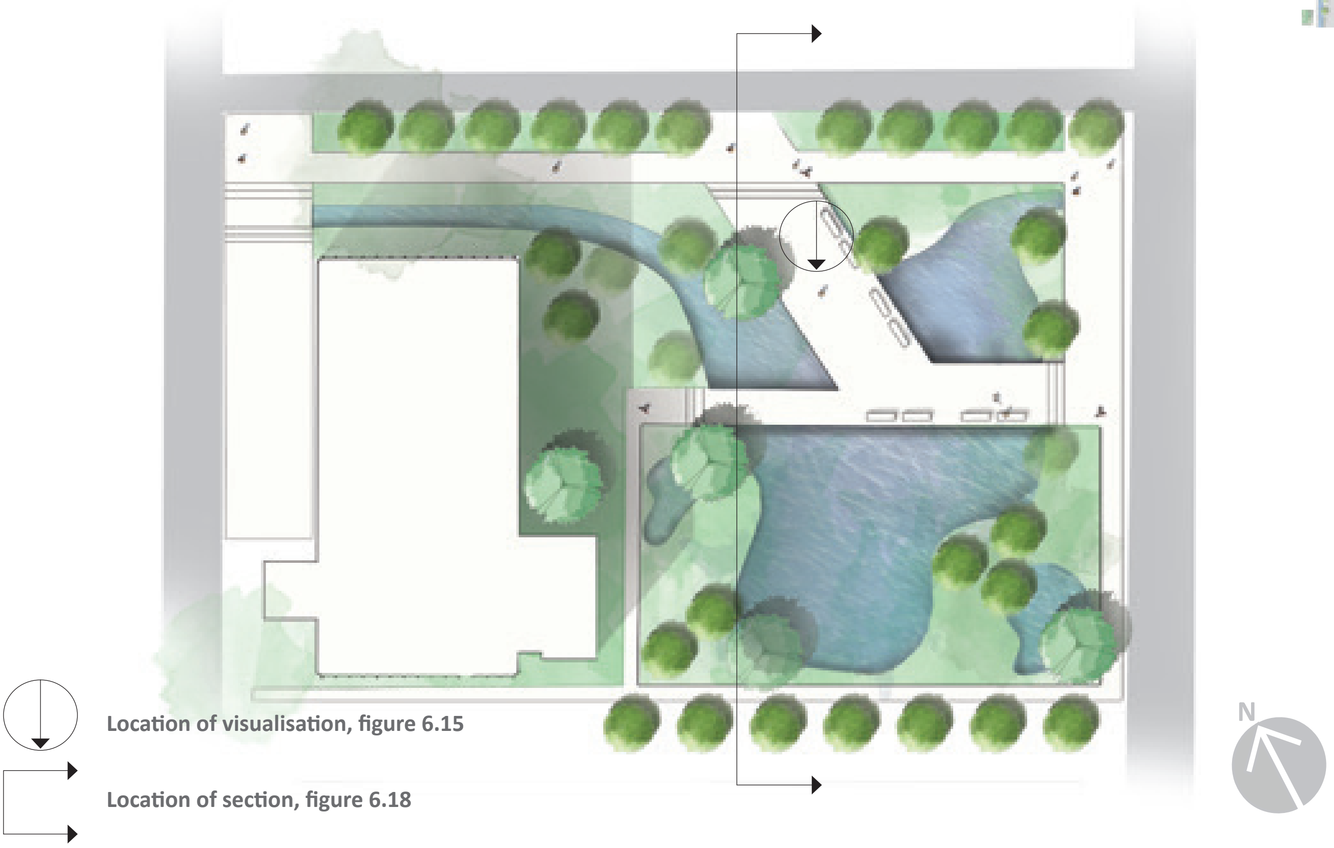


Figure 6.17 Detail of the retention area on Strijp-S. This area contains a permanent pool of water, supplied by effluent and stormwater. Besides its recreational function, it also provides a habitat for biodiversity and will improve the soil conditions in the area

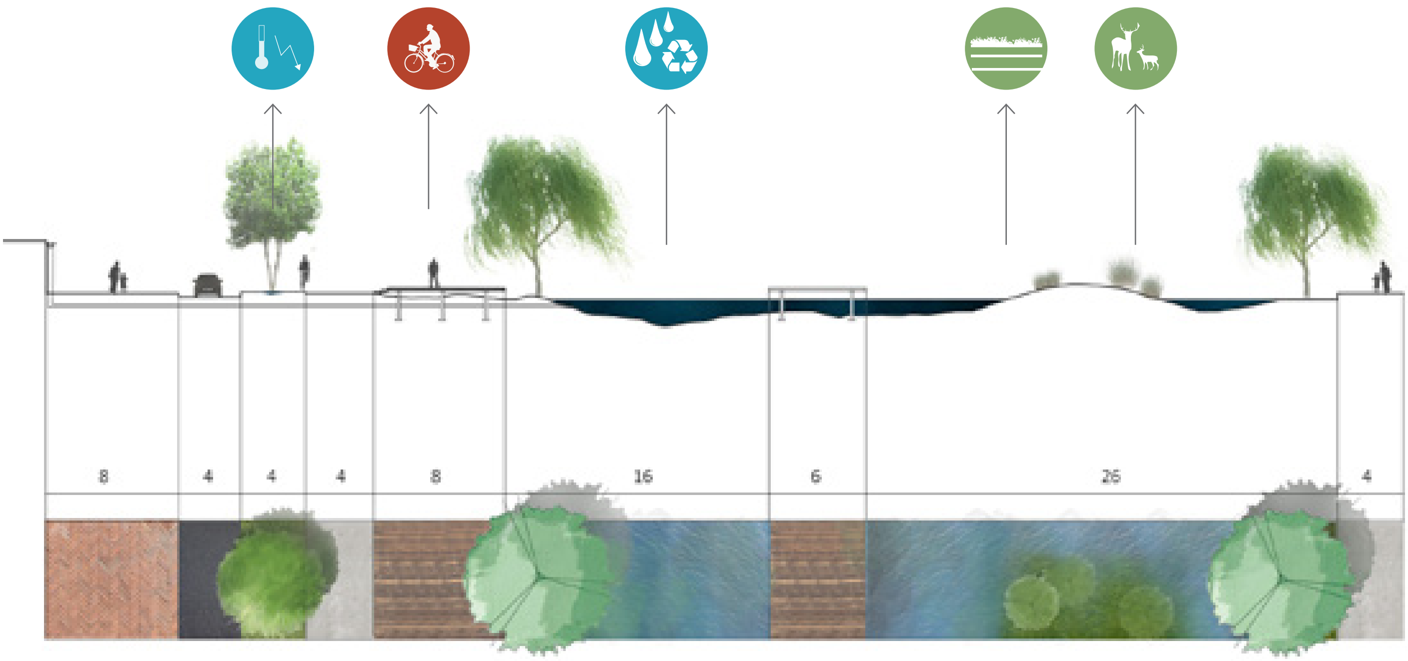


Figure 6.18 Section of the retention area including the enhanced ecosystem services (widths indicated in meters)

6.2.4 The fountains

The availability of water in public space creates opportunities for water-based recreation. People value the presence of water in their living environment and like to recreate in close distance to water (Stowa, 2014). In the current design practices, water is often integrated in landscape design, and solutions are sought by combining functions, such as the adaptation to extreme precipitation events combined with recreational functions. Fountains can contribute to the environment as a recreational facility, yet they can also contribute to the thermal comfort in the area, see figure 6.23 (Lenzholzer, 2013). Thermal comfort is dependent on air temperature, which is influenced by the amount of water that is evaporated in the air. This takes place by radiation of the sun and radiation of heat (Lenzholzer, 2013). During the evaporation process, energy is withdrawn from the air, which leads to a reduced increase of air temperature. Evaporation can be increased with fountains or other water elements such as waterfalls. These applications increase the humidity of the air by spreading the water into small droplets in the air. When the water drops are smaller, it is more effective to reduce the air temperature and therefore increase thermal comfort (Lenzholzer, 2013). Figure 6.22 shows the implementation of fountains on Strijp-S. For an impression of the fountains areas on Strijp-S, see figure 6.20

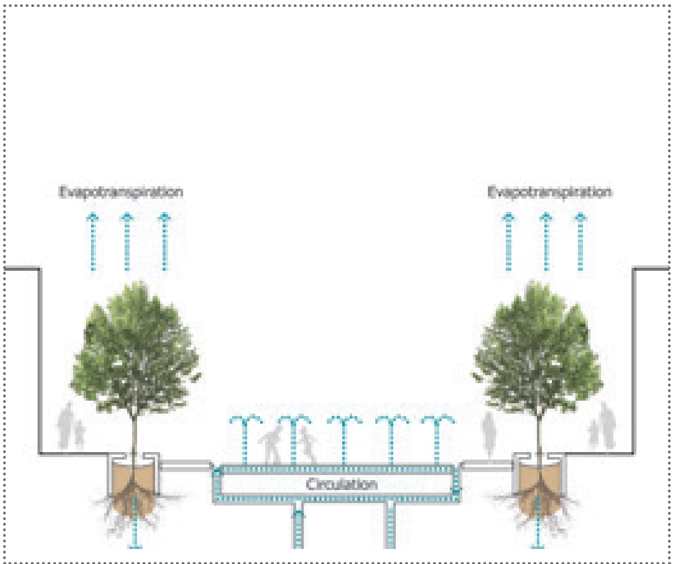
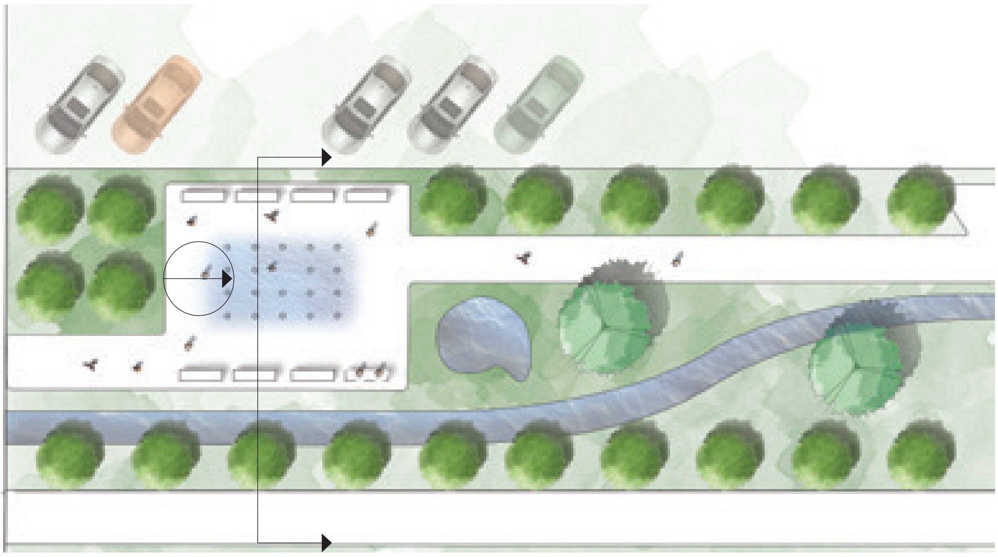


Figure 6.19 Functioning of a a fountain

Figure 6.20 Impression of the fountain area, where recreation is its main purpose, and the contributurion to the thermal comfort on Strijp-S an important benefit

Figure 6.21 Location of the fountains



Location of visualisation, figure 6.20

Location of section, figure 6.23

Figure 6.22 Detail of the fountains on Strijp-S. The square function s as a meeting place, with a pleasant climate due to the fountains

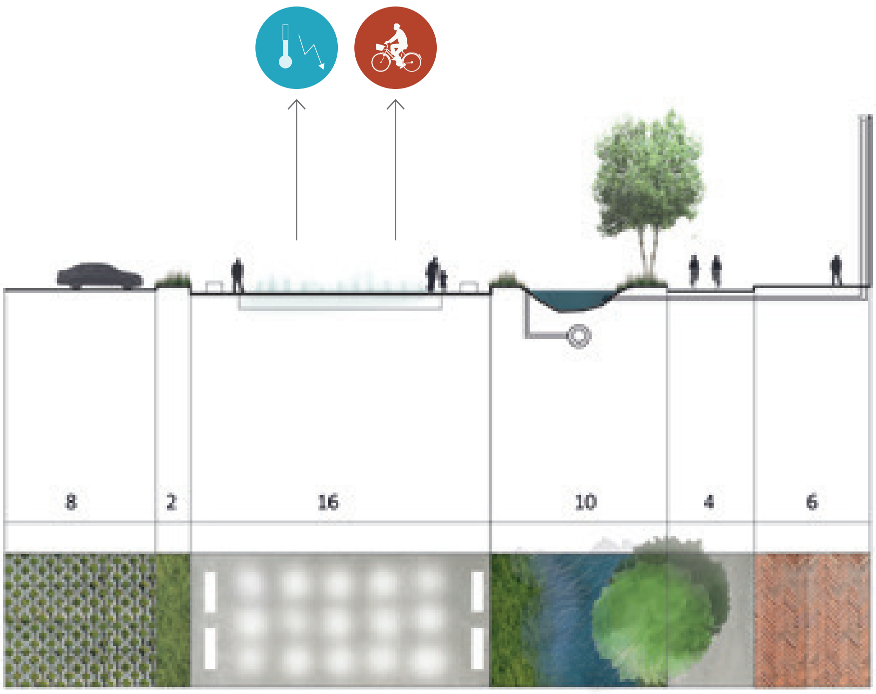


Figure 6.23 Section of the fountains on Strijp-S including the enhanced ecosystem services (widths indicated in meters)

6.2.5 The infiltration area

Infiltration basins are shallow impound areas that have a highly permeable soil (UACDC, 2011). They are designed to infiltrate and temporarily detain storm water runoff. They do not contain permanent water, only occasionally after storm water events, as explained in figure 6.24. Infiltration basins can be deep or shallow; in residential areas a depth of thirty centimeters is sufficient. Important are the roots of the plants and the animal activity, which makes sure that the permeability of the soil is retained (Pötz & Bleuzé, 2012). Increasing the proportion of soft surface areas allows for the (storm)water to naturally infiltrate in the soil, reducing the pressure on the sewage system (Pötz & Bleuzé, 2012). By reducing roads and other hard surfaces in the area and replacing them for porous paving materials to cover the ground the infiltration capacity increases. Additional benefits are that fewer paved materials can also improve the microclimate and biodiversity in the area (Pötz & Bleuzé, 2012). If hard surfaces are required, infiltration plains besides these surfaces would be an alternative. These plains of approximately the size of 50% of the paved surface area are sufficient to infiltrate the water (Pötz & Bleuzé, 2012). Storm water infiltration on Strijp-S would benefit from the existing soil type. The sandy ground allows for the water to infiltrate more easily than for example clay soils. Infiltration areas contribute to the main ecosystem services soil water regulation, climate regulation and soil quality improvement as indicated in figure 6.28. For an impression of the infiltration areas on Strijp-S, see figure 6.25.

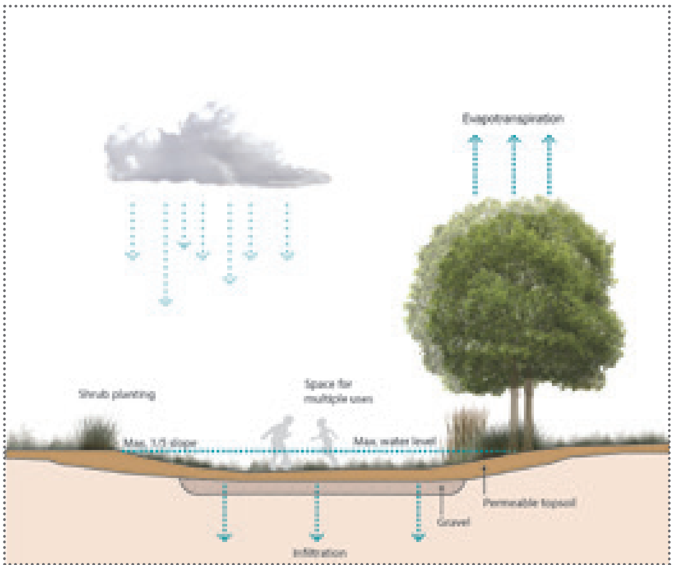


Figure 6.24 Functioning of an infiltration area (adapted from UACDC, 2011)

Figure 6.25 Impression of the infiltration area on Strijp-S

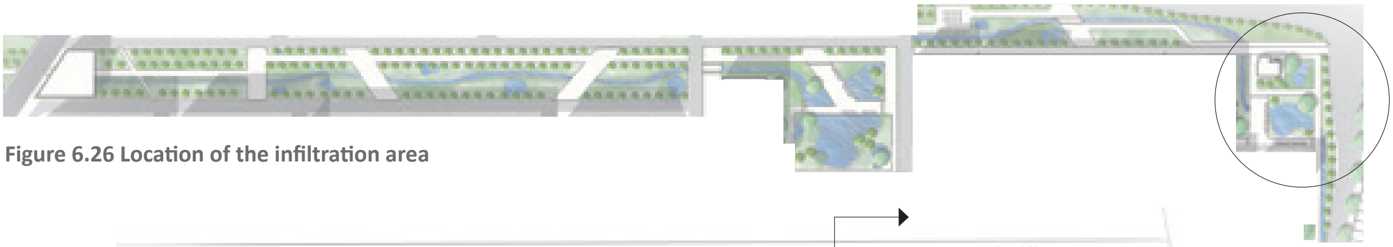
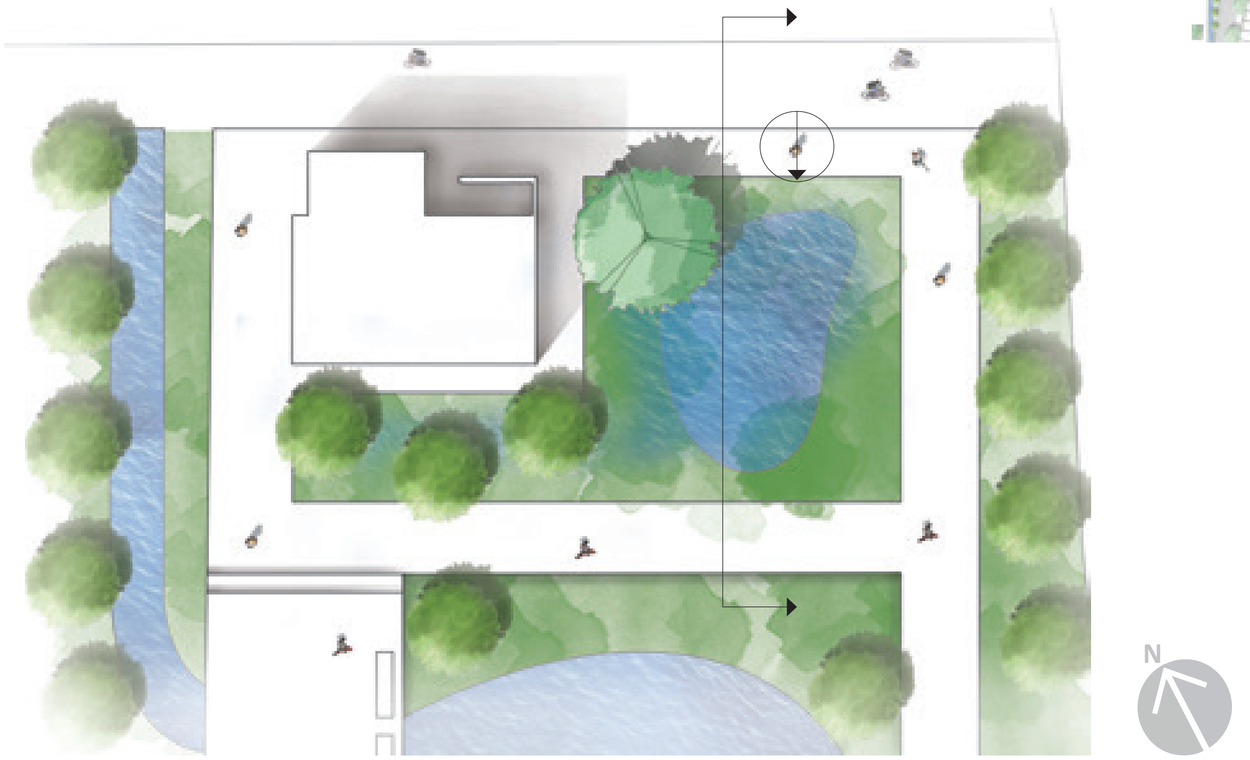


Figure 6.26 Location of the infiltration area



Location of visualisation, figure 6.25

Location of section, figure 6.28

Figure 6.27 Detail of the infiltration area

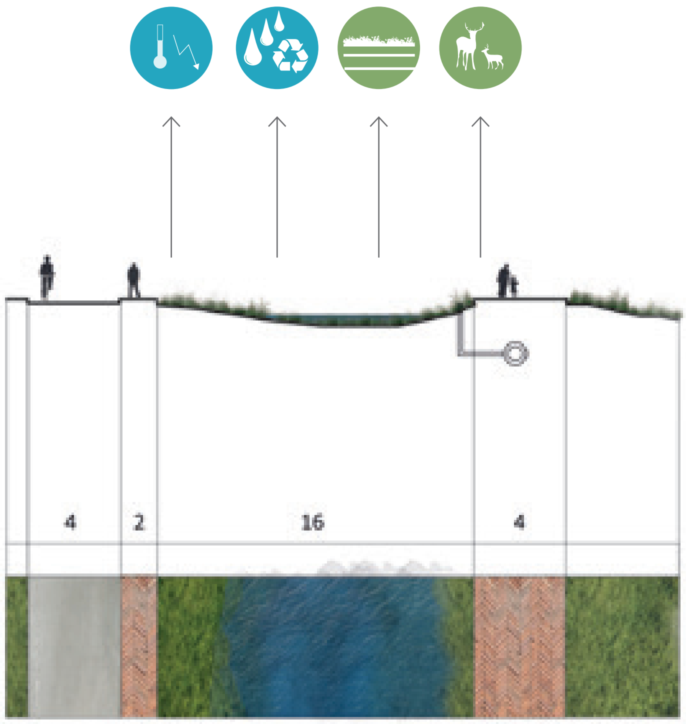


Figure 6.28 Section of the infiltration area including the enhanced ecosystem services (widths indicated in meters)

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Conclusion

The aim of this research was to provide a design solution for the integration of a wastewater treatment plant (WWTP) in public green space (PGS) that is supported by stakeholders. Design criteria for integrating a wastewater treatment plant and design criteria for enhancing ecosystem services in public green space are combined into landscape models. These landscape models are evaluated in terms of ecosystem functioning and on their potential to integrate a wastewater treatment plant, both by me and a group of stakeholders. This provided the required information to develop an integral landscape design for the integration of a wastewater treatment plant in public green space.

Public green spaces can contain ecosystems and the benefits that people can derive from these ecosystems are the ecosystem services. There are many ecosystem services but only a selection is relevant to be enhanced in public green space. There are several ways to enhance these services. For each ecosystem service there are design criteria for enhancing them in public green space. For example, the ecosystem service water regulation can be enhanced by integrating a retention area in public green space.
The design criteria for integrating a wastewater treatment plant depend on the type of treatment plant that is integrated. The conventional treatment system, activated-sludge, requires a large space and contains bufferzone requirements, whereas the Nereda® WWTP and the Biomakery WWTP require less space and have limited bufferzone requirements, which makes them more suitable to be integrated in public green space.

A model study on the integration of the design criteria for enhancing ecosystem services and integrating a wastewater treatment plant in public green space showed that ecosystem services can be enhanced by reusing the resources such as purified water from the wastewater treatment plant in public green space. The landscape models were developed for the location Strijp-S in Eindhoven. Strijp-S is an urban district for whom various stakeholders already have the ambition to integrate a wastewater treatment plant in the future that not only treats wastewater, but brings added benefits to the environment. The models showed that the purified water can be reused in bioswales, in retention areas, for fountains and in infiltration areas to contribute to the enhancement of ecosystem services in public green space. The models also indicated that the activated-sludge wastewater treatment plant is unsuitable to be integrated in pubic green space; that the Nereda® wastewater treatment plant is more suitable but has less potential to enhance ecosystem services and that the Biomakery wastewater treatment plant has the most potential since the treatment plant itself is accessible for the public and can provide recreational and educational benefits.

Feedback from the stakeholders with knowledge on wastewater treatment, water management and urban development was retrieved during a workshop and by conducting a survey. During the workshop the stakeholders gave feedback on models, particularly on the the enhancement of ecosystem services in public green space, the preferred treatment type and on the design location. An important remark made during the workshop was the need to emphasize the service ‘resource recovery’ in the landscape design. This indicated how important it is to reuse the resources from the wastewater treatment plant in pubic green space, especially reusing treated water. The remarks by the stakeholders on the design location in the models proved that there is a more suitable design location on Strijp-S, that has more potential to enhance ecosystem services than the location presented in the models. The final design therefore encompasses this alternative design location.

During the workshop the stakeholders indicated a strong preference for the Biomakery wastewater treatment plant and this is in line with the results of the survey. The stakeholders already indicated that the Biomakery wastewater treatment plant has most potential to enhance ecosystem services and this was confirmed by the survey, which showed that the characteristics of the Biomakery wastewater treatment plant such as a small footprint, no bufferzone requirements, the potential for recreation and education and a good accessibility for the public are very important when integrating a wastewater treatment plant in public green space. Nevertheless, it should be noted that the development of the Biomakery treatment plant is still in an experimental phase whereas the Nereda® treatment technique is a proven and reliable technique.

Thus, to integrate a wastewater treatment plant in public green space with the aim to enhance ecosystem services, the Biomakery wastewater treatment plant has the most potential in combination with the integration of bioswales, retention areas, fountains and infiltration areas. The integration of these principles enhance several ecosystem services, most importantly water regulation, climate regulation, habitat for biodiversity, soil quality improvement and recreation. The integration of the wastewater treatment plant and the integration of the principles are connected with each other and require an understanding of the available resources to reuse in public green space and their quantities. Therefore, the collaboration with a MSc student of the chair group Environmental Technology was required to obtain the needed information about resources in relation to the wastewater treatment plant. It can be concluded that the solution to integrate a wastewater treatment plant in public green space can be found by understanding which resources of the treatment process can be reused in public green space to enhance ecosystem services. Most evidently the purified water can be reused in several ways for the enhancement of ecosystem to provide many benefits for the environment and the residents.

Discussion and recommendations

Enhancing ecosystem services

Using the concept ecosystem services as a guide for enhancing benefits in public green space turned out to be very helpful to qualify what the specific benefits are, but it is also a difficult concept to grasp since it is very broad. There is a large amount of literature available on ecosystem services in general, but knowledge about particularly urban ecosystems is still developing. Current literature has strived to advance the understanding of urban ecosystem services, for example in their socio-cultural dimensions. In major initiatives, like the Economics of Ecosystems and biodiversity (TEEB, 2010) and the Millennium Ecosystem Assessment (MEA, 2005) the urban ecosystem that could be provided in urban areas received increasing intention, nevertheless, in comparison to ecosystems in the natural environment such as forests and wetlands, the attention given to the urban ecosystems is modest. Moreover, most studies focus on single ecosystems or values, rather than all potential ecosystem services in the urban context.
The selection of ecosystem services described in this study is chosen because they were mentioned in scientific articles in relation to the urban context. Since knowledge about this topic is still developing, there might be other services that are not mentioned in this study, but that could potentially also be beneficial in public green space.
It turned out that not all of the ecosystem services are equally important. For example, climate regulation and water regulation proved to be be major ecosystem services to enhance when integrating a wastewater treatment plant, but sense of place turned out to be much harder to enhance with the integration of a wastewater treatment plant since this service is not clearly definable. Nevertheless, the concept of ecosystem services helped to define design criteria that enhance benefits in public green space and is therefore suitable to use when the aim is to integrate a wastewater treatment plant in public green space.

Integrating a wastewater treatment plant

In this study it is researched how three different treatment types can be integrated in public green space, of which one conventional technique, one new and proven technique and one new and experimental technique. This selection was based on the selection of wastewater treatment plants by de Bonth (2016) and was chosen in order to include varying range of treatment techniques. However, there are more wastewater treatment techniques available that might have potential as well but were not examined in this research.
An issue that might arise when integrating a wastewater treatment plant in public green space is a lack of public support. Although there would be no negative consequences for the residents when a wastewater treatment plant would be integrated, the idea of a WWTP in their neighbourhood might not be appealing for people. Generally, when people envision a wastewater treatment plant, they think of the conventional activated-sludge technique and it is very reasonable not to want such a technique in close distance to your living environment. Alternative techniques and their potential to be integrated in public green space are relatively new and unfamiliar to people. Good communication to residents and description of what a wastewater treatment plant like the Biomakery type involves is therefore important when realizing a wastewater treatment plant in public green space.

Models and workshop

The development of models and the evaluation by stakeholders were a useful tool in order to come up with a suitable design solution for Strijp-S. During the development of the models, focus was already on part of the available space of Strijp-S for the integration of the wastewater treatment plant that seemed the most suitable from the analysis results. During the workshop it turned out that this area is considered as unsuitable for the integration of a wastewater treatment plant in public green space and an alternative location was preferred by the stakeholders. This indicates the importance of the workshop in a project like this. The expert knowledge of stakeholders on the area and water treatment turned out to be crucial in order to come with a suitable design solution. Especially in projects were the knowledge of multiple research disciplines are combined, organizing a meeting were people can share their ideas is essential. The transdisciplinary approach this study was beneficial for the process and it is recommended for similar projects to cooperate through a transdisciplinary approach with both landscape architects, water management experts and urban developers.

The group of stakeholders participating in the workshop consisted of ten people of whom eight had a background in water treatment, water infrastructure or water management people and one person participating with knowledge on the area development of Strijp-S was present plus my supervisor with a landscape architects background and knowledge on ecosystem services. Ideally, the participating group would have consisted of an equal amount of experts on water treatment and experts in landscape architecture. Due to contact with waterboard the Dommel, fortunately many people with a background on water treatment participated in the workshop although this resulted in a slightly one sided discussion with emphasis on wastewater treatment. Limited feedback was given on the actual design from a landscape perspective due to this.

The integral design

The potentials for integrating a wastewater treatment plant in public green space relies on the location desired for the integration of a wastewater treatment plant. Every urban context is unique and need different ecosystem services to be enhanced. This makes the analysis of the area in terms of the ecosystem functioning essential in order to understand what the potentials are. Besides understanding which ecosystem services could be enhanced, it is important to understand the green infrastructural network in the city, in order to contribute to a stronger green infrastructure on a larger scale as well.

The integral design is developed according to the idea of reusing resources of the WWTP to enhance ecosystem services. Water was the most evident resource aimed on in the design with clearly a high potential to enhance ecosystem services. However, there are also other potentials that are not elaborated on because they are complex processes that require further research, for example the reuse of purified water to generate energy through thermal storage. Possibly there are more resource recovery potentials that could lead to an even more sustainable integration of a wastewater treatment plant. Further research could investigate this in order to utilize all the actual possibilities when integrating a wastewater treatment plant in public green space.

Appendix 1

Glossary

Green infrastructure

"A strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, Green Infrastructure is present in rural and urban settings" (European Commission 2013, p.3)

Ecosystems

"An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit. Humans are an integral part of ecosystems" (MEA, 2005, p. 49)

Ecosystem services

''The benefits human populations derive, directly or indirectly, from ecosystem functions'' (Costanza et al., 1998, p. 253)

Urban ecosystems

"All natural green and blue areas in the city, including streets and ponds. In reality, street trees are too small to be considered ecosystems in their own right, and should rather be regarded as elements of a larger system" (Bolund & Hunhammar, 1999, p. 294).

Urban ecosystem services

"The services provided by urban ecosystems and their components" (Gómez-Baggethun & Barton, 2013, p.236).

Decentralized wastewater treatment

"An onsite or cluster wastewater system that is used to treat and dispose of relatively small volumes of wastewater, generally originating from individual or groups of dwellings and businesses that are located relatively close together" (U.S Environmental Protection Agency, 1997, p. 2).

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Appendix 2

UITNODIGING WORKSHOP:

'Water op Strijp-S'

Het inpassen van een multifunctionele afvalwaterzuiveringsinstallatie in de stedelijke omgeving van Strijp-S

Dinsdag 02-02-2016

14.00 - 16.30 uur

Videolab (6e etage), Torenallee 20, Eindhoven

STRIJP-S   WAGENINGEN UR   Waterschap De Dommel

Strijp-S is een innovatieve plek waar initiatieven uit allerlei vakgebieden samenkomen. Zoals de meeste van jullie inmiddels zullen weten, is ook Waterschap de Dommel actief met een initiatief om het 'waterbeheer van de toekomst' te realiseren op Strijp-S. Dit initiatief wordt vormgegeven middels een proeftuin met als basis een afvalwaterzuivering, waar meerdere functionaliteiten aan gekoppeld kunnen worden.

Momenteel wordt verkend of het concept Biomakery van Biopolus hiervoor geschikt is. Daarvoor is het nodig om een verkennend en vergelijkend onderzoek met andere technieken uit te werken. Om dit te bepalen organiseert Wageningen Universiteit en Waterschap de Dommel op de locatie van Park Strijp Beheer een workshop. Deze workshop zal verzorgd worden door ons! Twee studenten van de Universiteit van Wageningen. Op dit moment zijn wij bezig met de voorbereidingen van het project 'Water op Strijp-S' in de vorm van een MSc thesis. De workshop maakt deel uit van ons afstudeertraject en zal dienen als input voor de MSc thesis. Bij deze willen wij u daarom uitnodigen op dinsdagmiddag 2 februari, van 14.00 uur tot 16.30 uur bij Park Strijp Beheer.

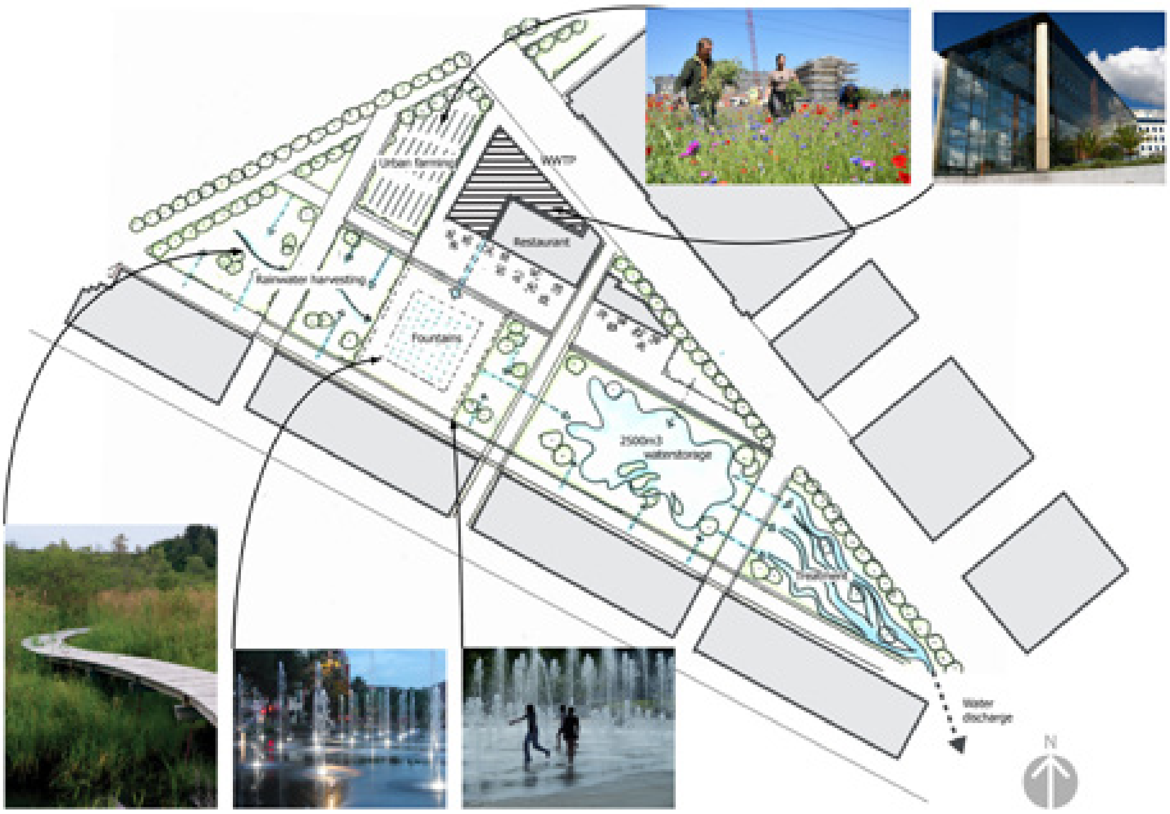
Tijdens deze workshop krijgt u inzicht in drie verschillende waterzuiveringstechnologieën (Actief slib, Nereda® en Biomakery). Tegelijkertijd wordt er gekeken naar de landschappelijke inpassing van deze waterzuiveringen in de stedelijke omgeving van Strijp-S. Hiervoor zijn drie verschillende landschappelijke en technologische modellen opgesteld. Het doel van de workshop is om de verschillende modellen kritisch te beoordelen en zo tot een goede keuze te komen voor Strijp-S. Om dit te bereiken hebben we jullie kennis en inzichten van Strijp-S en het gebruik van (afval)water in de stedelijke omgeving nodig. Hopelijk kunnen we op deze wijze, tezamen met jullie, de huidige plannen voor het project 'Water op Strijp-S' naar een hoger niveau brengen!

U bent van harte welkom,

Vera Hetem en Loek de Bonth.

Appendix 3

The alternative Biomakery models



Appendix 4

List of participants of the workshop

István Koller- Waterschap de Dommel
Jack Crielaard- Waterschap de Dommel
Doy Schellekens- Waterschap de Dommel (only filled in survey)
Wiebke Klemm- Landscape architecture department Wageningen University
Lars Kuiperi- Hydroscope
Eric van Griensven - Brabantwater
Erik van Kronenburg- Waterschap de Dommel, gemeente Eindhoven
Alwin Beernink- Park Strijp Beheer
Paul van der Wee- MJ Oomen
...

Loek de Bonth- MSc student Wageningen University
Vera Hetem- MSc student Wageningen University

Appendix 5

Survey

Beste genodigden,

In de workshop willen we gezamenlijk met stakeholders drie modellen (landschappelijk en technologisch) voor het Strijp-S terrein beoordelen middels een multi-criteria analyse (MCA). Als input voor de MCA willen we u, voorafgaande aan de workshop, vragen om de onderstaande criteria te beoordelen. Op deze wijze kunnen we inzicht verkrijgen in de meest en minst belangrijke criteria voor de mogelijke RWZI op Strijp-S. Om dit op een goede manier te kunnen bepalen, vragen we u aan iedere stelling behorende bij het criteria een score van 1 tot 5 toe te kennen. Onderstaand vindt u een overzicht van de toe te kennen scores:

1 = Zeer mee oneens
2 = Mee oneens
3 = Neutraal
4 = Mee eens
5 = Zeer mee eens

Indien u nog commentaar hebt op bepaalde criteria, graag nog andere criteria zou willen toevoegen of iets anders bij zou willen dragen dan kunt u dit kwijt in de kolom '*opmerkingen*'. We zouden het zeer op prijs stellen als we deze ingevulde lijst met een score per criteria, **vóór 27 januari** weer retour van u zouden mogen ontvangen. De resultaten zullen vervolgens door ons worden verwerkt en gepresenteerd tijdens de workshop op 2 februari. Alvast bedankt voor uw medewerking!

Met vriendelijke groet,

Vera Hetem en Loek de Bonth.

Continued appendix 5

Ingevuld door: ....
Functie: ....

Beoordeling stellingen (Beoordeel ieder stelling met een score tussen 1 – 5)			
Criteria	Stellingen	Score	Opmerking
Milieu criteria/stellingen			
Effluent kwaliteit	Het gezuiverde afvalwater moet van goede kwaliteit zijn en mag niet van invloed zijn op de ontvangende waterstroom.		
Energie verbruik	Een RWZI moet in staat zijn om energie neutraal afvalwater te zuiveren.		
Chemicaliën verbruik	Het verbruik van chemicaliën voor de zuivering van afvalwater dient minimaal te zijn.		
Polymeer verbruik	Het verbruik van polymeren voor het onttrekken van water uit slib om vervolgens de verbranding van slib te bevorderen is belangrijk.		
Slib productie	De hoeveelheid geproduceerd slib dient zo laag mogelijk gehouden te worden.		
Hergebruik van (grond)stoffen	Het terugwinnen van waardevolle (grond)stoffen uit afvalwater is geen functie van een RWZI.		
(Afval)water hergebruik	Indien mogelijk dient het gezuiverde afvalwater hergebruikt te worden voor diverse functies (bijvoorbeeld huishoudelijk).		
Technische criteria/stellingen			
Aanpassings-vermogen	Een RWZI moet zich eenvoudig aan kunnen passen aan een veranderende omgeving (bijvoorbeeld als gevolg van bevolkingsgroei).		
Flexibiliteit	Een RWZI dient naast het zuiveren van afvalwater ook andere functies (bijvoorbeeld energie opwekking of grondstoffen terugwinning) te vervullen.		
Proces stabiliteit	De gezuiverde afvalwater kwaliteit dient ook onder variërende omstandigheden (bijvoorbeeld hogere vervuilingsgraad) nagenoeg gelijk te zijn.		
Landschappelijke criteria/stellingen			
Footprint	Een kleine 'footprint' van de RWZI is belangrijk voor de ontwikkeling van een RWZI in de stedelijke omgeving van Strijp-S.		
Grootte van bufferzone	De afstand van de RWZI tot de dichtstbijzijnde publieke functies is belangrijk vanwege veiligheidsvoorschriften (bijv. geluid, geur, etc.).		
Toegankelijkheid	De bufferzone van de RWZI hoeft niet toegankelijk te zijn voor inwoners en bezoekers van Strijp-S.		
Waterhuishouding	De stedelijke omgeving rondom de RWZI dient aspecten zoals regenwater afvoer en -regenwater buffercapaciteit te bevatten op Strijp-S.		
Landschappelijke inpassing	Inpassing van een RWZI incl. bufferzone is van toegevoegde waarde voor de omgeving van Strijp-S en verhoogt de landschappelijke uitstraling.		
Recreatieve en educatieve waarden	De RWZI incl. bufferzone dient nieuwe recreatieve en educatieve mogelijkheden voor de omwonenden en bezoekers van Strijp-S te bevatten.		
Zichtbaarheid water	Het gezuiverde water van de RWZI dient zichtbaar te zijn in het landschap, bijvoorbeeld d.m.v bovengrondse waterafvoer en fonteinen.		
Vergroening door water	De RWZI in de stedelijke omgeving van Strijp-S dient bij te dragen aan de vergroening van de stad.		
Sociale criteria/stellingen			
Lokale ontwikkeling	De RWZI dient lokale ontwikkeling te stimuleren, door samenwerking tussen overheidsorganisaties, industrie en educatieve instellingen op Strijp-S.		
Bewustzijn	Het is van belang dat de RWZI mensen bewust maakt van de waarde van water en de inspanningen die vereist zijn om afvalwater te zuiveren.		
Economische criteria/stellingen			
Investeringskosten	De investeringskosten bepalen in grote mate de keuze van de waterzuiveringstechnologie.		
Operationele kosten	De operationele kosten bepalen in grote mate de keuze van de waterzuiveringstechnologie.		

Appendix 6

All categories of the survey, consisting of five criteria groups. The percentages are the scores that the stakeholders gave for each statement, the other scores that are indicated per treatment type are the scores given by de Bonth (2016). These scores are combined and this resulted in a total score for each WWTP type.

		AS		Nereda		Biopolus	
Milieu criteria/stellingen	**Weighing**	**Score**	**Preference**	**Score**	**Preference**	**Score**	**Preference**
Effluent quality	4,7%	4	0,18755609	4	0,18755609	4	0,18755609
Energy consumption	3,3%	2	0,06580915	5	0,16452288	1	0,03290458
Chemical usage	4,2%	1	0,04195334	5	0,20976668	1	0,04195334
Polymer usage	2,8%	3	0,08390667	4	0,11187556	1	0,02796889
Sludge production	3,9%	4	0,15465151	5	0,19331439	1	0,03866288
Resource recovery and reuse	4,2%	2	0,08390667	3	0,12586001	2	0,08390667
(Waste)water reuse	4,4%	4	0,17439426	4	0,17439426	4	0,17439426
Closing cycles	4,4%	4	0,17439426	5	0,21799282	5	0,21799282
			0,79217768		1,16728986		0,58734669
Technische criteria/stellingen							
Adaptability (population)	4,2%	2	0,08390667	5	0,20976668	5	0,20976668
Flexibility	4,2%	3	0,12586001	5	0,20976668	5	0,20976668
Process stability	4,3%	3	0,12832785	5	0,21387975	5	0,21387975
			0,33809453		0,6334131		0,6334131
Landschappelijke criteria/stellingen							
Physical footprint	4,3%	1	0,04277595	3	0,12832785	5	0,21387975
Buffer zone requirement	3,3%	2	0,06640742	5	0,16601855	5	0,16601855
Accesibility	3,5%	1	0,03537242	2	0,07074484	4	0,14148968
Water management	4,1%	1	0,04113072	5	0,2056536	5	0,2056536
Aesthetic appearance	4,4%	1	0,04359856	3	0,13079569	5	0,21799282
Recreational and educational values	4,2%	1	0,04217768	3	0,12653305	5	0,21088842
Urban water	4,4%	1	0,04359856	3	0,13079569	5	0,21799282
Urban green	4,7%	1	0,04688902	3	0,14066707	5	0,23444511
			0,14455579		0,36509124		0,52138797
Social criteria/stellingen							
Local development	4,4%	3	0,13326354	3	0,13326354	5	0,22210589
Awareness	4,7%	1	0,04688902	3	0,14066707	5	0,23444511
Responsibility	3,9%	4	0,15794197	4	0,15794197	5	0,19742746
			0,18015256		0,2739306		0,456551
Economische criteria/stellingen							
CAPEX	2,6%	1	0,02632366	5	0,13161831	4	0,10529465
OPEX	3,7%	3	0,11105295	4	0,1480706	1	0,03701765
Social costs	3,3%	1	0,03290458	4	0,13161831	4	0,13161831
			0,13737661		0,2796889		0,14231229
TOTAL SCORE			1,59235716		2,7194137		2,34101107
RANKING							