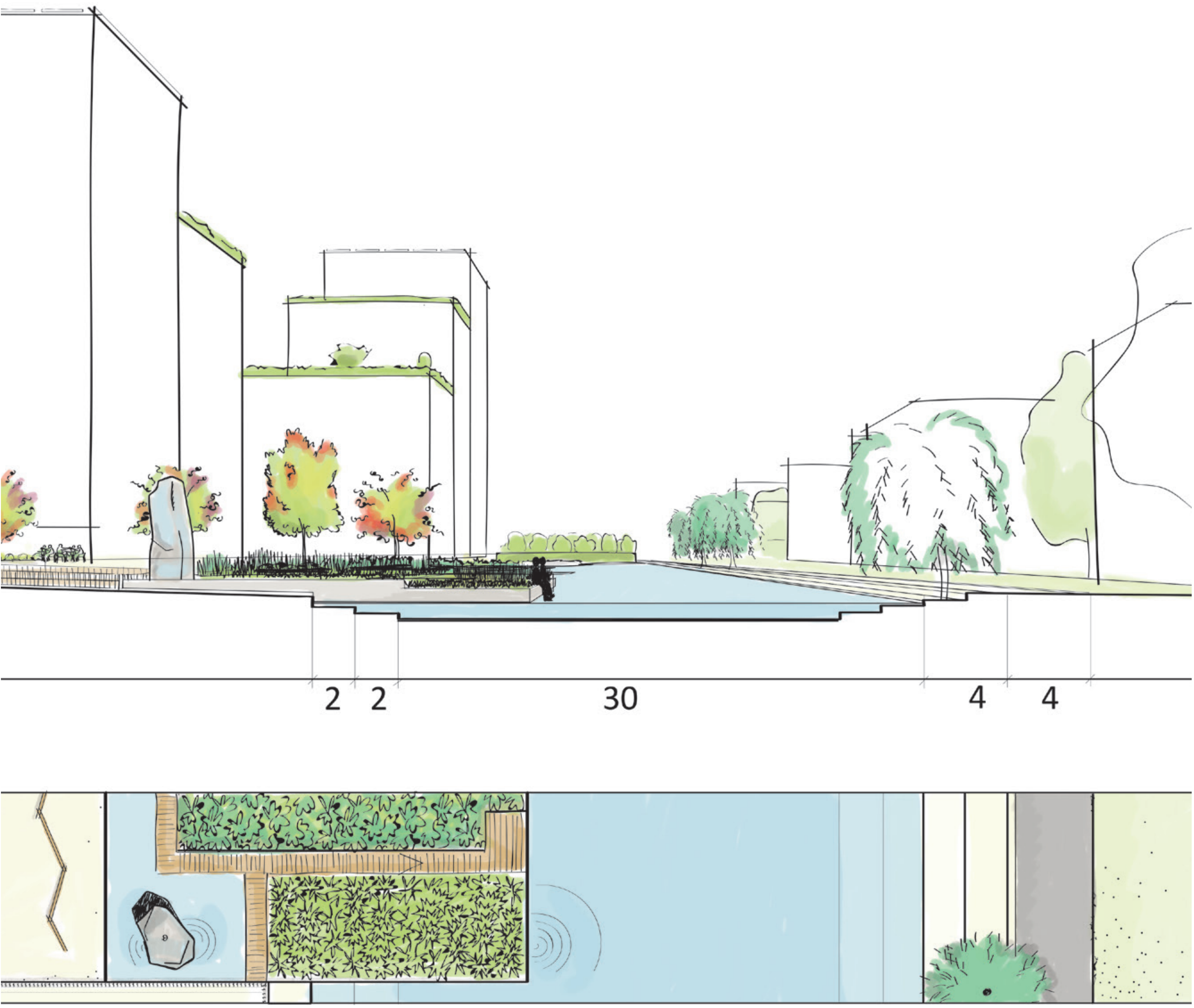
URBAN LIVING WITH WATER
Sustainable stormwater management for Liesing in Vienna



Caroline Bruens

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ABSTRACT

This thesis addresses how sustainable stormwater management can play a self-evident role in a trans-disciplinary landscape design process. It will be seen that experts, community and an urban designer are needed in order to explore improvements of the urban drainage system and possibilities for synergies. These synergies will enable stormwater management to become part of urban planning and design. Research by design has to be central in which it is important to approach stormwater as a system and work through different scales. The Sustainable Urban Drainage System (SUDS) approach and the derived design criteria are used as guidance for the design. Integration of sustainable stormwater management into the urban landscape is explored for the Liesingbach catchment area in Vienna and elaborated for the region Liesing Mitte and the new-build area Wiesen-Ost.

Keywords: Stormwater management/ Sustainable Urban Drainage System (SUDS)/ trans-disciplinary design process/ through the scales/ Liesingbach/ Vienna

CONTENT

PART I FASCINATION

1. INTRODUCTION THEME

This chapter introduces my fascination and the way I think water and green should be integrated into the city, followed by the context of research & design of the thesis, my aim, research & design process and my perspective from a landscape architect.

1.1 FASCINATION: HANGING GARDENS OF BABYLON

The Hanging Gardens of Babylon evoke a romantic picture of lush greenery and exotic, sweet smelling flowers hanging down from the buildings. The sight must have been magnificent, which is why Herodotus considered them as one of the seven Wonders of the Ancient World, without even seen it (Ancient History Encyclopedia, 2015). With no archaeological evidence, many have dismissed these gardens as a myth.

Over the years images were created of how the Hanging Gardens of Babylon could have looked like (Figure 1). Water and green were well integrated in the urban design and form the source of living for this city in the dessert.

Figure 1: Hanging Gardens of Babylon (Wallerz, 2015).

1.2 CONTEXT OF RESEARCH & DESIGN

Water isn't always given the priority and attention it should have in design of the built environment. Over the past centuries we built, paved and excluded green and water from our cities.

Stormwater was designed out by the traditional (civil engineering) system in which underground storm sewers discharge water as quickly as possible. Heavy rainfall events and impacts of climate change make the urban water system more sensitive and piped system incidentally insufficient to protect properties from flooding.

Therefore, stormwater should be really designed in. As responds to that, holistic approaches have been developed over the last decennia and applied in projects worldwide. Sustainable Urban Drainage System (SUDS) is one of the approaches. Besides dealing with water quantity, it also deals with water quality, amenity, and ecology.

Sustainable stormwater management cannot be separated from wider urban challenges, since it is part of the urban environment. In order to know what is going on in an area, experts and local community should be involved so solutions are community and environmental specific. Design has to be central in the trans-disciplinary design process.

The location of the Liesingbach catchment basin, in Vienna is being studied. In August 2010 a heavy rainfall event, with a return period of 50 years, caused urban flooding and a lot of damage. The traditional stormwater system is calculated for heavy rainfall events with a return period of 5 years. Changing the traditional stormwater sewers is prohibitely expensive. By integrating small-scale SUDS in the urban open spaces, the area can be made less sensitive to heavy rainfall events.

1.3 AIM

To explore, through landscape design, the possibilities for integrating sustainable stormwater management in the urban landscape of the Liesingbach catchment basin, and look at the same time to synergies.

1.4 RESEARCH AND DESIGN PROCESS

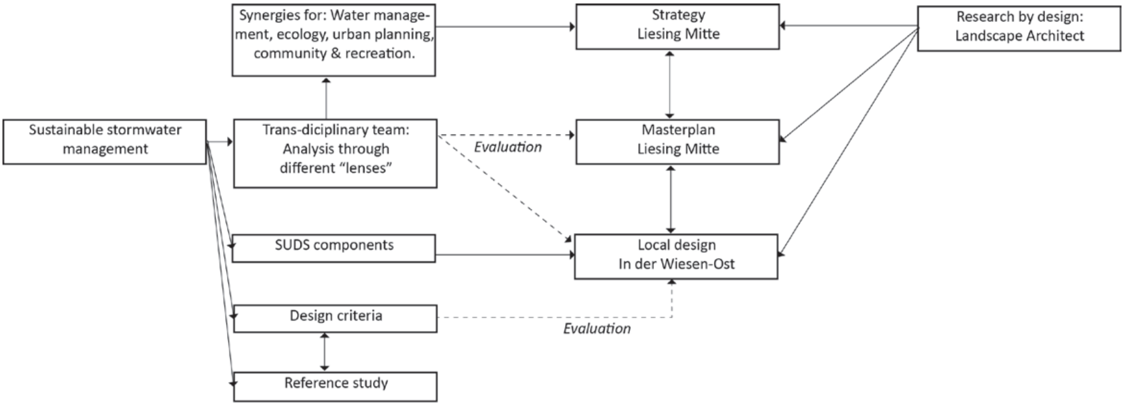


Figure 2: Research and design process

The research and design process is build upon the theme sustainable stormwater management for the case of Liesingbach catchment basin. The research part consists of literature study, reference study, and analysis through different "lenses" in order to look for wider urban synergies.

Research and (research by) design come together in the regional strategy for the urban area of the Liesingbach catchment basin and in the landscape design on the scale of Liesing Mitte and In der Wiesen-Ost.

Different "lenses" and design criteria are used for the evaluation of my landscape design.

1.5 PERSPECTIVE FROM LANDSCAPE ARCHITECT

In this thesis I will explore the next generation of stormwater systems, through landscape design. Sustainable stormwater management should not be seperated from present and future urban challenges. By looking through different "lenses" (perspectives of experts and community) and researching on different scales, my landscape design proposes integrated solutions which are community and environmental specific.

2. INTRODUCTION SITE

From the introduction on the theme into the introduction on the site. This chapter will give background information on the project area: the Liesingbach catchment basin, in Vienna. We will look into the human occupation, urban drainage system and climate.

2.1 LIESINGBACH IN VIENNA

Vienna is the capital city of Austria with a population of 2,6 million. The city is located on the edge of the Alps and along the river Danube (Figure 3). Due to the protected environments in the east and west of Vienna, urban growth has occurred in a wedge shape to the south (Figure 4) (Wien Voraus (b), 2014).

Two streams (Wienfluss and Liesingbach) flow from Vienna Woods to the Danube and connect the protected environments with each other. Both streams are characterized as heavily modified. The regulation of the Liesingbach happened between 1947 and 1969 (Figure 5) (MA 45, 2014).

In this thesis I focus on stream the Liesingbach, which connects Vienna Woods, urban area, Terrace landscape, and Donaupark-Auen (Figure 6).

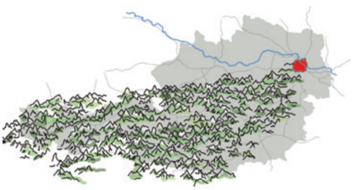


Figure 3: Vienna in Austria.

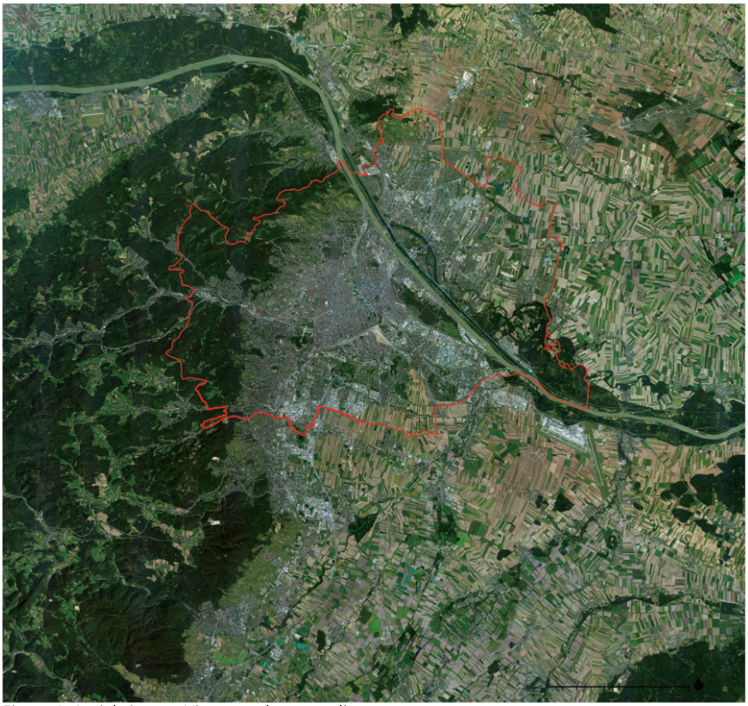


Figure 4: Aerial view on Vienna and surroundings.

Figure 5: Vienna with rivers and streams.

Figure 6: Liesingbach connects 3 protected environments.

2.2 HUMAN OCCUPATION OF THE CATCHMENT BASIN
2.2.1 From villages to Viennese district

The (natural) catchment basin of the Liesingbach is defined by relief of the area (Figure 7). The length of the stream is 17 km and the total catchment area is 112,4 km^{2}.

In the natural situation the catchment basin was part of a forest with a broad and dynamic streambed (Figure 8). In the current situation the largest part of the forest made place for urbanization and agriculture. The Liesingbach lost its space and dynamics (Figure 9).

The changes over time of the Liesingbach and the landscape are explained and shown on the next page and figure 10.

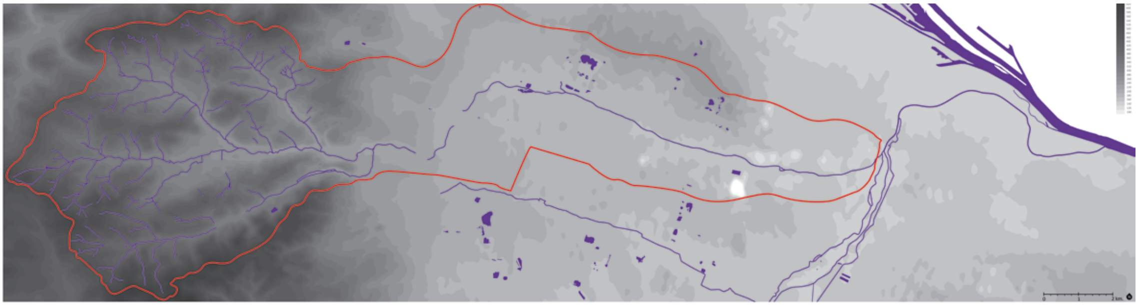


Figure 7: Catchment basin and relief

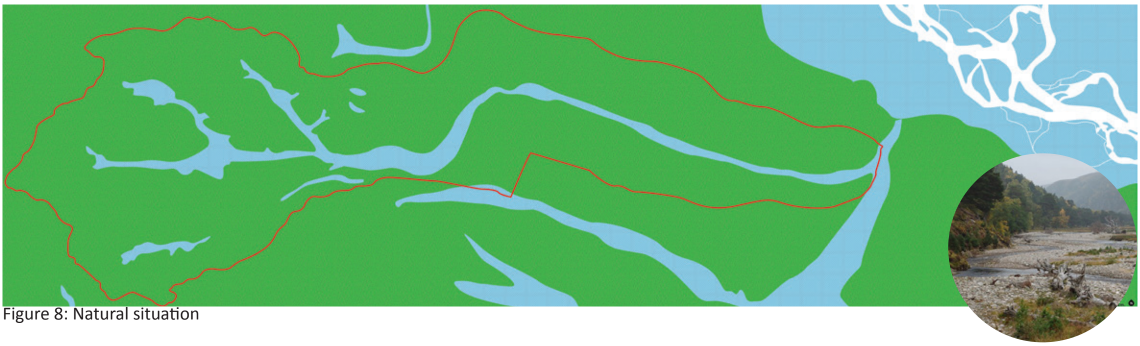
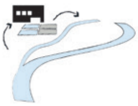


Figure 8: Natural situation

Figure 9: Current situation.

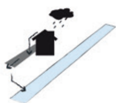
The first settlements begun along the stream in the 11th-12th century. The following villages centres orginate from that time: Rodaun, Liesing, Kalksburg, Atzgersdorf, Erlaa, Inzersdorf, Rothneusiedl, Oberlaa, and Unterlaa. On the banks of the Liesingbach were meadows, around the villages cropland and in the south (Oberlaa) vineyards. Wine was an important economic activity in every village.

In the 13th century, many (water)mill sites appeared along the Liesingbach. These were important centers for grain processing.

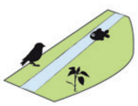


The opening of the railway in 1841 was an important change for the villages: Liesing, Atzgersdorf and Inzersdorf. Approximately 1000 companies (in textile, food and later chemical production) settled in the area. In Inzersdorf there was also a huge brick producer. The Drasche straße and park are reminders of this.

Al this economic activity resulted in paved streets with lighting and rebuilding bridges, which was not very common in that time. In the 20th century the city of Vienna expanded, and in 1952 Liesing was incorporated as the 23rd district of Vienna combining eight former municipalities: Atzgersdorf, Erlaa, Inzersdorf, Kalksburg, Liesing, Mauer, Rodaun, and Siebenhirten.



Floods of the Liesingbach happened mainly in Inzersdorf. As result of that, a regulation of the Liesingbach (1947-1969) was executed for quick discharge and no flooding. Creek loops (middle stream) and meanders (downstream) were cut off and filled up. The increase of urbanization and hard surfaces in the catchment basin led to an increase in the peak in the hydrograph and new measures had to be taken to provide flood safety.



In 1980, three retention basins were constructed and the banks were raised. This was an opportunity for the appearance of bushes and trees. Nevertheless the self cleansing ability of the Liesingbach was poor and had a negative influence on flora and fauna species and species composition. In order to improve the ecological quality, revitalization Liesingbach projects had to be executed between 1995 -2015 for the European Waterboard.

The Liesingbach is now seen as the “leisure and pleasure area” of the region (Berger et al., 2010) (MA 45, 2014).

The human occupation of the Liesingbach catchment basin in the past centuries has resulted in a patchwork of urban structures (Figure 11). Each type of urban structure has its own imperviousness rate. The current green network is shown in Figure 12. The Liesingbach stands out.

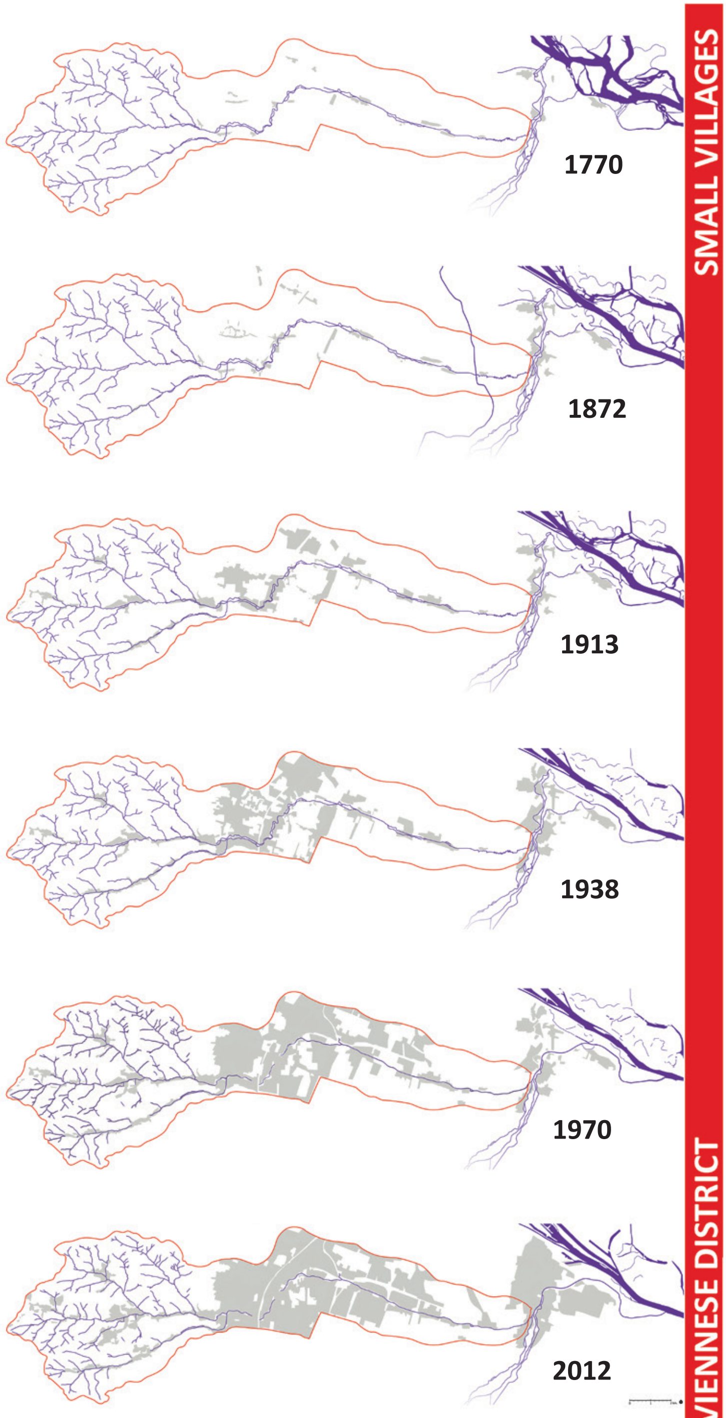
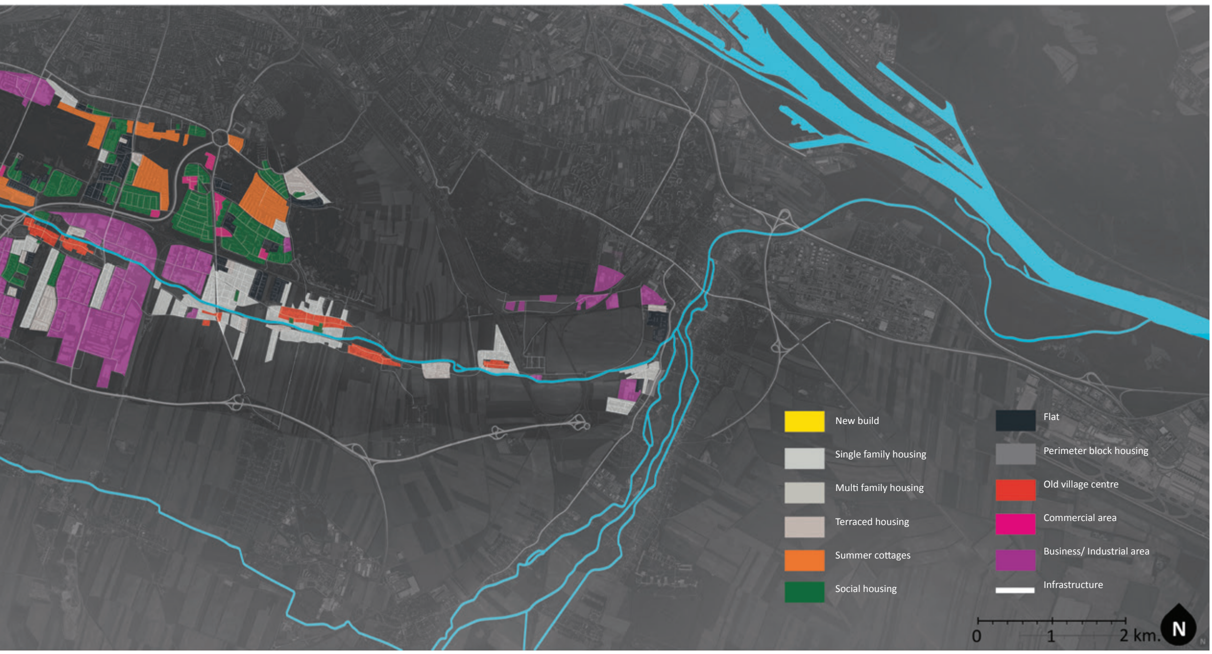


Figure 10: Urbanization in the catchment basin

Figure 11: Catchment basin and urban structures with different imperviousness rates (Berger et al., 2010).



New build
?%

Single family housing
21-30%

Multi family housing
21-30%

Terraced housing
21-40%

Summer cottages
26-40%

Social housing
31-35%

Flat
35-60%

Perimeter block housing
46-60%

Old village centre
51-60%

Commercial area
81-90%

Business area
60-100%

Infrastructure
100%

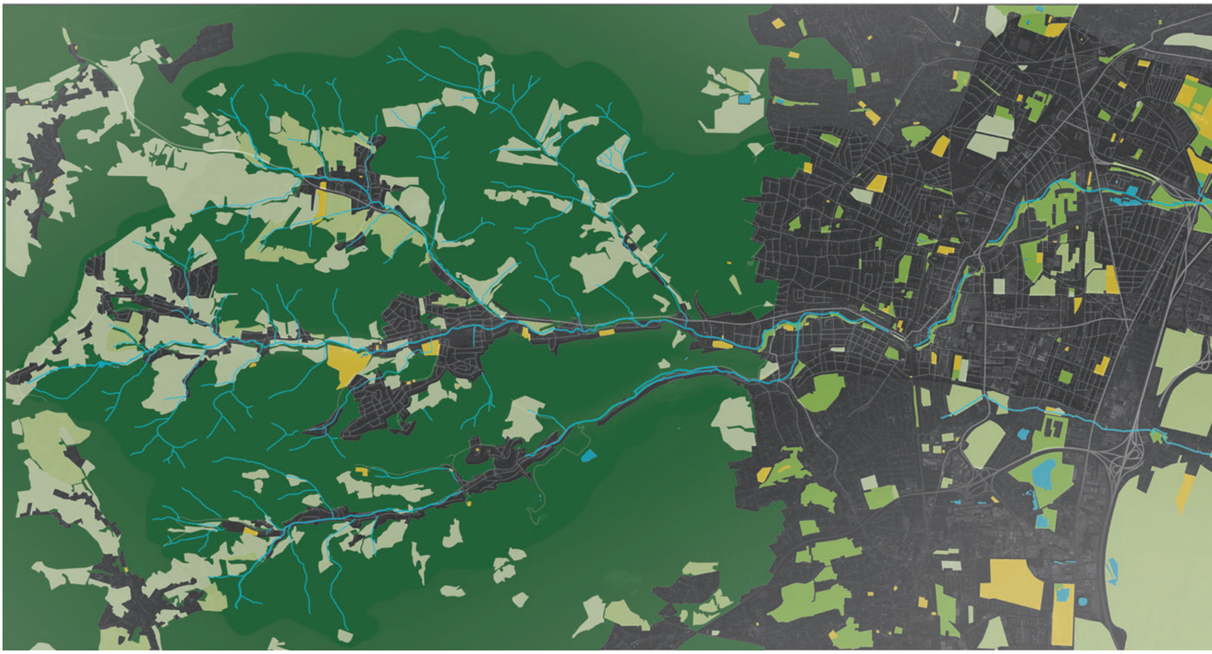
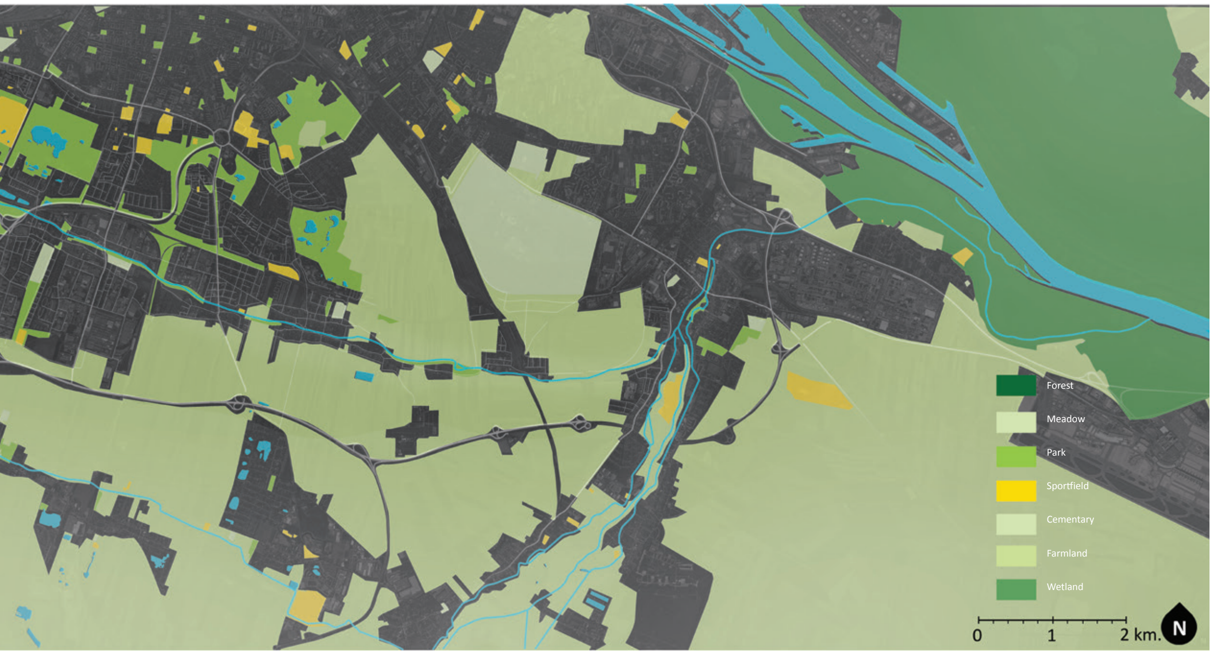
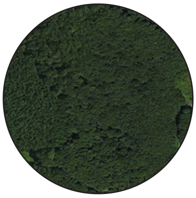


Figure 12: Catchment basin and green-blue network.



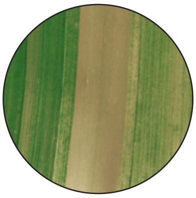

Forest


Meadow


Park


Sportfield


Cementery


Farmland


Wetland

2.2.2 Urban drainage

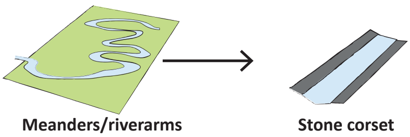
Figure 13: Catchment basin and urban drainage sytem.

The major part of the urban area in the Liesingbach catchment basin has a separate sewer system (Figure 13). This means that stormwater runoff is discharged through stormwater pipes into the Liesingbach (WKN, 2015).

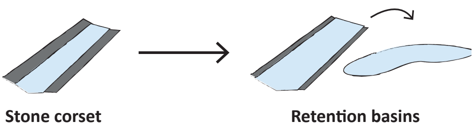
As we will see in Chapter 4, urbanization has a huge impact on the drainage system. It produces higher and more sudden peaks in the volume of stormwater and introduces pollutants (Butler et al., 2011) (Ven, 2011). After a heavy rainfall event, the watervolume of the Liesingbach can be up to 2000 times more (Grimm, 2010). In order to cope with these high and sudden peaks of stormwater in the Liesingbach, changes had been made for quick discharge to avoid flooding. It started in 1947-1969 with a regulation of the Liesingbach. Creek loops (middle stream) and meanders (downstream) were cut off and filled up. This measure was sufficient for a decade, till the next wave of urbanization. In the 80's, three retention basins were built. Regulation and retention basins dealt with the quantity of the stormwater. In order to improve the ecological quality, revitalization Liesingbach projects had been executed between 1999 -2015 for the European Waterboard (Figure 14) (MA 45, 2014).

With an eye on the future, the focus will be on sustainable stormwater management. Sustainable stormwater management consists in reducing stormwater runoff by keeping water on the surface, storing it at its source, and delaying its trip to the main watercourse. More on this topic will be explained in Chapter 4.

Regulation (1947-1969)



Three retention basins (1980)



Revitalisation (1999 - 2015)

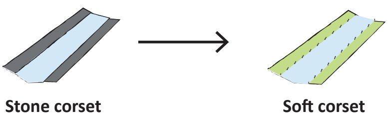


Figure 14: Changes to the Liesingbach.

2.3 CLIMATE

Because of its geographic location, Vienna is located in a transition zone of two climates: The marine west coast climate and the continental humid climate. These two zones cause differences in rainfall, temperature and amount of heat and frost days, within the city. (Berger et al., 2010). The imperviousness rate between the city centre and the suburbs of Vienna increases the effect.

Overall, the average annual rainfall is 600 mm in a year. With highest average rainfall in the month of June (Figure 15) (Worldweather, 2015). Differences in annual rainfall within the catchment basin can be seen in figure 16 (Berger et al., 2010).

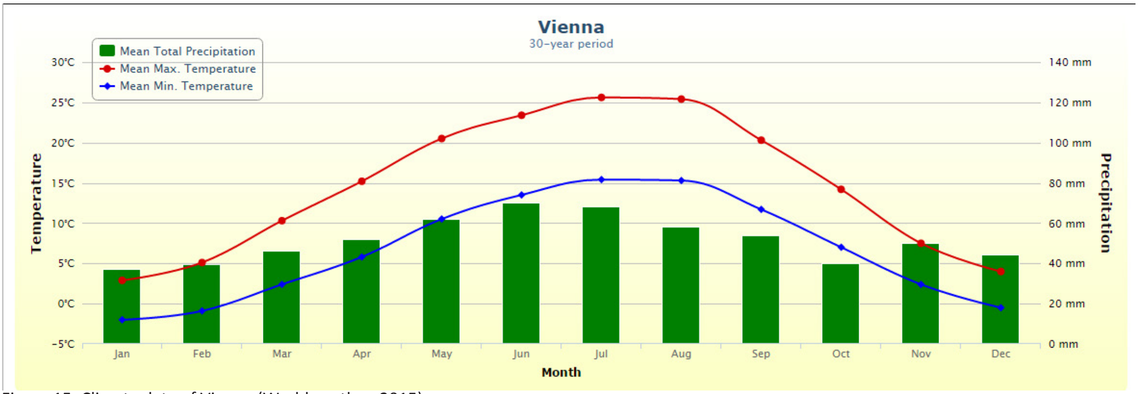


Figure 15: Climate data of Vienna (Worldweather, 2015).

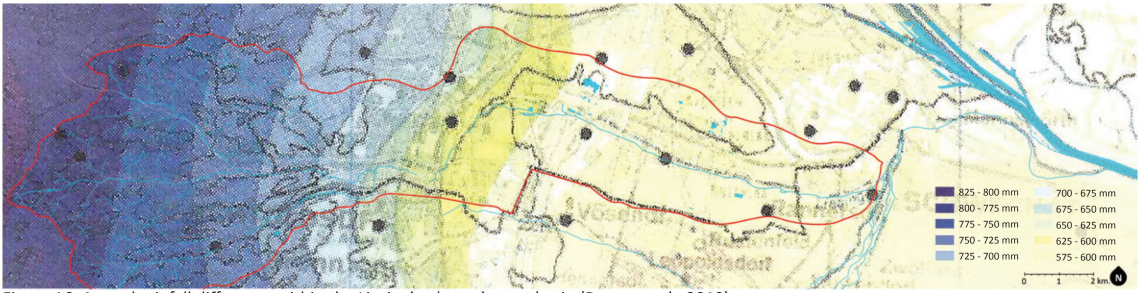


Figure 16: Annual rainfall difference within the Liesingbach catchment basin (Berger et al., 2010).

PART II EXPLORING

3. RESEARCH METHODOLOGY

This chapter clarifies the graduation studio in which this thesis takes place, followed by a more general research questions, methodology and the research methods I used.

3.1 GRADUATION STUDIO: FLOWSCAPES

This graduation project takes place in Flowscapes studio in master of Landscape Architecture at the TUDelft. "*The landscape architecture graduation laboratory explores spatial, societal and environmental issues by design research and research by design approaches. It addresses landscape architecture themes and projects from different perspectives and in various contexts.*" (Nijhuis et al., 2014:1)

3.2 RESEARCH QUESTION

How can sustainable stormwater management play a self-evident role in a trans-disciplinary landscape design process to improve urban quality in general? This is tested in the case of the Liesingbach catchment basin.

Subquestions:

1. How can the fact that stormwater management be approached as a system be used in landscape design processes?
2. What is the potential of stormwater management to improve not only the urban drainage, but also the urban quality?
3. How can (sustainable) stormwater management become self-evident in urban planning and design?

3.3 METHODOLOGY: RESEARCH BY DESIGN

The process of design is used as a tool to make problems visual and spatial and to generate solutions (Bobbink et al., 2012). Sustainable stormwater management will be explored, through research by design, for the urban area of the Liesingbach catchment basin.

3.4 RESEARCH METHODS

This research is based on mixed methods, with a masterplan for Liesing Mitte and a design for In der Wiesen-Ost as outcome.

1) Literature review: of scientific articles, books, data in order to understand sustainable stormwater management and the different roles, analyze the landscape, and set design criteria which can be used as guideline for the designer.

2) Role play: as basis for landscape analysis in order to get the holistic approach of integrating sustainable stormwater management.

3) Map study: to analyze landscape and its systems on maps.

4) Reference study: to get inspiration for my project area and check the set of design criteria.

5) Field trip: to my projectarea Liesing in Vienna and I have also been in Malmö to visit two SUDS projects: Augustenborg and Exhibition area Bo01.

6) Calculations: with ACO Stormbrixx Configuration Software in order to estimate the impact of proposed SUDS components on the stormwater runoff.

4. THEORETICAL BACKGROUND

Stormwater is rainfall (or water from any other form of precipitation) that has fallen on a built up area and runs off from urban surfaces, like streets, sidewalks, rooftops, and parking lots (Butler et al., 2011). This chapter explains how the flow of stormwater goes in the urban area and how urban drainage functions. Then the impacts of climate change on the watersystem in Europe and Vienna are discussed, followed by the transition from traditional towards sustainable urban drainage systems.

4.1 FLOW OF THE RAIN AND DRAINAGE IN URBAN AREAS

4.1.1 Effects of urbanization on drainage

In natural areas, the hydrologic cycle consists of three processes: Evapotranspiration, infiltration and surface runoff. In the first process rainwater vaporizes back into the atmosphere, whereas in the last two processes rainwater find their way to the watercourse. Surface runoff arrives much faster than infiltrated water. The proportions of the three processes depend on the nature of the surface and vary with time during the storm (Figure 17) (Butler et al., 2011).

In urban areas rainfall goes through the same processes as in natural areas. Evapotranspiration and infiltration still exists, but their proportion is largely reduced due to the decrease of vegetation and open water areas as well as the increase of imperviousness of the urban area, compaction of soils and the presence of an artificial drainage system (Figure X) (Marsalek et al., 2008). Therefore the amount of surface runoff increases and flows quicker over hard surfaces and through sewers than it does over natural surfaces and along natural streams. This means that the flow will both arrive and die away faster and therefore the peak flow will be greater (Figure 18) (Butler et al., 2011).

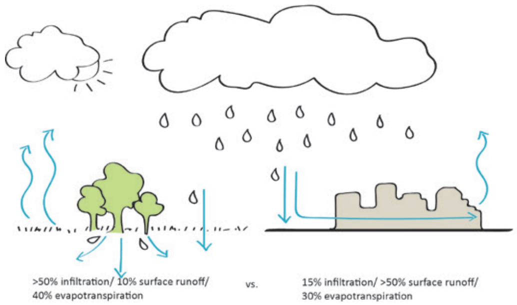


Figure 17: Effects of urbanization on watercycle.

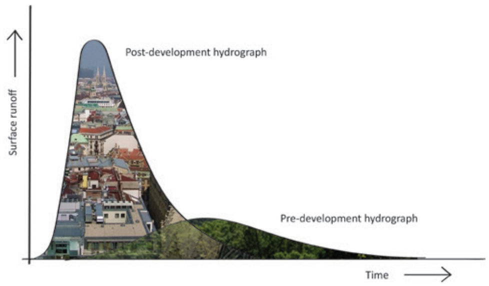


Figure 18: Peak flow before and after urbanization.

Furthermore, water quality in urban areas is influenced by many pollution sources. Stormwater in urban area often contaminates pollutants that are in the air and on the catchment surface. The rapid stormwater runoff washes off the pollutants and sediments on the surface. Factors that could affect the quality of stormwater include: the type and use of the surface, traffic, maintenance, type of roofing, street furniture, pavement, location and seasonal conditions (Ven, 2011).

So, urbanization has a huge impact on drainage. It produces higher and more sudden peaks in the volume of stormwater and introduces pollutants.

4.1.2 Urban drainage

Drainage systems consists of all the elements of the landscape through which or over which water travels. Included are natural as well as artificial constructed elements (Booth, 1991). It serves to decrease flood risk and inconvenience due to surface water ponding, alleviate health hazards and improve aesthetics of urban areas (Marsalek, 2008).

In an urban area there are two types of water that require drainage: Stormwater and wastewater. The first type, stormwater has two interconnected drainage systems: The minor system is designed for drainage and the major system is designed for control of flooding (in an urban area) (Figure 19).

The minor system includes swales, gutters, stormwater sewers, open drains and surface and subsurface storage facilities and conveys stormwater runoff from frequent rainfall events up to a five year return period (Marsalek et al., 2008). The rate of runoff by more intense rainfall events may exceed the capacity of the minor system. In that case, stormwater runoff flows to the planned or unplanned ponding areas and overland flow routes of the major system. The minor system elements serving drainage areas of 30 ha. and are designed to convey 1.25 times the rate of runoff which occur in 5 year rainfall event with a maximum ponding depth of 15 cm in the streets (City of Edmonton, 2015).

The major system consists of natural streams and valleys as well as large constructed drainage elements such as large swales, streets, channels and ponds (Marsalek, 2008). If the major system is adequately planned, designed and incorporated into the urban infrastructure, it should have no significant hazard to the public, erosion or other property damage. It is designed to accommodate runoff rates and volumes for a 50 year or even a 100 year return period rainfall event with a maximum ponding depth up to 35 cm in the streets (City of Edmonton, 2015).

Besides the stormwater drainage system, there is the wastewater system. Stormwater runoff is carried away through pipes and gutters and finds its way to either the nearest watercourse, or the nearest sewer of the wastewater system. There are basically two types of wastewater systems: Combined and separate (Figure 20).

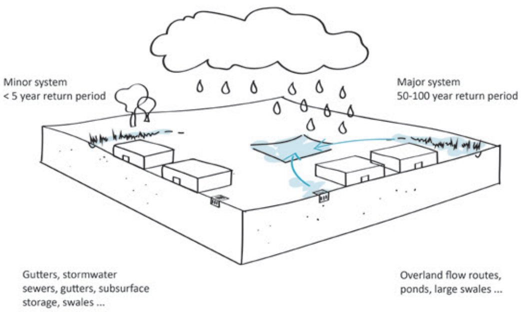


Figure 19: Stormwater system: Minor vs. Major system.

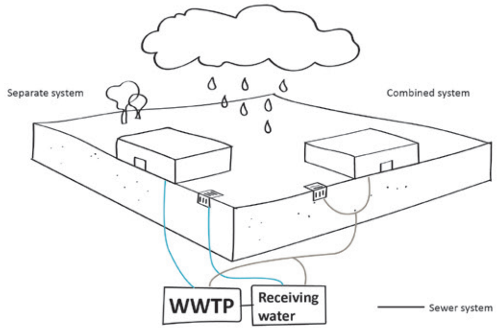


Figure 20: Wastewater system: Separate vs. Combined system.

A combined system transports both wastewater and stormwater in the same pipe into the Waste Water Treatment Plant (WWTP). In dry weather the system transports just the wastewater flow. During heavy rainfall the stormwater could be fifty or even hundred times the average waste water flow and cause a Combined Sewer Overflow (CSO) into a nearby natural watercourse.

In a separated system, wastewater and stormwater are transported in separate pipes, usually laid side-by-side. The stormwater pipe may be about the same size as the equivalent combined sewer, and the wastewater pipe will be smaller (Butler et al., 2008).

4.2 CLIMATE CHANGE

4.2.1 European context

Climate change has impact on our water-, food-, eco-, health-, and energysystems (EEA,2012). In this section I focus primarily on the changes in climate in the European and Viennese context.

The European Environment Agency (EEA) released the report on: Climate change, impacts and vulnerability in Europe 2012. This report presents an indicator-based assessment of past and projected climate changes, their observed and projected impacts, and the associated vulnerability of and risks to society, human health and ecosystems in Europe (EEA,2012).

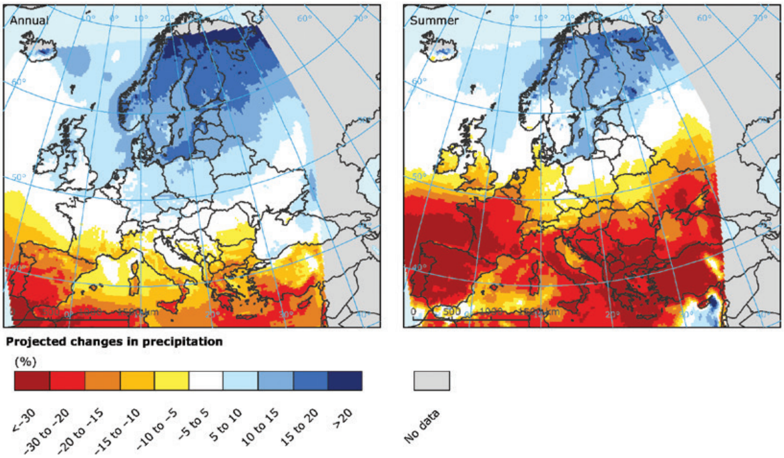


Figure 21: Projected changes in annual (left) and summer (right) precipitation (%) for 2071-2100, in relative to the baseline 1961-1990 (EEA, 2012).

As we see in Figure 21, predictions indicate that northern Europe will experience a strong increase of annual precipitation (+10 to +20%), whereas southern Europe will experience a decrease of annual precipitation of (-10 till -30%).

In Central and Eastern Europe (also where Austria and the Vienna region fall under), there will be more extreme weather conditions: An increase in warm temperature extremes and a decrease in summer precipitation (EEA, 2012).

4.2.2 Viennese context

The Institut für Meteorologie and the Universität für Bodenkultur looked further into the climate change scenario for 2050 and discussed the possible impacts on the city of Vienna. In table 1, the key climate variables are described against a 1981 -1990 baseline.

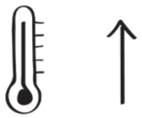
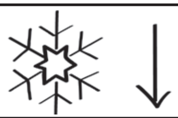
	Averages: The increase and decrease in precipitation by 2050 depend strongly on the season. Winter: +15 till 30% Summer: -15 till +30 % Spring: till -15% Autumn: -25 till 35%. Wet days A decrease of 6% is expected in 2050.
	Averages: Annual increase of 1,8 - 2 °C Winter: +1,3 till 1,8°C Spring: +1,8 till 2,5°C Summer: +2 till 2,5°C Autumn: +2,5 till 3°C Warm days Summer days above 24 °C are projected to occur more than twice as frequently in 2050.
	Averages: Decrease in frost days: – 25%
	Extreme events: Summer days: double Heat days: 25% of summer days are heat days/ occur 4 times more frequent in 2050. Heavy rainfall: >50 mm/day occurs 1-2 days more a year.

Table 1: Snapshot of projected changes in climate for Vienna 2050, in relative to the baseline period 1981-1990 (Clementschitsch et al., 2007).

On 13th of august 2010, an heavy rainfall event took place, corresponding to a 50-year return period: 50 mm of rainfall in half an hour. The peak flow of stormwater runoff in the sewer system caused household flooding as well as serious damages to the transportation networks of the city Vienna (Strommer, 2015).

The Viennese sewer system (minor system) is aligned to international standards on rainfall events with a 5 year return period (MA45, 2015). The size of the stormwater drains in the catchment basin of the Liesingbach are not sufficient enough to deal with such heavy rainfall events as described above (Pamer, 2014).

Besides less wet days and heavier rainfall events, also longer periods of drought and more heat days are expected. Providing seasonal stormwater storage for warm and dry periods is also a challenge.

4.3 SHIFT TOWARDS SUSTAINABLE URBAN DRAINAGE SYSTEM

4.3.1 Introduction

The traditional urban drainage of stormwater is accomplished by piped storm sewers, through which the runoff is conveyed directly to the receiving water. Before the 1970's, the focus was mainly on the water quantity and how to discharge stormwater runoff as quickly as possible. In the 1970's more attention was drawn to the water quality. Measures were taken in order to protect the receiving waters from being polluted by urban stormwater runoff. In the 1990's the concept of sustainable development was introduced. The focus was not only on reducing the potential impacts of development on the quantity and quality of the stormwater runoff, but also on maximizing amenity and ecology opportunities (Stahre, 2008). Amenity means something that makes it comfortable or enjoyable to live or work somewhere (Jantscher, 2015). An ideal SUDS solution will achieve benefits in all three categories (Figure X) (Woods-Ballard et al., 2007).

The transition from traditional to sustainable urban drainage is illustrated in Figure 22.

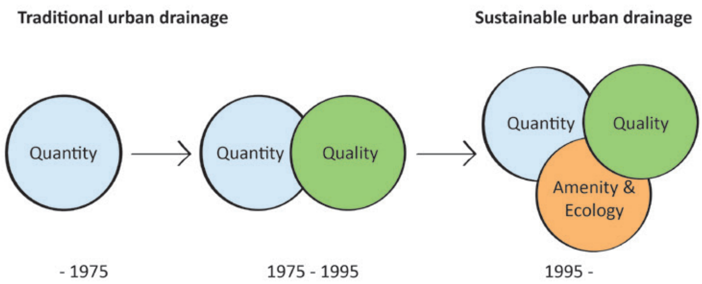


Figure 22: Transition from traditional towards sustainable urban drainage and the dimensions (Stahre, 2008)(Butler et al., 2011).

The time line, shown in the Figure X, varies between cities and countries. The transition towards a sustainable urban drainage is an ongoing process in many countries (Stahre, 2008). Countries like Australia, USA and Sweden have been using this approach for many years (Butler et al., 2011).

The movement towards making better use of natural drainage mechanisms has been given different names in different countries. In the US, it is called "Best Management Practices' (BMP). In Australia they use the expression of 'Water Sensitive Urban Design' (WSUD), and in the UK, since the mid-1990's, the term SUDS has been used (Butler et al., 2011).

In this project I use SUDS as main concept and add knowledge of the other concepts when needed.

4.3.2 Components

The most important aspect in SUDS designs is reducing stormwater runoff, by integrating small scale SUDS components. In Table 2, common SUDS elements are described and in what way benefits in: Water quantity, water quality and amenity & ecology, are achieved. Section 4.3.3 considers how they can be linked together (Woods-Ballard et al., 2007).

4.3.3 Management train

The SUDS elements are not placed randomly on the site. To mimic natural catchment processes a management train is necessary. This means that drainage elements are used in a serie to reduce pollution, flow rates and volumes. The hierarchy of the drainage elements is as follows:

1. Prevention: The use of good site design and site housekeeping measures to prevent runoff and pollution and rainwater reuse/harvesting.
2. Source control: Runoff control at or very near its source.
3. Site control: Runoff control in a local area or site.
4. Regional control: Management of runoff from a site or several sites.

The conveyance of water between individual SUDS elements of the management train should be considered in a natural way, such as swales and filter drains (Woods-Ballard et al., 2007).

The last column of Table 2, shows in which stage of management train the SUDS element can be used.

4.3.4 Trans-disciplinary design process

Urban drainage is the responsibility of the city. As the traditional urban drainage is located underground, the design and construction can be carried out by the city's drainage department. Involvement of other departments is not necessary.

This differs from sustainable urban drainage, which is mainly above the ground. As we have seen in Section 4.3.1, other aspects than just drainage purposes have to be taken into account. Integrating stormwater requires a creative holistic approach to the design process of the urban environment. Therefore experts and community need be involved (Stahre, 2008). Example of experts who can be part of the design team, are: Spatial planner, water company, architect, local authority, house builder, ecologist, local residents, housing association, landscape architects and water engineers (Morgan et al., 2013).

	SUDS element	Description	Water quantity	Water quality	Environmental benefits	Management train
	Green roofs (GR)	A roof with plants growing on its surface, which contributes to local biodiversity. The vegetated surface provides a degree of retention, attenuation and treatment of rainwater, and promotes evapotranspiration. Sometimes referred to as an alternative roof.				
	Water butts, site layout	Small scale garden water storage device which collects rainwater from the roof via the drainpipe.				
	Permeable pavements (PP)	A permeable surface that drains through voids that are integral to the pavement.				
	Filter strips	A vegetated area of gently sloping ground designed to drain water evenly off impermeable areas and to filter out silt and other particulates.				
	Soakaway	A sub-surface structure into which surface water is conveyed, designed to promote infiltration.				
	Filter drain	A linear drain consisting of a trench filled with a permeable material, often with a perforated pipe in the base of the trench to assist drainage.				
	Swales	A shallow vegetated channel designed to conduct and retain water, but may also permit infiltration. The vegetation filters particulate matter.				
	Bioretention areas	Depressions backfilled with a sand soil mixture and planted with vegetation. Water enters through a vegetated surface and then trickles via a filter layer entering a perforated pipe at the bottom before				
	Infiltration trenches	A trench, usually filled with permeable granular material, designed to promote infiltration of surface water to the ground.				

Table 2: Capability of common SUDS elements (Woods-Ballard et al., 2007).

	SUDS element	Description	Water quantity	Water quality	Environmental benefits	Management train
	Pipes and subsurface storage	Conduits and their accessories as conveyance measures and/or storage. Water quality can be targeted using sedimentation and filter media				
	Sand filters	Treatment devices using sand beds as filter media.				
	Infiltration basins	A dry basin designed to promote infiltration of surface water to the ground.				
	Ponds	Permanently wet depression designed to retain storm water above the permanent pool and permit settlement of suspended solids and biological removal of pollutants.				
	Wetlands	Retention pond in which the water is shallow enough to enable the growth of bottom-rooted plants.				
	Detention basin (DB)	A vegetated depression that is normally dry except followin g storm events. Constructed to store water temporarily to attenuate flows. May allow infiltration of water to the ground.				
	Silt removal devices	Manhole and/or proprietary devices to remove silt.				

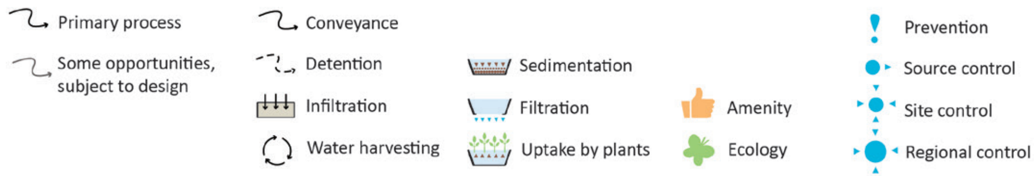


Table 2: Capability of common SUDS elements (Woods-Ballard et al., 2007).

4.3.5 Through the scales

SUDS is part of the Green Infrastructure (GI) of a city. Green Infrastructure does not only include green space, such as parks and woodlands, but also blue infrastructure such as ponds and SUDS elements.
Green Infrastructure can be incorporated in four different scales: Building, street, neighborhood, and regional scale, including the green connections between the scales (Scottish Government, 2011). Figure 23, shows the scales of GI together with different stages of the SUDS management train.

Figure 23: Green Infrastructure and SUDS through the scales (Scottish government, 2011)(Woods-Ballard et al., 2007).

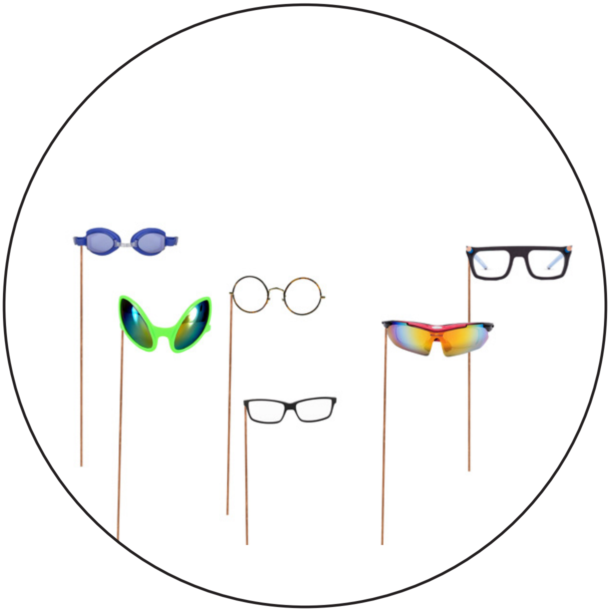
4.3.6 Design criteria

Derived from the literature review and complemented with the outcome of the reference study (see Appendix A), a list of design criteria are set (Table 3). These design criteria can help me in the design and the evaluation.

The design criteria are based on the three categories of SUDS, as we have seen in Section 4.3.1, and elaborated with sub criteria and objectives for my project area.

	Sub criteria	Objectives for my area
Water quantity	Prevention of urban flooding	The capacity of a minor SUDS should deal with a runoff amount in a designated precipitation condition of 15 minutes storm with a return period of 5 years. The major SUDS should deal with precipitation condition of 15 minutes storm with a return period of 50 years.
	Prevention from drought/ water supply	Provide seasonal water storage for supplement to drought.
Water quality	Protection of receiving watercourses	Improve the quality of stormwater runoff before it reaches watercourse by using SUDS components in management train.
Amenity	Aesthetics	Create beauty of pleasure experience as a result of design composition (e.g. visual appeal and the absence of odors). Consider site specific characteristics.
	Usability	Provide opportunities for education and recreation to those who live close to area.
	Health and safety (Operational risks)	Freedom from exposure to public health and safety risks (e.g. drowning hazards, sudden inflows, breeding ground for mosquitos or noxious weeds).
	Maintenance	Set an appropriate maintenance and management plan.
	Community acceptability	Consider the public's preference towards the appearance of SUDS. Engage stakeholders in the design process.
Ecology	Habitat creation	Create a range of habitat types for native flora and fauna and corridors for connection. Use plants that grow under local conditions. Enhance natural processes.

Table 3: Design criteria



PART III UNDERSTANDING

5. LANDSCAPE ANALYSIS

As seen in the SUDS approach, a trans-disciplinary design process is needed in order to find integrated solutions that look for synergies over individual solutions. Synergies are very important, because they will enable stormwater management to become part of urban planning and design. To mimic this trans-disciplinary design process, I did a role play and looked through five different lenses of experts and community to the Liesingbach catchment basin.

In the introduction round, experts, community and myself as landscape architect point out our aim for the Liesingbach catchment basin, followed by a landscape analysis in which we show the problems and opportunities we see in our field. A small discussion on the findings leads to a strategy for the Liesingbach catchment basin.

5.1 I AM... : THE INTRODUCTION ROUND

5.1.1 I am... a water expert

SUDS can deliver benefits over traditional urban drainage systems. My aim is to use SUDS in order to bring the peak of stormwater runoff in post-development closer to the pre-development hydrograph. It will result in less direct stormwater runoff to the Liesingbach, no further increase of flood risk of the Liesingbach, and groundwater recharge. Besides that, the water quality can be further improved by disconnecting stormwater sewers from polluted business areas and main infrastructure, and clean it locally before it flows into the Liesingbach.

5.1.2 I am... an ecologist

The Liesingbach is an important ecological corridor between Vienna Woods and Donau-Auen. With several streambed revitalization projects in the last decade, a lot has been achieved for the ecological water quality. However, much more can be gained! Large parts of the stream are not liberated from its “stone corset” and obstacles. The major part of the Liesingbach has a uniform flow with no habitats for flora and fauna, and no self-cleansing ability. This improves when we give the stream more space and bring back its former dynamics. I hope to see the entire Liesingbach green! Furthermore, I think it is interesting to implement SUDS in the urban area and design it in such a way that it contributes to urban nature.

5.1.3 I am... a planner

SUDS is an essential part in sustainable development. It will help to meet runoff targets and water efficiency targets, contribute to place making, and bring value to the community. In Liesing Mitte a few new build projects, urban renewal projects, green infrastructure and bicycle routes have been planned. For example, in the area “In der Wiesen” we work on a SMART-city project in which we aim for zero emission and urban farming. I think it is interesting to explore how SUDS can be integrated in an innovative way.

5.1.4 I am... a local resident

I would like to have more trees in the street and water for my garden while at the same time save on energy bills. But also green connection needs to be improved between the Liesingbach and other green areas. Furthermore, we want new playgrounds for the children and more free space for (temporary) community projects.

5.1.5 I am... an outdoor tourist

The Liesingbach is an important and popular recreational corridor for cyclists and city dwellers. Along the stream is the "Liesingbach radweg" (bicycle route) which connects Vienna Woods with the Donau. On a sunny afternoon or weekend day, it is very busy. With this route, the first step is made. The second step will be expanding the green recreational network to other recreation areas. I think that SUDS can be integrated in this green network.

Besides that, if we look into the different "modes of experience" from Lengkeek and Elands, we see that the Liesingbach is mainly focused on the mode of change. This means basically going away from stress and boredom. However, the rich cultural history (the mode of interest) is hardly to be experienced. In order to experience the watersystem better, we could make the water accessible, make cultural/ historic stories visible (not by paintings on buildings), and do something special with the ends of the stormwater pipes in the Liesingbach.

5.1.6 I am... a landscape architect

As landscape architect, I have the ability to explore through research by design for integrated solutions of how sustainable stormwater management can be best introduced and what it could look like in the Liesingbach catchment basin. By collecting and clustering problems and opportunities, I think we made the first step in understanding the site and exploring the first win win solutions. The next step is design and see how it could look like.

5.2 PROBLEMS AND OPPORTUNITIES FOR INTEGRATING SUDS

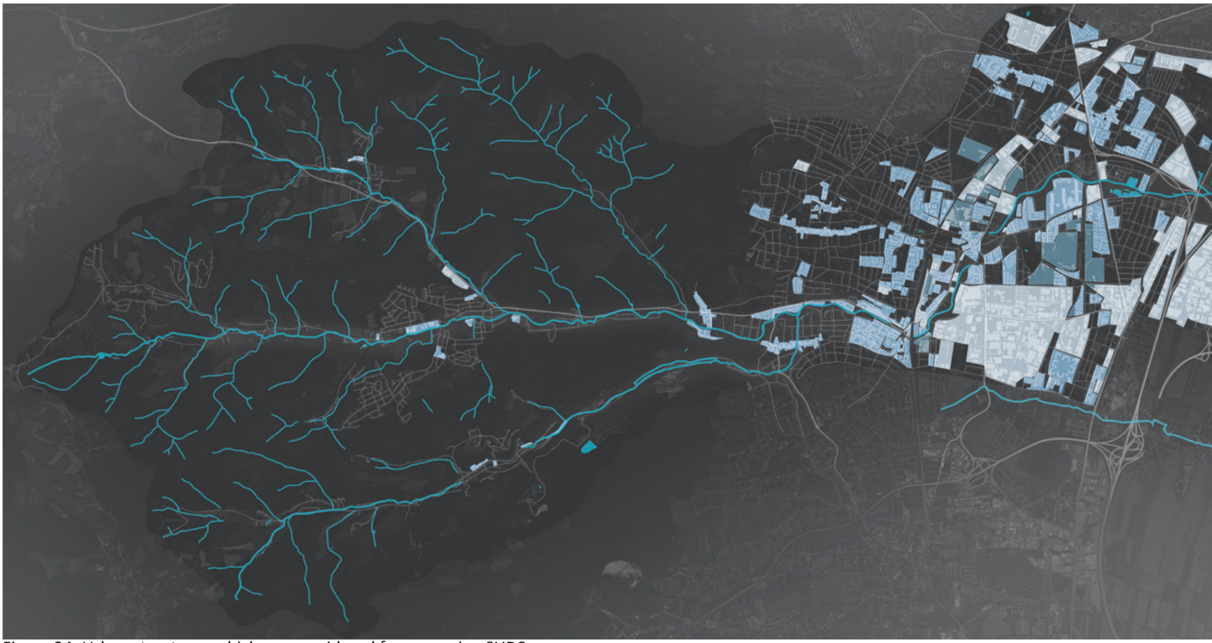
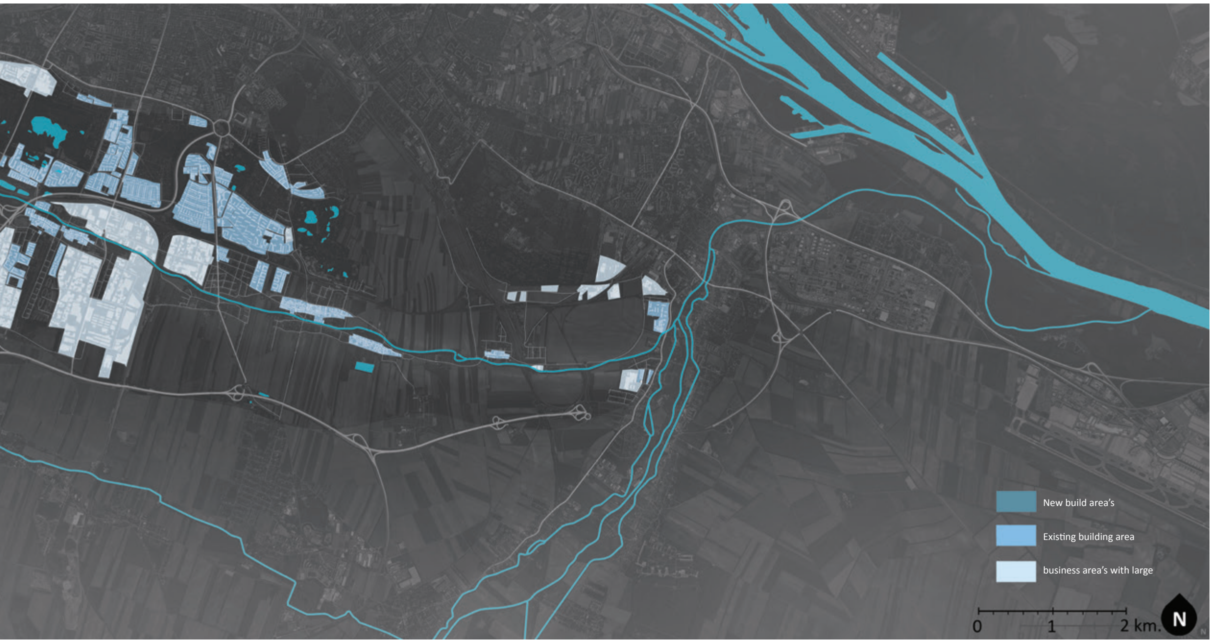


Figure 24: Urban structures which are considered for proposing SUDS.

Urbanization has a huge impact on the amount of stormwater runoff. As we have seen in Section 4.1.1, urbanization produces higher and more sudden peaks in the volume of stormwater runoff. With no data available on sensitive urban flooding areas, I approached it by studying types of urban structure with different level of imperviousness and public space. In figure 25, urban structures which are present in the Liesingbach catchment basin are classified by the level of unpaved vs. paved on the x-axis and public vs. private space on the y-axis. A development for proposing SUDS can be considered when an urban structure has either a high level of public urban space, or a high level of imperviousness. Figure 24 comes from the landscape analysis of the water expert and show opportunities to integrate SUDS in the urban area.



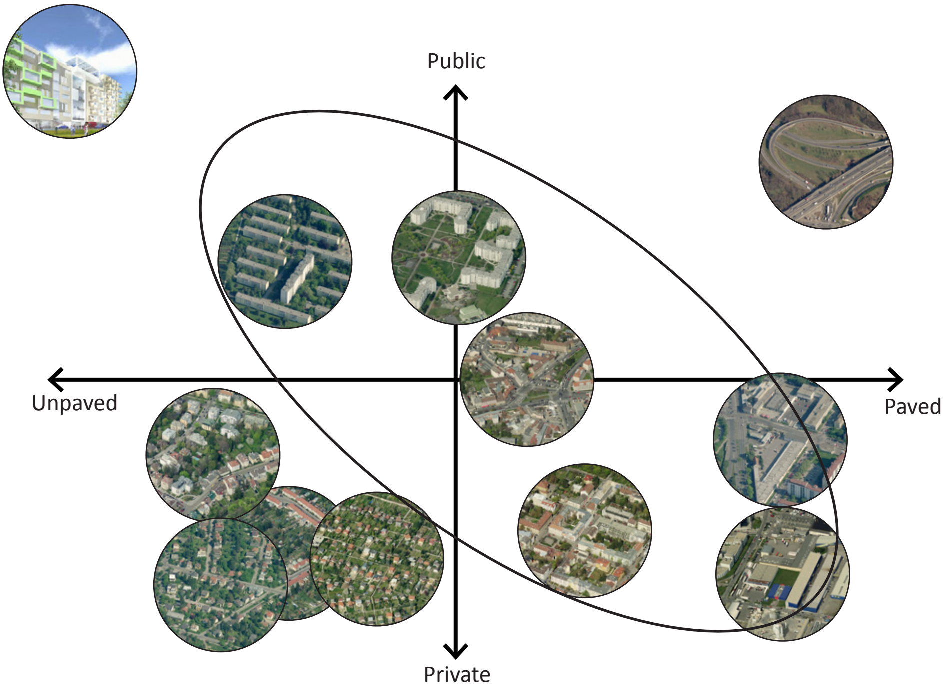


Figure 25: Urban structures of the Liesingbach catchment basin and their level of public space and imperviousness.

Figure 26: Conclusion map with problems & opportunities for integrating SUDS.

In figure 26, problems and opportunities in the Liesingbach catchment basin are collected by looking through different lenses of the water engineer, ecologist, urban planner, local resident and outdoor tourist and clustered. The landscape analysis per “lens” is worked out in Appendix B.

Legend:

(Urban) Sponge

- Contaminated stormwater runoff
- SUDS
- Water re-use

Urban challenges

- New build project in planning
- Urban renewal project in planning
- Zero emission target
- Urban farming
- Expand green network
- Expand bicycle network
- Innovation
- Runoff target
- Combine projects
- Small scale urban ecology

Community wishes

- No new building project!
- New playground
- Culture centre
- Villages centre more attractive
- Green in streets
- Make history/stories visible
- Room for urban experiments
- Make Liesingbach visible
- Liesing identity

Regional system

- Liesingbach not visible
- Significant floodrisk
- Uniflow, no habitat
- Obstacle
- More space, dynamic and green banks
- Treatment contaminated stormwater runoff
- Improve aquatic ecology

5.3 DISCUSSION

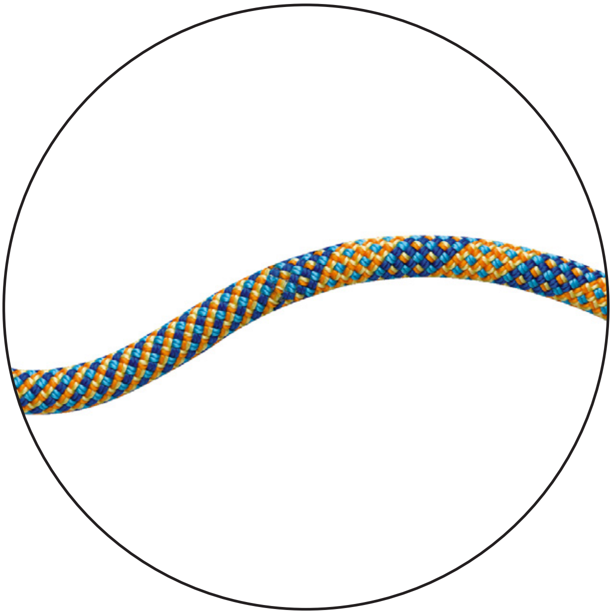
As stated in the introduction, integrating sustainable stormwater management needs a holistic approach. In the previous sections we have explored the first improvements of the current drainage system and possibilities for synergies.

One of the main findings on the regional scale is the need of an expansion of the green (-blue) network. According to the urban planner, ecologist, local resident and outdoor tourist, a robust green network is lacking in the urban area of the Liesingbach catchment basin. A green network doesn't only connect parks, neighbourhoods, village centres but has also the opportunity to incorporate stormwater management, climate adaptation, less heat stress, more biodiversity, recreation etc.

Furthermore we see some water and ecology problems in the Liesingbach. Especially the significant floodrisk will increase with the large new build projects in planning. Sustainable stormwater management should become part of these projects. Eventhough SUDS are rather small scale measures, a sum up of these measures have a large impact. For integrating SUDS in these projects we have to explore also possibilities for innovation, water efficiency, and water reuse. Besides new build and urban renewal projects, SUDS can also be applied in making village centres more attractive, new playgrounds or the new culture centre.

In the design we need to think too about: Liesing identity, room for urban experiments, visibility of history/stories, and ecology.

As we have seen in figure 26, especially for the urban area of Liesing Mitte has a lot of synergy opportunities. Therefore Liesing Mitte will be worked out in the strategy and master plan.



PART IV STRATEGY & DESIGN

6. STRATEGY FOR THE LIESINGBACH CATCHMENT BASIN

As a result of the discussion, this Chapter introduces a strategy for the urban area of the Liesingbach catchment basin. The strategy will be used as basis for the masterplan of Liesing Mitte.

6 STRATEGY FOR THE LIESINGBACH CATCHMENT BASIN

In the last two decades, the Liesingbach transformed into a strong recreational of the region (Pamer, 2014). Also revitalization projects have improved the ecological waterquality.

So, the next phase will be expanding the Liesingbach into a robust green network which connects the Liesingbach with neighbourhoods, parks, old village centres, important public transportation hubs and vice versa. This green nework carries opportunities for functions as stormwater management, groundwater, ecology, culture/history and recreation. Along this green network, SUDS projects are selected in which the urban drainage system can be improven (depending on the urban structure) together with possiblility for synergy with urban planning, community wishes, ecology and recreation demands. These synergies will enable stormwater management to become part of urban planning and design.

So, the strategy with a time-span for the coming 15 years:

1. Expand green network.
2. Along and within this network, select projects in which SUDS can be integrated and explored.
3. Research by design has to be central in the landscape design process.

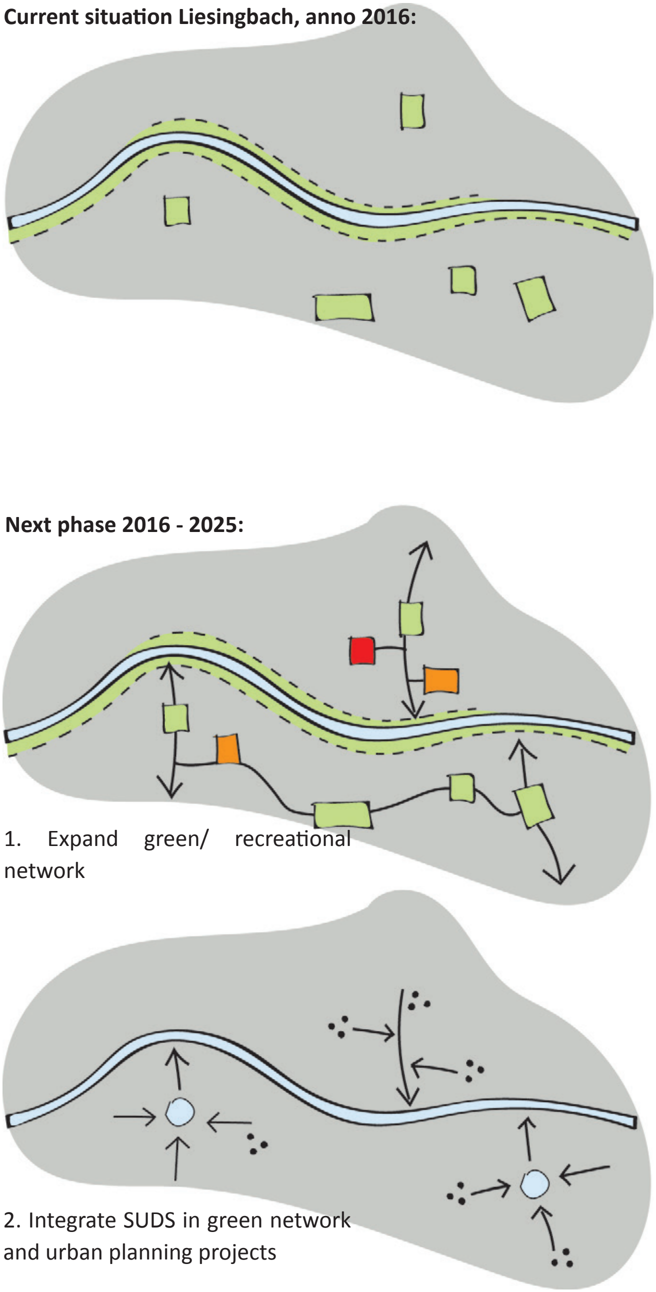
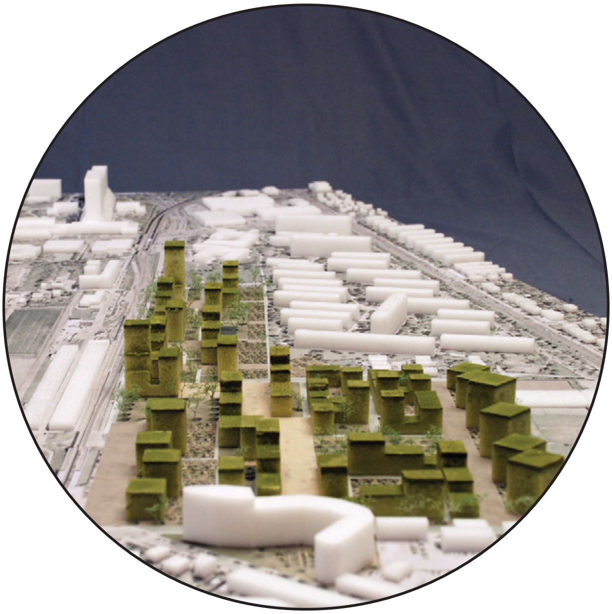


Figure 27: Strategy for Liesing Mitte.



7. LIESING MITTE DESIGN

From the landscape analysis and strategy a master plan is constructed for Liesing Mitte. The new build project: 'In der Wiesen-Ost' is selected and worked out with a landscape design.

7.1 LIESING MITTE DESIGN

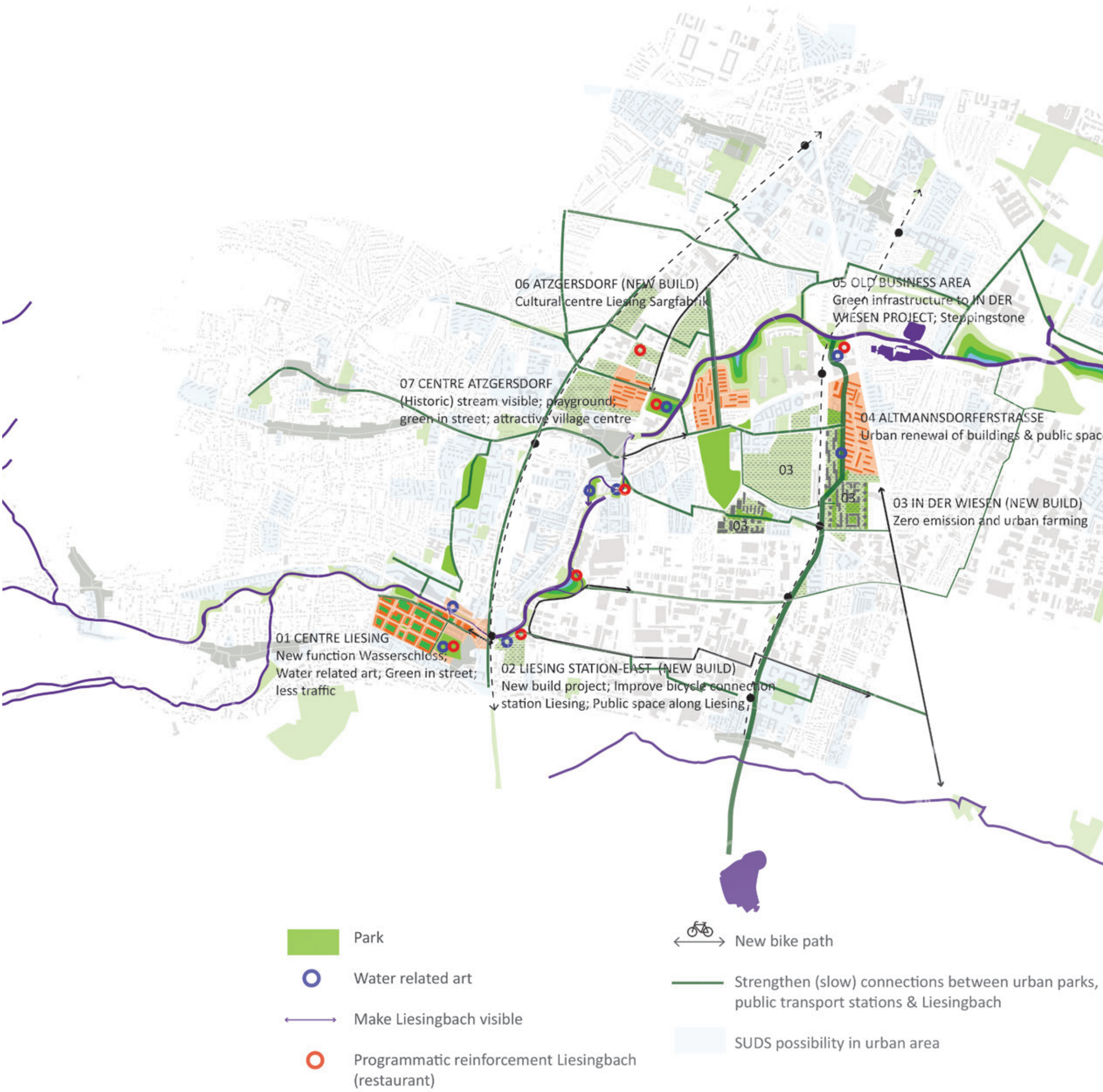


Figure 28: Master plan for Liesing Mitte 2030 with selected projects in which SUDS can be further explored.


Old Village centra
Public transport (train/ metro)
New built locations - 2025
Urban renewal (buildings and public space)
0
1
2 km.
N

7.2 IN DER WIESEN-OST
7.2.1 Site Inventory

Along the green infrastructure of Liesingbach - In der Wiesen - Siebenhirten - Petersbach - Lake Wienerbergteich, we zoom in on my project area: In der Wiesen-OST. Figure 29 shows the area in the urban context and in relation to the Liesingbach.

The northern part of In der Wiesen is a plant nursery, the southern part mainly large fields. The ambition of the urban planner is to transform this area into a SMART city project with two main key aspects: Zero emission and urban farming. In the workshop XXX a preliminary design is presented for In der Wiesen-OST. I will use the building layout as basis for my design.

Figure 29: Aerial view on In der Wiesen-Ost and context.

7.2.2 Landscape experience

Below an axonometric projection of existing buildings and the preliminary design of In der Wiesen Ost. Photos of different subareas show already some of the site characteristics.

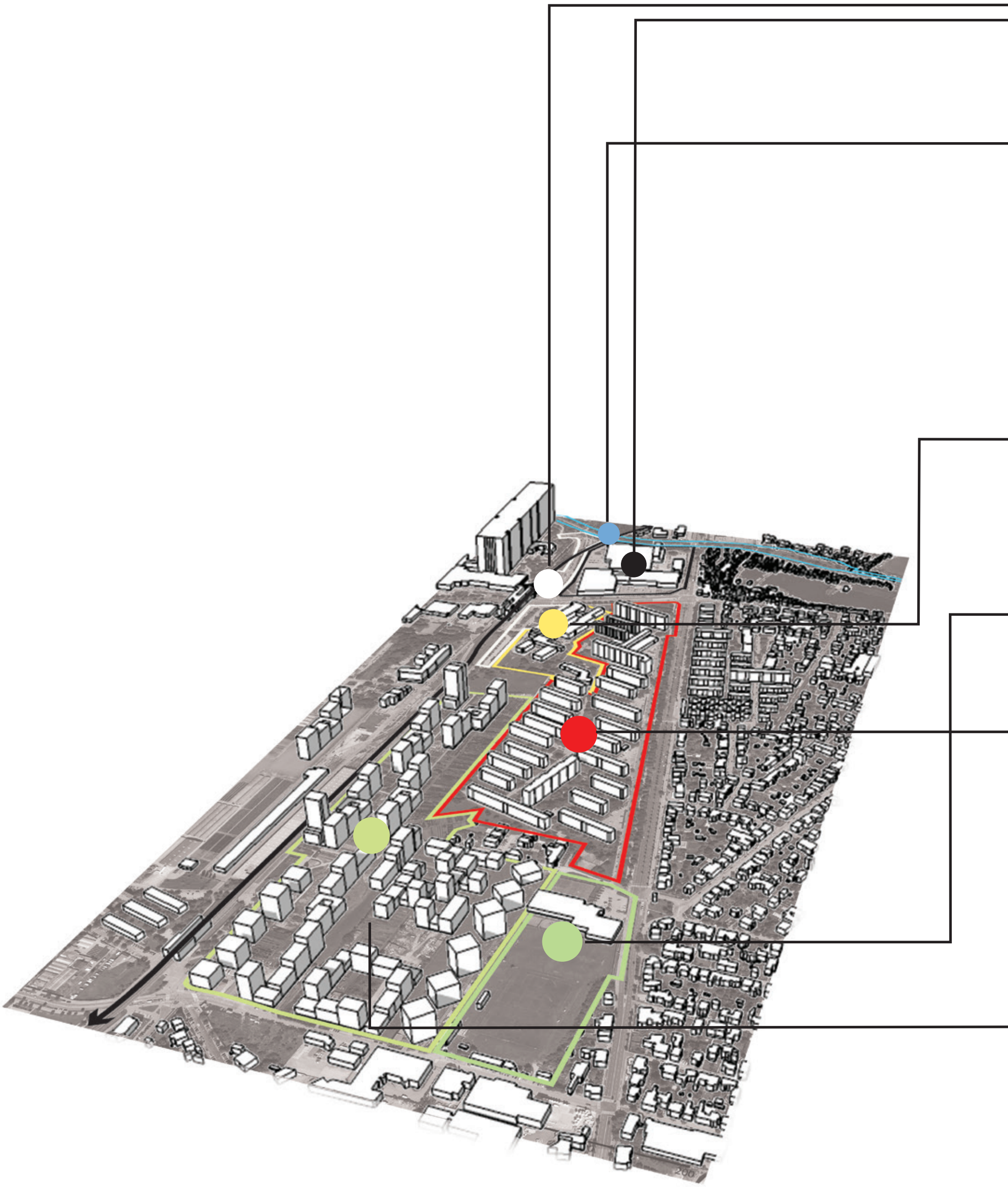
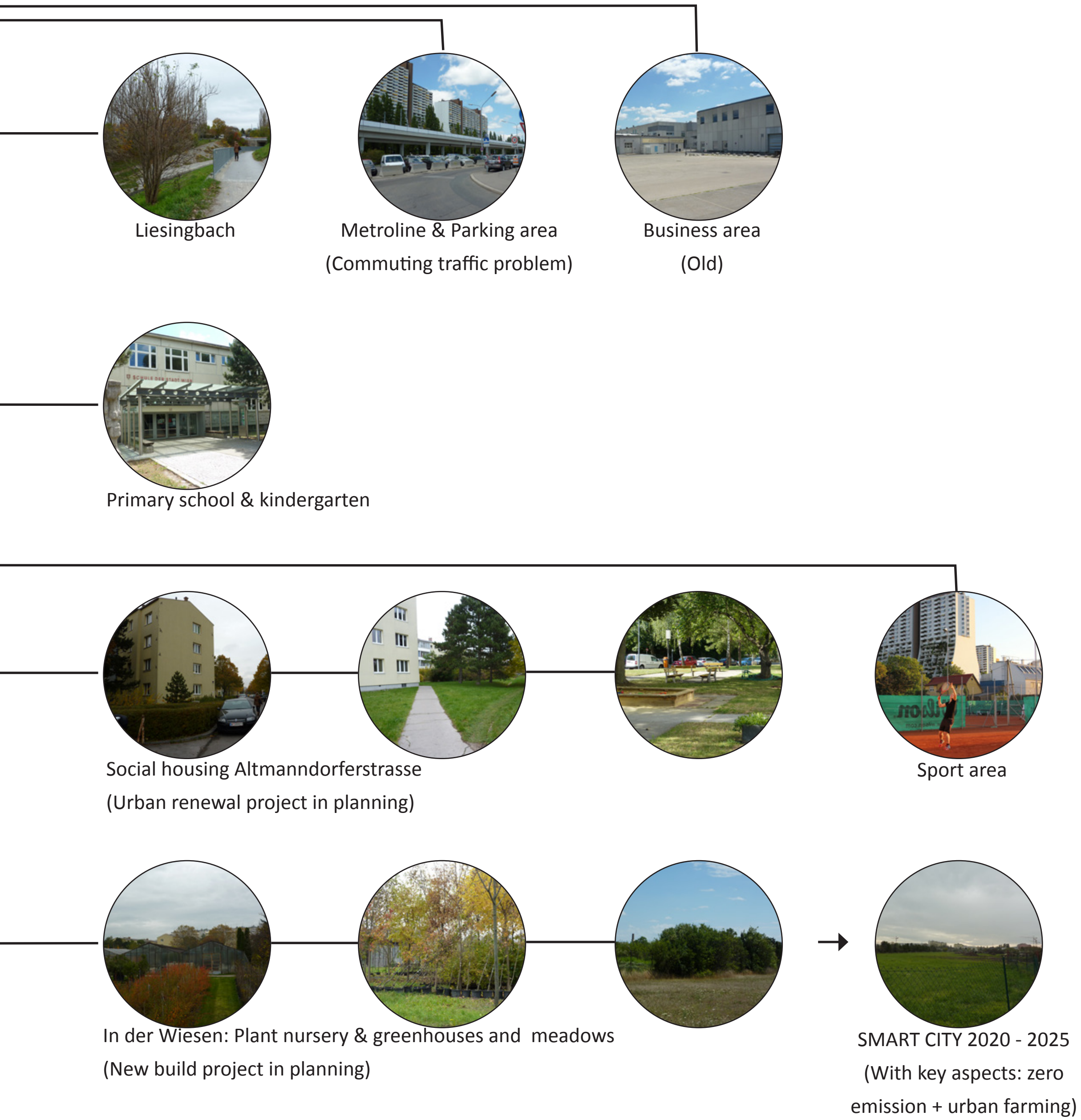


Figure 30: Axonometric projection of In der Wiesen-Ost in context.


Liesingbach
Metroline & Parking area
(Commuting traffic problem)
Business area
(Old)
Primary school & kindergarten
Social housing Altmanndorferstrasse
(Urban renewal project in planning)
Sport area
In der Wiesen: Plant nursery & greenhouses and meadows
(New build project in planning)
SMART CITY 2020 - 2025
(With key aspects: zero
emission + urban farming)

7.2.3 Landscape analysis

As we have seen in Section 4.1.2, stormwater has two interconnected drainage systems: The minor system is designed for drainage and the major system is designed for control of urban flooding (in an urban area). In this area the SUDS minor system should deal with a runoff volume of 20,3 mm = 225,56 l/s*ha. and the major system of 39,8 mm = 436,67 l/s*ha. (eHYD, 2015).

In this section a few landscape analysis maps are presented, followed by a concept for my project area.

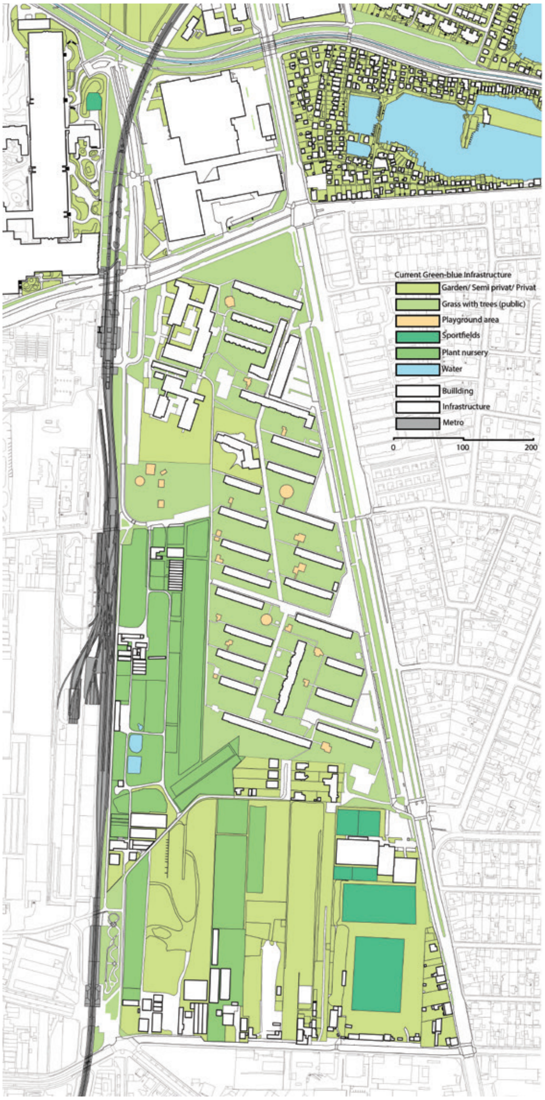


Figure 31: Green-blue infrastructure map.

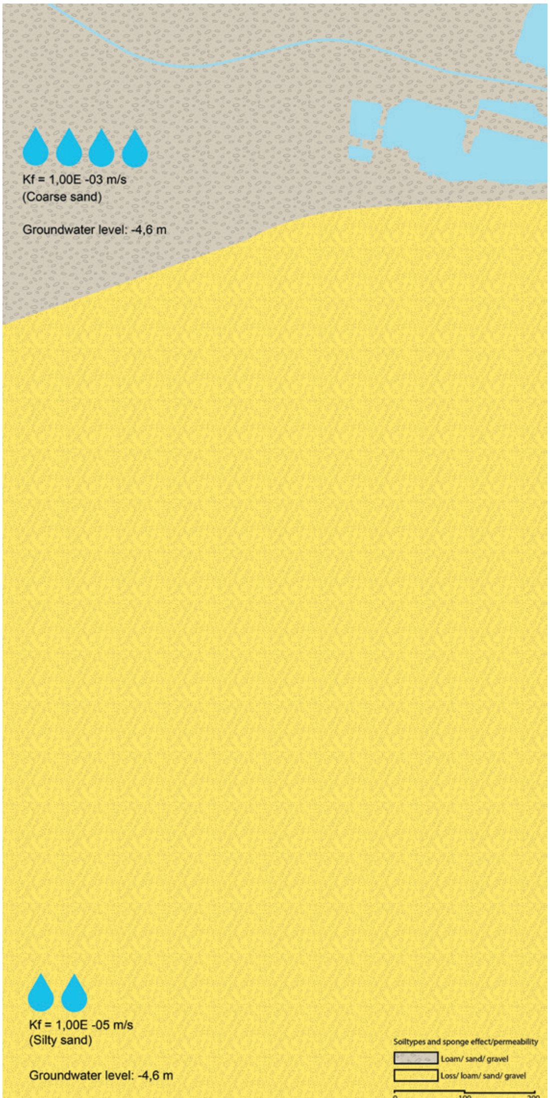


Figure 32: Soil permeability and groundwater elevation (Grimm, 2010) (ACO, 2015)

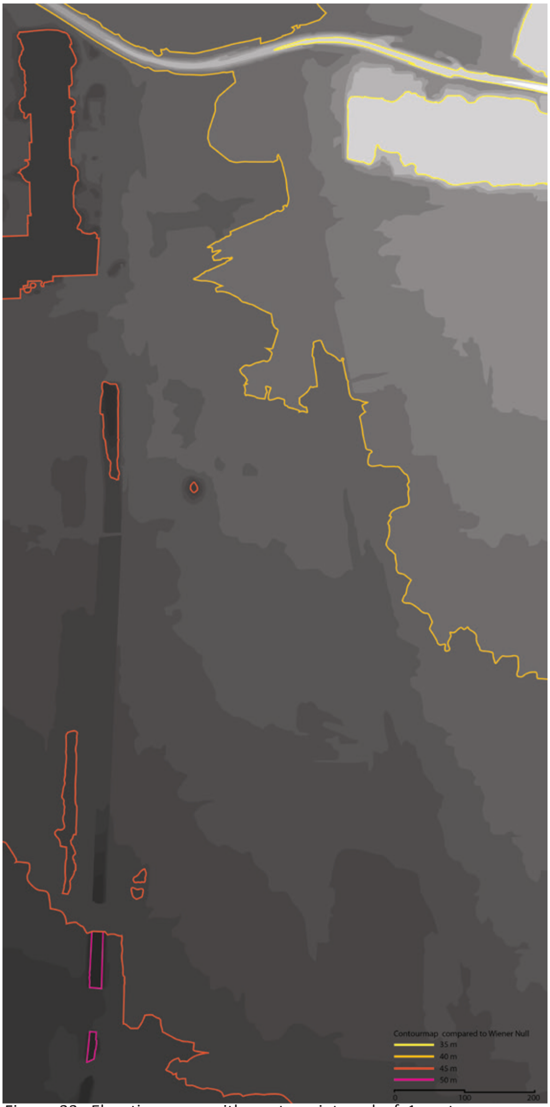


Figure 33: Elevation map with contour interval of 1 meter (Streetmap, 2015).

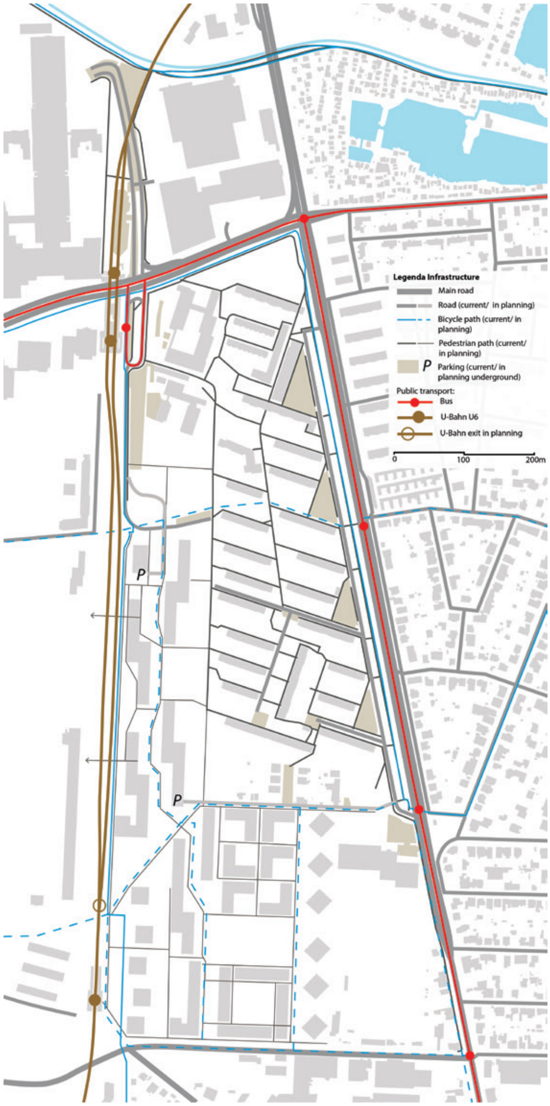


Figure 34: Traffic infrastructure

Figure 35: Drainage system (WKN, 2015)

Figure 36: Occupation & Social functions

7.2.4 Concept

The green infrastucture goes from the Liesingbach through the green heart of the In der Wiesen-Ost and further in direction of Village centre Siebenhirtern. In order to make a strong entrance, redevelopment is needed. I propose a stepping stone for the ecology and a iconic building which represents the Wiesen area. The green infrastructure connects the Liesingbach with primary schools and neighborhood park. East west connections are important as well

For stormwater runoff, prevention and source control measures happen on the scale of building and street level. Site control takes place in areas with no underground parking. In the north where the infiltration rate is good, measures are taken to increase natural infiltration. In subarea nursery and field, the infiltration rate is slow. For the nursery a pond is proposed and in the field detention basins and swales.

In the design spatial characteristics of the subareas have to be considered.

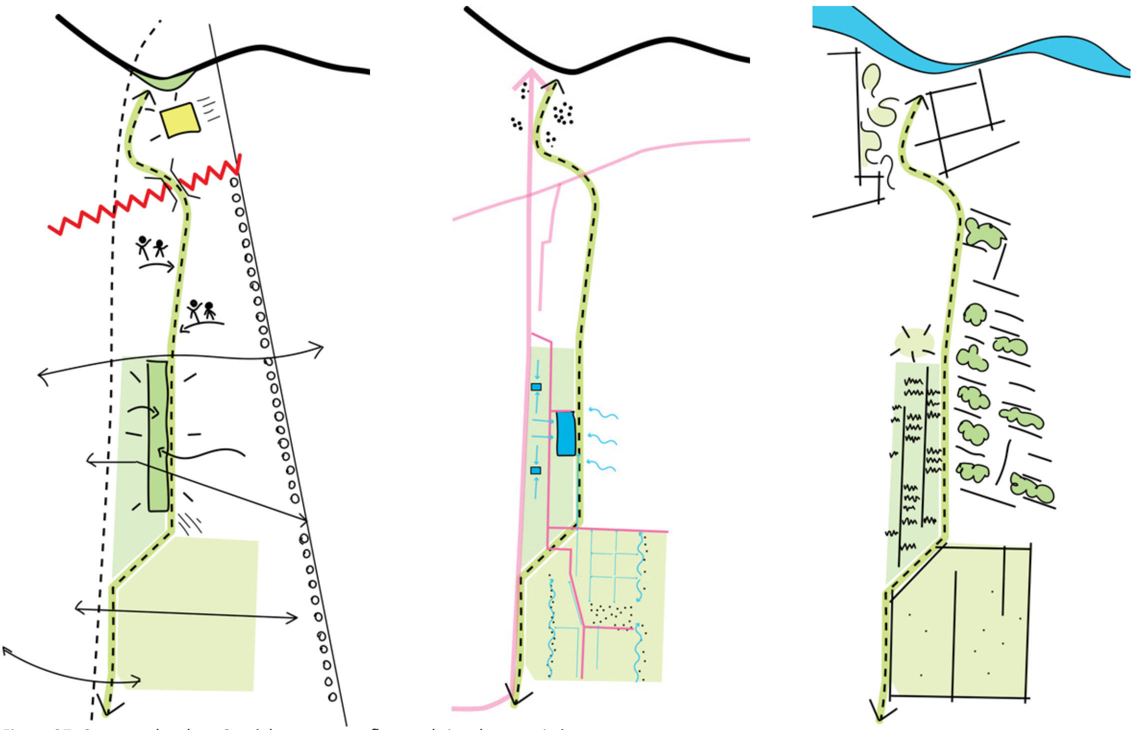


Figure 37: Concept sketches: Spatial, stormwaterflow and site characteristics

7.2.5 Plan

Figure 38: Spatial plan

7.2.6 Waterplan & Waterscheme of Wiesen-Ost

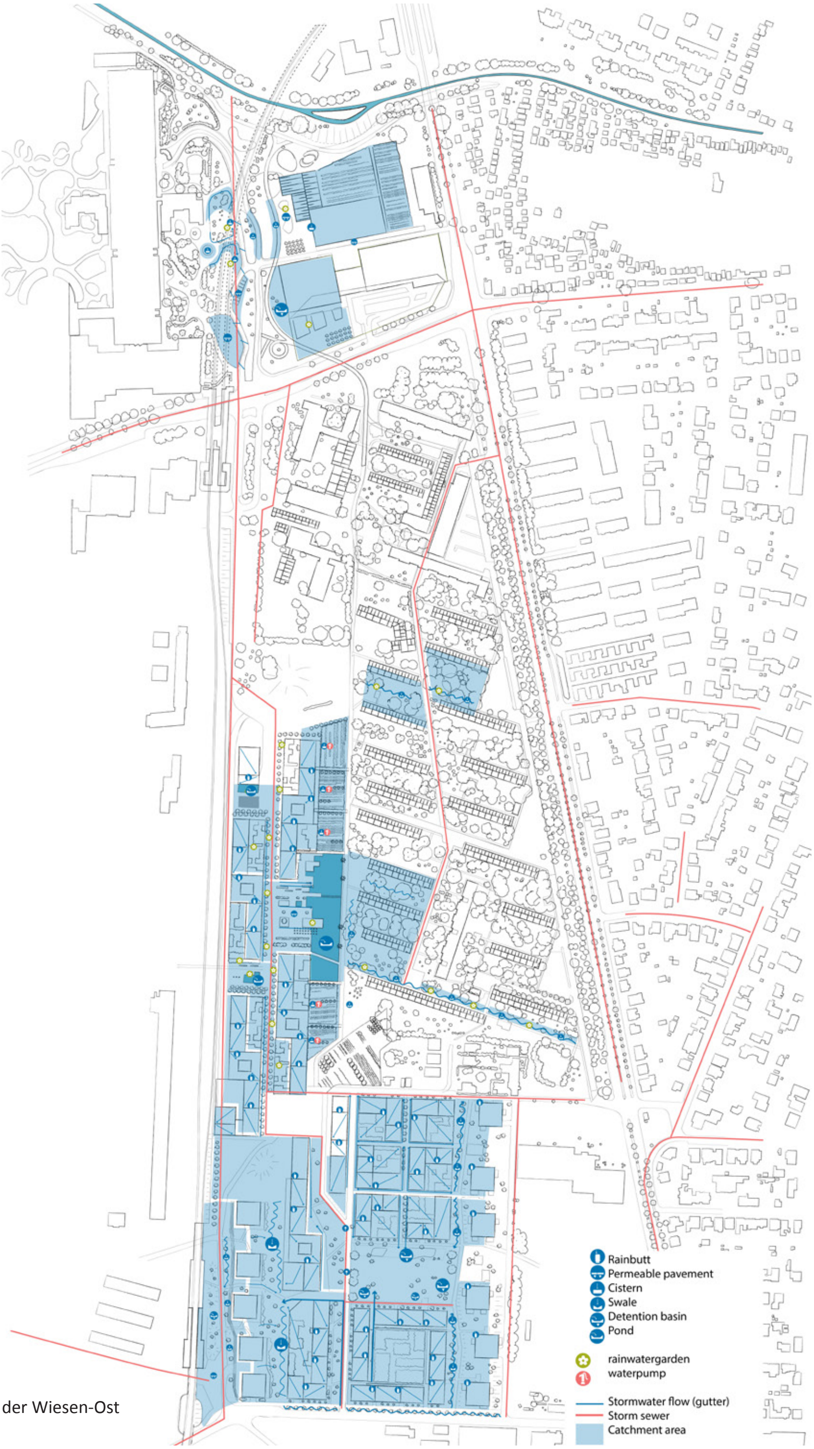


Figure 39: Waterplan In der Wiesen-Ost

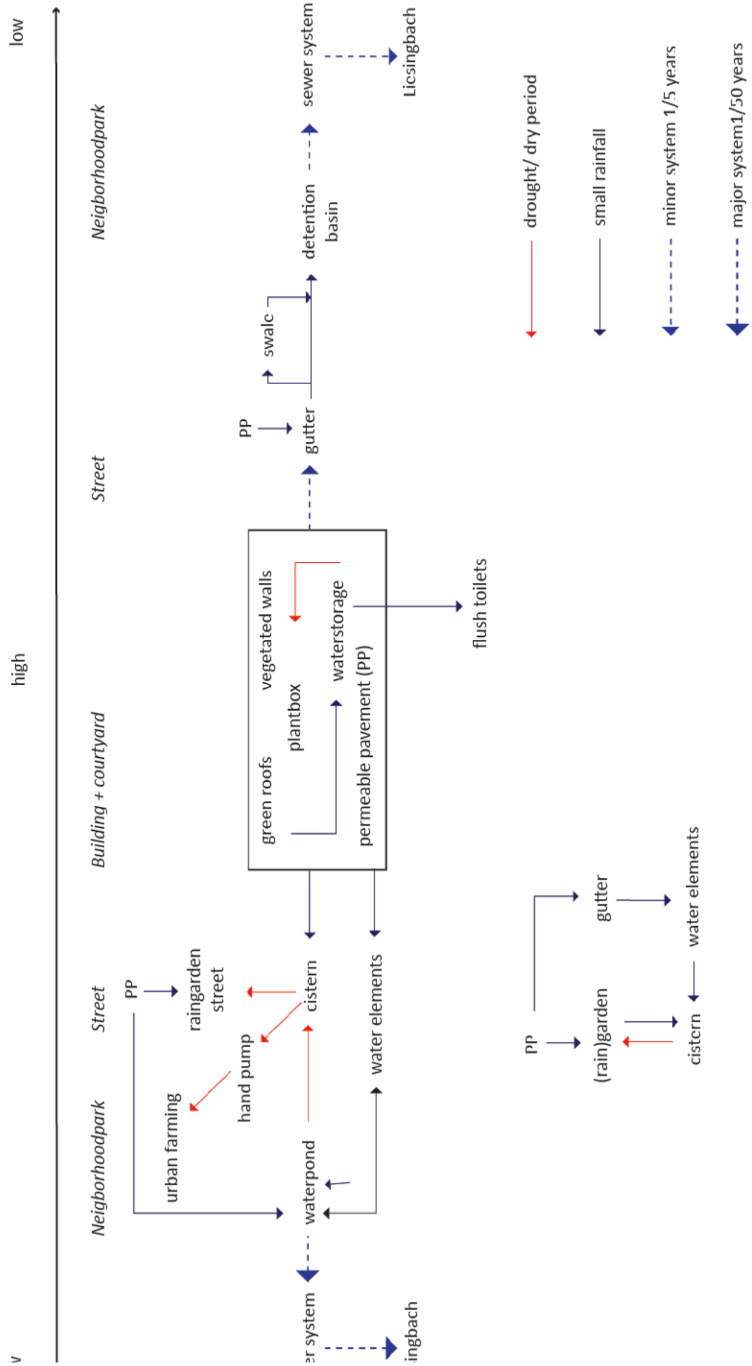


Figure 40: Waterscheme In der Wiesen-Ost

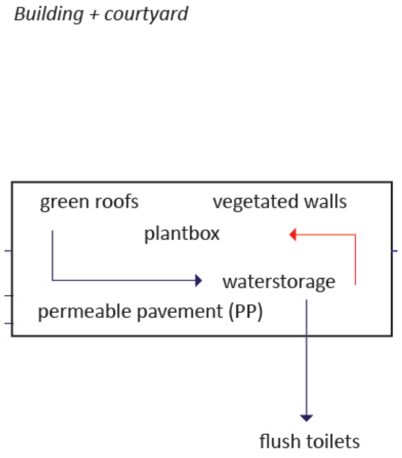
8. DETAIL DESIGN

The subarea's In der Wiesen-Ost will be elaborated further. see how the watersystem works and spatially could look like.

8.1 SMART GREEN ROOF

In the preliminary design of in der Wiesen-Ost, the buildings are drawn with flat roofs. Flat roofs offer possibilities to catch, store and re-use stormwater in a smart way. This means: Re-use water for plants in dry times, otherwise use it for flushing toilets. In that way, tanks can be filled aigain during the next rainfall.

The function of the roof influences the quality of stormwater. In figure 41 & 42, functions are examined for different levels within one buildingblock.



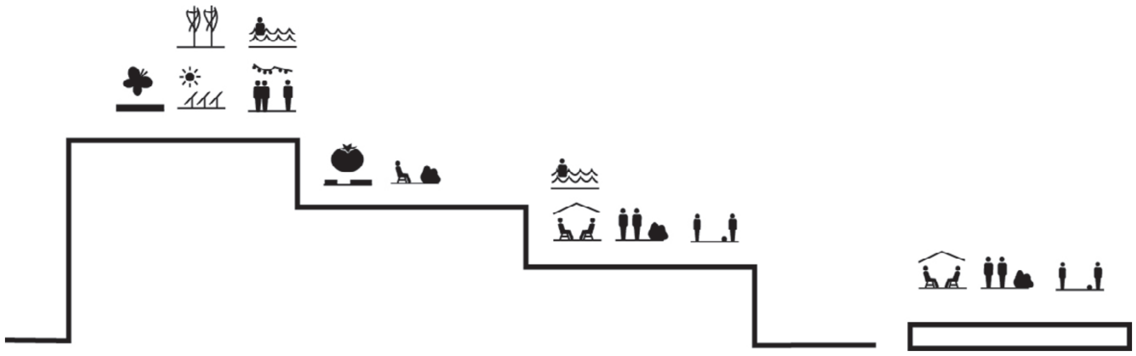


Figure 41: Functions on different levels.

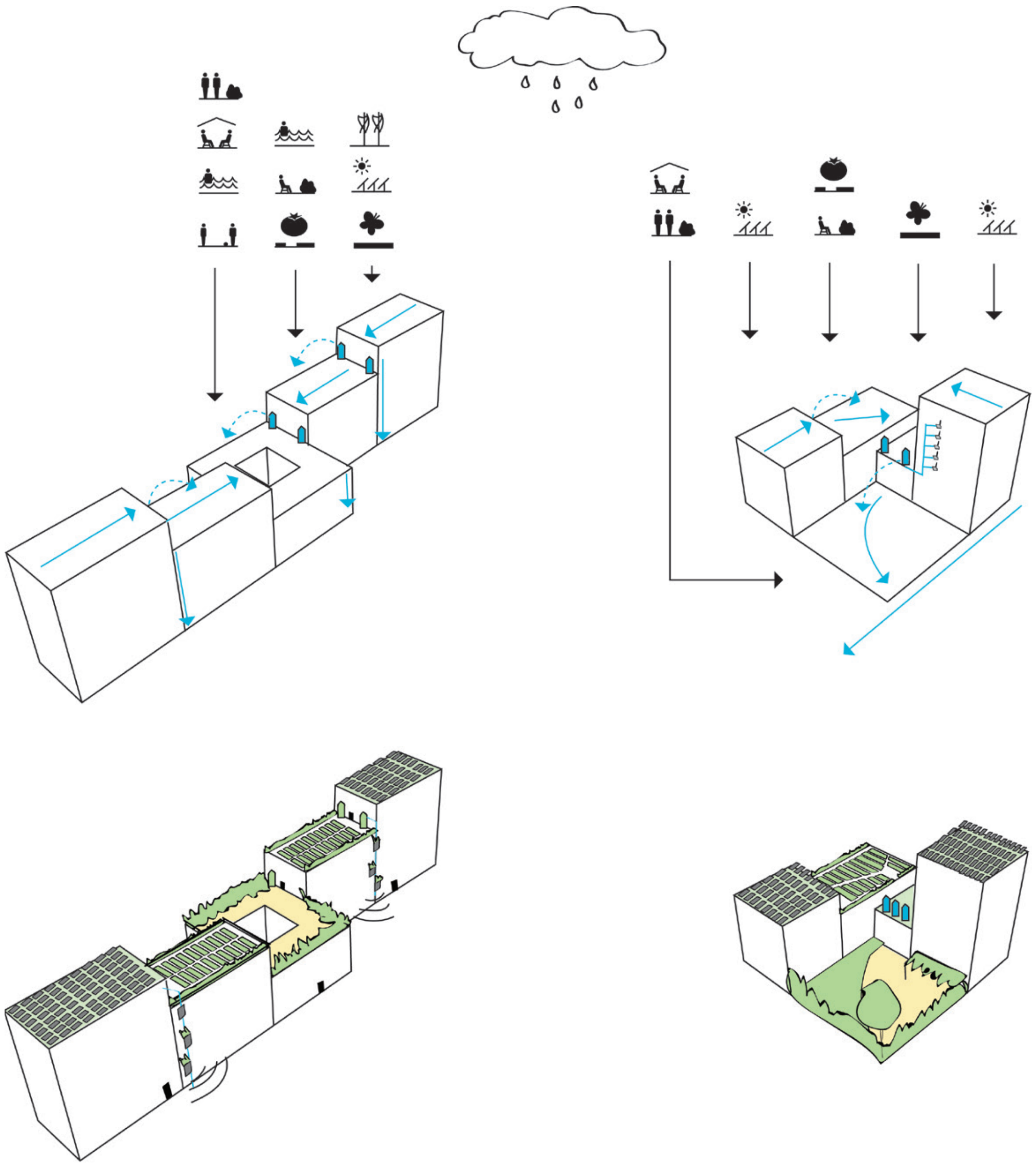
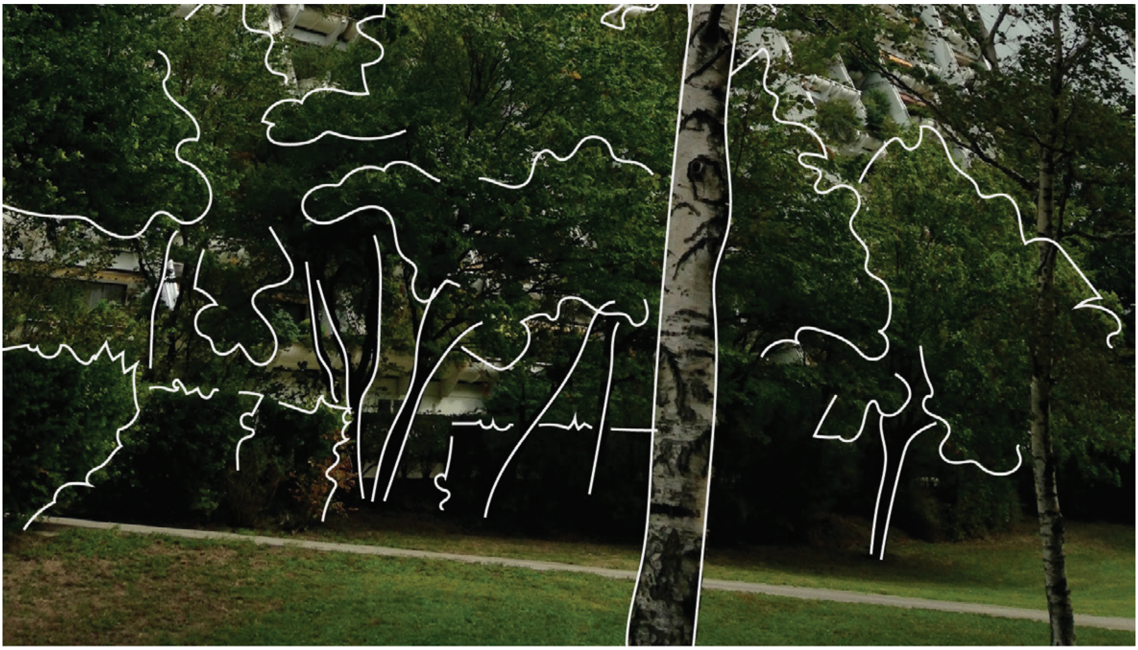


Figure 42: Waterflow & functions on rooftop.

8.2 GREEN ENTRANCE
8.2.1 Existing site



Characteristices: Liesingbach, park setting, parking, business area, aspalt,

8.2.2 Plan

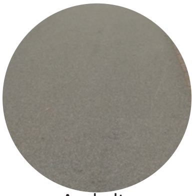
Figure 43: Zoom-in on the entrance to In der Wiesen-Ost

8.2.3 Section

Figure 44: Spatial section of entrance

Park -forest

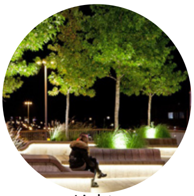
Grass (mowed)



Asphalt

Brick stones (permeable)

Stones



Lights

Gutters

Detention basin

Raingarden

Underground storage

Green Roof

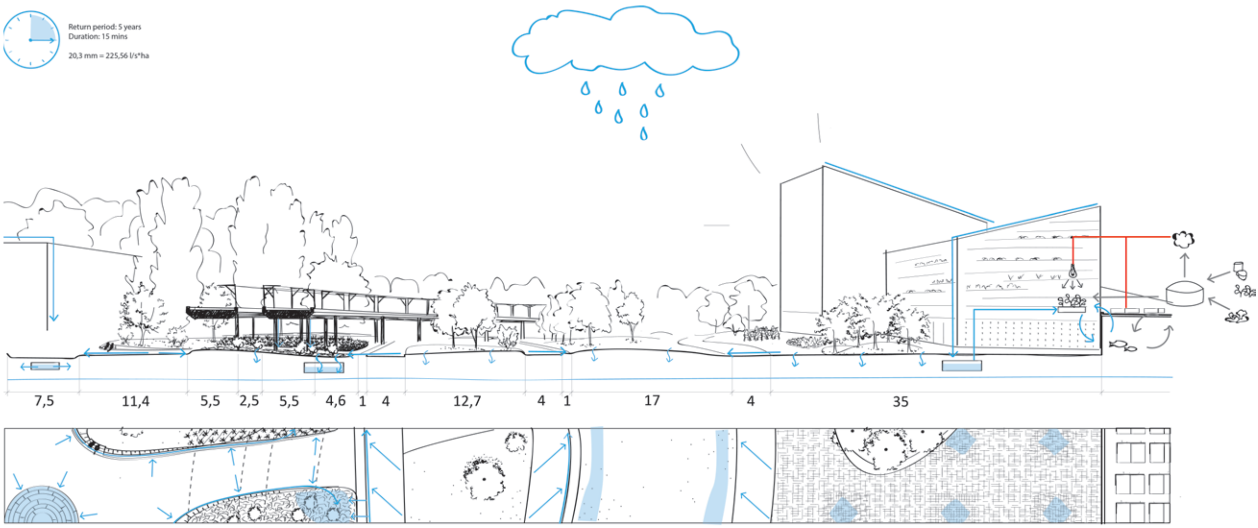


Figure 45: Section of entrance with minor system.

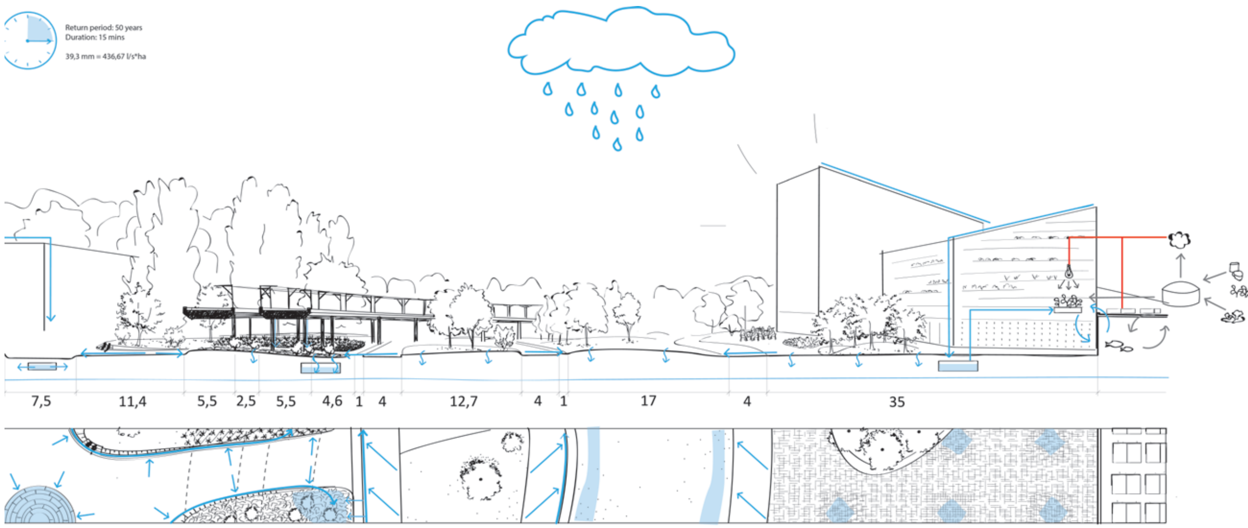


Figure 46: Section of entrance with major system.

8.2.4 Technical detail: SUDS & wonder

This area is one of the few location direct close to the Liesingbach where in the past clay was taken out for the production of brickstones. To refer to these days, brickstone is used in the public space.

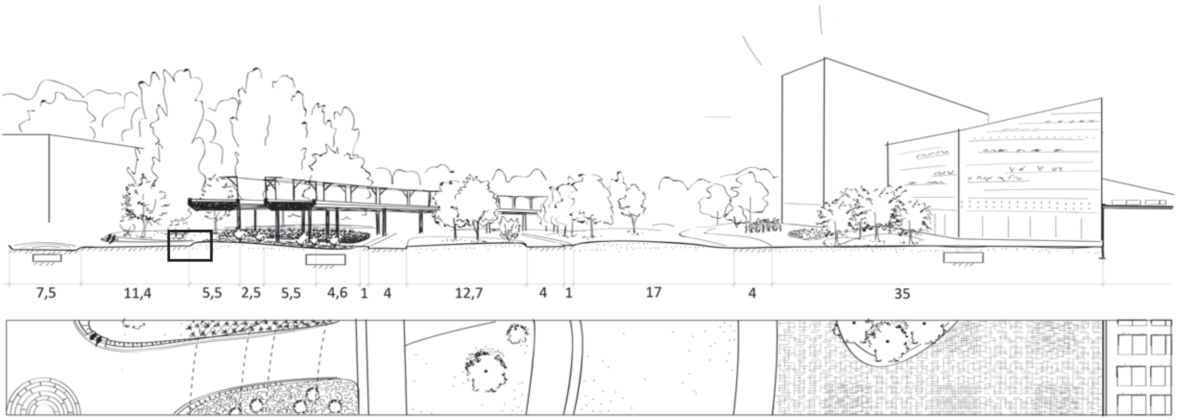


Figure 47: Section of entrance with technical details.

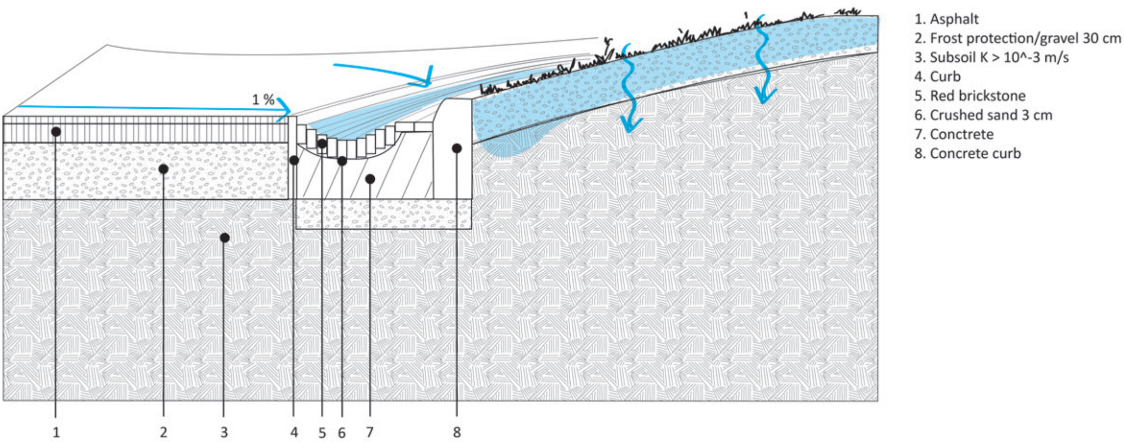


Figure 48: Detail open gutter with brick

8.3 POND- NURSERY
8.3.1 Existing site

Characteristics of the site: Long sightlines, a large variety of trees and perrenials species, in line with close distance, greenhouse, nursery fenced off, surface water storage basins with drip and sprinkler systems to water the plants

8.3.2 Plan

Figure 49: Zoom-in on nursery subarea of in der Wiesen-Ost.

8.3.3 Sections

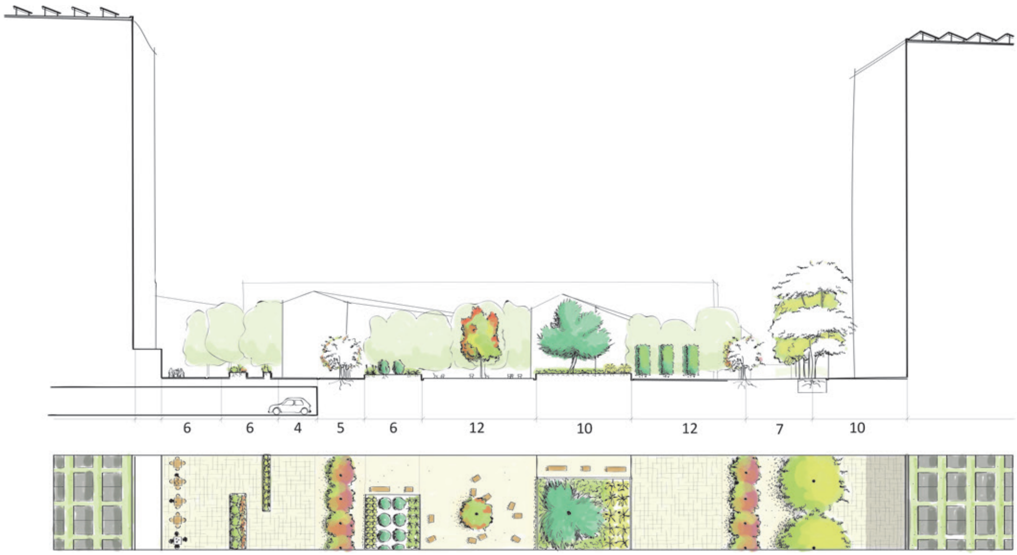
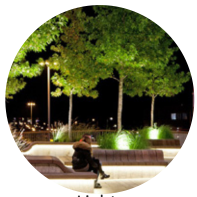


Figure 50: Spatial section of main square (15 years after implementation).

Gravel

Grafilux

Stone



Lights

(Monumental) perrenials in boxes

Liquid amber styraciflua

Silva

Rhododendron

Prunus avium

Robinia pseudoacacia "Frisia"

Trees and perennials are selected from the current nursery Alt-Erlaa. A mixture of 'exotic', decicious and evergreen plants form together a beautiful colourful composition. Therefore the choice of pavement is kept simple.

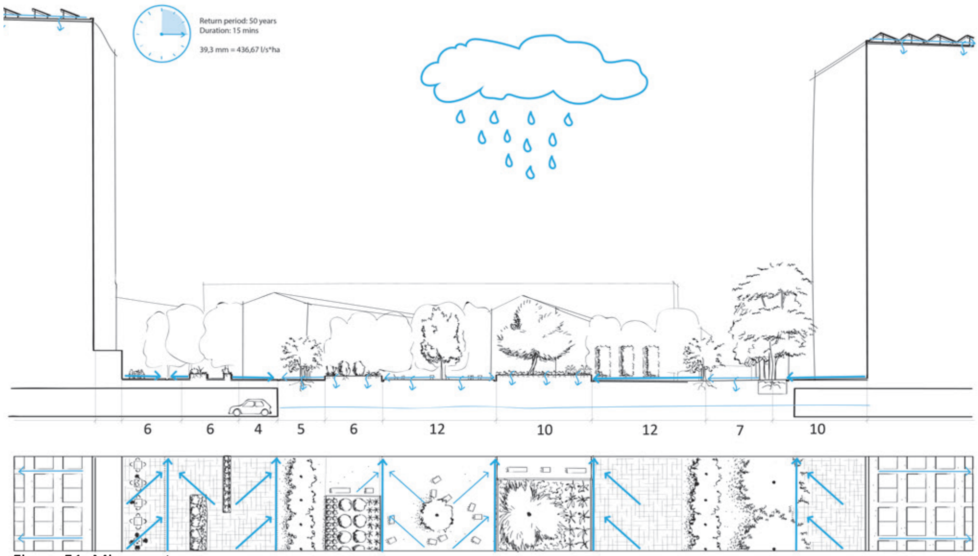


Figure 51: Minor system

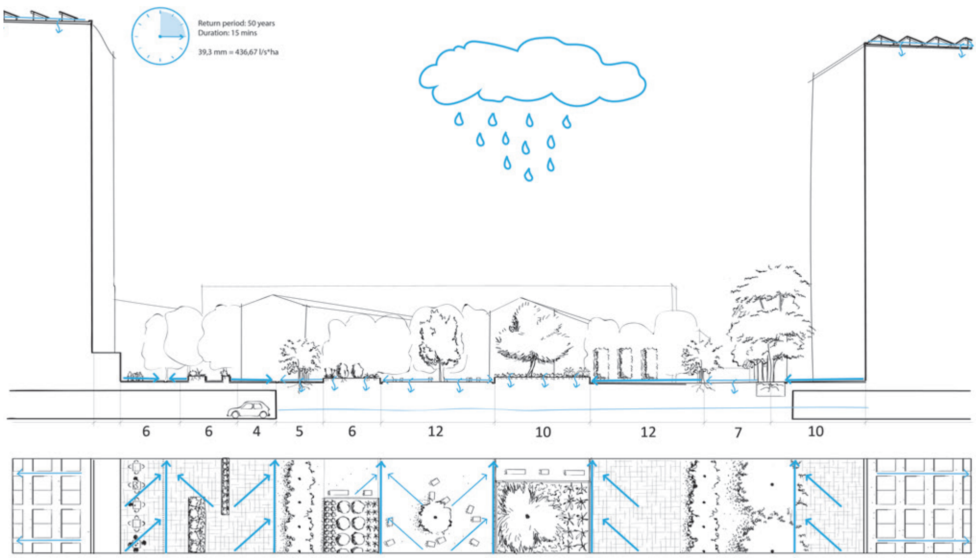
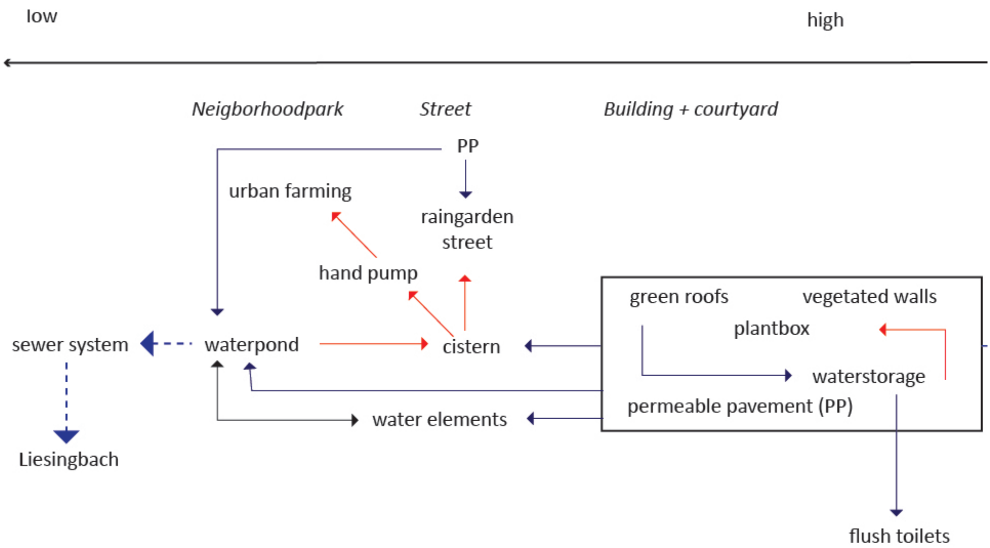


Figure 52: Major system



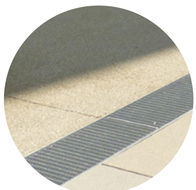

Gravel


Grafilux


Stone

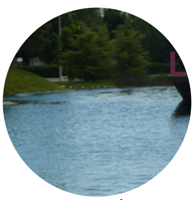

Green Roof


Filter drain


Drain


Permeable pavement


Raingarden


Pond

Currently, in the plant nursery, water storage ponds are used for watersupply. In the design, ponds are used again. Not only for storage and supply, but also because of large-scale underground parking. The main square has a low gradient towards the pond. Stormwater runs off the land as little infiltration is possible.

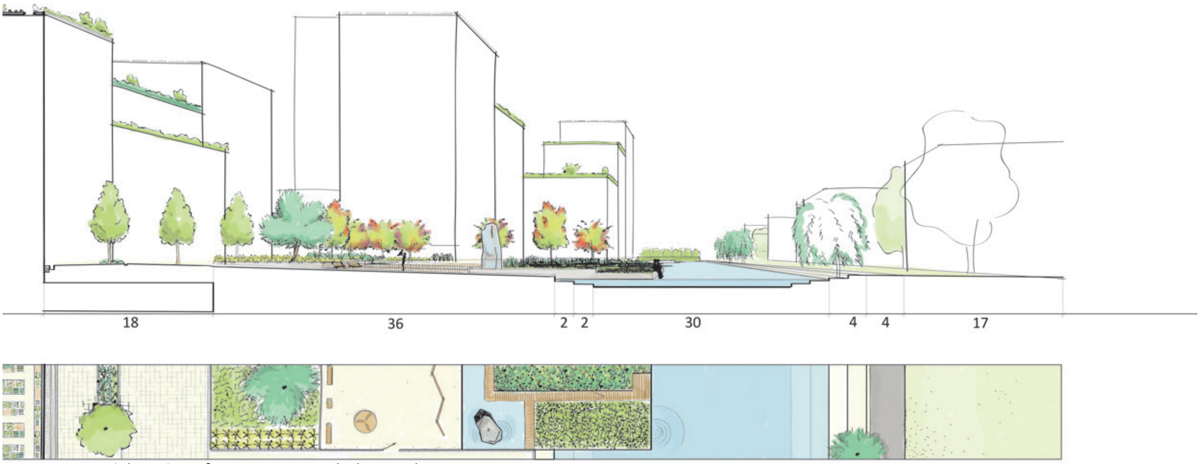


Figure 53: Spatial section of main square with the pond.


Stone


Gravel


Water related art


Mixture of helophyten


(Monumental) perrenials
in boxes


Silva


Salix


Prunus avium


Liquid amber styraciflua

The pond forms, together with the urban farming, social meeting point between the two neighborhoods. The form of the pond refers to the former nursery.

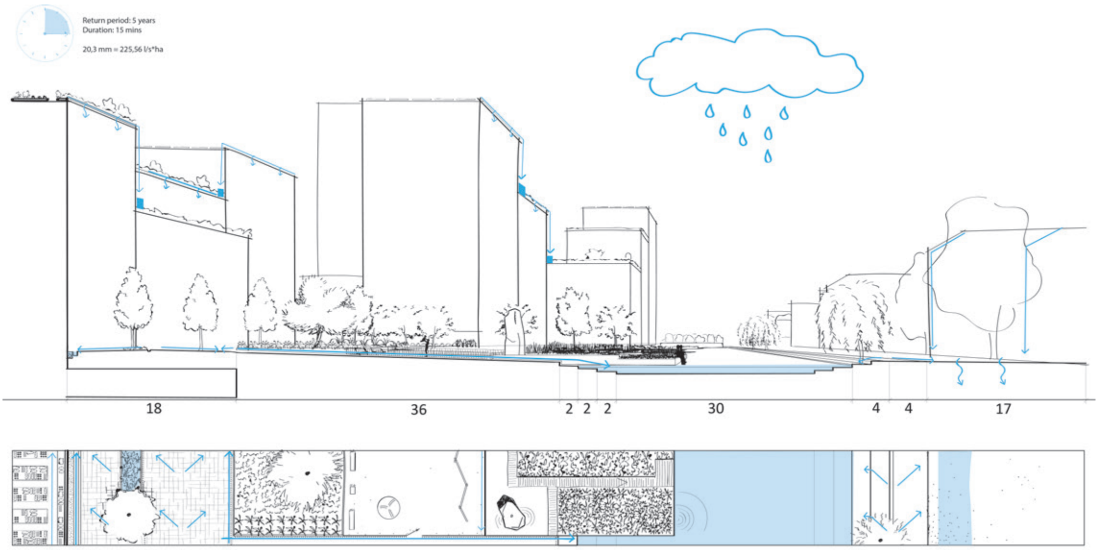


Figure 54: Section of main square and pond with minor system.

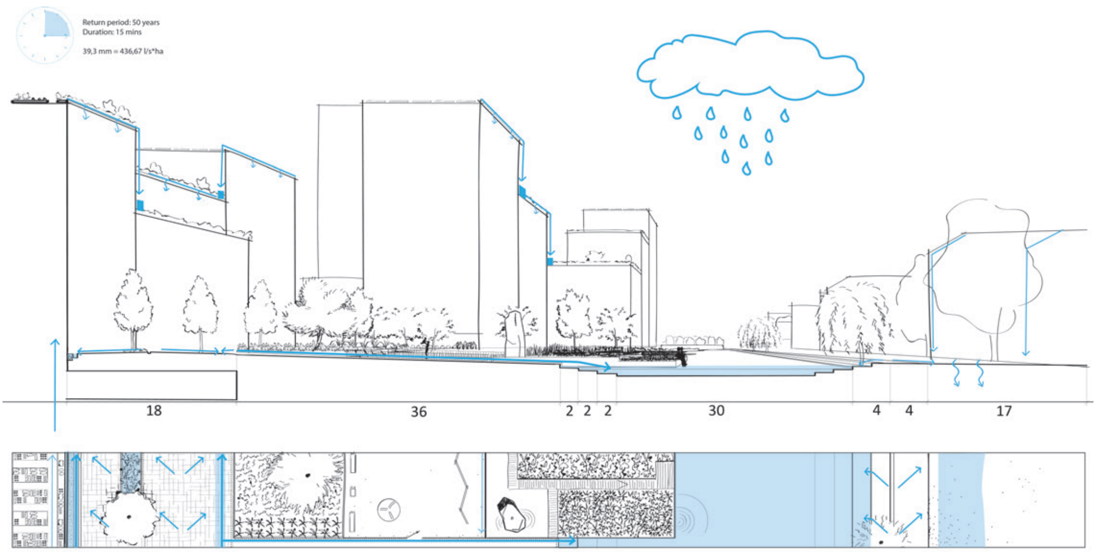
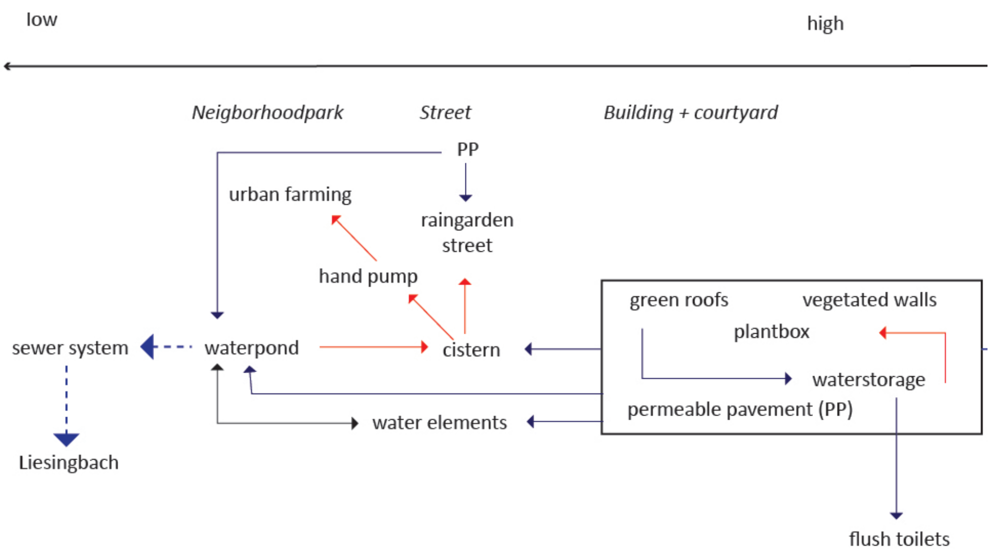


Figure 55: Section of main square and pond with major system.




Green Roof


Rain barrels on roof

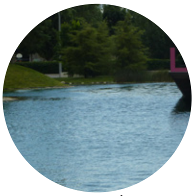

Filter drain


Gutters

The pond functions as site control. With the size of 3700 m2, the waterlevel will slowly rise after rainfall.

To prevent the growth of algae, water is pumped arou with the other ponds and helofytenfilters.


Pond with helofyten filters


Pond

8.3.4 Technical detail: SUDS & Safety

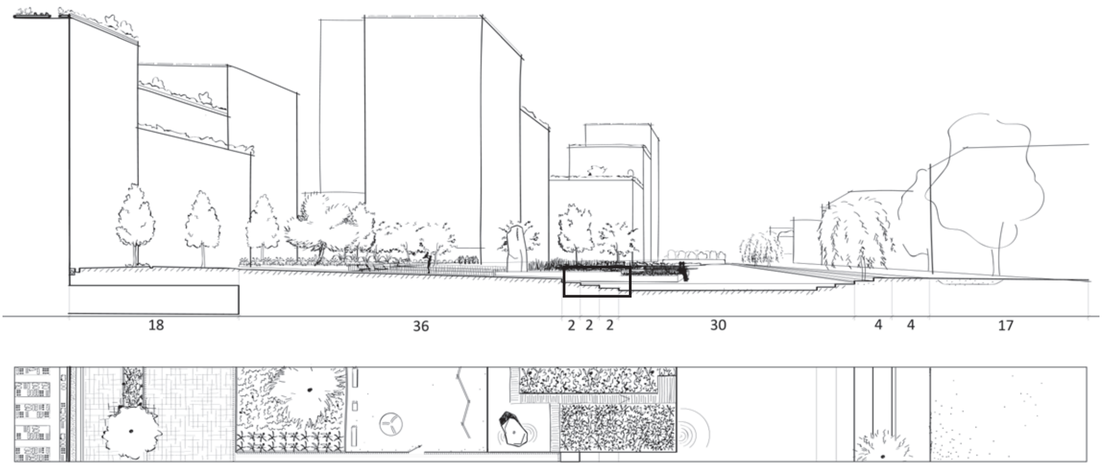


Figure 56: Section of main square and pond with technical details.

Austrian laws with regard to surface water in the city are strict!

The pond has longer steps to avoid drowning/ falling in. The depth of the pond is 55 cm. After a rainfall event with a 5 year return period the waterlevel will increase with 4 cm. In a rainfall event with a 50 year return period the increase will be 11 cm. Groundwater is 4,6 metres below groundlevel. If necessary a layer of geotextile is applied, to avoid infiltration.

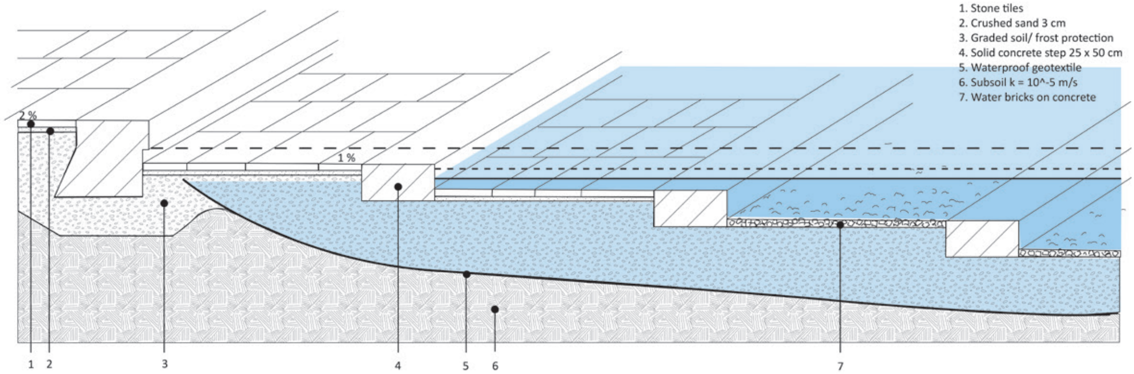


Figure 57: Detail longer steps to avoid drowning.

8.3.4 Waterplan

Figure 58: Zoom-in on nursery subarea of in der Wiesen-Ost.

8.4 DETENTION BASIN - FIELD
8.4.1 Existing site

Characteristics of the site are: Open space, fenced, undeveloped land which is used for storage, tree and bush species are native, no urban drainage system present: stormwater runoff wil infiltrate naturally.

8.4.2 Plan

Figure 59: Zoom-in on subarea Field

8.4.3 Section

Figure 60: Spatial section of detention basin.

Grass mowed

Grass ecological

Carpinus betulus

Quercus robur

(Acer campestre)
Elsrijk/

Prunus avium

Sorbus aucuparia
(multistem)

Sambucus nigra

Pebbles

Concrete slaps

Sand

Concrete bench

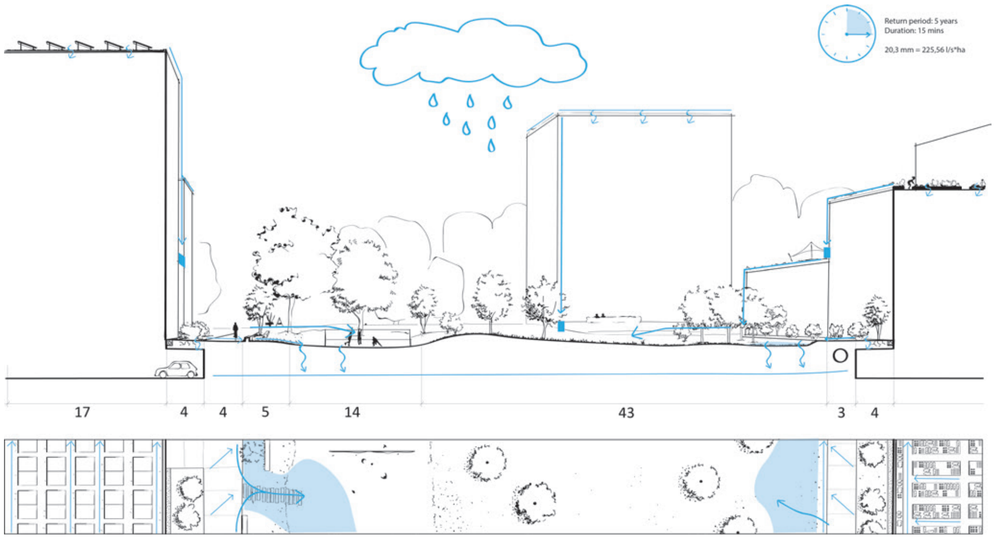


Figure 61: Section of main square and pond with minor system.

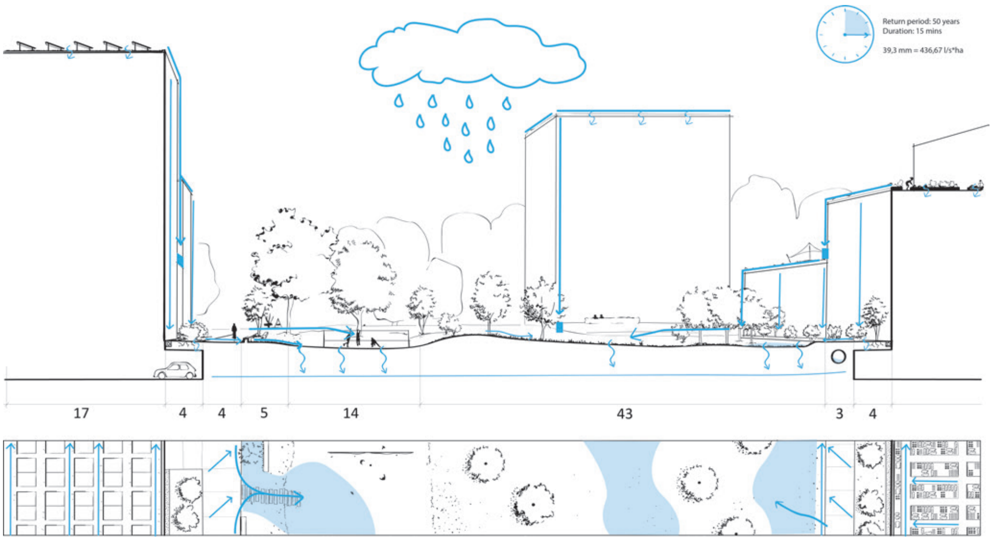
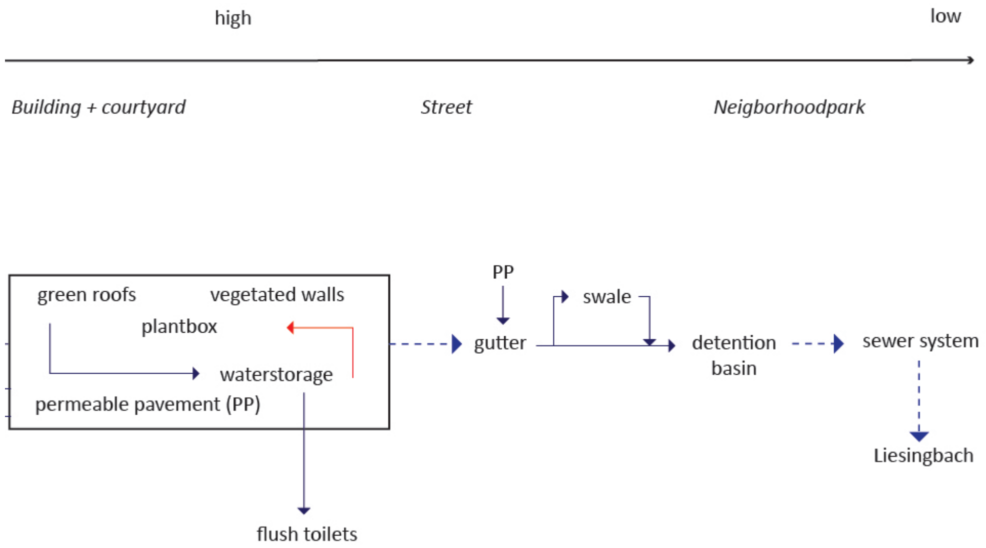


Figure 62: Section of main square and pond with major system.




Green Roof


Rainbutt


Filter drain


Gutters


Detention basin


Grass pavers

8.4.4 Technical detail: SUDS & Play

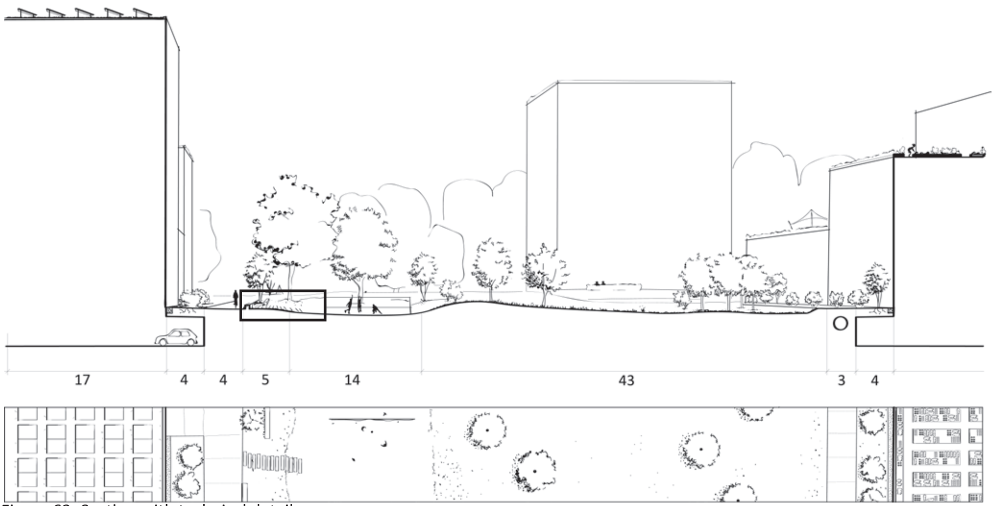


Figure 63: Section with technical details.

A smart detention basin can be combined with a sport & play field. Sand has a high infiltration rate.

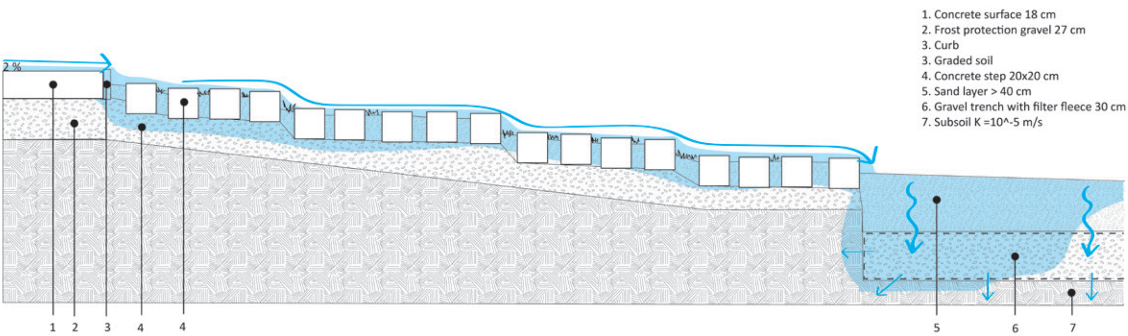


Figure 64: Detail use of sport/ playground for infiltration.

8.4.5 Waterplan

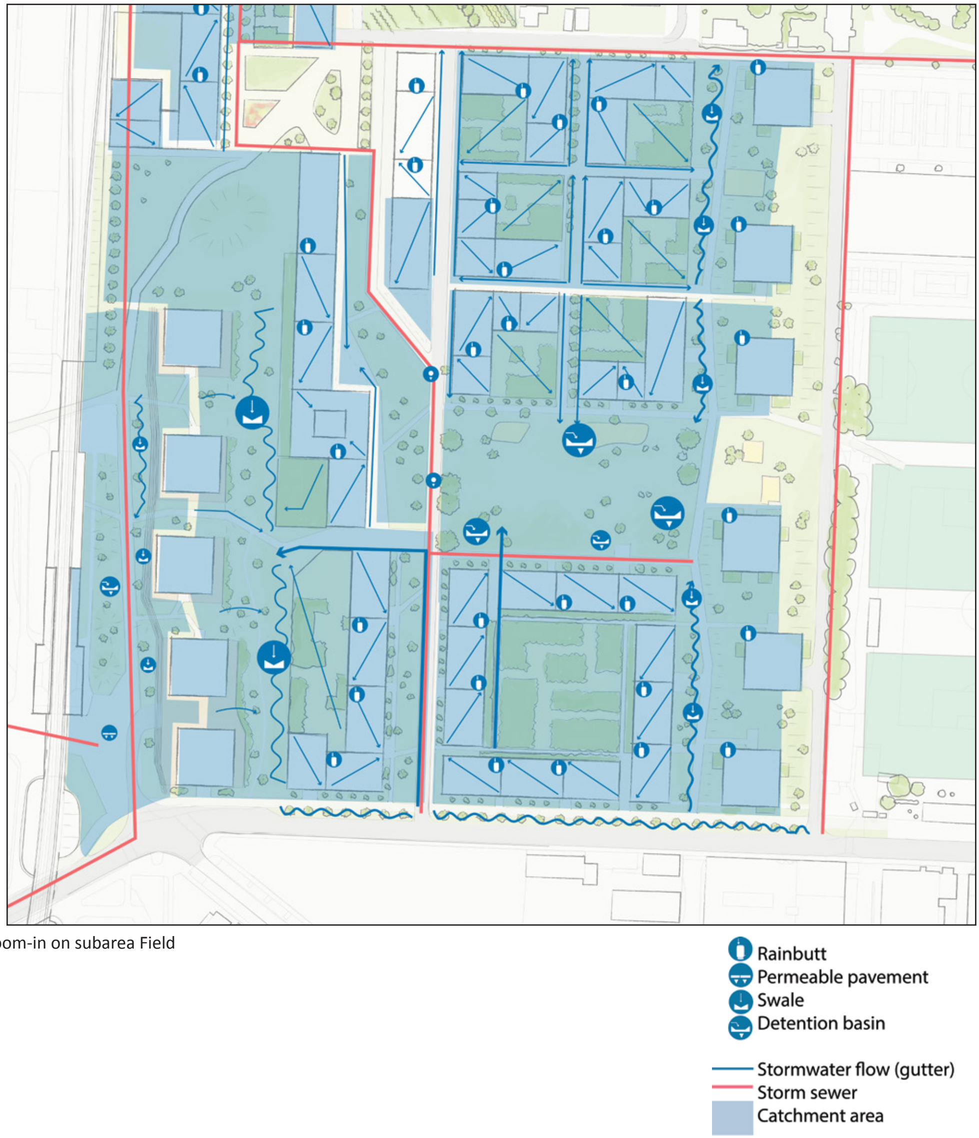


Figure 66: Zoom-in on subarea Field

PART V: CONCLUSION

9. CONCLUSION

In this chapter I will reflect on the research & design process, evaluate my design by using design criteria and different lenses, and reach a conclusion that answers the research questions.

9.1 REFLECTION
9.1.1 Research & design process

In this section I reflect on what I have learned in my research, what choice I have made and applied in the design and where it went well.

The research part, including: Literature review, field trip, reference study, map study, and role play, contributed to the design process and the landscape design. Different from traditional stormwater management, sustainable stormwater management is part of the urban landscape. As we have seen in the literature review, synergies are very important and will enable stormwater management to become part of urban planning and design. Therefore I used a role play and studied problems and opportunities for synergies in the Liesingbach catchment basin, by looking through **different lenses** of experts, community and myself as designer. Placing chips of problems and opportunities on the map of the Liesingbach catchment basin, helped to search for win-win solutions and generate ideas. It resulted in a community and environmental specific strategy and master plan. The master plan is composed of 7 projects in which SUDS can be explored further. For the transdisciplinary design process I selected six lenses: Water expert, ecologist, urban planner, community, outdoor tourist, and the landscape architect. These lenses I used on the different scales. So each scale should have a tailor made stakeholder design team. In addition, for development of innovative solutions, stakeholders should come from the domains of production, use, evaluation and regulation. Also called distributed agents.

Besides that, derived from literature review on SUDS and what I have seen in two reference projects in Malmö, for a good **SUDS design** it is important to think from the start (of the design process) about the stormwater system and how SUDS components are placed in the management train. What I have learned is that SUDS not only deal with stormwater quantity and quality, but also contribute to ecology and amenity. For the designer there is a lot of subject to design and choice of SUDS components. In case of the landscape design for In der Wiesen-Ost I looked first at the characteristics of the site and what kind of image I want for the subarea. The design and choice of SUDS components, in management train or individual, depend on that. The design criteria and set objectives were used as guideline for the designer.

Design should be done **through the scales** when working with a green and (storm)water systems. In my project I worked on the scales between the Liesingbach catchment basin to the small scale of the building and street. In addition it is important to not focus only on the site that matters to stormwater drainage system, but that it also contributes/ create spatial urban quality. In case of In der Wiesen-OST, a connection with the context and Liesingbach was made.

9.2 EVALUATION
9.2.1 Introduction

The main objective in this thesis is: Integrating sustainable stormwater management in the urban landscape for the Liesingbach catchment basin. As we have seen in the literature review, synergies are very important and will enable stormwater management to become part of urban planning and design.

The evaluation of the design is on two scales: Liesing Mitte and In der Wiesen-Ost.
For the evaluation of the master plan Liesing Mitte 2030, I use the aims of the different lenses stated in Section 5.1, and evaluate what was accomplished and how it was accomplished.
For the evaluation on the scale of the Wiesen Ost, I use the aim of the different lenses again in order to evaluate what was accomplished and how it was accomplished as well as the objectives in the design criteria. In addition I will evaluate the design criteria also.

9.2.2 Liesing Mitte

Water expert: The main problems on the scale of the Liesingbach are the significant floodrisk and the quality of stormwater runoff. The new urbanization wave till 2025 can worsen it. To improve this, changes shouldn't be made on the Liesingbach, but by small-scale SUDS should in the urban area instead of making changes to the Liesingbach. In the master plan for Liesing Mitte, projects are selected in which SUDS can bring the peak of stormwater runoff in post-development closer to the pre-development hydrograph. This can be explored for different urban structures and projects in planning. After realization, monitoring and evaluation can help in how to address SUDS for the rest of the Liesingbach catchment basin.

Ecologist: Small measures are taken in the Liesingbach in order to improve the hydromorphological and biological condition, like tree trunks, small dams to slow down the uniform waterflow and a nature friendly bank. There is not much support from other disciplines, because the hard surface along the Liesingbach is important for quick discharge and offers opportunities for recreation. In the robust green network and the selected SUDS projects, soft stormwater measures create a green environment and natural processes can improve stormwater quality.

Planner: The robust green network for Liesing Mitte carries opportunities for new bike routes, stormwater management, and contribute to sustainable urban development. Besides that, SMART city projects and urban renewal projects are part selected projects in which SUDS can be integrated in the design process and look for innovative synergies.

Community: The wishes of the community are for specific locations. In the masterplan of Liesing Mitte the project of Atzgersdorf, playground, make Liesingbach visible and village centre more attractive together with SUDS projects.

Tourist: The Liesingbach is the identity carrier of the region. The expansion of the green network carries recreational connections between parks, village centre, public transportation stations & Liesingbach. Programmatic reinforcement and waterrelated art contribute to the mode of interest. Wasserschloss is one of them.

Landscape architect: to design and explore how SUDS can contribute to the (spatial) urban quality. The masterplan contains very different projects which are connected by green infrastructure. On a different scale it can be worked out.

All in all, different lenses can find themselves in the selected projects on the Liesing Mitte scale Although, not every lens and aim are applicable on this scale.

9.2.3 Wiesen-OST

Water expert: A waterproof design is achieved for In der Wiesen-Ost, which has minor and major system. This is achieved by applying SUDS components in management train. Also looked at technical detail.

Ecologist: A steppingstone in the Liesingbach is created with a nature friendly bank. Small habitats for wildlife, natural processes and native flora and fauna species are proposed for the subarea: Field. Bushes are planted for small animals.

Planner: In the SMART City project In der Wiesen-OST with key aspects zero emission and urban farming, rainwater harvesting and re-use are explored. However not so much worked out on the architecture level. The use of site characteristics contributes to place making.

Community: A green environment which is well connected to the Liesingbach and other neighborhoods. This is achieved by underpasses in the metro line, bridge and redevelopment of the area at the Liesingbach

Outdoor tourist: Recreational infrastructure is integrated in the green infrastructure. The iconic greenhouse/culture centre presents the entire “In der Wiesen” area along the Liesingbach and invite people to stop and explore the area. In this greenhouse we share innovative methods for sustainable food production, energy conservation. A mix of workshop, local production, café, restaurant, small business are accommodated in the building.

Landscape architect: SUDS is spatially integrated in the urban landscape. This is achieved by using knowledge of the other lenses, selecting suds components and thinking about the stormwater system.

	Sub criteria	Objective for project area	Evaluation project by objective	Evaluation Sub criteria
Water quantity	Prevention of urban flooding	The capacity of a minor SUDS should deal with precipitation condition of 15 minutes storm with a return period of 5 years. The major SUDS should deal with precipitation condition of 15 minutes storm with a return period of 50 years.	Heavy rainfall will not lead to urban flooding. SUDS measures + stormwater sewers should be sufficient to deal with stormwater runoff volume of a 15 minutes storm with 5 and 50 year return periods.	Prevention of urban flooding differs from bringing the peak of stormwater runoff close to the pre-development hydrological
	Prevention from drought/ water supply	Provide seasonal water storage for supplement to drought.	Waterstorage measures are taken on rooftops, underground cistern and ponds. For the greenhouse at the Liesingbach a closed watercycle is worked out and groundwater is used for the agriculture plots.	Besides storing stormwater runoff, groundwater could also be considered as water supply in periods of drought.
Water quality	Protection of receiving watercourses	Improve the quality of stormwater runoff before it reaches watercourse by using SUDS components in management train.	In most cases, stormwater runoff is treated before it enters the receiving watercourses. Because underground parking, stormwater runoff is not so much treated in my design. To keep the pond clean from algae, water will be pumped around and cleaned by helophytenfilters.	An addition can be made: Water quality should also be considered for protection of storage measures, like a pond or cistern.
Amenity	Aesthetics	Consider site specific characteristics. Create beauty of pleasure experience as a result of design composition (e.g. visual appeal and the absence of odors).	Good. I looked first at the site characteristics and based my choice of SUDS measures and design on that. For example in the former nusery I found inspiration in little water storage basins, plant species, and the rhythm of the plants. These site specifics can be found back in the composition of the design.	Not only visual, also other senses part of aesthetics.

	Sub criteria	Objective for project area	Evaluation project by objective	Evaluation Sub criteria
	Usability	Provide opportunities for education and recreation to those who live close to area	The usability of In der Wiesen is increased because green infrastructure goes through the area and connects recreation parks and neighborhoods together. SUDS provide places for sport, play and contemplation.	Through the scales of building, street, neighborhood.
	Health and safety	Freedom from exposure to public health and safety risks (e.g. drowning hazards, sudden inflows, breeding ground for mosquitos or noxious weeds).	Safe. Water will not deeper than 60 cm and longer steps prevent from drowning	Laws in Austria are very strict when it comes to implementing SUDS and safety risks. Design should consider these laws and/or discuss it by design.
	Maintenance	Set an appropriate maintenance and management plan.	No maintenance plan. I expect the design requires high maintenance. Maintenance will be executed by the city of Vienna and housing associations. Especially in autumn leaves will accumulate in the open gutter system.	
	Community acceptability	Consider the public's preference towards the appearance of SUDS. Engage stakeholders in the design process.	The community wont be very happy to bring under in the parking in a parking garage.	
Ecology	Habitat creation	Create a range of habitat types for native flora and fauna and corridors for connection. Use plants that grow under local conditions. Enhance natural processes.		Optional, not a must to think of

10.3 CONCLUSION

The main aim of this master thesis is to explore, through landscape design, possibilities for integrating sustainable stormwater management in the urban landscape of the Liesingbach catchment basin.

The thesis starts with the fact that water is not always given the priority and attention it should have in design of the built environment. Stormwater systems have been traditionally designed aiming to discharge water as quickly as possible through underground sewersystem. Heavy rainfall events and impacts of climate change can make the urban water system more sensitive and piped system incidentally insufficient to protect properties from flooding. In this context a more general research question is stated: How can stormwater management play a self-evident role in landscape design processes and improve urban quality in general. This is tested in the case of the Liesingbach catchment basin.

Research question 1: "How can stormwater management, approached as a system, be used in landscape design processes?"
(Sustainable) stormwater management measures have an effect on the urban water system on the scale of the entire catchment basin. Therefore in a landscape design process it is important to have an understanding of the complex urban water system, including the minor & major system and heavy rainfall events with a 5 and 50 year return period, and work through the scales.

In my design process I addressed four scales: The Liesingbach catchment basin, urban area Liesing Mitte, neighborhood In der Wiesen-Ost and context, and finally I elaborated the design on building and street level and show how the stormwater system works with rough calculation for heavy rainfall events with a 5 and 50 year return period.

Research question 2: "What is the potential of stormwater management to not only improve the urban drainage, but also the urban quality?"
The approach of Sustainable Urban Drainage Systems (SUDS) does not only achieve benefits in stormwater quantity and quality, but also in maximizing ecology & amenity opportunities. The balance of these three categories is in most cases subject of design. For a landscape design with a SUDS solution, design criteria are set which help the landscape architect to state (design) objectives.

In the landscape design for In der Wiesen-Ost, SUDS solutions do not only consider stormwater quantity and quality. The selection of SUDS components and the way they are put in management train were subject of design. The landscape design incorporates the characteristics of the landscape and the local ambitions/demands. For example, in the sub area: The field, I propose detention basins for natural infiltration and at the same time it emphasizes the 'open' character and gives more space for ecology. In the sub area: The nursery, I proposed a large pond which not only deals with the large volume of stormwater runoff, but also incorporated recreational opportunities and spatial characteristics of the former site.

Research question 3: “How can sustainable stormwater management become self-evident in urban planning and design?”
In a trans-disciplinary design process experts, community and designers, preferable from distributed agencies, work together in order to come to an innovative, environmental and community specific design. In this design process, possibilities for synergies with SUDS are explored together. Depending on the scale, a different team can be composed. The input can be used by the landscape architect to explore the possibilities by research by design and thereby use the design criteria & objectives as guideline. Reflection on the design can be done by using the aims of different trans-disciplinary team members and by the design criteria.

On the scale of the Liesingbach catchment basin, I used a role play for the landscape analysis and together we generated ideas and searched for synergies with SUDS. For the roleplay I used the lenses of: Water expert, ecologist, urban planner, community, outdoor tourist, and landscape architect. In the analysis as well as the evaluation, I used the same team.

REFERENCE

Ancient History Encyclopedia (2015). Retrieved September 3, 2015, from: http://www.ancient.eu/article/129/

Aspegren, H., Cour Jansen, J. la, Haghighatafshar, S., Jönsson, K., Lidström, V., Mattsson, A. (2014). Storm-water management in Malmö and Copenhagen with regard to Climate Change Scenarios. VATTEN - Journal of Water Management and Research, 3 (14) p. 157-168.

Batik, H., Käfer, A., Linsberger, N., Mellauner, M., Moßburger, G., MA 21b, MA 20, MA 22, Seethaler, C., Volksbau, Vlay, B., Weichenberger, J., Wiener Heim, Wohnfonds Wien, Zoufal, A. (2012). In der Wiesen Ost Urban gardening: Kooperatives Klausurplanungsverfahren 2012, Municipality Vienna, Vienna.

Berger, R. Ehrendorfer, F. (2010). Ökosystem Wien: Die Naturgeschichte einer Stadt. Böhlau Verlag, Wien-Köln-Weimar.

Bleuze, P. Pötz, H. (2012). Urban green-blue grids for sustainable and dynamic cities, Coop for life, Delft.

Booth, D.B. (1991). Urbanization an the Natural Drainage System – Impacts, Solutions, and Prognoses. The Northwest Environmental Journal, 7 p. 93-118

Breiling, M., Ruland, G. (2008). Chapter 9 – The Vienna Green Belt: From Localized Protection to a Regional Concept, in: M.Amati (Ed.) Urban Green Belts in the Twenty-first Century, Aldershot, Ashgate.

Butler, D., Davies, J.W. (2011). Urban Drainage – 3rd Edition, Spon Press, New York

City of Edmonton (2015). Design and Construction Standards: Volume 3 Drainage, Retrieved June 20, 2015, from: http://www.edmonton.ca/city_government/documents/Volume_3_Drainage_.pdf

Clementschitsch, L., Formayer, H., Kromp-Kolb, H. (2007). Auswirkungen des Klimawandels auf Wien unter besonderer Berücksichtigung von Klimaszenarien, Institut für Meteorologie & Physik Universität für Bodenkultur, Vienna.

EEA (2012). Climate change, impacts and vulnerability in Europe 2012: An indicator-based report, EEA Report No 12/2012, European Environment Agency, Copenhagen.

eHYD (2015). Bemessungsniederschlag, Retrieved July 20, 2015, from: http://ehyd.gv.at/#

Elands, B.H.M., Lengkeek, J. (2012). The tourist experience of out-there-ness: theory and empirical research. Forest Policy and Economics, 19 p. 31-38.

Grimm, K. (2010). Integratives Regenwassermanagement: Motivenbericht. Magistratsabteilung 22 - Wiener Umweltschutzabteilung, Vienna.

Jantscher, O. (2015). Presentation ACO. Presented on July 17, 2015.

JSCWSC (2009). Evaluating Options for Water Sensitive Urban Design – A National Guide, Joint Steering Committee for Water Sensitive Cities (JSCWSC), Canberra.

MA 18 (2014). STEP 2025 Stadtentwicklung Wien, Magistratsabteilung 18 – Stadtentwicklung und Stadtplanung, Vienna.

MA 18 (2015). Hauptradverkehrsnetz Wien Gesamt , Magistratsabteilung 18 – Stadtentwicklung und Stadtplanung, Vienna.

MA 45 (2013). IST-Bestandsanalyse 2013 Wien, Retrieved November 20, 2014, from: http://alt.umweltdachverband.at/fileadmin/user_upload/pdfs/Veranstaltungen/Veranstaltungen_2014/Seminarreihe_NGP/3._SE-Reihe/Ofenb%C3%B6ck_IBA_2013_Wien.pdf

MA 45 (2014). Verlauf und Einzugsgebiet der Liesing, Retrieved Oktober 30, 2014, from: http://www.wien.gv.at/umwelt/wasserbau/gewaesser/die-liesing/verlauf.html

MA 45 (2015). Die Liesing, Retrieved February 2, 2015, from: https://www.wien.gv.at/umwelt/wasserbau/gewaesser/die-liesing/

Malmö Stad (2015). Awards and prizes, Retrieved June 5, 2015, from: http://malmo.se/English/Technical-visits/Awards-and-prizes.html

Marsalek, J., Jiménez-Cisneros, B., Karamouz, M., Malmquist, P., Goldenfum, J., Chocat, B. (2008). Urban water cycle processes and interactions, Taylor and Francis, Leiden; and UNESCO Publishing, Paris.

Morgan, C., Abbott, J., Bevington, C., Davis, P., Levin, D., Robinson, P., Simkins, P. (2013). Water Sensitive Urban Design in the UK – Ideas for built environment practitioners, CIRIA, London.

Nijhuis, S., Bobbink, I. (2012). Design-related research in landscape architecture. Journal of Design research, 10 (4) p. 239-257.

Nijhuis, S., Jauslin, D., Vries, C. de, (2014). Flowscapes: Infrastructure as landscape, landscape as infrastructure: Graduation lap landscape architecture 2014-2015, TUDelft, Delft.

Scottisch Government (2011). Green Infrastructure: Design & Placemaking, Retrieved Mai 25, 2015, from: http://www.scotland.gov.uk/Resource/Doc/362219/0122541.pdf

Stahre, P. (2008). Blue-green Fingerprints in the city of Malmö, Sweden: Malmö's way towards a sustainable urban drainage, VA SYD, Malmö.
Strommer, G. (2015). Unwetter vom 13. August 2010, Retrieved Mai 22, 2015, from: http://gabriel-strommer.jimdo.com/starkregen/starkregen-im-gro%C3%9Fraum-wien/%C3%BCberschwemmungen-2010/

Ven, F. van der (2011). Water Management in Urban Areas. Faculty of Civil Engineering and Geosciences. TUDelft, Delft.

Wallerz (2015). Retrieved September 3, 2015, from: http://wallerz.net/wp-content/uploads/2014/06/2088_hanging_gardens_of_babylon.jpg

WGM (2014). Hydrogeologische Forschung, Retrieved November 30, 2014, from: http://www.wgm.wien.at/Hydrogeologische-Forschung.17.0.html

Wien Voraus (a) (2014). Kommen Sie vorbei und mischen Sie sich ein! Perspektivenwerkstatt 08 – 12 September 2014, Magistratsabteilung 21 – Stadtteilplanung und Flächennutzung, Vienna.

Wien Voraus (b) (2014). Eckpunktepapier: Perspektive Liesing, Magistratsabteilung 21 – Stadtteilplanung und Flächennutzung, Vienna.

Wien Voraus (c) (2015). Zielgebiete der Stadtentwicklung, Retrieved at March 22, 2015, from: https://www.wien.gv.at/stadtentwicklung/projekte/zielgebiete/

WISA (2014). Gebiete mit pot. sign. Risiko, Retrieved November 30, 2014, from: http://wisa.bmlfuw.gv.at/wasserkarten/hochwasser/gefahrenkarten.html

WKN (2015). Kanalnetz Wien Ubersichtslageplan Einzugsgebietsgrenzen, Wien Kanal, Vienna.

Worldweather (2015). Retrieved November 8, 2015, from: http://www.worldweather.org/en/city.html?cityId=17

Woods-Ballard, B., Bray, R., Jefferies, C., Kellagher, R., Martin, P., Shaffer, P. (2007). The SuDS manual, CIRIA, London.

APPENDIX

APPENDIX A: REFERENCE STUDY
Introduction Malmö

Malmö is the third largest city in Sweden. Together with Copenhagen it forms the Øresund region, the most densely populated area in Scandinavia.

Map of Øresund region with Malmö and Copenhagen.

The economy of Malmö was traditionally based on shipbuilding and construction related industries. From the mid-1970's till 1995 it caused a troubled economic situation. Since the opening of the Øresund Bridge (between Copenhagen and Malmö) in 2000, Malmö has undergone a revival of its economy and grows rapidly. This resulted in major transformations with architectural developments, attracted new biotech and IT companies, and a new university.

Over the last years, Malmö has won many awards for its sustainable urban development (Malmö stad, 2015). Also in storm water management a lot of interesting projects have been executed from the 1990's. The main problem at that time was to protect the downstream conveyance system from being overloaded during periods of heavy rainfall. Therefore Malmö has gradually shifted from traditional urban drainage towards an open storm water management.

Different from most countries, local municipalities in Sweden have a very strong influence on physical planning. Stormwater management in Malmö is driven by an official document (Storm-water Strategy for Malmö).

The basic idea in Malmö's storm water policy is that quantity issues, quality issues and various social aspects should be dealt with. Planning of facilities for sustainable urban drainage is in Malmö carried out in close cooperation between different departments in the city Other stakeholders are involved as well, like private developers, residents, schools, media, non-profit associations (Stahre, 2008).

Derived from this official (policy) document, the following general goals are identified/set for storm water management in Malmö:

- The natural water balance shall not be effected by urbanization;
- Pollutants shall to greatest possibility be extent be kept away from the urban runoff (source control of pollutants);
- The drainage system shall be designed so that harmful backing up of water in the existing drainage system is avoided;
- The drainage system shall be designed so that part of the pollutants in the runoff are removed along its way to the receiving waters;
- Storm water shall be wherever possible be looked upon as a positive resource in the urban landscape.

Until now over 20 projects within the context of sustainable urban drainage has been defined and implemented in the suburbs of Malmö. (Aspegren et al., 2014)

Two projects are used as reference study:

- Eco-district Augustenborg (1998-2005) source/onsite control.
- Bo01 housing exhibition (2000-2002) source control.

Both projects are located in the suburbs of Malmö, which is similar to the case of Liesing.

Map of Malmö

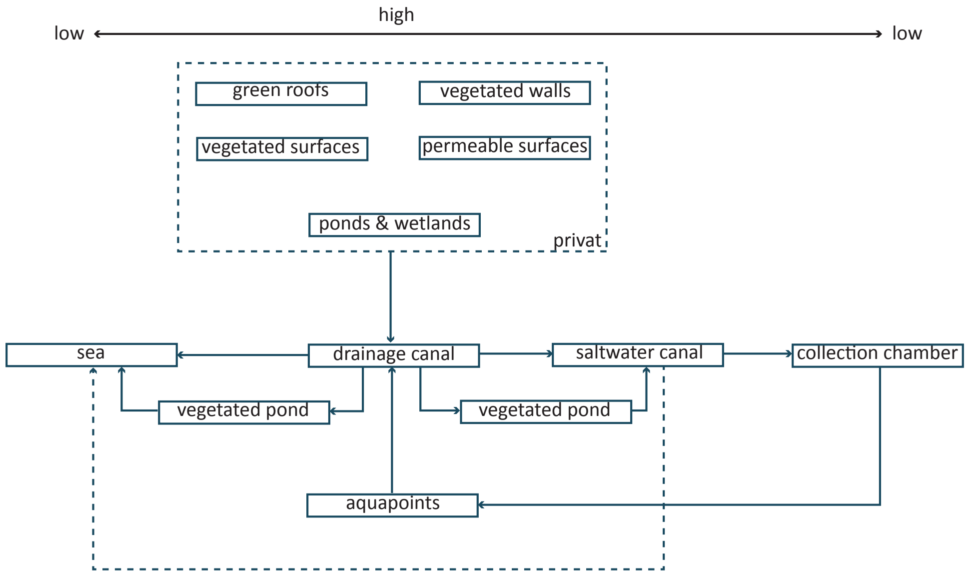
Bo01 Housing exhibition

In the late 1990's it was decided that an international housing exhibition was to be arranged in Malmö in the year 2001. The selected location for the housing exhibition was on the western part of the former wharf area in the district of Western Harbour.

The goal with the exhibition was to create a sustainable development with special demands on architectural quality, urban environment and technical infrastructure. By introduction of a so called green-area factor, the developers were encouraged to compensate the impermeable areas within the development with different types of green surfaces.

The concept is to visualize the drainage by creating an open storm water system with such qualities that it could give added aesthetic and environmental values to the area. Through mass-balancing, the central part of the exhibition area was elevated 2-3 meters above the ground level close to the water. In this way surface water from the area could run off by gravity.

Design Bo01 Housing exhibition



Watersystem of Bo01 Housing exhibition

1. Disposal of storm water on private properties

Special demands were set up in order to get the private developers to reduce the storm water runoff within the boundaries of their respective properties. The developers were encouraged to introduce permeable surfaces in the built environment and to detain the runoff before it enters the drainage canals in the streets. Done by the so called green space factor. Technical solutions favoured by this system are: green roofs, vegetated walls and surfaces, permeable surfaces and ponds and wetlands in private yards.

2. Drainage canals and vegetated ponds in the streets

Small concrete drainage canals have been constructed in all streets throughout the whole exhibition area. In most streets there are two canals. Between the house walls and the drainage canal there is a 30 centimeters strip of coarse gravel. Between the drainage canals and the streets there is a row of black concrete slabs with shallow groves. The intention with these is to give guidance to people with visual handicaps. In street crossings and the house entrances the drainage canals are covered with steel plates. Locations where the drainage canals make a bend and where downpipes from the roofs are connected to the canals have been marked with designed granite blocks.

At some locations small ponds have been introduced. These ponds are planted with wetland vegetation in order to get a filtering effect on the water. Drainage canals are designed for rainfalls with a recurrence period of at least 5 years.


Figure X: Pond in private yard.


Figure X: Drainage canals with granite blocks, black concrete slabs and steel plates.


Figure X: Small vegetated pond.

3. Saltwater canal, collection chambers and aquapoints

The drainage canals which run eastwards to the saltwater canal end up in especially designed collection chambers. These are built up of concrete and planted with wetland vegetation.

From the collection chambers the storm water can be pumped to aquapoints, which are located at the highest point of the exhibition area. These have been designed as places of contemplation and inspiration. Water is flowing up from granite structures surrounded by small ponds planted with wetland vegetation. The aquapoints are the starting points for the drainage canals.

4. Artwork and water

To strengthen the impression of water in the housing exhibition area it was decided to introduce some water related works of art in the settlement.


Saltwater canal


Collection chamber.


Aquapoint


Art work:


Art work: cascade of water before it flows into the sea.


Art work: wall of watertaps

	Sub criteria	**Objectives**
Water quantity	Prevention of urban flooding	Good. Drainage canals are designed for rain events with a recurrence period of at least 5 years.
	Prevention from drought	Good. Water from the saltwater canal can be pumped into the system.
Water quality	Protection of receiving watercourses	Multiple treatment measures: Infiltration, filtration and detention.
Amenity	Aesthetics	Good. The open drainage system gives an unique character to the whole settlement with water related works of art. Sound, illumination are also taken into account.
	Usability	Good. For rest and contemplation.
	Health and safety (Operational risks)	Good. Next to the canals black concrete slabs with shallow groves and granite blocks give good guidance to people with visual handicaps. Steel plates at entrances and street crossings work well. So far no accidents have occurred in connection with the open drainage canals. Water is flowing constantly by pumps.
	Maintenance	Good, divided between the property owners and the city of Malmö. Both parties have delegated the daily maintenance to the same private contractor.
	Community acceptability	Positive according to reflection interviews.
Ecology	Habitat creation	Good. In the private area green area factor is used. Uncertainty about the influence of brackish water.

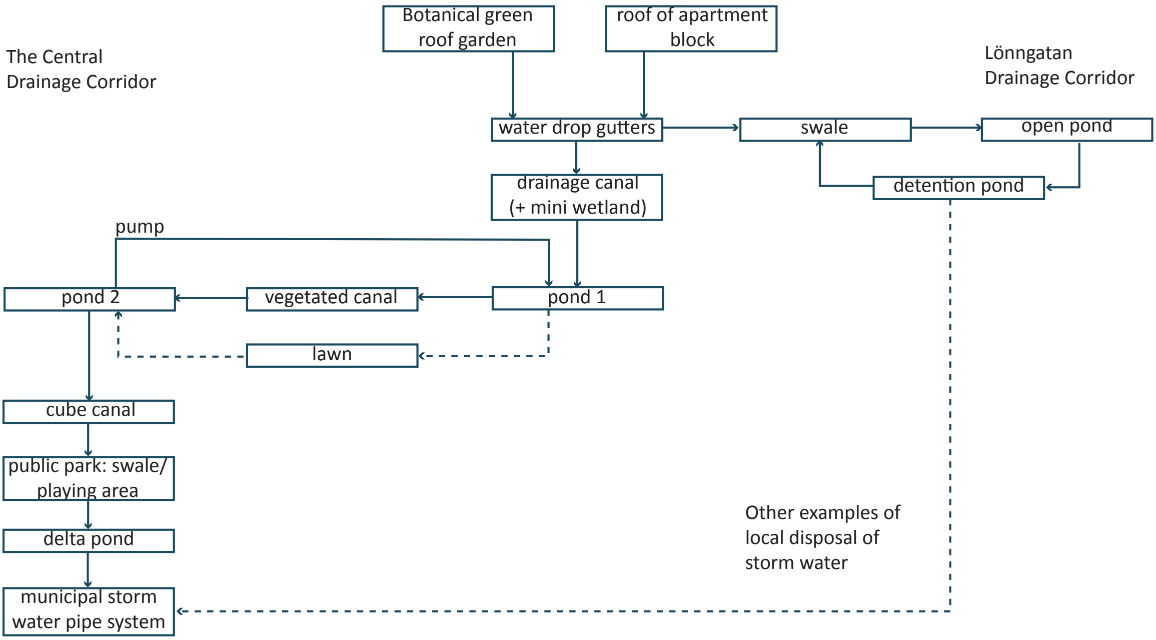
Eco-district Augustenborg

The settlement of Augustenborg was developed in the 1950's by Malmö's housing company MKB. The area is built up of 3–6 floor apartment blocks with public green in between. In the 1980's it turned into problem area. The "Eco-city Augustenborg" project, which started in 1998, is a partnership between the MKB housing company and the City of Malmö.

All storm water from the Augustenborg settlement is handled in a combined sewer system. (In which storm water and sanitary sewage water is running off in the same pipe.) The combined sewer system was heavily overloaded, which resulted in frequent basement floodings during periods of intensive rainfall.

Goal was to transform Augustenborg into a socially, ecologically and economically sustainable settlement. The project is an excellent example of how the ideas of sustainability can be applied in urban renewal. One important element in the project was to get the residents interested and actively involved in the upgrading of the settlement.

Plan Eco-district Agustenborg



Watersystem of Eco-district Augustenborg

1. Botanical green roof garden

Goal: Experimental site: to stimulate research and development of the green roof technology and to promote further use of green roofs in Scandinavia.

2. Central Drainage Corridor

Storm water from the roofs of the apartment blocks is diverted to the canal through especially designed "water drop gutters". The name refers to the shape of the bottom of the gutter, which has the form of concrete water drops. The intention with the design was to increase the water velocity at the bottom and hereby making the gutters self-cleansing. The water drop gutters are designed by artist Morten Ovesson who is a resident in the settlement of Augustenborg.

Botanical green roof garden: composed of different soil mixtures, plant mixtures, slopes.


Storm water runoff from downpipes is diverted to water drop gutter.


Water drop gutter end in concrete drainage canal

Here water from the water drop gutters flow into the concrete drainage canal with on certain spaces mini-wetlands as storage. The wetland vegetation is only fed with water, when the water level in the canal exceeds a predetermined level.

At the downstream end of the concrete drainage canal, water is discharged into an area with double ponds, connected to each other by a shallow canal. The water level in the upper pond is about 0,4 meters above the water level in the lower pond. To circulate water between the two ponds a pump has been installed in the lower pond. Special arrangements have been made to try to avoid algae growth in the two ponds. With the above mentioned circulation pump a small water fall and a water fountain have been created in the upper pond, vegetation filter where the shallow stone canal enters the lower pond, and arrangements have been made by which fresh water can be added to the ponds. The lawn between the two ponds is arranged as a flooding area, with a storm frequency 1: 10/15 years.

Having passed the outlet structure of the double pond, the water enters the so called cube canal. The name refers to the shape of the bottom of the canal, which was designed with regular concrete cubes. The intention with this design was to give the water an irregular and exciting movement during the transport and water vegetation could establish in the canal. The cube canal ends in the public park of the settlement of Augustenborg. At the point where the cube canal reaches the public park a small playing found was established with small concrete cubes, on which children could jump over the watercourse.


Concrete drainage canal with a mini-wetland for storage


Double pond.


Cube canal

After having passed the cube canal the water runs out into a swale, which runs through the public park. The swale has a the same location as a historic creek some 40-50 years ago. Only during very heavy rainfalls there is a free water surface in the swale.

The meandering creek ends in the delta pond from which water is discharged into the municipal storm water pipe system. The holding time of the pond is very long which stimulates the growth of algae in the pond as a result, the maintenance need is quite big.

3. Lönngatan Drainage Corridor

The swale is fed with storm water from the residential blocks along the drainage corridor. The swale is leading to an open pond at the Grangesbergsgatan.

From this pond there is a siphon pipe under the street which connect the upper part with the lower part of the Lonngatan Drainage Corridor.

Swale in public park

Swale in lower part of Lönngattan Drainage Corridor

Pond with siphon pipe

To improve the water quality a pump is installed in the pond, with which water can be pumped to the detention pond located 50 meters away.

4. Other examples of local disposal of storm water

Permeable parking lot, green roofs on a home for elderly people, and open detention in an amphitheatre in the schoolyard.


Detention pond


Green roofs on home for elderly people.


Amphitheatre in the schoolyard

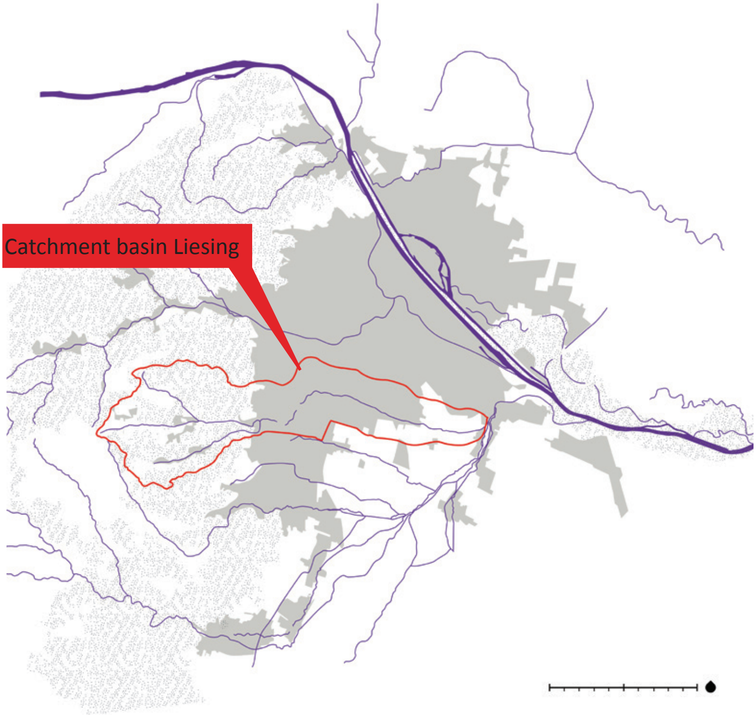
	Sub criteria	**Objectives**
Water quantity	Prevention of urban flooding	Good, private implement
	Prevention from drought	?
Water quality	Protection of receiving water-courses	Good. Multiple treatment measures: infiltration, filtration and detention.
Amenity	Aesthetics	Good, Water drop gutters by local artist. Colourful vegetation and little fountains.
	Usability	Good. Places for contemplation and the Botanical green roof for experiments and building up knowledge.
	Health and safety (Operational risks)	Good. Improvements were made over time (e.g. problem of algae growth in the double pond was tackled down with a circulation pump).
	Maintenance	Sufficient, maintainance is quite big in delta pond because of algae growth.
	Community acceptability	Positive, residents of the settlement were invited to their view on how to accomplish an open drainage system, reflection double pond gave algea growth
Ecology	Habitat creation	Good.

APPENDIX B: I AM... LANDSCAPE ANALYSIS THROUGH DIFFERENT LENSES

Water expert

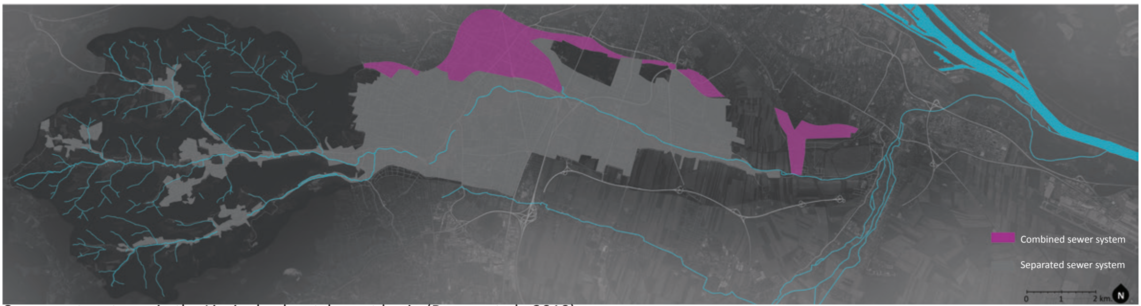
The largest part of the Liesingbach catchment basin has a separate sewer system. Stormwater runoff is discharged as quickly as possible to the receiving water the Liesingbach. Stormwater drainage pipes are not sufficient during heavy rainfall which can cause urban flooding and floods downstream.

SUDS brings the peak of stormwater runoff in post-development closer to the pre-development hydrograph. It will result in less direct stormwater runoff to the receiving watercourse the Liesingbach, more groundwater recharge, and no further increase of flood risk of the Liesingbach. Besides that, the water quality should be improved by disconnecting stormwater sewers from polluted business areas and main infrastructure and clean it locally before it flows into the Liesingbach.



Catchment basin of the Liesingbach in Vienna context (MA 45, 2014).

Conclusion map water expert



Sewer system types in the Liesingbach catchment basin (Berger et al., 2010).

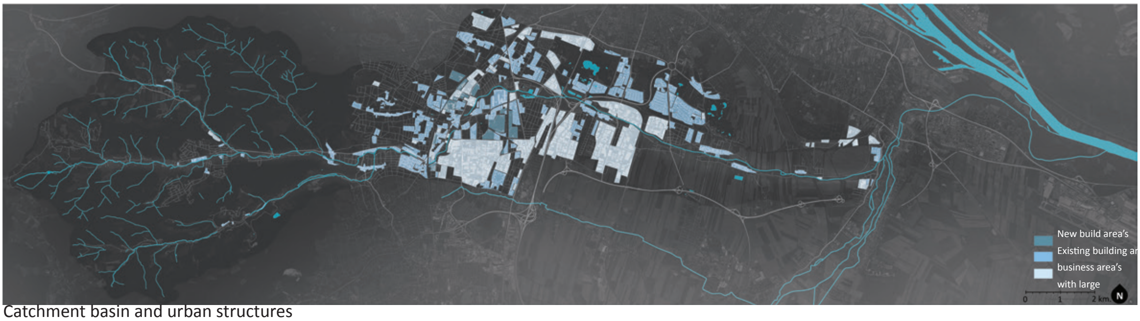
Significant flood risk Liesingbach (WISA, 2014).

Waterquality of the Liesingbach affected by storm water.

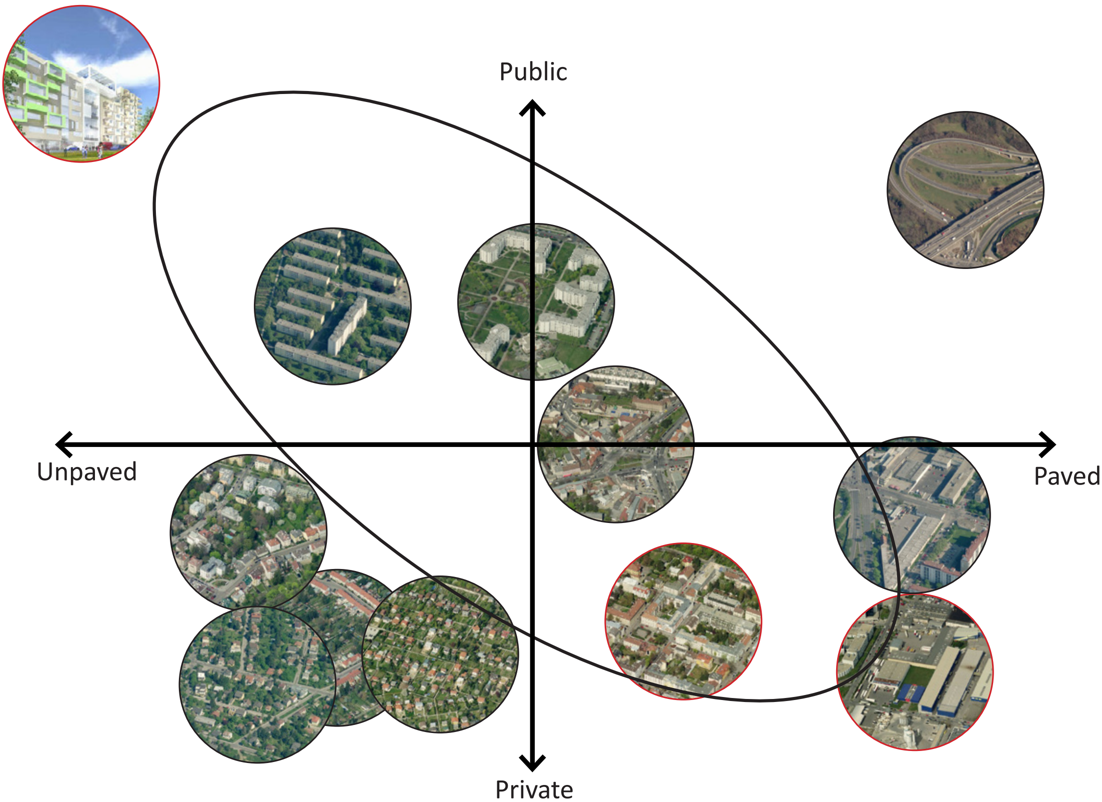
Soil permeability catchment basin

Groundwater flow

Urban structures in the Liesingbach catchment basin

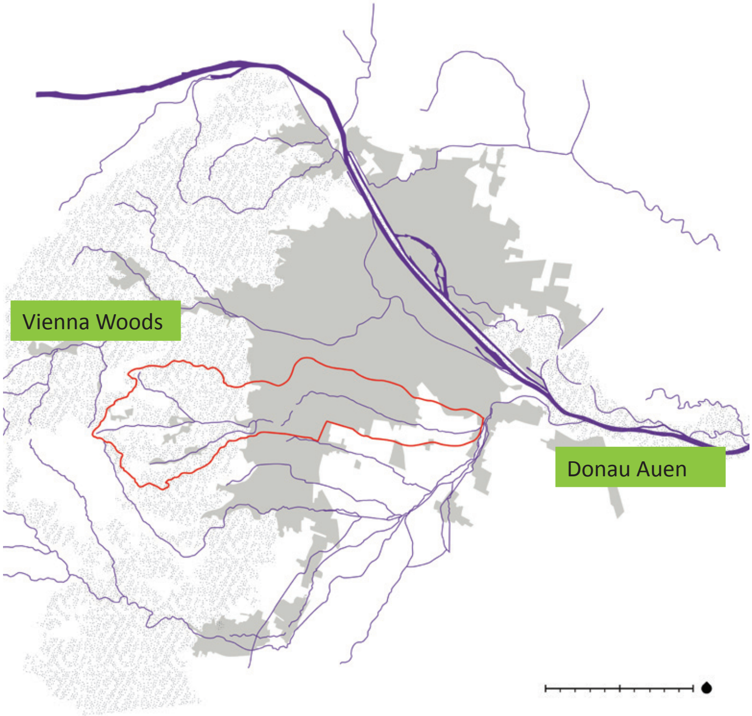


Catchment basin and urban structures



Ecologist

The Liesingbach is an important ecological corridor between Vienna Woods and Donau-Auen. With several streambed revitalization projects in the last decade, a lot has been achieved for the ecological water quality. However, much more can be gained! Large parts of the stream are not liberated from its "stone corset" and obstacles. The major part of the Liesingbach has a uniform flow with no habitats for flora and fauna, and no self-cleansing ability. This improves when we give the stream more space and bring back its former dynamics. I hope to see the entire Liesingbach green! Furthermore, I think it is interesting to implement SUDS in the urban area and design it in such a way that it contributes to urban nature.



Catchment basin of the Liesingbach in Vienna context.


Conclusion map ecologist

Hydromorphological condition (MA 45, 2013).

Fair hydromorphological condition has a huge influence on the biological condition:

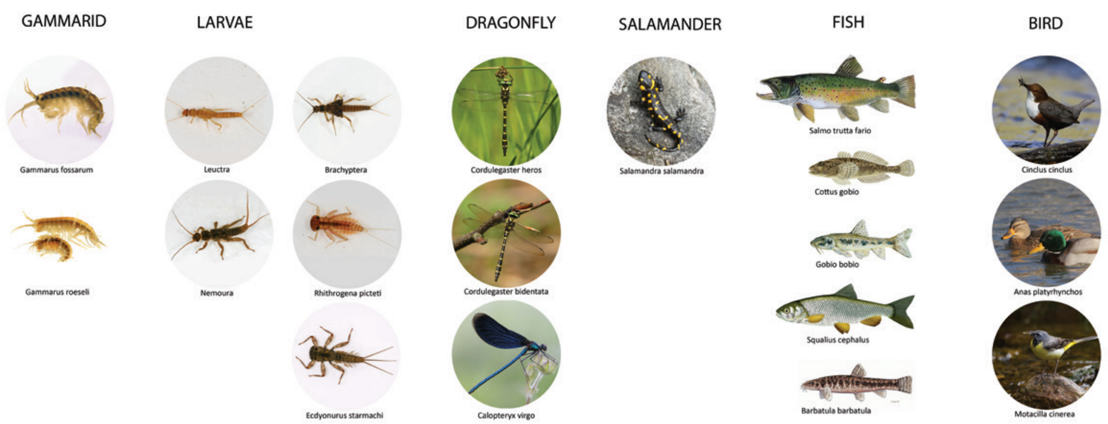
- Phytoplankton
- Macrophytes, phytobenthos
- Macrofauna
- Fish

Biological system

Species, which can be found in a Wienerwaldbach are shown below.

Chemical-physical condition

Is good, the percentage of organic matter in the water is rather high (Grimm, 2010).



Species which could be found in small streams (MA18, 2015).

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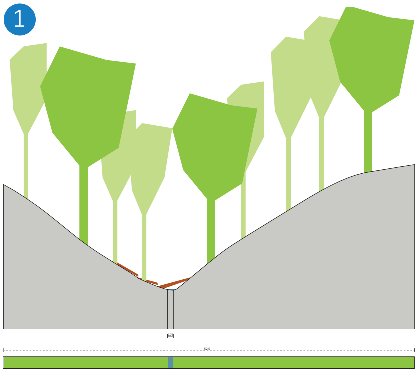

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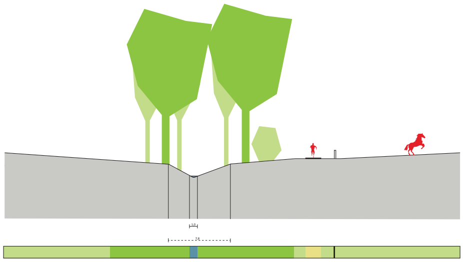

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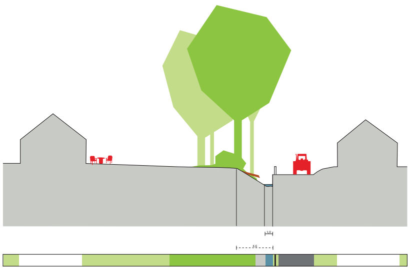

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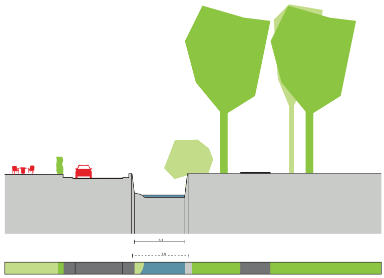

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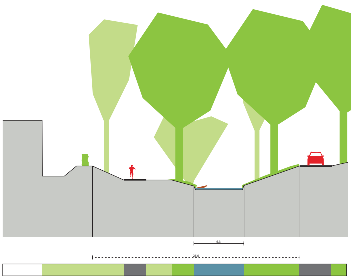

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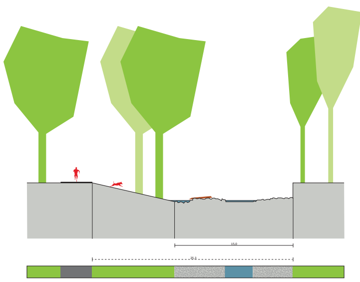

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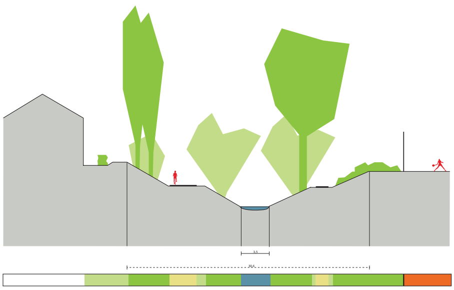

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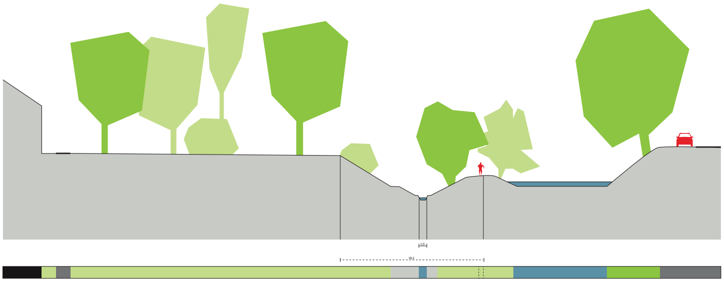

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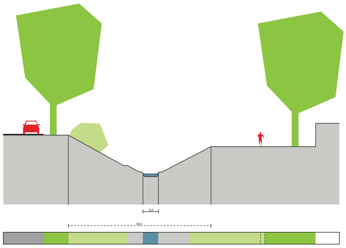

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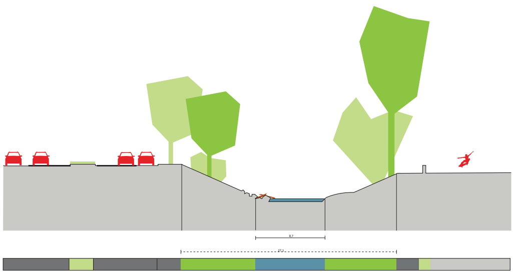

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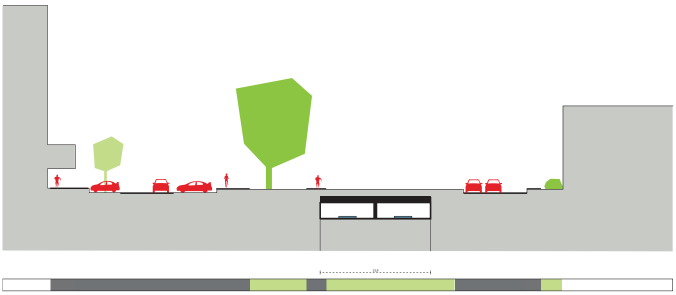

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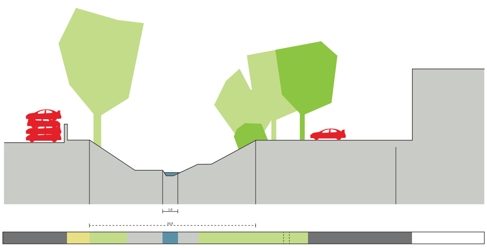

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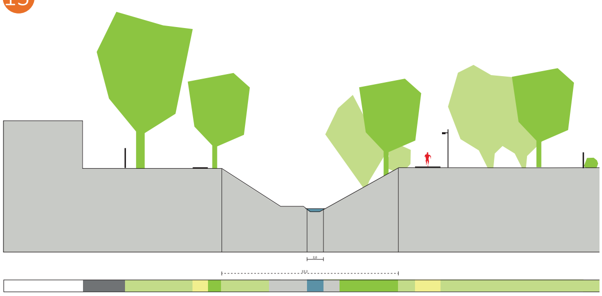

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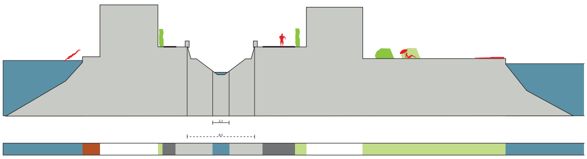

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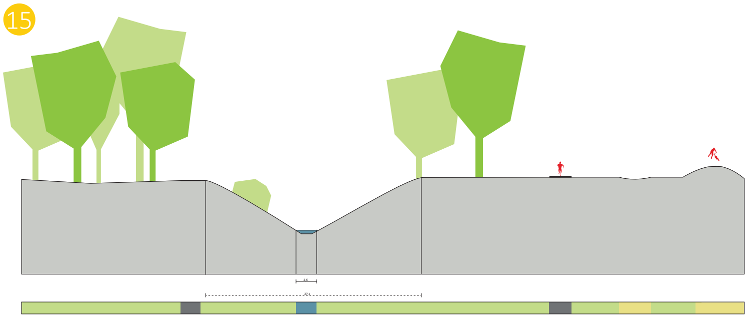

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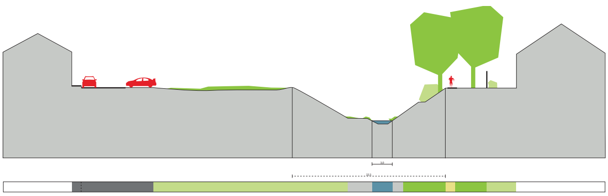

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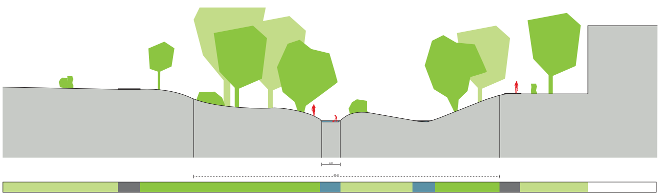

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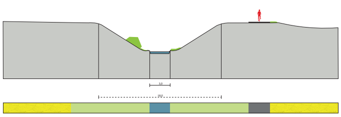


Hydromorphological condition (MA 45, 2013).

Small interventions to slow down the waterflow. This leads to a higher percentage of small organism

Stepping stones

Small dams

Tree trunk which catches twigs and leaves.

Remeander to decrease water excess downstream and create a stepping stone for nature.

Remeander

Nature friendly bank

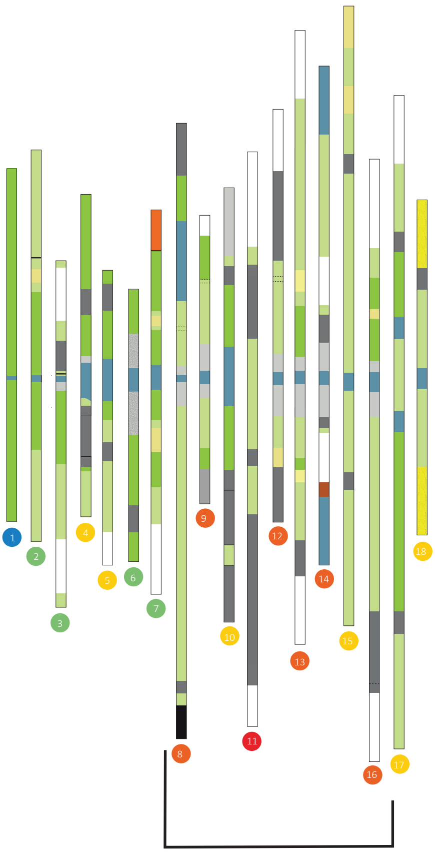
Hyssopus officinalis

Epilobium hirsutum

Centaurium pulchellum

Petasites hybridus

Sambucus



Stone corset --> GREEN!

Urban planner

Liesing Mitte is one of the main target area's for urban development in Vienna. Till 2025, 35.000 new residents are expected. That means:

- 16.750 housing (14ha.)
- 85 schoolclasses
- 65 kindergarten groups
- Attractive & accessible open space (28ha.)
- Efficient transport network (Wien Voraus (b), 2014).

SUDS is an essential part in sustainable development and can be integrated in new build & urban renewal projects, green network in planning, and bicycle routes in planning.

Target area's of urban development in Vienna (Wien Voraus (b), 2014)

Conclusion map urban planner

New build & urban renewal in planning (STEP25,2014) (Wien Voraus (b), 2014).

Green network in planning (STEP25, 2014) (Wien Voraus (b), 2014).

Bicycle routes in planning (MA18, 2015).

Local resident

From September 8 to 12 very different rounds of discussion about priorities and quality requirements for future developments treated from Liesing. These rounds of discussions had different themes: Public space & Mobility, Housing & Education, and Centres, Culture & Work.

A Wishlist of local residents is derived from this meeting.

Werkstatt September 2014

Conclusion map local resident (Wien Voraus (a), 2014).

Wishlist

Public space

- New playgrounds Atzgersdorfer platz/ Schrailplatz/Lasterstrasse/ S-Bahn Liesing Ost.
- Connect parks with green routes for Jogging/Walking/Cycling.
- Expand Liesingbach as backbone for recreation.
- Make water visible again in Atzgersdorf/ Liesing.
- Broad path (5m.) between Kalksburg - Schwechat.
- Connect bikepath at crosspoint Brunner/Erlaastrasse.
- Create enough public green space in housing projects.
- Make green space for everyone, urban gardening is just for a small group of people.
- Room for experiments in public space.
- Make Schlosspark-Erlaa public.

Mobility

- Create meetingpoint at Liesing bahnhof/ Atzgerdorf (Kirchenplatz)
- Less cars at Breitenfurter strasse.
- Fast bicycle connections.
- Make cycleroute U6 Erlaaer Strasse - Alt Erlaa - Liesingbach more attractive.
- Bicycle sheds.
- Expand bicycle highway network.

Housing

- Renovate old (industry) buildings.
- Keep campingsite.

Social programme

- Cinema
- District Liesing = boring/sleeping, we want Indoor swimmingpool + sauna, iceskating and communication centre where people like to go to.
- More good restaurants/bars.
- Make Liesing more attractive to young people.
- No place to go out.

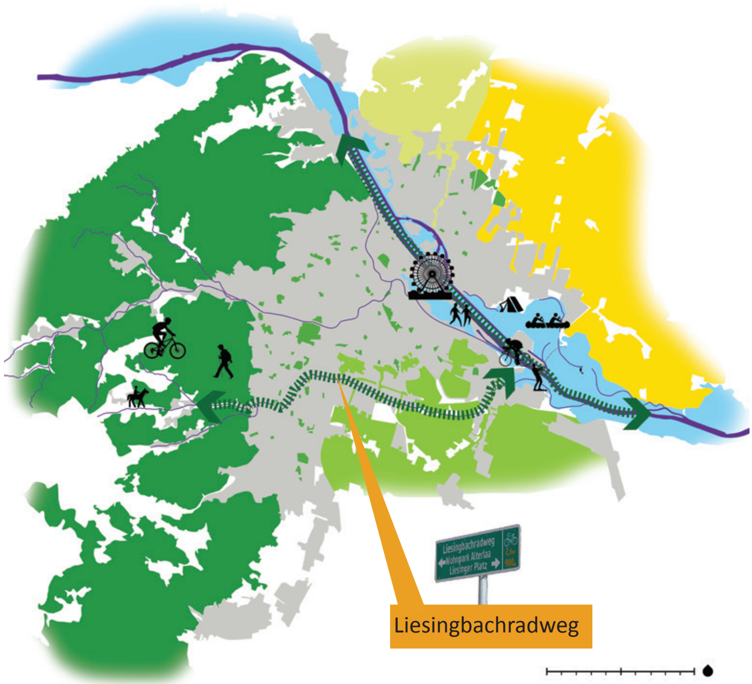
- Old village centres become obsolete. Maintain & more attractive.
- Create local identity: Ich bin aus Liesing.

Outdoor tourist

Around the city of Vienna is a green belt of protected environments. These protected green spaces are kept free of buildings for environmental and recreational purposes.

The Viennese green belt consists of five landscapes. The Liesingbach forms a green-blue corridor (with a continuous bikepath) and connects the following three landscapes in the south of Vienna: Vienna Woods, Terrace landscape, and Danube Zone (Breiling et al., 2008).

Each landscape has its own characteristics and how it is used for recreation by the Viennese.



Recreation landscapes in and around Vienna (Berger et al., 2010)(Breiling et al., 2008).

Conclusion map of the outdoor tourist

Not all tourists have or prefer the same experiences of the out-there-ness. The theory of “Five modes of experience”, from Lengkeek and Elands explained in the table below, gives more insight in the differences in tourist’s experiences. In addition, the modes of out-there-ness experiences are not independent from each other, because leisure implies mobility and tourists may connect one mode with another (Elands et al., 2012).

The Liesingbach, is mainly fulfilling the mode of change. The Liesingbach can be seen as identity carier of the region and is full of historic/cultural stories. But little is visible for a leek. Sometimes a drawing on the wall of a building is used for reminding.

Mode	Amusement	Change	Interest	Rapture	Dedication
Subjective distance	Close by	Going away from	Going to	Far away	Different world
Tension of consciousness	Fun, ease	Away from stress/ boredom	Imagination	Shock, new awareness unexpected	Immerse
Finite self	Light spirited, sense of continuity	Different mindset	New information	New identity	Appropriation
Sociality	Familiar social groups, own language	Not to be reminded of social claims	Stories	Open to the unknown	Authentic otherness
Time	Short break	Another sense of time	Ever, future, using your time	Unanticipated	Permanent
Space	Familiar symbolic and physical environment	Elsewhere, where exactly matters less	Vistas, gaze	Crossing borders, really different places	Backstage world

Key characteristics of each mode of experience (Elands et al., 2012).

Historic map from 1872 (Wikipedia, 2014)

Especially the old Wasserschloss in Liesing has potential for renovation and a new function.

COLOFON

Urban living with water
Sustainable stormwater management for Liesing in Vienna
MSc Thesis

Caroline Bruens
Mobile: +31646107034
carolinebruens@hotmail.com

Keywords:
Stormwater management/ Sustainable Urban Drainage System (SUDS)/ trans-disciplinary design process/ through the scales/ Liesingbach/ Vienna

Mentor team:
TU Delft, Faculty of Architecture, Department of Urbanism,
Chair of Landscape Architecture
Frits van Loon
F.D.vanLoon@tudelft.nl

TU Delft, Faculty of Architecture, Department of Urbanism,
Chair of Environmental Technology and Design
Fransje Hooimeijer
F.L.Hooimeijer@tudelft.nl

External Examiner:
TU Delft, Faculty of Architecture, Department of Urbanism,
Chair of 3D Geo-Information
Sisi Zlatanova
S.Zlatanova@tudelft.nl

In collaboration with
Faculty of Architecture, Delft University of Technology
MSc Architecture , Urbanism and Building Sciences
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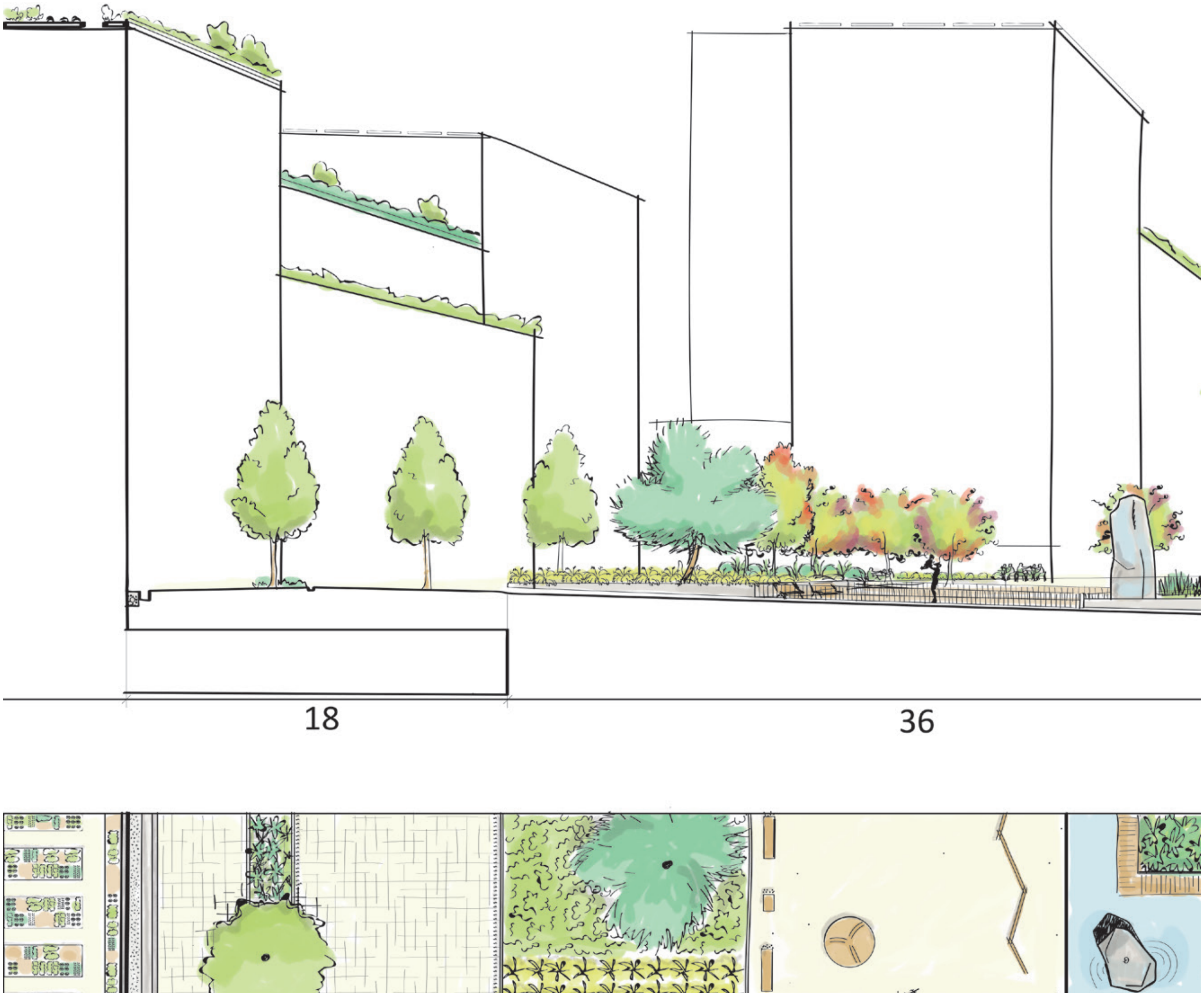
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