LAMK Lahden ammattikorkeakoulu
Lahti University of Applied Sciences

Concept Draft for Green Street

Storm water management: Case Jyväskylä

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Concept Draft for Green Street Storm water management : Case Jyväskylä

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ABSTRACT

Storm water management is no longer only water supply management, it is needed to focus on sustainable solutions. Urbanization increases the amount of hard covered surfaces, which prevents soakage and increases the need for sewer systems. The main effects for natural water circulation are the increase of surface runoffs, and the reduction of water flow in soil. The consequences can be flooding, erosion and also loss of habitat diversity.

This study was conducted to serve the purposes of the city of Jyväskylä. In the town planning and land use office there is a need to understand whether there could be other and possibly better ways to solve the storm water management in city centres than the present sewer systems. There is a need to re-evaluate the storm water system in the city centres where the amount of impervious surfaces is high. One possibility is to combine the storm water management systems more closely to urban green infrastructure.

The aim of this Master's thesis and the case study was to consider the possibilities of trees as a functional part of storm water management in the city centre of Jyväskylä. An option storm water management plan in the Rajakatu street in the city of Jyväskylä was planned by replacing the present system with an underground rain garden. This study assesses different options to make the underground rain gardens combined with trees to be a part of green infrastructure.

The work was started by studying the terminology, the laws and similar systems that are in use in other countries. The main problems, which need to be solved in this kind of work, are discussed. Next, the answers with the help of planning intruments are presented. A concept draft was made for the case area to find out, if these solutions would work.The final result of this Master's thesis is a concept draft with its calculations and conclusions.

Key words: green street, green infrastucture, storm water

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TIIVISTELMÄ

Hulevesien hallinnassa tulisi ennen kaikkea keskittyä ympäristöltään kestäviin ratkaisuihin. Kaupungistumisen lisää läpäisemättömiä pintoja, jolloin vesien normaali kiertokulku häiriintyy, vesien imeytyminen maaperään estyy ja hulevesien viemäröinnin kapasiteetin kasvava tarve lisääntyy. Tämän seurauksena hulevesitulvat ja eroosio lisääntyvät ja luonnon monimuotoisuus kärsii.

Työ on tehty Jyväskylän kaupungin kaupunkisuunnittelun ja maankäytön toimialalle. Tarkoitus on tutkia, onko mahdollista löytää parempia ratkaisuja hulevesien hallinnalle kaupunkialueilla ja ennen kaikkia kaupunkikeskustojen katualueilla, joissa läpäisemättömien pinnoitteiden määrä on suuri. Hulevesien hallinnalle on pyritty löytämään ratkaisuja vihreän infran keinoin.

Tavoitteena on myös yhdistää katupuut olennaiseksi ja toiminnalliseksi osaksi hulevesien hallintaa. Työn lähtökohtana on käytetty Rajakadun hulevesien hallintasuunnitelmaa. Suunniteltu hulevesiviemärikapasiteetin lisääminen tutkitaan korvattavaksi maanalaisen sadepuutarhan avulla.

Työ alkaa terminologian kartoittamisella sekä sivutaan hulevesiä koskevaa lainsäädäntöä. Green street –menetelmää, sekä samantapaisia hulevesien hallintatapoja on tutkittu ulkomaisten esimerkkien avulla. Menetelmien soveltuvuutta ja toimivuutta on tutkittu suunnittelutyökalujen avulla. Suunnittelualueesta on tehty ideasuunnitelma, jossa näitä menetelmiä on sovellettu. Suunnitelmien avulla on laskettu toteutuuko hulevesien hallinnan määrällinen tavoite näiden menetelmien avullla.

Asiasanat: green street, vihreä infrastructuuri, hulevedet

CONTENTS

1 INTRODUCTION

Climate change mitigation in Finland among other countries needs to be focused on. There are many acts for municipalities that are passed on the legislation. For cities the Land Use and Building Act is one part of the legislation that needs to be followed when managing storm water. The general objective of the Land Use and Building Act is “to ensure that the use of land and water areas and building activities on them create reconditions for a favourable living environment and promote ecologically, economically, socially and culturally sustainable development. The Act also aims to ensure that everyone has the right to participate in the preparation process, and that planning is high quality and interactive, that expertise is comprehensive and that there is open provision of information on matters being processed.” (Land Use and Building Act 132/1999, section 1).

According to the Land use and building act, storm water management is taken into place in a built up environment on its ground, roofs of the buildings. Storm water management is not anymore only water supply management. (Rontu, K. 2014). Urbanization increases the amount of hard covered surfaces, which prevents soakage, and increases the need for sewer systems. The main effects for the natural water circulation are the increase of surface runoffs and the reduction of water flow in soil. The consequences can be flooding, erosion and also loss of habitat diversity. (Sillanpää 2013). What makes the situation even worse is that as a consequence of the climate change the yearly rainfall in Finland is estimated to grow by 12 - 24 percent by the end of the century according to different scenarios. (Pervious pavements, VTT 2015, 12).

There are many options for storm water management, such as storm water sewer systems, detention systems, and in some places, the soaking to ground soil could be used. One way for managing storm water is land use. The main idea is that every property does the detention in their own area, whenever this kind of solution is applicable. The property owner has to find ways to deal with the storm water before it runs to the municipality's sewer system.

There is a need to re-evaluate the storm water system in the city centres where the amount of impervious surfaces is high. One opportunity is to combine the storm water management systems more closely to urban green infrastructure.

The aim of the study is to consider the possibilities of trees as a functional part of storm water management in the city centre of Jyväskylä. An option for street Rajakatu storm water management plan in the city of Jyväskylä is planned by replacing the system with an underground rain garden. This study seeks different options to make the underground rain gardens combined with trees to be a part of green infrastructure. The study evaluates the effects on planned system.

The results of this study may be utilised in other cases with similar problem set up, and as an alternative to solve the storm water cases with the help of green infrastructure.

1.1 Research questions

The goal of this thesis is to collect examples from different storm water systems linked in green infrastructure. The objective is to consider trees as a functional part of storm water management also by making the soil to suite for the vitality of the trees. Also the risk of managing the storm waters by green street system is taken into account. The questions considered are: 1) Will it make a difference for the trees on the streets? 2) Do the quality and quantity of the storm water make a difference? Also, is it possible to plan the parks at a city centre and their playgrounds to work as a part of flooding routes, water plazas that storage the water in heavy rain.

The research questions are:

1) What are the technical solutions needed to build a green street system?
2) How does the green street system effect on the quantity of storm water?
3) What are the advantages and disadvantages of the green street system compared to the traditional sewage system?

1.2 Key concepts

Storm water

Storm water means the urban runoff that is generated by human activities. The rain in paved surfaces in urban areas, like streets and buildings increase the runoffs and volumes of water. Urban areas generate an unbalance on storm water systems and weaken the downstream natural environment. Figure 1 shows the connection between impermeable pavements and surface runoff. Urban areas cause unbalance on storm water system. (Storm Water Management Typologies and Strategies)

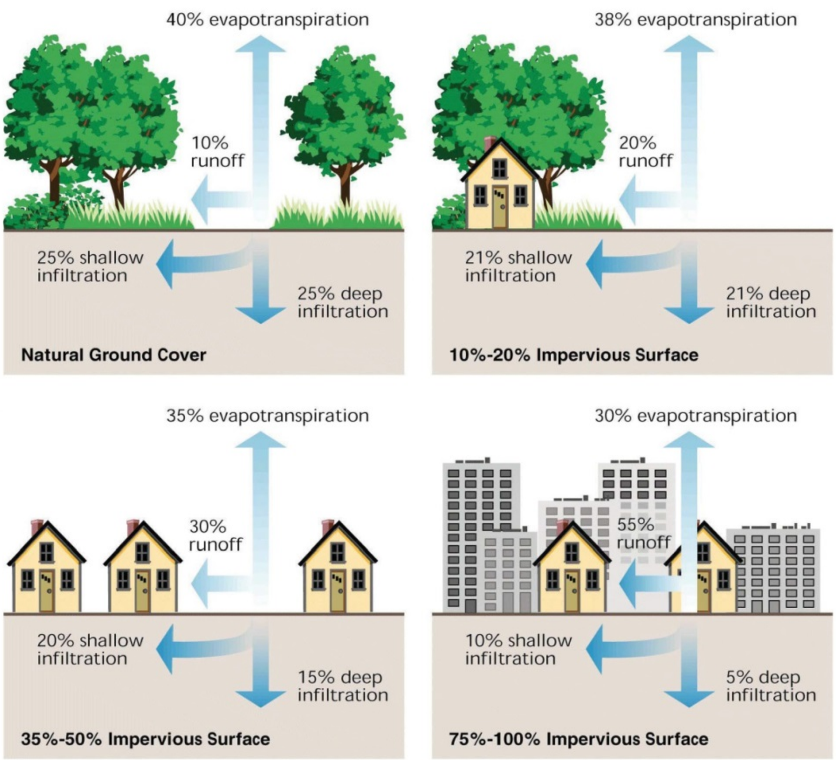

FIGURE 1 The connection between impermeable pavements and surface runoff. Urban areas cause unbalance on storm water system. (Storm Water Management Typologies and Strategies)

Green infrastructure

Green infrastructure means the basic structure of an urban environment that enables benefits to citizens. It helps reconnect existing nature areas and maintain and improve the ecological ecosystem. It produces ecosystem services. It is a network that connects it parts together and also to a wider environment. Green infrastructure cuts down and manages storm water at its source. At the same time, it benefits the living environment. Green infrastructure uses vegetation and other elements to produce a natural environment and balance to storm water managing thus leading. It aims to healthier urban environments. Figure 2 shows that the green infrastructure is a functional part of other infrastructures. (VirMa 2015; What is Green Infrastructure 2015)

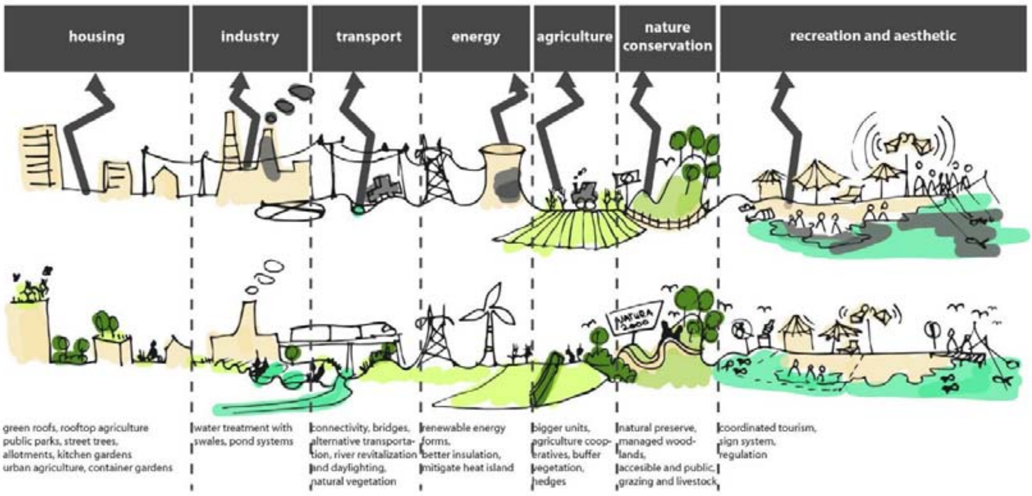

FIGURE 2. Green infrastructure is a functional part of other infrastructures (VirMa 2015 / Anna Szilagyi-Nagy)

Green street

Green street means managing the storm water in street areas with the help of green infrastructure. It increases liveability by making attractive street scapes that provide also habitat corridors. Green streets are mainly a chain of landscape swales or planters that manage storm water at the site. It answers to the requirements of water quality. Figure 3 is an examble on green street. (Gateway Green Streets master plan 2008)

FIGURE 3: Example on green street system with storm water curb extensions. (Gateway Green Streets master plan 2008)

Design rainfall

With the help of design rainfall the maximum amount of water can be defined, which the system can handle. The design storm has four dominant features: rainfall duration, rainfall intensity, the frequency of rainfall and the odds for an occurrence of a rain event. (Vettä läpäisevät päällysteet, VTT 2015, 9).

Storm water planters

Storm water planters are landscaped planters placed on the sidewalk area. They are used for storm water management. The top of the planting is lower than the street’s gutter elevation. Storm water runoff flows into the planters. Figure 4 is an example on the planter. (City of Philadelphia Green Streets Design Manual 2014).

FIGURE 4: View of storm water planter. (City of Philadelphia Green Streets Design Manual 2014)

Storm water curb extensions

Storm water curb extensions are placed on the sidewalk area and they bring curb lanes into the landscape area. Their basic idea is on managing storm water in curb extensions that narrows street scapes and has a calming effect on traffic. Figure 6 shows an example on storm water curb extension. (City of Philadelphia Green Streets Design Manual 2014).

FIGURE 5: View of storm water curb extensions. (City of Philadelphia Green Streets Design Manual 2014)

Permeable pavement

Permeable pavements are pavements that allow water to infiltrate to soil. Materials that are used are permeable interlocking concrete pavement, porous asphalt and pervious concrete. Figure 7 shows an example on structure of permeable pavement. (Vettä läpäisevät päällysteet, VTT 2015, 25).

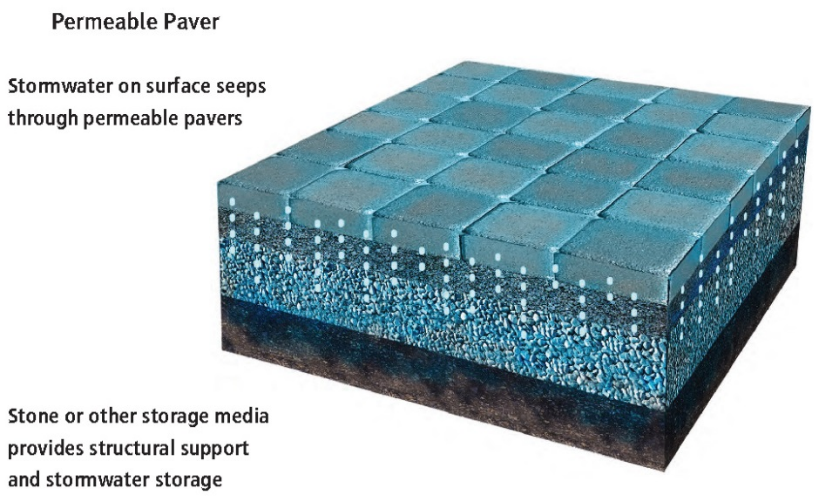

FIGURE 6: View of permeable pavement. (City of Philadelphia Green Streets Design Manual 2014)

2 BACKGROUND

This study is made, conducted to serve the needs of the city of Jyväskylä. In the town planning and land use office, there is a need to understand whether there could be other and possibly better ways to solve the storm water management in city centres than the present sewer systems.

2.1 Description of circumstances

Sustainable planning in city centres is a challenge because there are lots of impervious surfaces. In order to deal with storm water management in a sustainable way, one must pay attention also to the quality, not only to the quantity of storm water. To generate sustainable urbanism means to bring green design and green environment to the hard covered streets and buildings by straining the landscape and root it to townscape. (Gateway green streets master plan 2008) This also combines green design more closely to town planning systems.

Storm water management has become a very important issue in discussions about climate change. Climate change has come to our awareness little by little, and there are now huge challenges ahead of us concerning how to deal with it. In general, climate change increases precipitation, and heavy rains, and, at the same time our urban areas are made more compact. When precipitation increases, storm water causes uncontrollable flooding to tightly built-up environments, such as city centres. This could cause a lot of harm e.g. to buildings and streets. Storm water management is not only a technical problem; it also opens new possibilities to bring a new, visual and attractive green infrastructure to urban centres. Storm water also causes stress to lakes and other water systems when it floods straight to them, for example from pipes. There is a clear need to delay and infiltrate storm water. (Storm water guide 2012).

To understand what to achieve by making an urban environment greener one needs to consider the positive outcomes. Green streets in their simplest form mean planting more trees, bushes and other plants in streets. Trees are called the lungs of the cities, and they tie themselves the carbon dioxide and make the air we breathe healthier (Climate guide 2015).

The benefits of bringing more green into streets needs to be understood. Green streets help to provide a good microclimate by making the streets more attractive, active and interesting environments for pedestrians. Green streets creates a continuum of green areas, parks and yards in streets and in that way it makes housing in town centres more tempting. The same comes with green buildings. There isn’t always enough space to build green yards with different functions, but it is possible to compensate it by green roofs and walls. (Gateway Green Streets master plan 2008)

One of the biggest benefits that can be found by bringing more green to the streets is storm water management. Storm water management in urban centres is very challenging, because of the hard surfaces and the tradition that storm water management is solved by pipes, more pipes and bigger pipes. Although that may solve the quantity of storm water management, presently considering the climate change, there are not enough pipes dealing with the quality of storm water. This is where the vision of green streets and buildings plays an important role.

Green Streets as delaying the storm water will be important in city centres. The storm water sewerage system that is usually used in hard covered town centres does not make the detention possible. The sewerage systems lead the water too quickly and untreated straight to lakes and other water bodies. In that how pipes does not take at all a part the state of water ecology for example. It does not mean that the sewerage systems should not be used at all but that other systems should be used at side to delay the storm water. (Storm water guide 2012)

There are a variety of structures delaying the storm water that can be used many ways. Detention means a structure holding the storm water for a certain time before letting the water run into the sewerage system and further into the lakes and rivers. The detention could be solved for example by building different kinds of ponds, pools and ditches. The quality management of storm water grows bigger in detention of the water when the systems are integrated with plants. Big trees can use a huge amount of water when the substrate of trees is made to water detention and for the use of the water for trees. The detention substrates should be built by rough materials for example on rock storages. The depth and width of the detention substrate depends on the area that it is based on. (Gateway Green Streets master plan 2008) The plants also prevent the nutrients ending up to water systems by bending nutrients to plants. (Storm water guide 2012)

Detention of storm water and collecting the water in city centrums needs space from the streets. Basically it means that the amount of the parking spaces should be decreased and parking should be placed to parking houses. So the disengaged space could be used in managing the storm water with the help of green infrastructure. That needs to be planned carefully and with a long term perspective. It does not happen rapidly and it perhaps needs some attitude changes, but what could be the achievement from that is worth it.

2.2 Green street –case in Portland

There has been green street projects for planning sustainable cities in some cities like in Portland USA. The Portland Green Streets master plan is a basis for the plan that is made for Jyväskylä. The city of Portland is worried about the conditions of rivers and streams so to improve water quality the green streets –system has taken an important place. The population of salmon has been the driving force to improve the quality of the water systems. Good results have been achieved in many planning organizations with improvements of existing streetscapes. They have used specific Green Street Typologies including development patterns, land use, traffic volumes and the 10-year storm events. The Typology consists of the storm water swales in curb extensions. The building buffers to streets with courtyards. So there should not be any clear difference between public and private space. Where the yard buffers to streets there is a good place for trees, bushes and groundcovers. (Gateway Green Streets master plan 2008)

Water, as an element along the green streets, works as a passive storm water channel, which in a heavy rain fills up. Most of the time they work as a streetscape element so that should be considered also from the visual perspective. These green streets give a new role to the streets. Figure 7 shows that green streets not only work as auto-dominated streets but let residents use streets more widely, sensing the nature. (Southwest Montgomery Green Street 2009). The water elements and delaying storm water in the urban structure are not easy to work with. It is not at all a new thing but it is a case that needs to be solved carefully. It is a field that needs new innovations to solve the problems in a sustainable way.

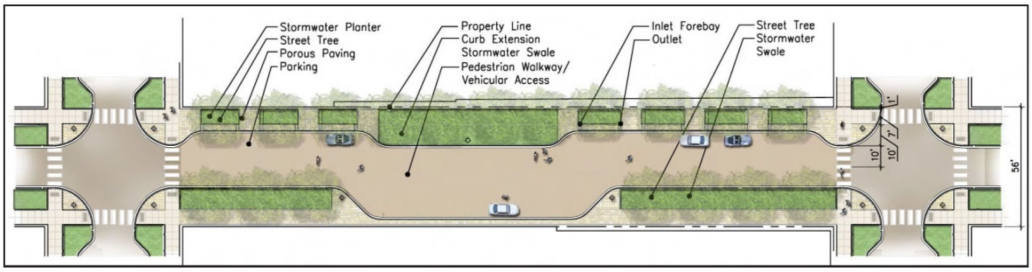

FIGURE 7: Green street master plan: ROW Plan. Figure shows that cars are encouraged to drive slowly, with the help of using the curb extensions. (Gateway Green Streets master plan 2008)

Another advantage of the system is the cost-effectiveness of the green street system. Some calculations have been made about the cost between green street systems and natural drainage systems, that is shown in table 1. The use of a life-cycle cost analysis shows that the green street systems are cost-effective solutions. (Seattle’s Natural Drainage Systems 2007).

Comparison between Pinehurst Natural Drainage System and traditional street and drainage design
Using Seattle Public Utilities' asset management life-cycle cost analysis

Project Basin Options	Number of Project Streets	Pros	Cons	Annualized Drainage Volume Reduction (gal.)	Achievement of Conveyance Goal	Percentage of Volume Reduction Goal[1]	Percentage of Drainage Peak Reduction Goal[1]	Achievement of Water Quality Goal	Achievement of Neighborhood Goal	Average Annual Maintenance Costs	Estimated Project Cost
Option 1 Do Nothing	0	• No capital cost expenditure	• Does not meet any project goals	0	No	0%	0%	No	No	$11,000	$0
Option 2 NDS	11.5	• Achieves all project goals except peak flow reduction • Achieves the highest level of peak flow reduction • Option is the most cost-effective	• Capital expenditure • Higher maintenance costs than Do Nothing	9,700,000	Yes	100%	51%	Yes	Yes	$18,800	$4,600,000
Traditional	11.5	• Achieves same number and level of project goals as Option 2	• Highest cost option • Mid range of maintenance costs • Must acquire 6 properties	9,700,000	Yes	100%	51%	Yes	Yes	$14,000	$8,854,000

TABLE 1. Cost analysis on Seattle's storm water management between natural drainage system and traditional street and drainage design. (Seattle's Natural Drainage Systems 2007)

2.2.1 Experience gained from the Green Street in North-America

Mervi Vallinkoski, Landscape architect of Jyväskylä, took part in an International Exchange Program in 2015. She was working in the City of Surrey in Vancouver, Canada. She also had an opportunity to visit the cities of Portland and Seattle in the United States. One of the main working tasks was planning a green infrastructure and storm water management systems. (Vallinkoski 2015). Figure 8 shows an example on green street of Portland.

The problems with storm water in North-America started to appear in 1980's when the water in rivers and lakes was much polluted, which caused the collapse of the population of salmon. After that, there has been a lot of work to revitalise the rivers and lakes again. The word "Green Street" is used in the city of Portland, but in the other cities the same kind of model has different names, such as Green Grid, Green Rivers and RainWice. (Vallinkoski 2015).

Vallinkoski thinks that the main benefit of this green street system is that it is a multipolar system where many little parts work to prevent the water to run. The main focus should be in thinking our own basis for preventing storm water. (Vallinkoski 2015).

An advantage of the multipolar system is that it is more reliable than a system where there is only one solution for catching storm water. This system also affects on the quality of the storm water, not just the quantity. (Vallinkoski 2015).

FIGURE 8: Picture shows an example on green street of Portland. (Mervi Vallinkoski).

2.3 Stockholm’s model

In the City of Stockholm, Sweden, a lot of studies concerning the trees in the streets have been conducted. The main challenges of the street trees have been the lack of space, the lack of oxygen because of a too tight topsoil, and the lack of water. Also other things complicate the living conditions of the city trees as is shown in figure 9. The basic needs for the trees are oxygen and water and also humus, the organic ingredient of soil. (Planting beds in city of Stockholm 2009).

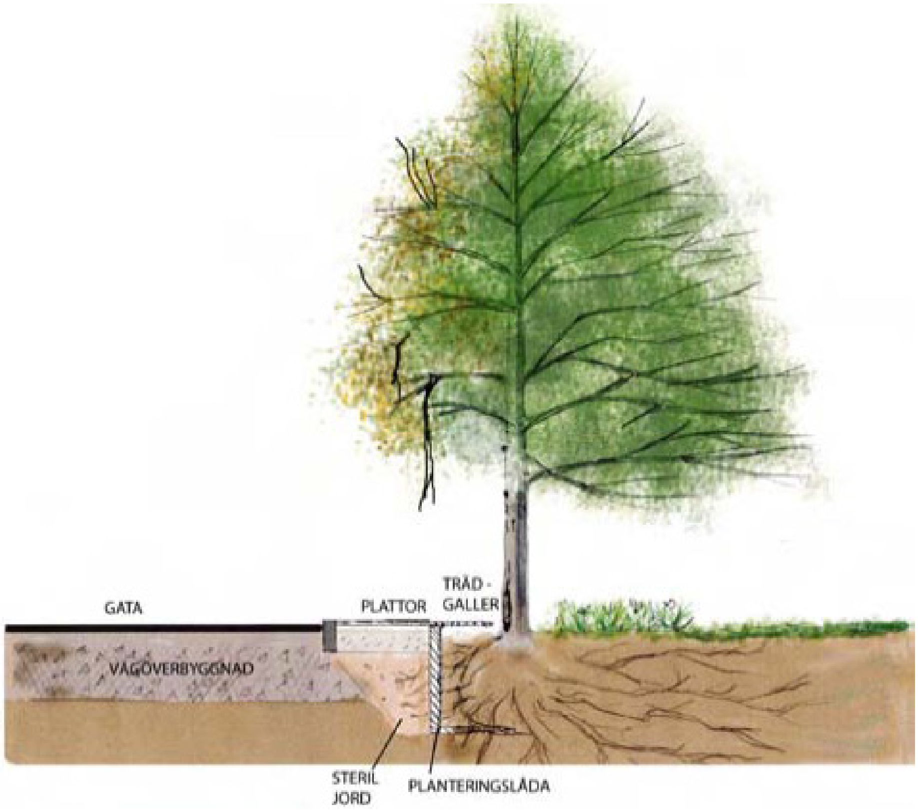

FIGURE 9: The illustrate picture of a typical situation where street tree does not have room for the roots. (Planting beds in city of Stockholm 2009).

One of the main opportunities of this study is to handle storm water in planting beds. The rainfall helps to improve the habitat of the trees. Trees can absorb a large amount of storm water and use. Thus the pressure in sewage systems can be reduced. It also reduces the risk of roofs to break sewer systems. In Malmö 2006 there has been a research on how much trees use the water in summertime and the result was about 670 litres per day. So it is not a minor capacity to use storm water. There are also risks when leading the water to planting beds. There needs to be good drainage in the case the water can lead a way when it is not needed. (Planting beds in city of Stockholm 2009).

In Stockholm there is a principle that every street tree has to have at least 15 cubic meters of ground soil. Roots need to have a possibility to grow at least in two directions. The planted bed should be at least 0,8-1,0 meters deep. In figures 10 and 11 is seen a planned system for trees of the street. (Planting beds in city of Stockholm 2009).

FIGURE10: Figure shows the system that is planned for street tree. (Planting beds in city of Stockholm 2009).

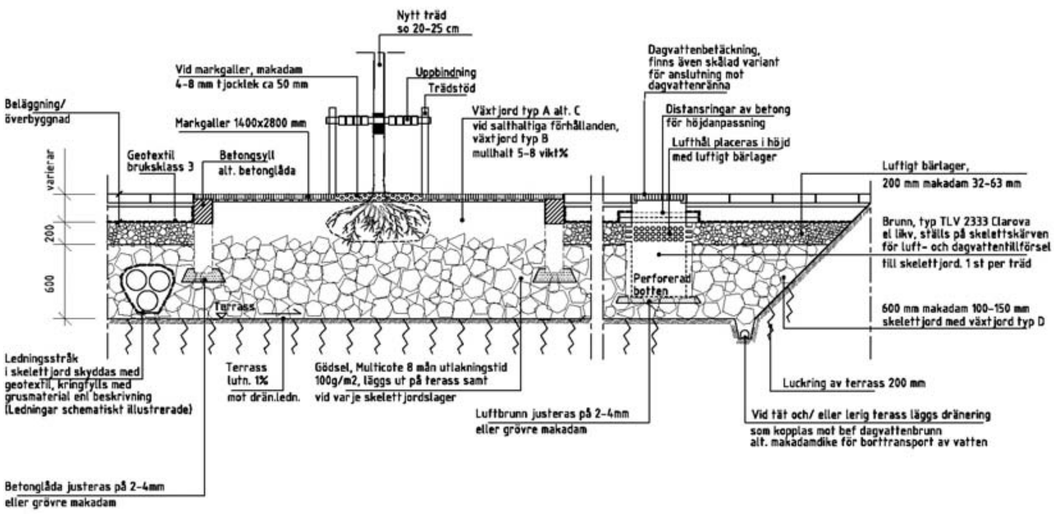

FIGURE 11: Figure is a cross section of planting beds planned in city of Stockholm. (Planting beds in city of Stockholm 2009).

2.4 Storm water management plan in the Jyväskylä case area

A storm water management plan has been made in the case area in Jyväskylä. That forms also the background of this study. The storm water management plan was made to displace a partly combined sewage system to storm water sewage system. It also covers the flooding routes and helps to solve the flooding problems. The catchment area for street Puutarhakatu street is 27 ha. This plan helps to solve the flooding problems and lead the water, now going towards city centrum, in another direction towards river Tourujoki. There is a problematic area outside this case area in the city centrum, where the water runs near the travelling centre. The catchment area is a very tightly built up environment where there are not much green areas. (Storm water management plan for street Rajakatu).

2.5 Green Street –case in VirMa

The Green Street case in Jyväskylä is part of the research project of Aalto University. “Research Group VirMa focuses on sustainable green infrastructure planning and design practices” (VirMa 2015). This started in August 2015 and the results of this project should be ready at the beginning of 2016. In this study, the green street case is only one case among others. There are three cases and three cities involved in the study. The cities that are also involved are Vantaa and Tampere. In this study, the research group are described the challenges of green infrastructure and looking for possible answers. In Vantaa, the case is Kaivoksela which is now mainly a working area, and there is a general plan going on. Tampere has also a case that is under a general plan, Hiedanranta. So both the cases are in a very different state of planning than the green street case in Jyväskylä.

In the working meeting the focus was on the main elements of green infrastructure, figure 12, in the green street case area. The main elements were public green areas, green-blue structure, build up pedestrian environments, green of streets and storm water elements. In this project the working groups from each city involve people who work closely with green infrastructure and people that are not so familiar with it. (Challenges of Green Infrastructure, Aalto university).

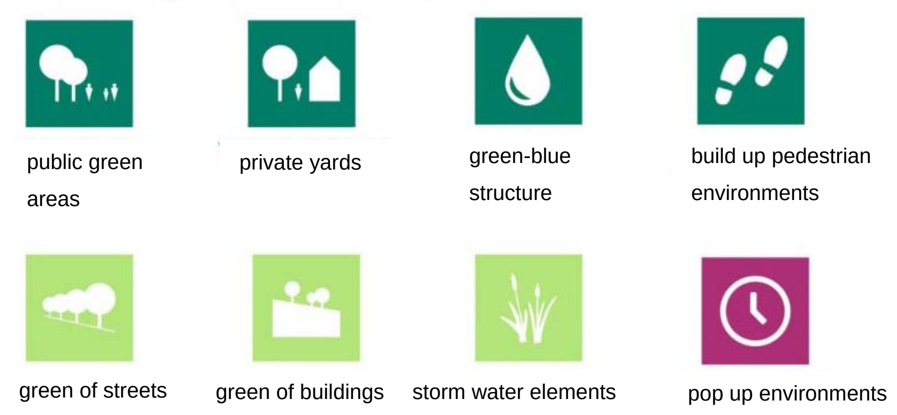

FIGURE 12: The basic elements of Green Infrastructure in Jyväskylä Green Street –case. (Challenges of Green Infrastructure, Aalto University).

2.6 CLASS project

Climate Adaptive Surfaces, CLASS project included a research about pervious pavements and their structure. Pervious pavements are one way to solve the problems that hard covered surfaces cause for cities. They could be very well used in areas that doesn't have heavy traffic, such as squares, market places, pedestrian streets and parking places. The main benefits of permeable pavements are that the surface runoffs are low as well as the ice, and snow does not accumulate. (Permeable pavement, VTT 2015, 3). This study focuses also on how to use pervious pavements in this green street case, in pedestrian streets.

The main benefit of pervious pavements is that the structure holds water in pavement, in storage layer and other structures. After that the water soaks in ground soil or diverts storm water into sewers. When planning to use pervious pavements there are a lot of different points to be considered carefully. Those are for example soil, traffic, hydrological activity, surrounding structures and costs. (Permeable pavement, VTT 2015, 16).

In planning and measuring storm water systems with pervious pavements hydrological processes, figure 13, need to be considered. (Permeable pavement, VTT 2015, 22).

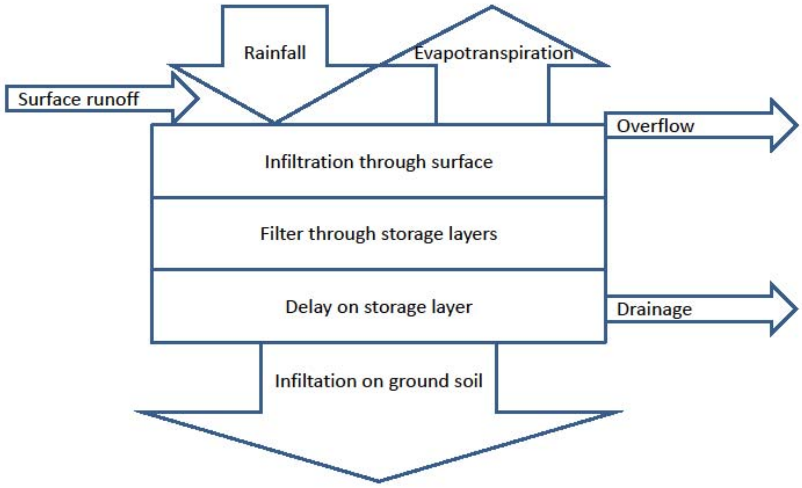

FIGURE 13: The hydrological processes that needs to take in notice in planning. (Permeable pavement, VTT 2015, 22).

The most common pervious pavements are a permeable, interlocking concrete pavement, porous asphalt and a pervious concrete (Permeable pavement, VTT 2015, 25). The essential part under the top surface is the structural layer. The stone material that is used in this layer, needs to find a balance between water permeability, the hold-up capacity of water, and also the load-bearing capacity. (Permeable pavement, VTT 2015, 28). In the structure, use other additional products like geotextile and –insulation should also be used. If is not possible to soak the rainwater and some or all the storm water, it needs to be lead off the drainpipes, cassettes or different kind of tanks needs. (Permeable pavement, VTT 2015, 29-31).

The cost of pervious pavement systems delaying and soaking rainwater is more permanent and a cost-effective solution compared to traditional storm water solutions, sewerage systems. The predicted life of pervious pavements is approximately 20 years, but there is not much experience about this in Finland. The CLASS- project revealed that the carbon footprint of pervious pavements is lower than in impermeable surfaces. (Permeable pavement, VTT 2015, 50). Winter is also one aspect that needs more study on how these materials work during winter times.

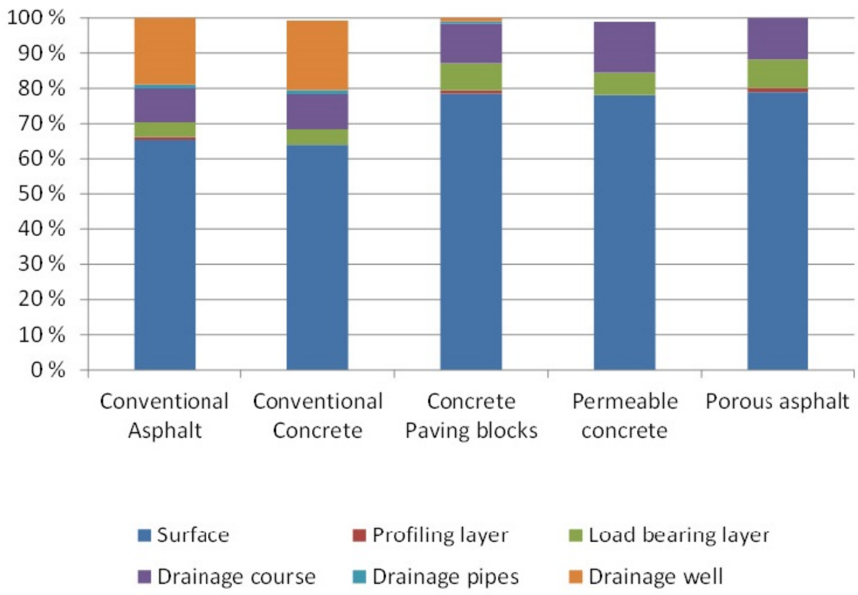

FIGURE 14. Example on carbon footprint in different surface structures on sidewalks. (Vares Pulakka 2014; Permeable pavement, 2015, 51).

2.7 Winter performance of pervious pavements

Cold climate conditions in pervious pavements and storm water have been studied in different projects. One study was made in the CLASS project. Frost heaving is one interest in porous pavements. Frost heaving is possible if there is frost susceptible soil under the porous pavement structure. It can be pre-empted with normal measures and design methods. Frost penetration is less under porous pavements than under conventional street structure. The main reason for minor frost penetration is because pervious pavements have an insulation property. Also the rain in spring times thaws the frost quicker in porous pavements. It seems that porous pavements have high infiltration capacity also during winter times. The maintenance in pervious pavements need a bit more focus than normal pavements. The streets need more snow plowing to maintain the infiltration rate. The streets with permeable paving allow water to infiltrate even when the ground is frozen. (Pervious pavement winter performance – State-of-the-Art and recommendations for Finnish winter conditions, 2014). More information and studies are needed about the subject and what are important more pilot cases. Theory does not always give all the answers and therefore it is important to test those in reality.

2.8 Street types in different cities

Street types give also one starting point for this study and what kind of street type's solutions could be found on case area. There is not one standard to plan the functions of the streets, like driveways, parking places, green areas. There are some guides to follow on how much parking places need space, how much driveways and pedestrian streets need space, what the minimum for the green band or the space that is needed for the trees. The city of Jyväskylä does not have any type of cross-section for the streets; it depends on the case and current situation.

City of Helsinki has one guide concerning the type of cross-section in different streets, figure 15. In the collector road, the width of the parking side of the street where both needed spaces at the same spot, the parking and the green band for the trees, is three meters in minimum. The crowns of trees are above the parking places. (Planning cross sections for streets, 2001).

local collector street

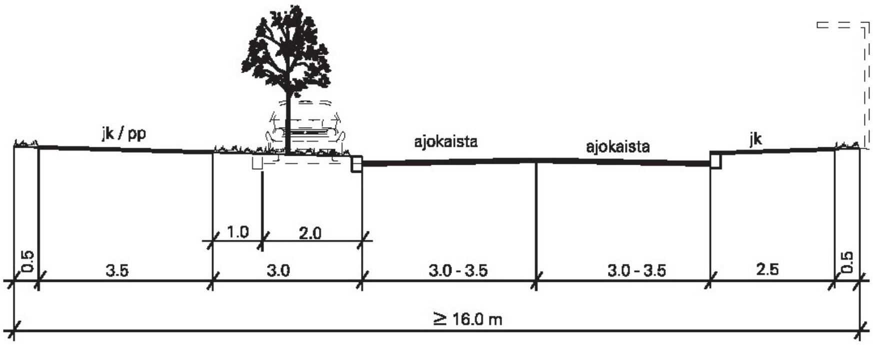

FIGURE 15: Cross section for local collector street in city of Helsinki. (Planning cross sections for streets, 2001)

In the city of Tampere, a similar kind of street type is found, the local collector street, a cross-section where the width of the space for parking and trees is 3,25 meters, figure 16. (Cross sections for streets in the city of Tampere, 2008)

local collector street

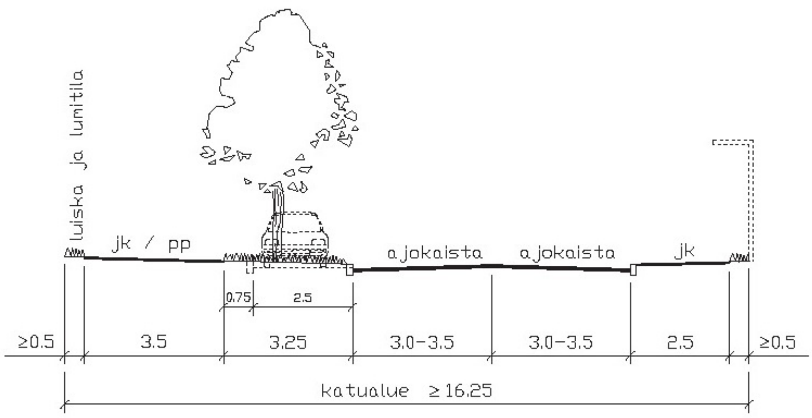

FIGURE 16: Cross section for local collector street in city of Tampere. (Cross sections for streets in the city of Tampere, 2008)

3 RESEARCH METHODS

3.1 The research questions

The objective of this study is to study the opportunities that the green street system could bring to storm water management. The case area was chosen from the City of Jyväskylä. The main research questions of the topic are:

1) What are the technical solutions to build a green street system?
2) How does the green street system effect on the quantity of storm water?
3) What are the advantages and disadvantages of the green street system compared to the traditional sewage system?

3.2 Methods

The methods that are in use in this study are chosen to serve the town planning office of the City of Jyväskylä. The literature review and the case studies abroad were a starting method to this study. A lot of interesting cases are available abroad. During the study, a few of them were chosen to be under closer investigation.

1) literature review and review of case studies abroad
2) previous detailed plan concerning the storm water in the case area
3) study about the quantity of storm water
4) own inventory and plans

The technical solutions of a green street system is to be investigate by the case studies abroad and applied to serve the purpose of storm water management. The method for investigating the case studies abroad were also the interview of Mervi Vallinkoski, landscape architect of Jyväskylä, who took part in an International Exchange Program in 2015. When choosing the exchange country the intrerest was to get familiar with different solutions for storm water management with the help of green infrastructure. The previous detailed plan of the area is the basis for the case area. It is important that the same value, such as like design rainfall, are used also in this study. That is how the existing storm water management plan and the planned green street approach could be compared. The study about the quantity of storm water is to be done with the help of the consultant office Sweco. By calculating with the help of the maps. My own inventory of the green street concept draft in the case area is done with a planning programme. The advantages and disadvantages of the green street system compared to the traditional sewage system are to be estimated in the end of the study.

4 CASE STUDY

The concept of the green street –system is used on making a concept draft on the case area streets Puutarhakatu, Puistokatu and Tourukatu, figure 17. The study is made on a rough scale to seek out if there is a possibility to make it work in hard covered city centres. The case area also consists of two parks, Puistotori and the park next to graveyard.

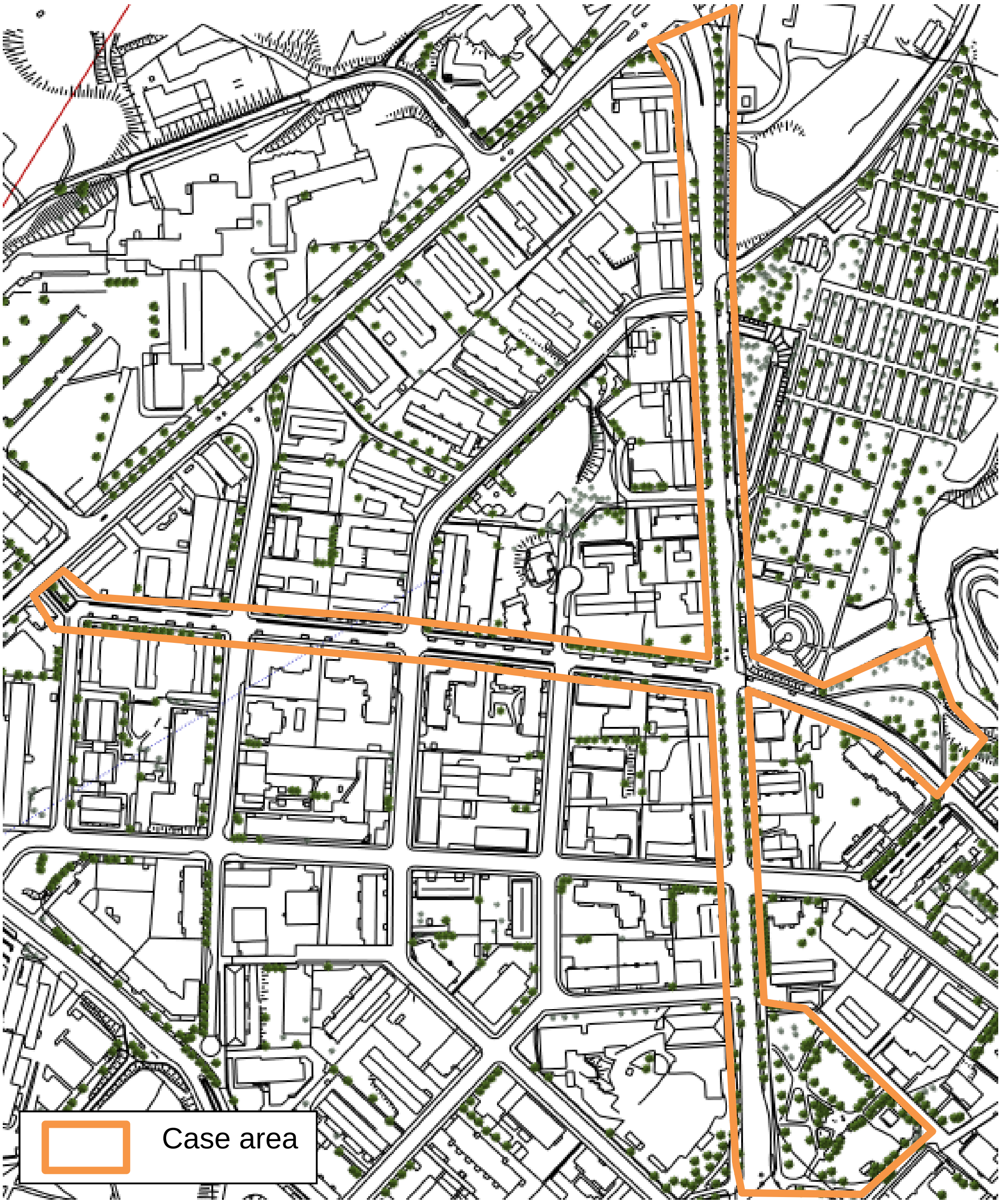

FIGURE 17: Case area: Puutarhakatu –Tourukatu – Puistokatu, Paula Tuomi

4.1 Case area: streets Puutarhakatu –Tourukatu - Puistokatu

The study area consists of two street areas and two green areas. In the streets of Puutarhakatu and Tourukatu have two driveways and two pedestrian streets and also street parking. The wideness of the street Puutarhakatu is on average 15 meters and in street Tourukatu 10 meters. In the existing situation, there is no green in the street, figure 19. That makes the streetscape quite cold and it is not a vital environment for pedestrians. Street Puistokatu, figure 18, has also two driveways and two pedestrian streets, street parking and trees in the row. The wideness in street Puistokatu is 20 to 25 meters. The trees in street Puistokatu are lime so they are quite big and make the street scape more liveabe and sheltered for pedestrians.

FIGURE 18: Street Puistokatu, photo Paula Tuomi

FIGURE 19: Street Puutarhatu. Photo Paula Tuomi

The case area consists also of two parks that are in the end of the streets. The park at the end of the streets Puutarhakatu-Tourukatu, figure 20, is a green area between the old graveyard and river Tourujoki. The other green area, Puistotori, is playground at the end of the street Puistokatu, figure 21 and 22.

FIGURE 20: Green area at the end of the streets Puutarhakatu – Tourukatu, photo Paula Tuomi

FIGURE 21: Green area, Puistotori, at the end of the street Puistokatu. Photo Paula Tuomi

FIGURE 22: Green area, Puistotori, and its water element at the end of the street Puistokatu. Photo Paula Tuomi

4.1.1 Land use

The case area is situated next to the city center, and it is mainly residential and workplace area, figure 23. The area is very densely built up and there are not much green areas. Because of the land use the parking is working in two shifts. In the day time, parking is mostly serving the offices for employers and customers, and at the night time it serves the residents.

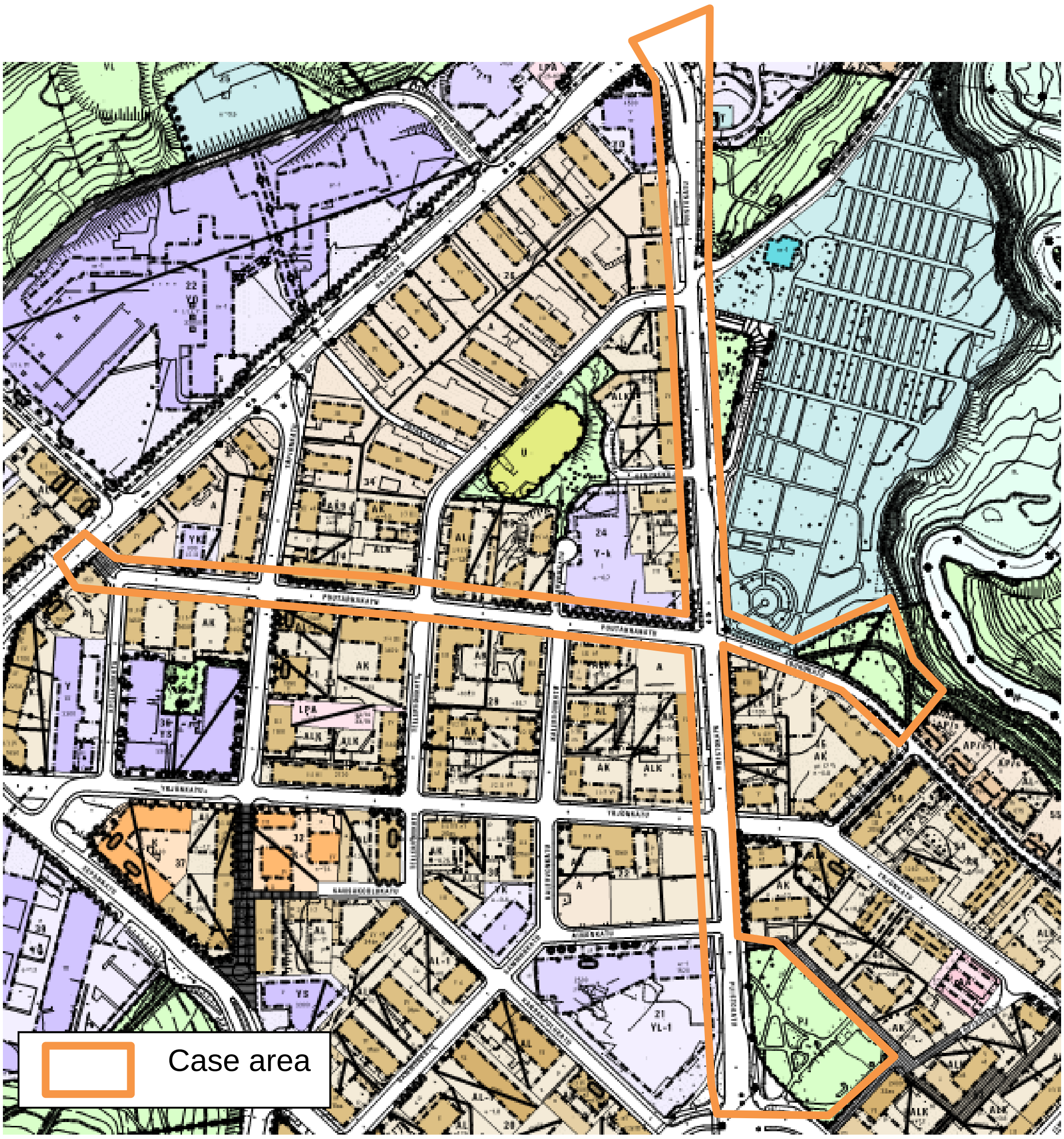

FIGURE 23 : Land use map. City of Jyväskylä, Land Use

4.1.2 Topography and hydrology

Landscape in the area is between the ridge and the valley, figure 24. That is why there are much topography changes in the area. The topography slides slowly to the South, Figure 25 and 26.

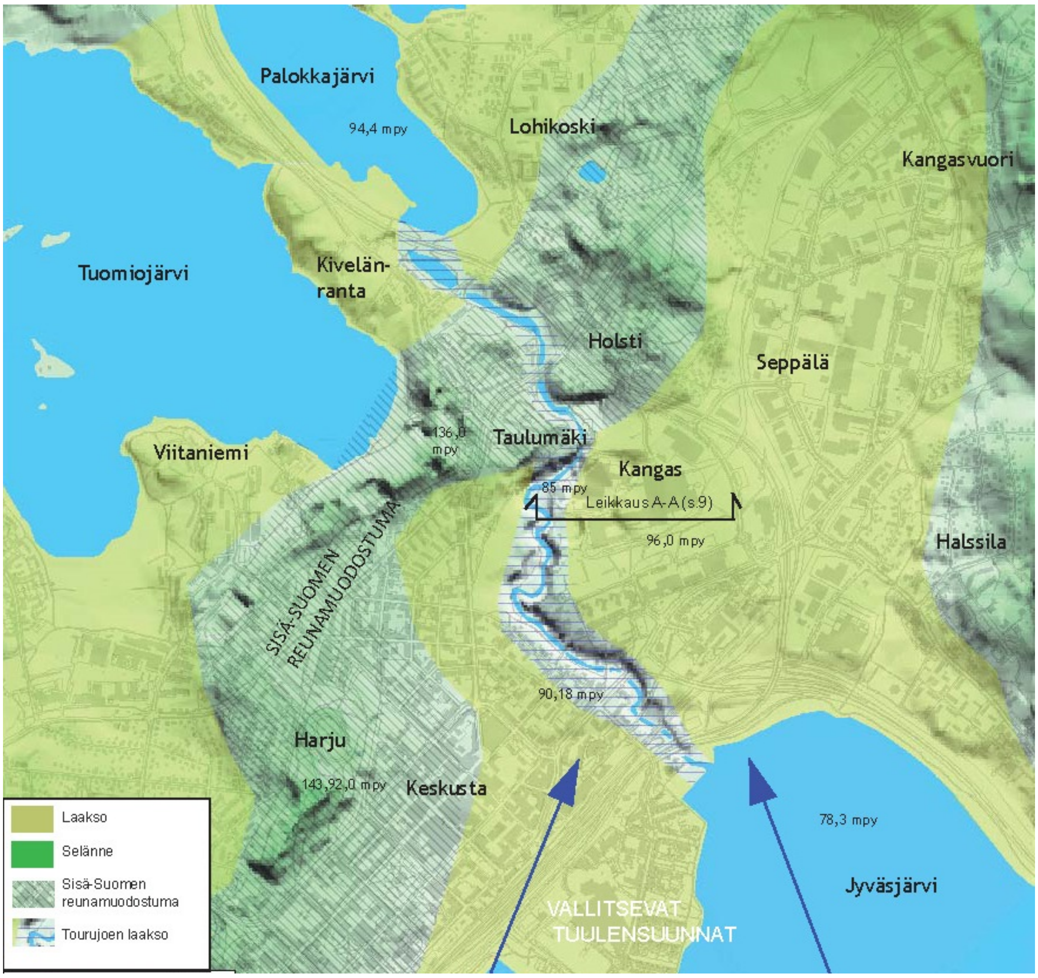

FIGURE 24: The Figure shows that the case area is between the valley of river Tourujoki and the ridge Harju. (Landscape in the residential area Kangas at City of Jyväskylä)

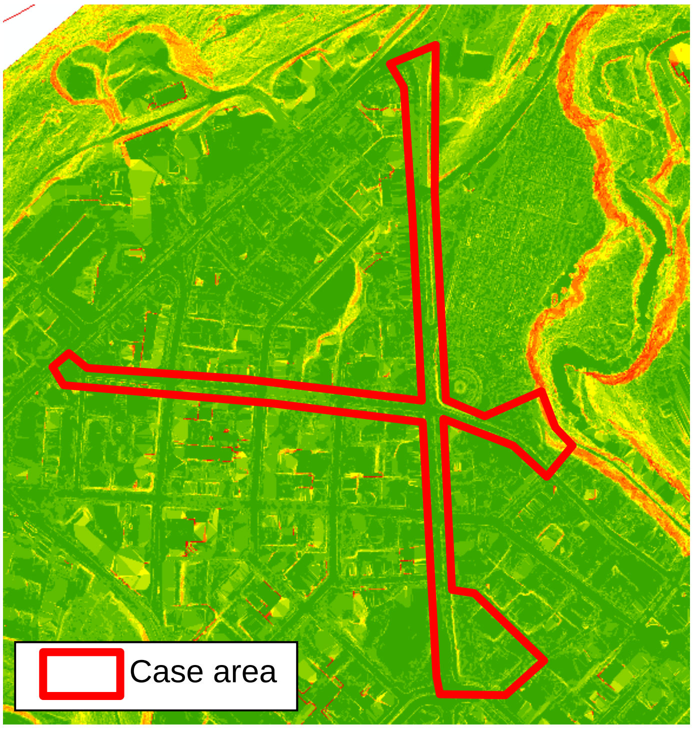

FIGURE 25: Figure shows the slope of the landscape in case areas. Map: Paula Tuomi.

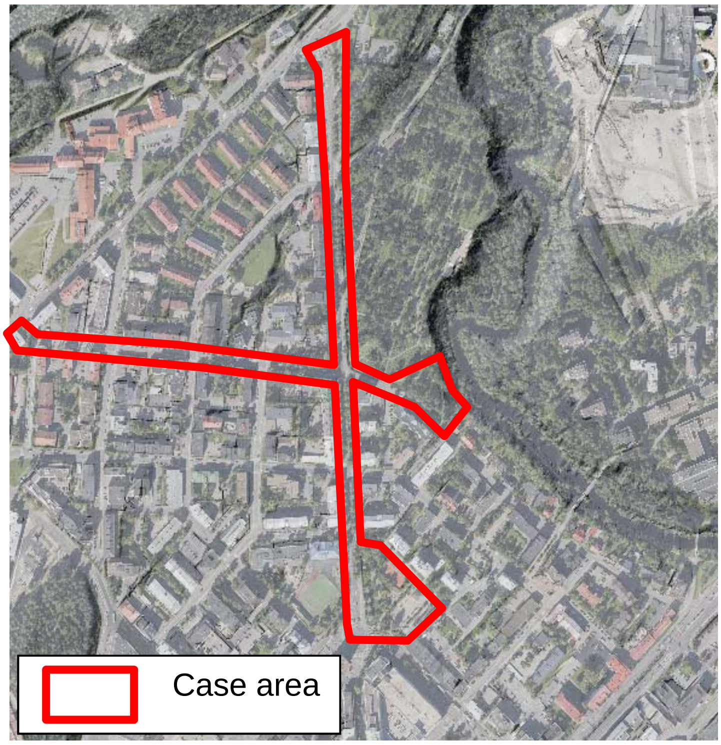

FIGURE 26: Slope of the landscape. Map: Paula Tuomi.

Hydrology in the case area shows that the water leads in two directions in the case area, figure 27. Some of the water leads toward river Tourujoki and some of the water towards the city centrum.

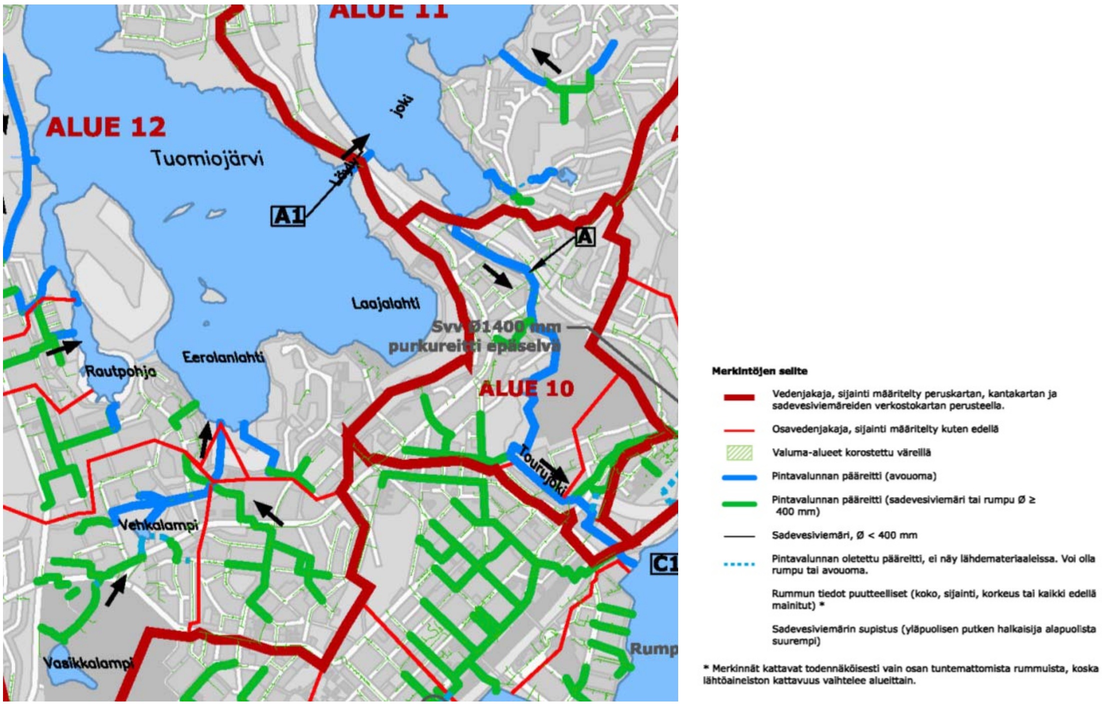

FIGURE 27: Figure shows the watersheds of Jyväskylä. (Watersheds in city of Jyväskylä 2009)

4.1.3 Soil

Information of the soil in whole planned area is not available. The soil near the area is moraine and gravel. The green area between the graveyard and river Tourujoki is in the soil map gravel so it suitable to soaking storm water. Because there are no buildings and there is only green area the area next to graveyard fits well for soakage, Figure 28. (Storm water management plan for street Rajakatu 2012, Watersheds in city of Jyväskylä 2009)

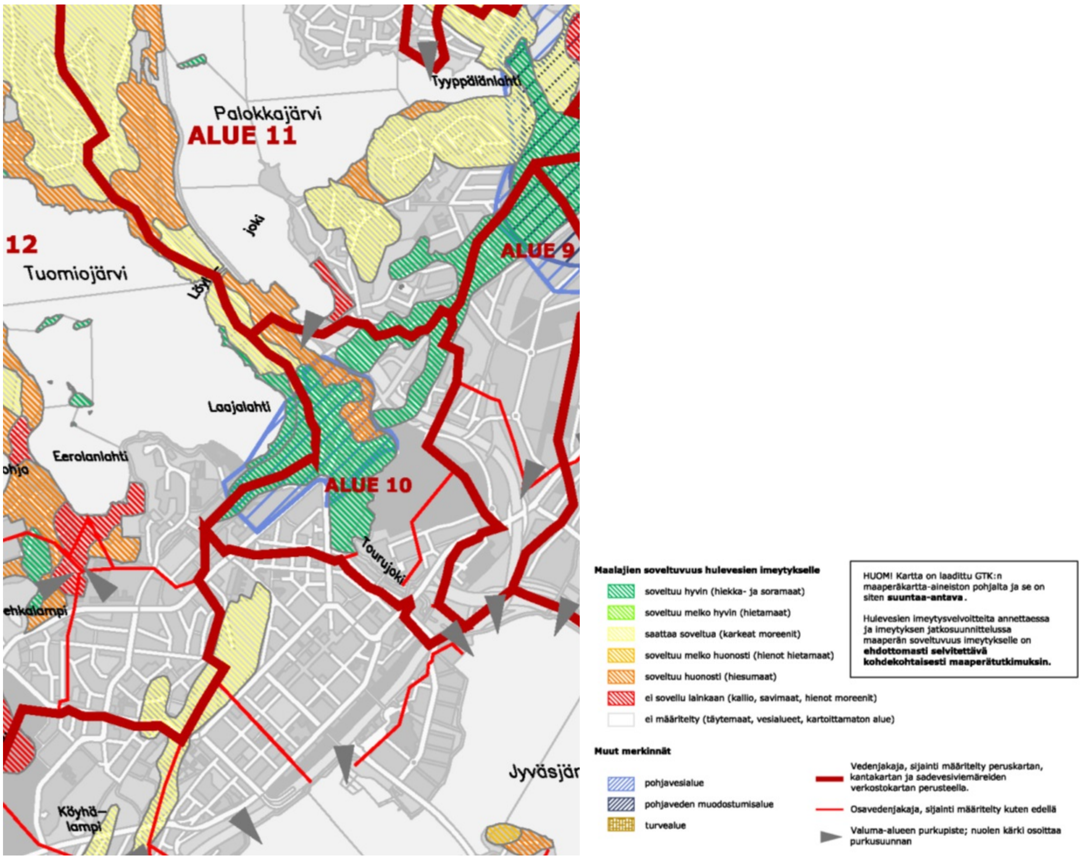

FIGURE 28: Soil in case area. The green color in the Figure shows that it fits well to infiltration to ground. (Watersheds in city of Jyväskylä 2009)

4.1.4 Existing storm water system

The existing storm water system is reported in the Storm water plan for Rajakatu that is made in 2012. Some of the storm water lines are combined sewer system, Figure 29. One problem in the existing system is that the water floods towards city centrum, where there is already flooding problems. (Storm water management plan for street Rajakatu 2012).

As design rainfall once in 5 years event was used to model the main discharge of the area, Table 2. The design rainfall repetitive was used once in 5 years event the main discharge of the area are investigated by modelling. By the help of that the design fall assorted to be 15 minutes. The 15 minutes design fall is relevant for the sewer capacity. (Storm water management plan for street Rajakatu 2012).

Toistuvuus	Kesto [min]	Sademäärä [mm]	Rankkuus [l/s/ha]
Kerran 5 vuodessa, nykytilanne	5	6,5	217
Kerran 5 vuodessa, nykytilanne	15	11	122
Kerran 5 vuodessa, nykytilanne	30	15	83
Kerran 5 vuodessa, tulevaisuus	5	7,8	260
Kerran 5 vuodessa, tulevaisuus	15	13	146
Kerran 5 vuodessa, tulevaisuus	30	18	100

TABLE 2: Design rainfall in case area. The amount of rainfall is 13 millimeters. (Storm water management plan for street Rajakatu 2012).

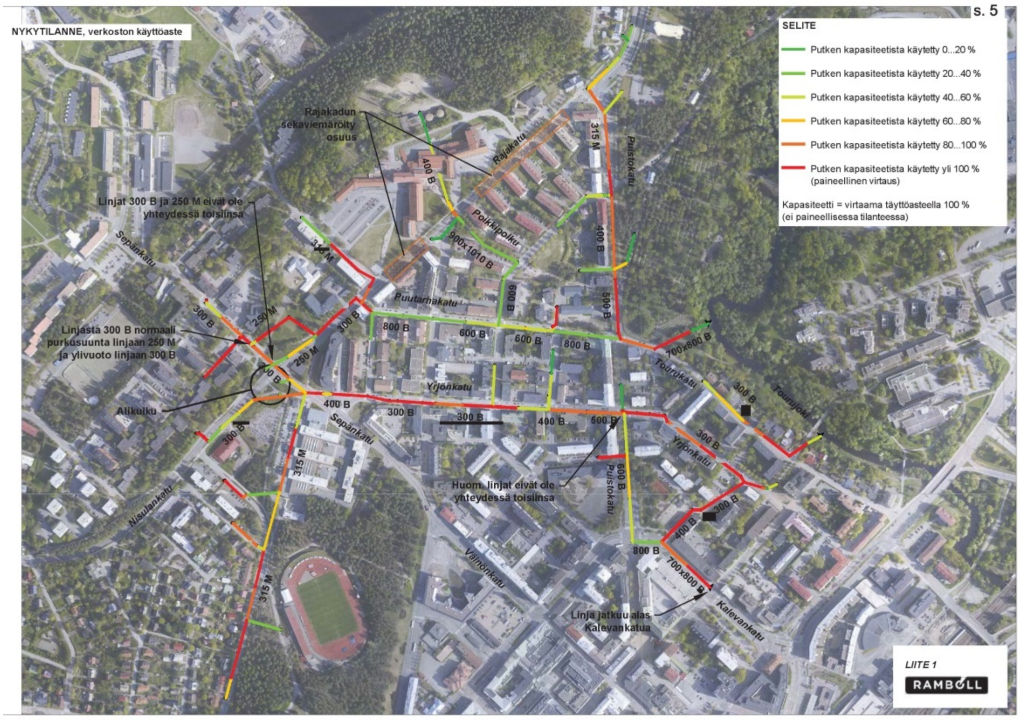

FIGURE 29: Existing storm water system. (Storm water management plan for street Rajakatu 2012).

4.1.5 Planned storm water system

The main objective of the system is to reduce the flow towards city centrum. Therefore, the capacity of the sewer systems towards the river Tourujoki need to be enlarged, Figure 30 and 31. (Storm water management plan for street Rajakatu 2012).

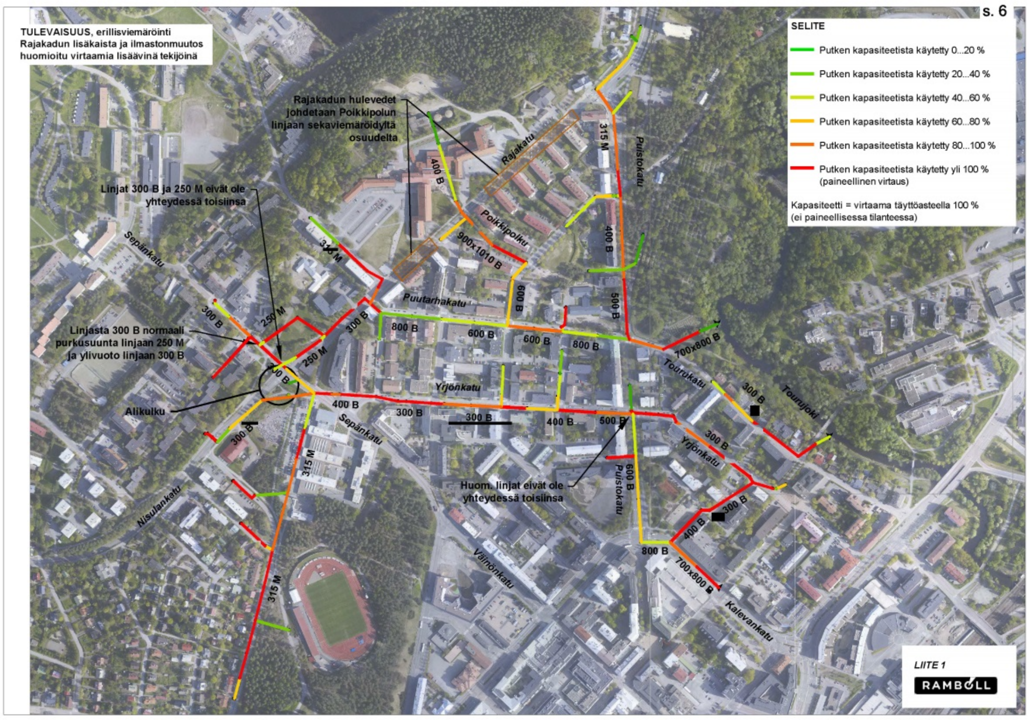

FIGURE 30: Capacity of pipes. (Storm water management plan for street Rajakatu 2012).

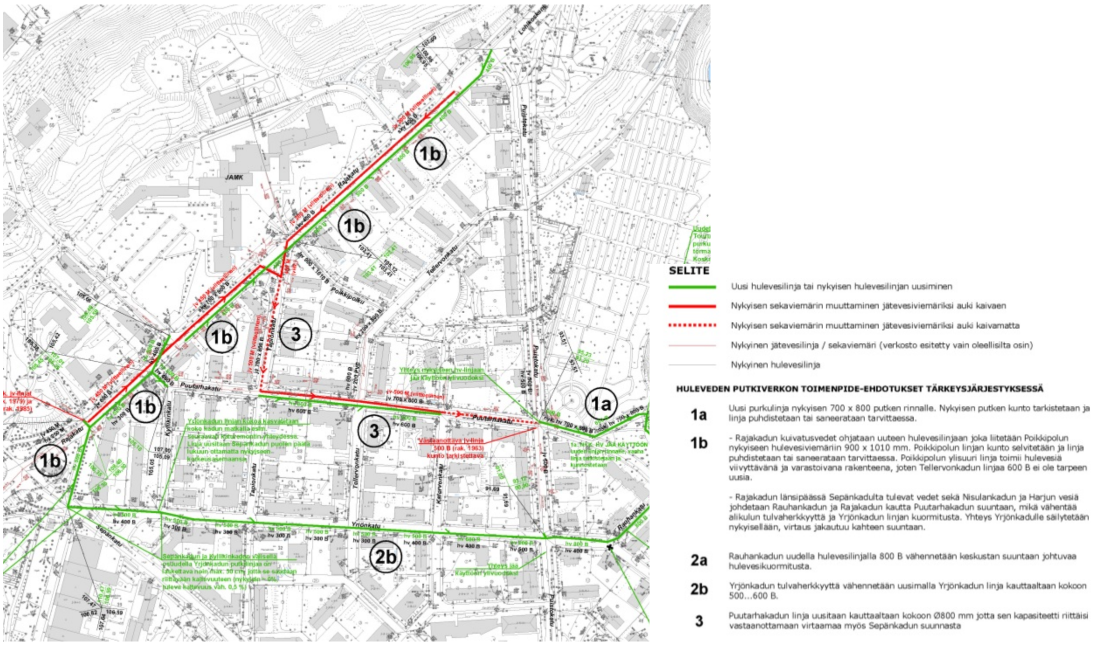

FIGURE 31: Planned storm water system. (Storm water management plan for street Rajakatu 2012).

4.1.6 Green Street approach principles

The main object of this research is to find out if the Green Street approach would offer a alternative way to deal with storm water. One of the main principles is that it is decentralized systems, where the storm water management has been split into several smaller systems, Figure 32. In the pavements for pedestrian street and parking places the pervious pavements is used. To the streetscape is brought green, like trees and bushes, to use the storm water, Figure 33 and 34. The pervious pavements and load bearing substrate are also used in the green areas of the streets.

Under the pervious pavements there is a storage layer of crushed stone for the detention of storm water, Figures 35, 36 and 37. In a heavy rainstorm, the storm water runoff runs in surface layers. Therefore, is needed to plan the surfaces with gutters. The pedestrian streets are gradient towards green planting belt so the gutters in between catch the surface runoff. The planting belts could also be a bit under the street level, so the surface runoff could be leaded directly towards those. The storage layer is planned to be a closed system where the water leads of only by subsurface drains.

The driveways are also gradient towards green planting belts and the water runs on wells. The wells lead the water under the planting belts. If the storage layer starts to fill, the water flows back to the wells. There is a subsurface drain in the well where the water runs towards a storm water sewer system under the driveway.

The number of parking places decreases only at the street Puutarhakatu. The amount of existing parking places are 45 and the amount after green street arrangement are 31.

FIGURE 32: Street Puutarhakatu (Paula Tuomi)

FIGURE 33: Street Puutarhakatu (Paula Tuomi)

FIGURE 34: Street Puutarhakatu (Paula Tuomi)

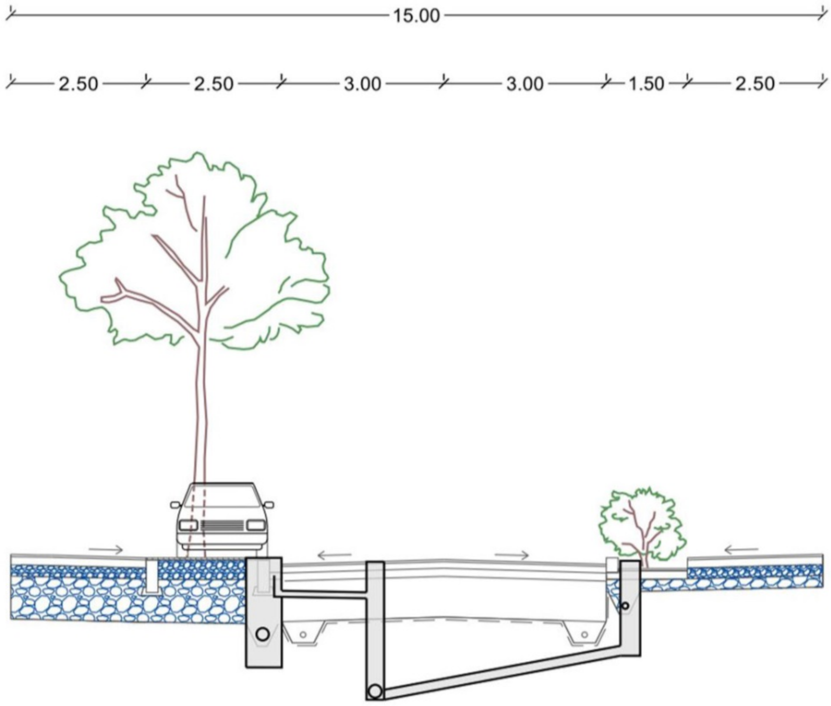

FIGURE 35: Example on cross section of street Puutarhakatu (Green Street, Sweco 2016).

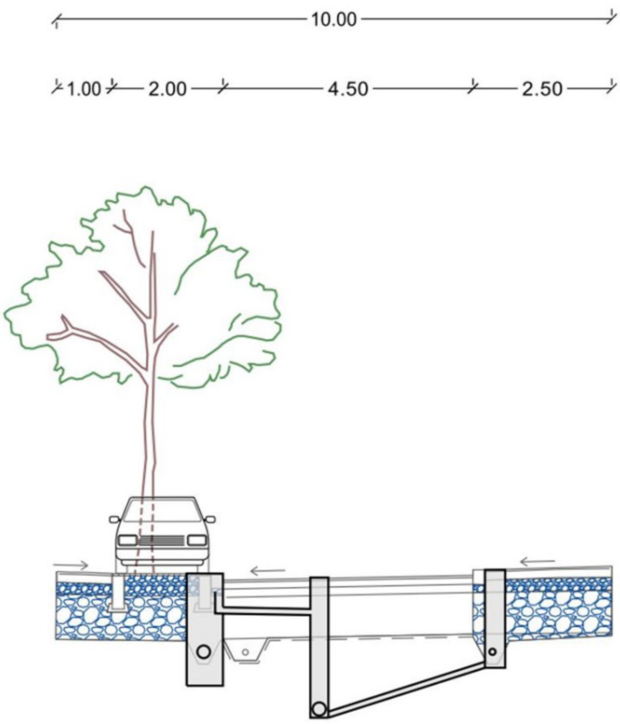

FIGURE 36: Example on cross section of street Tourukatu (Green Street, Sweco 2016).

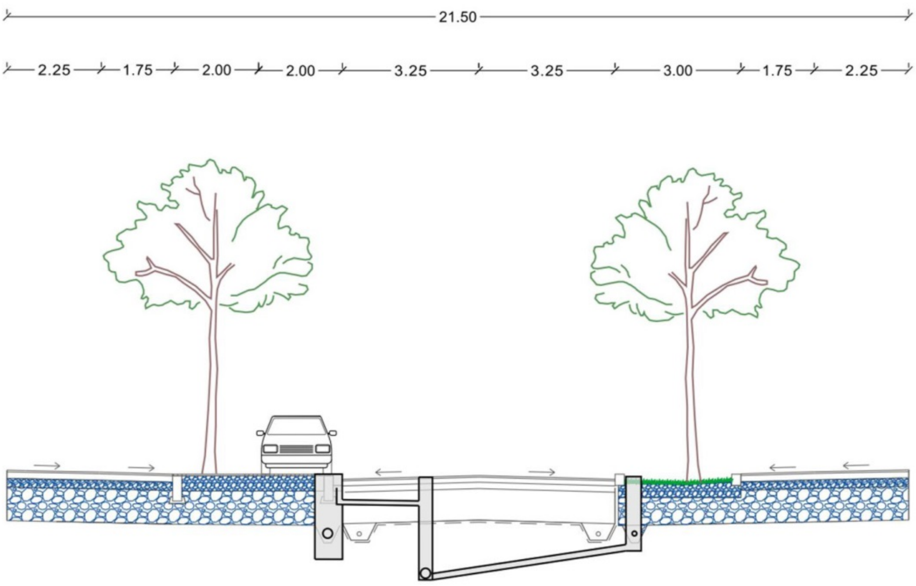

FIGURE 37: Example on cross section of street Tourukatu (Green Street, Sweco 2016).

4.1.7 Detention capacity of Green Streets

The detention capacity of Green Street has been prepared by the consult office Sweco. The capacity has been calculated with the help of the maps and measures, Table 3. By pervious pavements and vegetation create about 2300 square meters of detention capacity in the whole case area, Table 4. The amount is almost the detention capacity that is needed, which is 2500 square meters. The capacity of detention is only 800 square meters if the pervious pavements that are on the pedestrian streets would not be used. (Green Street, Sweco 2016).

The main problem is that the capacity is enough if you only look at the whole number, but when checking it more closely, it shows that the capacity of detention on streets Puutarhakatu and Tourukatu is 700 square meters and it should be 1950 square meters. At the same time, the capacity in street Puistokatu is more than is needed. (Green Street, Sweco 2016).

Structure	Minimum width	Seedbed		Other structure		Width of water layer
		Hour	Capacity	Hour	Capacity	
Parking + trees	2,5	0,4	10 %	0,6	30 %	-
Planting belts, Puutarhakat	1,5	0,4	10 %	-	-	0,1
Planting belts, Puistokatu	2,75-3,0	0,4	10 %	0,6	30 %	-
Pedestrian street	2,25-2,5	-	-	0,7	30 %	-
Cycle path	1,75	-	-	0,7	30 %	-

TABLE 3: Detention capacity is calculated with the measures in table 1. (Green Street, Sweco 2016).

Street	Parking + trees	Planting belts	Pedestrian street	Cycle path	Altogether
Street Puutarhakatu	120	15	350	-	485
Street Tourukatu	60	-	120	-	180
Street Puistokatu	220	370	620	480	1690
Altogether	**400**	**385**	**1090**	**480**	**2355**

TABLE 4: Detention capacity. (Green Street, Sweco 2016).

4.2 Detention capacity of green areas

The detention capacity is also found in green areas. There is a possibility to catch up a bigger amount of storm water for detention. In the green areas, it is possible to both catch up the surface runoffs, and take the water from sewerage systems or subsurface drains. The planned systems in both green areas are maximum 1,5 meters deep and there are wells in the bottom of the detention area, Figures 39 and 40. The capacity of detention next to graveyard is on average 450-670 square meters and in the park Puistotori 125 square meters. (Green Street, Sweco 2016).

FIGURE 39: Green area next to graveyard (Paula Tuomi)

FIGURE 40: Green area Puistotori (Paula Tuomi)

5 RESULTS

The results of the green street system approach was be considered from different perspectives. One question was to find out the technical solutions to build a green street system. The solution doesn't have only one answer, and the solutions differ a lot. The basic idea is to have on top a pervious pavement that leads the water under the ground. Under the pervious pavement there is a storage layer that is used for the detention of storm water. The storage layer could be, for example, crushed stone. Important is that the capacity is porous. The green street system could be either a closed or an open system. In the closed system, is needed a subsurface drains that leads the water away when the capacity fills up. In the open system, the water could be soakage to the ground. The closed up system is more reliable to use in tightly build up city areas, where there are, for instance, basements of the buildings that need to be aware of. The open system could be used in areas that are safely away of buildings and there is no risk for water to run where it should not be.

One outcome of this study is that in the case area it is possible to use pervious pavements in storm water planters, planting belts, parking places and pedestrians streets. When using it in storm water planters or planting belts by the streets, pervious pavements are combined with a load bearing substrate. When replacing some of the parking places with storm water planters, the amount of parking capacity will lower. The case area is situated closely next to the city centrum and the parking places easily to found to replace the lost places.

Another question was to find out if the green street system has an effect on quantity of storm water. The quantity of storm water to handle was measured, calculated and compared with an existing storm water plan. A green street system could be an opportunity for the sewer systems in the street areas. It was calculated that green street system will take a great amount of storm water for detention. The quantity of storm water that it catches up depends on the space on the streets and on the amount of the storm water. In the case area, the space could be found for these solutions. Splitting up the storm water management system into many smaller green street systems could answer the problem in many places. In the case area, it depends on the existing pipeline system where some of the water is managed.

It was not possible to study the quality of storm water during this case. It is likely that the quality has also a positive outcome as a result of these arrangements. When water infiltrates in a green street system it does not go straigtly through the pipes to water bodies but it stays in the green street system taken some of solids.

The advantage of the green street system is that it would make the streets to be more liveable for pedestrians by bringing the green to the streets. It also makes the storm water system reliable by splitting the management in many places. It also has been studied that these kinds of systems are more cost effective than the traditional sewage systems. During this study the calculation was not made. And maybe by bringing the storm water into a visible part of the streets may help people to rethink the efforts that everyone could do in their own properties.

The disadvantages of the green street system in the case area are that the existing pipeline system is crossing under the streets and it is hard to find a good place where to make these systems. Because of that the capacity to manage the storm water may not be as good with the traditional sewerage system this needs space from the street scape. The situation differs a lot in new planned areas, where it is possible to found solutions and needed spaces more easily.

The capacity for detention next to a graveyard is possible not to be made-up at all. In the street Rajakatu, the storm water management plan was meant to be for detention of storm water. The Rajakatu storm water plan could be needed to manage also the quality of storm water before water heads on towards river Tourujoki. If building up the green street system for street Puutarhakatu there may not be a need for detention. The detention goes through the whole green street. There is an existing pipeline by side the river Tourujoki, whose capacity would be enough for the waters.

The questions to consider were will it make a difference for the trees on the streets? The benefits of these solutions are obvious to the trees. Main challenges of the street trees were lack of space, a lack of oxygen and a lack of water. With the green street solution there is a good space for the roots in planting bed where there is enough space, water and oxygen. When leading the water in storage layers will improve the habitat of the trees and when trees are using a huge amount of water the storm water is handled at the same.

The park next to city centre, park Puistotori, was planned to work as a part of flooding route that storage the water in heavy rain. The park with its features suites well to be planned and constructed as water plazas under redevelopment. The park could have many functions serving as playground and water managements. During heavy rain, the users of the parks are not there, and on the other hand, the water as element suites well for children’s play. There it would a park with several meanings. For citizens refresh and enjoyment and also for reserve the water in heavy rains.

The observation that came by the end of the project Virma were the benefits that these solutions could bring to the green infrastructure. It was clarified that this green street solutions with its multifunctional green infra generates ecosystem services. The ecosystem services that green street could bring are the cultural services like recrerational experiences, enjoyment and regulating services like climate regulations.

In conclusion, main benefit of a green street system is that the storm water is managed decentralized. The surface layer is made-up with porous pavements that lowers the storm water flow. And with all the technical solutions this system brings more green to our streets, our environment.

6 CONCLUSION

The case study shows that there is an opportunity to make the green street system work. In the case area, there should be more specific modelling about the storm waters that would show if the planned green street areas could still be enough. By the help of the property owners in the streets there could be found more places for the detention for storm water.

The study has received positive feedback so far from the town planning level. It shows that there is a clear need for these kinds of investigations for combine green infrastructure and storm water management. The study only illuminates the narrow sector for the opportunities that this could bring and there is a clear need to continue this research.

There are also many doubts towards this study. This is not a common way that storm water is managed. Many examples are from other countries so there is a need for making real test areas for giving more answers for example from winter performance. For managing the storm water with sewage systems is what we are used to do. The past years have proved that the traditional system is not a sustainable any more. The increase of flooding events could cause us to situation where we have to rethink the different ways of managing it. By that these kinds of solutions could be found a new way for dealing the storm water in a suitable way.

It was found in the study that it is important to make many multipolar green infra networks where different parts work for preventing the water to run. Concurrently we need the traditional sewage systems, green streets and other decentralized solutions. When making the small solutions in many places slowly would answer the storm water problems in the long run.

The amount of storm water is summoned in draft scale by maps and calculating. When seeking out more answers, it is necessary to step in the next planning state. A more detailed plan combined with modelling the real amount of storm water would give more specific solutions.

One of the main conclusions of the study is that we need to find a pilot area in the city of Jyväskylä to test green street system in real. The new kind of approach for managing storm water has now the guidelines to proceed with studies and pilot environments. There is a clear vision to continue with this project and make more detailed plans according to this concept. It is clear that these methods arise many questions, like how they work during the winter period, if it manages the storm water, is cost effective and so on. Many studies that has been made for this subject give a positive signal but what really needs to be done is to find an area where it could be possible to test this method.

One of the studies to continue with the subject could be the effect on the quality of storm water in a green street system.

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APPENDICES

APPENDIX 1. EXPERIENCE OF GREEN STREET QUESTIONNAIRE (IN FINNISH)

Maisema-arkkitehti Mervi Vallinkosken kokemukset kansainvälisessä henkilöstövaihdossa 2015 hulevesien hallinnasta ”Green street” –kohteista Pohjois-Amerikassa.

Haastattelu 23.12.2015

Läsnä: Mervi Vallinkoski ja Paula Tuomi

1. Miksi ”Green street”-menetelmää on ruvettu Vancouverissa käyttämään?

Itse asiassa ”green street”-termiä on käytetty ainoastaan Portlandissa? Surreyssä, missä olin vaihdossa, ei ollut niin hyvä tilanne. Siellä toteutuneet esimerkit ovat hyvin rajallisia. Surreyssä katupuoli ei suhtautunut kovin myönteisesti näihin kadulle tuleviin hulevesijärjestelmiin. Koko Vancouverin alueelta löytyy kuitenkin hyviä esimerkkejä. Seattlessa, missä kävin vierailulla, on hyvin samantapainen menetelmä kuin Porlandin ”green street”-menetelmä. Portlandissa tämä on ollut käytössä jo pitkään. Pohjois-Amerikassa ja Kanadassa Tyynenmeren rannikolla on lohikalojen kannan romahdus ollut se tekijä, mikä on herättänyt toimimaan. Lohi on siellä niin symbolinen eläin. 1980–90 luvulla on vedet saastunut niin paljon, että on aiheuttanut lohikalojen määrän romahduksen. Amerikan ja Kanadan puolella on havaittavissa eroja, siinä miten asiaa on lähdetty viemään eteenpäin. Amerikan puolella on lähetty enemmän siitä lähtökohdasta, että tehdään tonteilla ja kiinteistöillä hulevesien viivytykset ja Kanadan puolella enemmän siitä, että viranomaiset toteuttavat toimenpiteet. Aluetasoiset valuma-alueyleissuunnitelmat rupeaa olemaan valmiita Surreyssä. Surreyssäkin on 20 vuotta ollut Sharp-ohjelma jossa koulut toteuttaa purojen kunnostuksia. Ongelmat vesistöissä johtuu sielläkin siitä, että 90-luvulla on rakentaminen lisääntynyt ja sitä kautta hulevesien määrä. Surreyssä on ryhdytty käyttämään ”day lighting”- termiä joka tarkoittaa sitä, että tuodaan hulevesijärjestelmät näkyväksi osaksi kaikille. Tämä lisää esimerkiksi kaupunkikosteikkoja ja muita avoimia järjestelmiä. Yhteenvetona ”Green street”-termi lähti 2000-luvun alulla Portlandista liikkeelle. Seattlessa käytetty termi on ”Green grid”. Se on hyvin samantyylinen Portlandin mallin kanssa.

2. Kauan tämän aiheen parissa on työskennelty siellä?

Strategiat on käynnistynyt jo 90-luvulla. Ongelmat ovat konkretisoituneet 1980-90 luvulla. 2000-luvun alusta on ryhdytty toteuttamaan ensimmäisiä kohteita. Seattlen ensimmäiset ”Green gridit” on toteutettu 2002. Ne oli toteutettu mutkittelevina katuina, jotka olivat ympäristöinä erittäin kiinnostavia. Myöhemmin huomattiin, että suorat kadut toimivat paremmin, koska niistä saadaan enemmän viivytyspintaa toteutettua. Seattlessa ja Portlandissa on käytännöt vakiintuneita. Surreyssä ollaan vielä aika alkutekijöissä.

3. Mitkä ovat olleet huomattavimmat hyödyt? Entä haitat?

Hajautettu järjestelmä yksittäisinä pieninä toimenpiteinä on toimivampi ehkäisemään hulevesien syntyminen, kuin yksi keskitetty iso järjestelmä. Alapuolisten vesien virtaamat pysyvät tavoitellulla tasolla eikä tule hulevesien määrällisiä tai laadullisia ongelmia. Kalakannat ovat ruvenneet elpymään. Rakentaminen, hulevedet ja ympäristön suojelu voi aiheuttaa ristiriitaisia tilanteita eri intressien kohdatessa. Talven vaikutus pitäisi selvittää enemmän. Olisiko esimerkiksi Winnipegissä tai Calgaryssä löydettävissä vastaavia esimerkkejä.

4. Missä suunnittelun vaiheessa pitäisi erityisesti päästä vaikuttamaan?

Tavoite täytyy määritellä valuma-aluetasolla. Asemakaavassa tulisi miettiä tilantarve. Rakennuslupa ja toteutussuunnitelmataso ovat erittäin tärkeä. Järjestelmät ovat niin paikkaan sidottuja eli missä katsotaan järkevämmäksi putkien käyttö.

5. Onko ollut kustannusvaikutuksia? Positiivisia, negatiivisia?

Tämä on oikeasti edullisempi vaihtoehto. Kaupungin kustantaa jopa yksityisten tonteille sadepuutarhoja, jottei tarvitsi lisätä uusia viemäreitä. Niitä on tehty Seattlessa etenkin sekaviemäröidyillä alueilla. Seattlessa raporteissa löytyy vertailulukuja kustannusvaikutuksista. Portlandissa kerrottiin että on laskettu että tämä on edullisempaa. Green rivers- ja Rainwice- ohjelmat ovat olemassa oleviin vanhoihin kiinteistöihin soveltuvia ohjelmia joissa vaikutetaan nimenomaan vanhoihin kiinteistöihin.

6. Miten toivoisit että tästä voitaisiin erityisesti Suomessa ottaa oppia?

Hulevesissä on otettu hyvin mallia, mutta ei ole pysähdytty miettimään alueen omia lähtökohtia. Mikä on olennaista juuri Suomessa ja Jyväskylässä? Suomessa ei ole edes ollut tutkimukseen riittävästi aikaa. Pitäisi selvittää malleja muualta maailmasta tai esimerkiksi Pohjoismaista.

7. Mitä muuta haluaisit tuoda esille?

Ilahduttavaa Portlandista oli se kokonaisvaltainen ajatus, joka ei ole pelkkää teknistä suoritusta vaan hyvän yhteistyön tulos!

APPENDIX 2. CONCEPT DRAFT FOR GREEN STREET