Assessing the applicability of Water Sensitive Urban Design principles in Enschede, The Netherlands

NEDA MORADI
February, 2014

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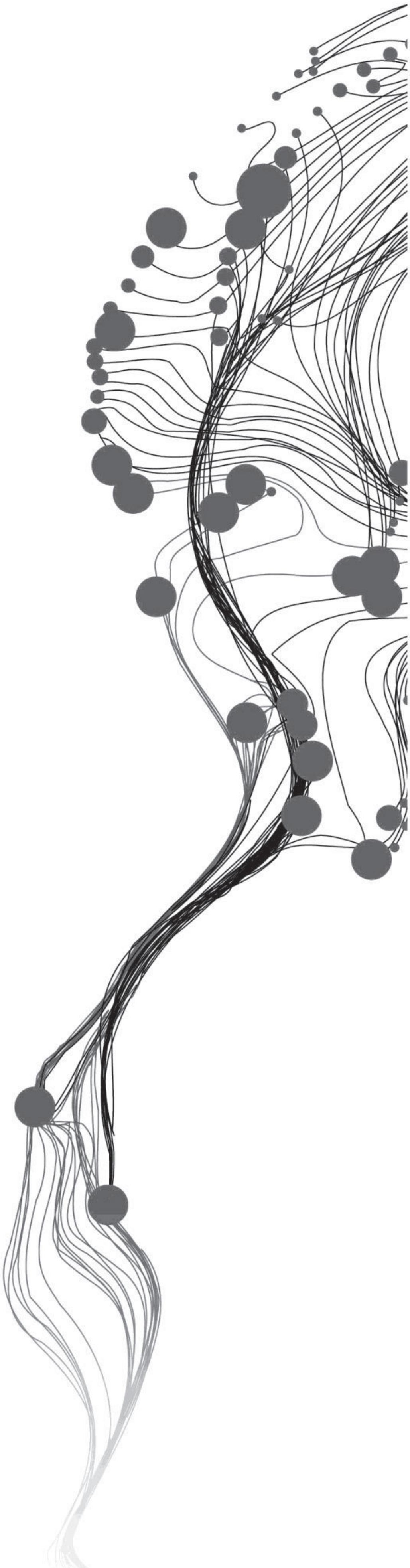

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NEDA MORADI
Enschede, The Netherlands, February, 2014

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Urban planning and Management

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ABSTRACT

Water Sensitive Urban Design (WSUD) is an emerging concept which aims to integrate water management system with urban planning and landscape architecture. Although comprehensive researches about the WSUD concepts have been developed in Australia, not enough effort has been done to define an empirical method or framework to a these principles in other locations. In this research, an empirical case study was selected to assess the applicability of the WSUD principles in the context of Enschede, Netherlands. It was found WSUD framework is highly dependent on the site specifications and water system's concern. Due to the presence of different influential factors in the study a multi-dimensional framework was proposed to establish integration between different components of the water system. High level of the groundwater, groundwater pollution, street flooding, and cultural heritage value of the neighbourhoods are examples of the inflectional factors in this study. Multi Criteria Analysis –MCA– method was used to manage the multi-dimensional goals of the study and assess different alternative solutions for the study area. The inherent uncertainty of the MCA were tried to be addressed by participating different groups of the stakeholders in the assessment. Results revealed that WSUD and the water vision of Enschede have common goals and objectives. Although, local context and water management concerns are different between Enschede and Australia, it can be concluded that Enschede is in a transition phase towards more sustainable practices to address its water related problems. Nonetheless, a number of problems were identified as the obstacles in the way forward. Among them, relatively isolated water management system from land use planning and the water vision which is not spatially localized, are remarkable. Finally, the integration of principles in different levels of planning process, especially harmonizing water management and land use planning is a positive step towards a more water sensitive city.

Keywords: water sensitive urban design, integration, multi criteria analysis, water management, urban planning

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1. INTRODUCTION

1.1. Background information

Water is an issue that is dominating the contemporary agenda of urbanism. The consequences of global warming and rising sea levels, uneven distribution of sacred water resources, disturbed terrain and effected watersheds, pollution water storage and harvesting, flood protection are among current water issues which we are facing (Shannon, 2008).

In cities, wastewater, stormwater, natural water bodies and artificial water bodies such as ponds and lakes are different occurrence of the water. Cities are experiencing major challenges recently, extreme rainfall events due to the climate change, increased surface run-off driven by impervious surfaces and urban growth, heat island effect due to the climatic change in the built environment are examples of these challenges (Huong & Pathirana, 2011).

Due to the shortcomings of the conventional water management to solve the above-mentioned problems, and increased complexity of the water management systems in the urban area around the world , an integrated approach toward more sustainable solutions is inevitable (Rijke, 2007). Therefore, new approaches such as modern water management systems, adaptive water management, sustainable water management and water sensitive urban design (WSUD) have emerged. These approaches emphasise on the adaptive and inclusive practices toward the more sustainable water management (Davis & Farrelly, 2009).

This research focuses on the WSUD approach which is a holistic approach to the planning and design of urban development that aims to minimise negative impacts on the natural water cycle and protect the health of aquatic ecosystems. The objective of this approach is to integrate the water management, urban planning and landscape architecture and incorporate all streams of the water in the urban area, storm water, groundwater, waste water and drinking water in this integrated design (Joint Steering Committee for Water Sensitive Cities, 2009).

The concept of WSUD starts by looking beyond the idea that a pipe in the ground is the best option for solving the rainwater discharges problem. This is a 19th-century solution that is neither the best nor the only solution to a growing 21st-century problem (Mitchell, 2006). Unlike the conventional approaches which consider water in the urban area as a treat, WSUD looks at the water as an opportunity. Thus, it tries to manage the stormwater locally, integrate the storm water in the landscape and enhance the visual characteristics of the built environment. According to the WSUD, managing the water in the urban area and particularly tackling the flood, doesn't have to be in isolation for creating the liveable cities.

Originally, this concept has a holistic approach toward water management system and aims to manage the whole water cycle. Water demand, water supply, health of the water bodies, quality and quantity of the stormwater discharges are among the main components of the water systems which has been considered in this concept. Although, WSUD is mostly concerned with managing the stormwater discharge in the built-environment (Hoyer et al., 2011).

The water sensitive urban design term origins in Australia and was a response to the current water management challenges there (Joint Steering Committee for Water Sensitive Cities, 2009). Drought and floods are the main challenges in this water system which poses number of problems. Some instances of the problem are the increased stormwater discharge from the built-environment, pollution of the stormwater discharges, water quality of the water bodies, security of the water supply. Hence, this concept attempts to address above mentioned issues while considering the whole water cycle (Rijke, 2007).

The key principles of the WSUD in Australia, is to protect natural systems, integrate stormwater in the landscape, protect water quality, reduce run-off and peak flow and to add value while minimising the development costs (Melbourne Water, n.d.).

The main contribution of this research is defining a framework to adopt these principles. In order to do that, the WSUD principles and their integration will be analysed. Then, a framework will be developed which will be applied to the empirical case study. Subsequently, the applicability of the WSUD principles in this case study will be assessed.

The study area:

The study area, Enschede is located in the East of Netherlands in the Overijssel province (Figure 1-1). Recently, due to the heavy rainfall, Enschede has experienced pluvial flood incidents in some neighbourhoods ("Enschede in Crisis," 2013). These floods occur after short, intense downpours which cannot be quickly enough evacuated by the drainage system or infiltrated to the ground. Pluvial floods often occur with little warning in areas not prone to flooding – hence the 'invisible hazard' tag (Houston et al., 2011). In the wake of climate changes, more extreme weather situations might follow and flooded city districts are one possible scenario. In addition to the street floods, high level of the groundwater in some neighbourhoods, groundwater pollution, stormwater quality problems are main challenges that water system in Enschede is facing.

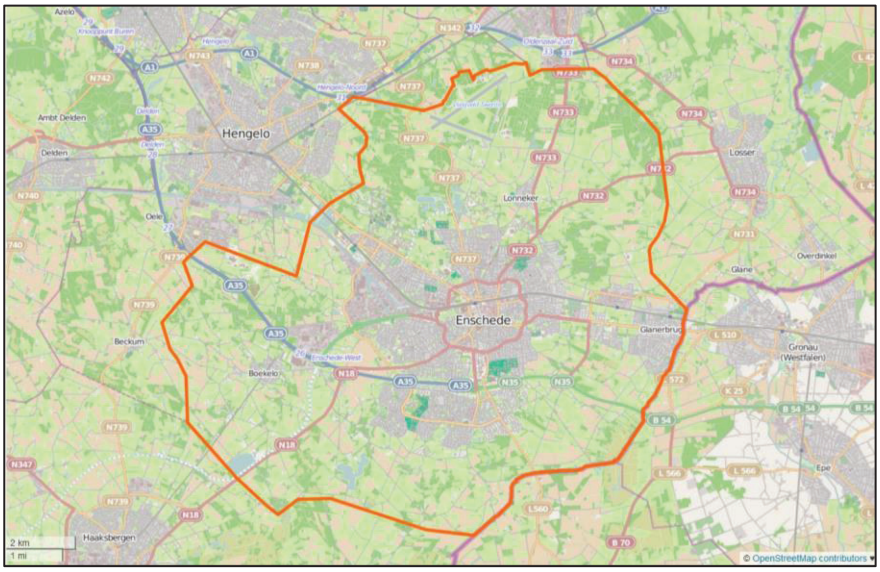

Figure 1-1. Map of Enschede.
Source (open street map, 2013).

Enschede participates in the 'water chain lab': Waterketen-Proeftuin together with the foundation of applied water management research STOWA and RIOND (SWOTA, 2012), they want to develop a new water management method in Enschede and the cooperation runs till 2015. This indicates that a necessity to move toward a more sustainable approached in Enschede has been recognized.

In addition, towards sustainable water management in Enschede, the WADI concept has been already implemented in some of the neighbourhoods. The word WADI has playfully given inspiration to a Dutch acronym "W.A.D.I" which stands for "water afvoer door infiltrate (evacuation of water by infiltration). Implementing this concept, landscape based stormwater drainage has been an integral part of the planning and development of the housing district in Ruwenbos and Oikos (The Danish Architeture Centre, 2012). This research will provide a framework which based on that, the current situation of these neighbourhoods with respect to the WSUD principles can be assessed.

Due to the above mentioned challenges in the water management system, municipality of Enschede presented a water vision toward a more sustainable approach. In this water vision, bringing the water back to the urban area and constructing a stream was proposed. Therefore, Enschede was a potential case study for analysing challenges and opportunities toward a more water sensitive approaches. The neighbourhoods of the Stadsveld and parts of Pathmos were selected for further analysis.

Figure 1-2. Orthographic photo of the Ruwenbos district in Enschede.
Source (Google Maps, 2013).

1.2. Research Problem

Conventional water managements are "top—down" technical approaches that cities are highly reliant on them (Global Water Partnership, 2008). In these robust systems there is an emphasis on reduction of the uncertainty and controlling the water system (Pahl-Wostl, Sendzimir, & Jeffrey, 2009). The elements and components of these systems are fragmented and the storm water is managed centrally.

Due to the climate change, heavy rainfall events and land cover change, cities are facing water related problems. These include increased impervious surfaces, low groundwater recharge rate, low soil infiltration rate, high speed of the storm-discharge, overflows of the run-off from the sewage system, water bodies pollution (Hoyer et al., 2011).

It can be observed that due to the technical and economical limitations, conventional water management systems are not completely able to tackle these problems in the cities. Above-mentioned challenges in the current water management under increasing complexity and uncertainty calls for a need toward more sustainable approaches in the worlds (Rijke, 2007).

Hence a paradigm shift has been happened from conventional water systems toward new approaches. Number of new approaches such as adaptive water management, modern water management, sustainable water management and WSUD has been emerged across the world (Davis & Farrelly, 2009). The great emphasize on the adaptable built-environment and inclusive solution, is the common aspect between these emerging approaches. These new approaches gives emphasize to considering different aspects of the urban water system that relate to each other.

Although comprehensive researches about the WSUD concepts and principles have been already developed in Australia, not enough effort has been done to define an empirical method or framework to adapt these principles in other locations. Hence, the research problem is to develop a framework to assess the applicability of the WSUD principles and the integration between them in Enschede. Subsequently to analyse similarities and differences between WSUD principles with the current water management approach in Enschede.

1.3. Conceptual framework

The conceptual framework introduces main concepts and interactions in this research. First, this research introduces the WSUD concept and its components, subsequently it investigates how these principles of this holistic approach are integrated in practice. Second, it analyses the current water management system and assesses the current situation of Enschede with respect to the WSUD principles. Third, a framework will be developed to adopt the WSUD principles in Enschede. Through this framework a number of alternatives for Enschede's water management system will be assessed. The outcome indicates the difference between Enschede's current water management system and WSUD concept, hence illustrates the applicability of the WSUD principles in Enschede.

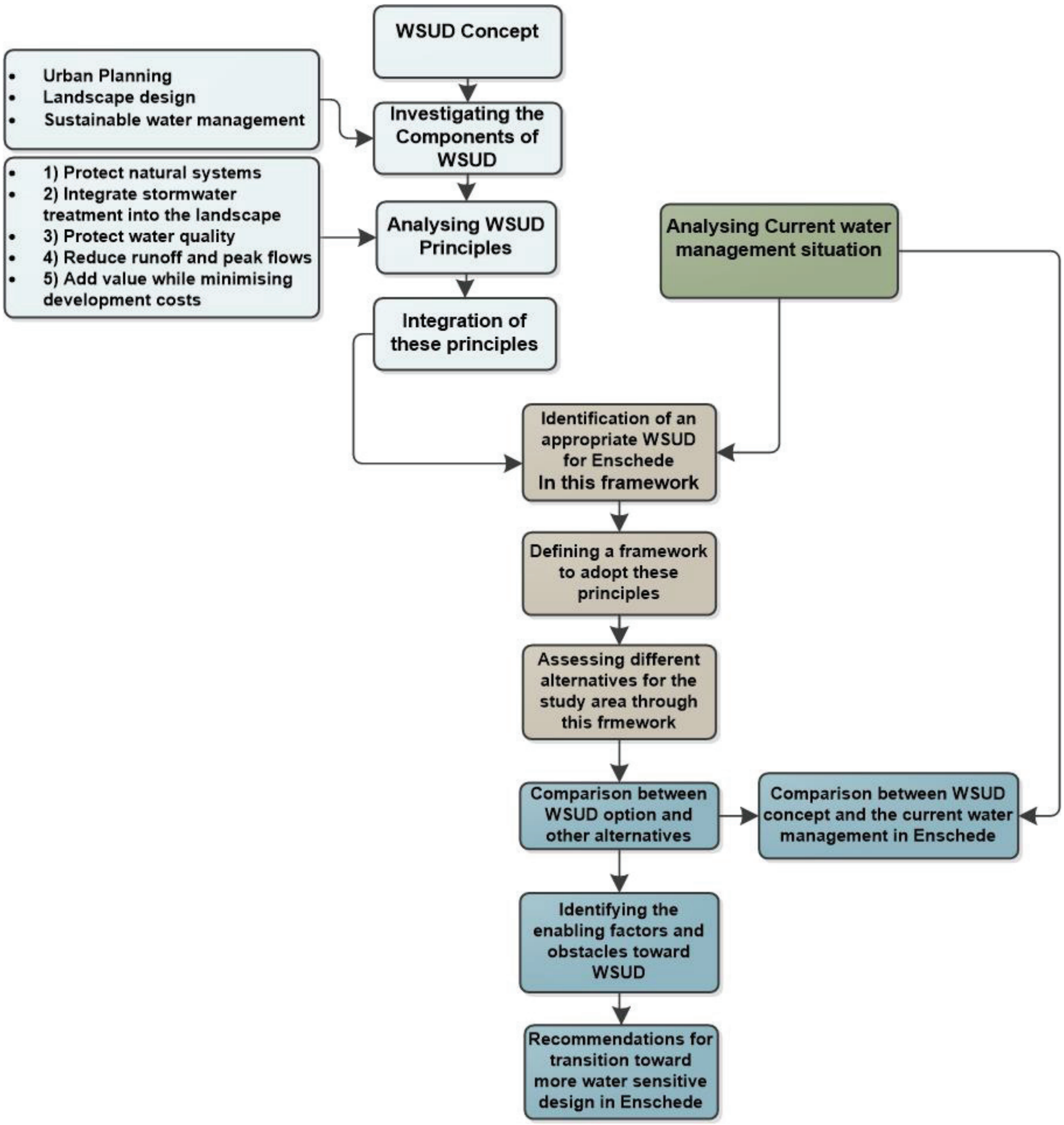

Figure 1-3. Research Conceptual Framework.
Own source.

1.4. Research questions and objectives

The main objective of this research is to develop a framework to adopt principles of the WSUD in Enschede.

Table 1-1. Research questions and objectives.
Own source.

Sub Objectives		Research questions
1	To analyse the WSUD concept and it's principles.	• What are the major principles and components of the WSUD concept? • How does the integration of these principles works? • What is the need for the emergence of the WSUD?
2	To analyse the situation of the current water management in Enschede and particularly two neighbourhoods of the Stadsveld and Pathmos.	• What are the components of the current water management system in Enschede? • What are the problems that current water management system in Enschede and particularly two case study neighbourhoods are facing? • What are the different strategies that water system take into consideration to solve the problems? • What are the stakeholder's perspective and information about the existing problems in their neighbourhoods? • What is the information with regard to the land use pattern, groundwater level, soil characteristics, stormwater discharges and drainage capacity in the neighbourhoods?
	To define a framework to adopt WSUD principles in Enschede.	• What are the components of the framework and how they can be related to each other? • How can WSUD principles be translated into specific adaptable measures? • What are different strategies which can be implemented in the selected neighbourhoods?
4	To assess the applicability of the framework.	• What are the criteria to be used in the assessment? • How to measure the water sensitivity of different alternatives through this framework? • How to compare WSUD in this framework with the current situation in Enschede? • What are the differences between the current water management and the WSUD concept? • What are obstacles and opportunities toward application of the WSUD? • What water management, urban planning and landscape design aspects should be taken into consideration? • What are the recommendations for improvement of Enschede neighbourhoods toward WSUD by applying the framework?

1.5. Research design

The main objective of this research proposal is to develop and apply a framework to adopt the principles of the WSUD. A four stage process is designed to carry it out. The first step is analysing principles and components of the WSUD, which will be done based on the literature .The research carried out in this step will:

- Explore how water flows across the water cycle in urban environments.
- Analyse the current urban water management system and its shortcomings.
- Identify new approaches towards water management.
- Review the philosophy of the WSUD, its components and principles.
- Analyse how these principles are related to each other.
- Identify similar terms to and relevant use of the WSUD concept.
- Review relevant empirical case studies of WSUD applications.

The second step is analysing the current water management system in Enschede, particularly two neighbourhoods of the Stadsveld and Pathmos. To investigate the current water management system in Enschede, required data and information will be obtained from the Municipality of Enschede. On investigating the current water management in Enschede, the existing problems in the study area will be analysed and different strategies to solve these problems will be explored. In this process stakeholder's perspective and information about water related problems in the study area will be obtained. The unit of analysis from planning perspective is the neighbourhood and, from a hydrologic perspective, it is the catchment.

The third step is defining a framework based on the WSUD principles to assess the applicability of the WSUD concept in Enschede. For this purpose, methods that have been previously implemented based on the literature will be reviewed and adopted. Methods such as multi criteria analysis, ranking key factors and parameters, case study approach, best management practices (BMP), best planning practices (BPC), or stakeholder consultation have been implemented in other studies. This research will adopt geographical approach (spatially explicit), which considers the integration of WSUD principles as a key component.

In the last step, number of the current water management alternatives to solve the neighbourhoods' problems will be assessed through the framework. The result of the assessment shows the differences and similarities between these alternatives and WSUD proposed options of the study area. Then, the similarities and differences between current water management and WSUD concept will be investigated and final conclusions and recommendation for improvement toward WSUD in Enschede will be proposed.

1.6. Structure of thesis

Chapter1, contains the brief introduction of the study, background, research objective, questions and research design.

Chapter2, introduces the WSUD concept and its components, principles and justification in adopting new concepts based on the literature review.

Chapter3, describes a case study and analyses of the current water management in Enschede and specifically two selected neighbourhoods for this study.

Chapter4, describes the methodology of the research to define a WSUD framework in which different alternatives are assessed through this framework.

Chapter5, presents the result of the research including what water management, urban planning and landscape design aspects should be taken into consideration in Enschede to move toward WSUD concept by applying the defined framework.

Chapter6, synthesize the finding of the research addressing the research objectives. Final conclusions and recommendations for further study are proposed.

2. LITERATURE REVIEW

2.1. Conventional urban water systems

The conventional water management systems have highly technical approaches to water management (Global Water Partnership, 2008) which aims to control and predict the system and therefore reduce the existing uncertainty in it (Pahl-Wostl et al., 2009). The fragmented components, managing the water centrally are the main characteristics of these systems thus these systems are dealing with individual problems in isolation (Pahl-Wostl, Sendzimir, et al., 2007).

Increased urban run-off driven by impervious surface , climate change, urbanisation pressure and lack of natural resilience of the water system to absorb water surplus are the challenges facing the modern urban cities (Hoyer et al., 2011). Adapting to these changes is a difficult process which requires higher running costs and investments and conventional water management approaches cannot adopt to these new changes (Davis & Farrelly, 2009).

As an example, conventional stormwater management systems have been focused on collecting storm water runoff and drain it instantly from the city. These highly efficient systems which cities are highly reliant on them, raises many concerns:

- Rapid drain of storm water from the surface, less infiltration process resulting in groundwater depletion.
- Negative effects on local climate (Heat island effect), because of infiltration and evaporation reduction.
- Difficulty to tackle the risk of the flood, overflow of the storm water from the sewage system in the heavy rainfall events.
- Difficulty to adapt to the uncertain or changing conditions, leading to unmanageable storm-water runoff (Hoyer et al., 2011).

Due to these new introduced challenges, complexity and uncertainty , there is an increasing need for transformative change towards adopting more sustainable practices across the world (Rijke, 2007). In this new sustainable approach the different aspects of urban water systems should be viewed in relation to each other.

2.2. History of WSUD

The term 'water sensitive urban design' was originally coined in Western Australia in the early 1990s by a multi-disciplinary group of practitioners and academics, to describe the 'new thinking' about sustainable water cycle management in the urban landscape (Argue, 2002). The aim of this concept is to manage the whole components of the water cycle together in the more economically and less environmentally damaging ways(Joint Steering Committee for Water Sensitive Cities, 2009).

WSUD is being encouraged widely across the Australia. WSUD in Australia is a water cycle approach towards urban water management that integrates urban water management with spatial planning. The main issue in Melbourne is water supply and water quality, that results from drought, population and economic growth (Rijke, 2007).

In the transition phase of this concept to real in Australia, WSUD has been accepted faster in some area rather than others. In recent years number of guidelines intended to assist with the adoption of WSUD on a more widespread scale (Joint Steering Committee for Water Sensitive Cities, 2009). These guidelines have been created to promote the implementation of WSUD and create the technical consistency across the Melbourne (Melbourne Water, 2013). In the Australia, in some states and certain project scale, implementing the WSUD measures is obligatory (Joint Steering Committee for Water Sensitive Cities, 2009).

Integrated Urban Water Management (IUWM)

The concept of IUWM originates from the idea that conventional urban water system's component should be more integrated. In this concept there is an emphasis on the considering both sides of the water supply and water demand. In addition, integrating the land use planning with the water management, considering the local context in the planning and stakeholder participation has been focused (Mitchell, 2006).

Parallel initiatives

Parallel initiatives were also taking place in Japan with ESS (Experimental Sewer System) (Argue, 2002), UK where the terminology Sustainable Urban Drainage Systems (SUDS) is used, the Vancouver/Seattle region, where it is called LID (Low Impact Development), and in the New Zealand where Low Impact Urban Design and Development (LIUDD) is used (Lottering Naomey Olive, 2011). Comparison between different concepts has been presented in the Table 2-1.

Table 2-1. Comparisons between IUWM, LID, SUDS and WSUD concept.
Source (Lottering Naomey Olive, 2011).

LID	SUDS	LIUDD	WSUD
• Stormwater quantity management via implementation of rainwater harvesting tanks, green roofs and pervious pavements.	• Stormwater quantity management via separation of stormwater system from sewage system; • Stormwater quality management via solid waste management and constructed wetlands.	• Stormwater quantity management via rainwater harvesting and pervious pavements; • Re-use of water via greywater re-use and reclamation of treated wastewater.	• Stormwater quantity management via rainwater harvesting, water-wise gardening, pervious pavements, etc. • Stormwater quality management via solid waste management and constructed wetlands; • Demand reduction techniques via retrofitting of appliances, leakage detection and fixing, water use restrictions, pressure reduction , awareness campaign, etc.; • Re-use of water via fit for purpose water use, reclamation of treated wastewater and localised sanitation; • Green roof installation linked to stormwater quantity management.
LID	**SUDS**	**LIUDD**	**WSUD**
Positive • The natural state of an area is kept intact; • Beautification of an area. **Negative** • homeowners prefer wider streets and paved areas; • not preferred on contaminated land; • Proper education needed to ensure maintenance.	**Positive** • Less pressure on the sewage system if stormwater system is separate; • Beautification of an area. **Negative** • Will not be sustainable if community is not on board.	**Positive** • The natural state of an area is kept intact; • Beautification of an area. **Negative** • The community, private developers and council is not well informed and prepared; • Demand for the design is low.	**Positive** • Well documented research; Various/diverse activities to implement; • Activities can be done in combination on household level to city level **Negative** • Maintenance of developments not kept; • The community, private developers and council is still getting accustomed to WSUD.

2.3. The need for emergence of WSUD

Changes in urbanisation, urban expansion, population growth and increasing urban density have increased impervious surfaces dramatically. Sealed surfaces have reduced soil infiltration and highly affect both quality and quantity of water in the urban areas (Bayside City Council Corporate Centre, n.d.). A prominent characteristic of impervious surfaces is the production of run-off. Stormwater which previously infiltrated the ground now collects and flow along the path of least resistance. As it can be observed in Figure 2-1, the water flow rate increases and run-off carries a wide range of pollutants in to the waterways, this might affect the quality of downstream aquatic habitats (Coffs Harbour City Council, 2009).

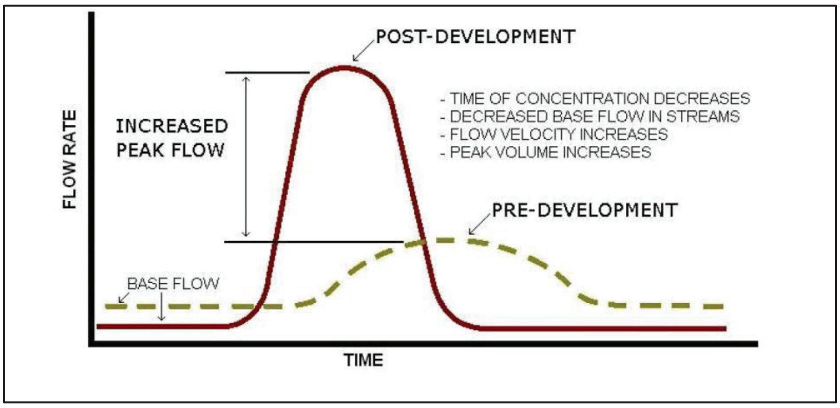

Figure 2-1. The impact of urbanisation on the water cycle.
Source (Coffs Harbour City Council, 2009).

In the natural hydrological cycle, the water cycle is made up of continuous processes of precipitation, infiltration, surface runoff, and evaporation. While in the urban area, due to the increased impervious surfaces, high speed of the run-off discharges and decreased soil infiltration rate, this process has been interrupted. As the Figure 2-2 demonstrates, WSUD aims to bring the water cycle closer to a natural one and achieve a more natural hydrologic regime (Hoyer et al., 2011).

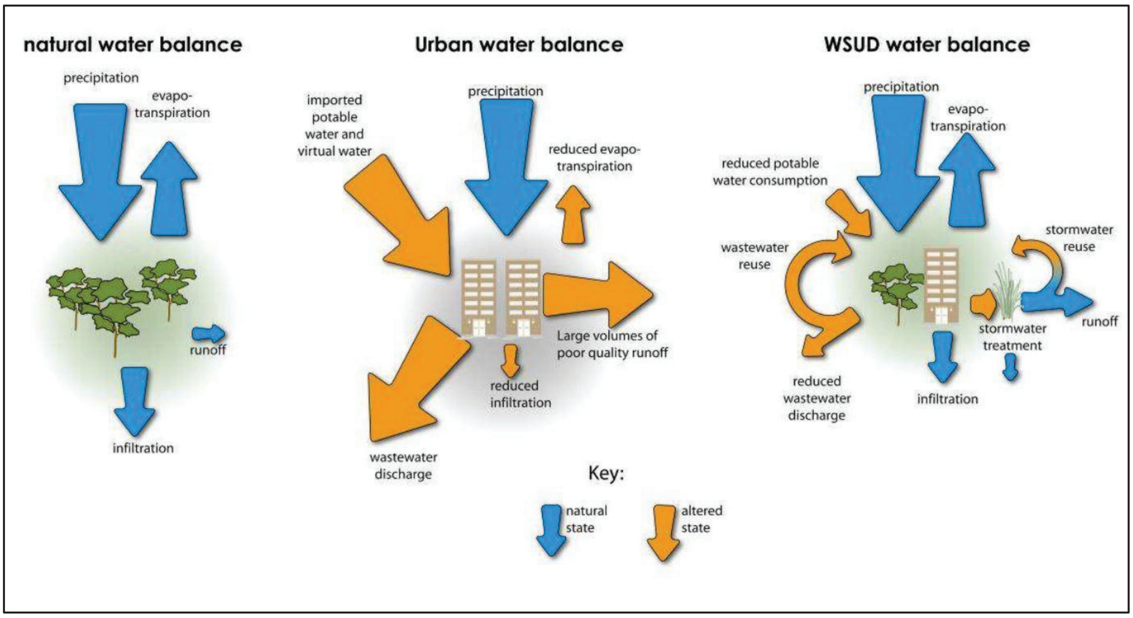

Figure 2-2. Water Sensitive Urban Design water balance.
Source (Water Sensitive Urban Design in Sydney, 2012).

2.4. What is WSUD exactly?

" WSUD is an holistic approach to the planning and design of urban development that aims to minimise negative impacts on the natural water cycle and protect the health of aquatic ecosystems"(Water by Design, 2007). This approach aims to incorporates all streams of the urban water and integrate them with the urban design and landscape architecture while considering the environmental protection (Joint Steering Committee for Water Sensitive Cities, 2009). It is notable that, although originally the WSUD concept aims to manage the whole components of the water systems, but it is mainly concerned with the storm water management (Hoyer et al., 2011). Figure 2-3 illustrates the components of the WSUD.

Coombes et al (2000), remarked that WSUD is a local solution to the common water management problems in different contexts caused by managing the water in the urban area centrally (P. J. Coombes, Argue, & Kuczera, 2000). This concept is not possible with implementation of schematic solutions, instead its objective is to develop a solutions which are customized with local basic conditions. Hence, morphology of the location, typical elements of the landscape and the structure of the surrounding surface waters and other local condition should be taken into consideration (Langenbach, Eckart , & Schröder, 2008).

Climate change mitigation and adaptation, built environment resilience, integration of the storm water in the landscape and accordingly enhancing the aesthetic characteristics of the built environment are some major benefits for undertake WSUD concept (Water Sensitive Urban Design in Sydney, 2012).

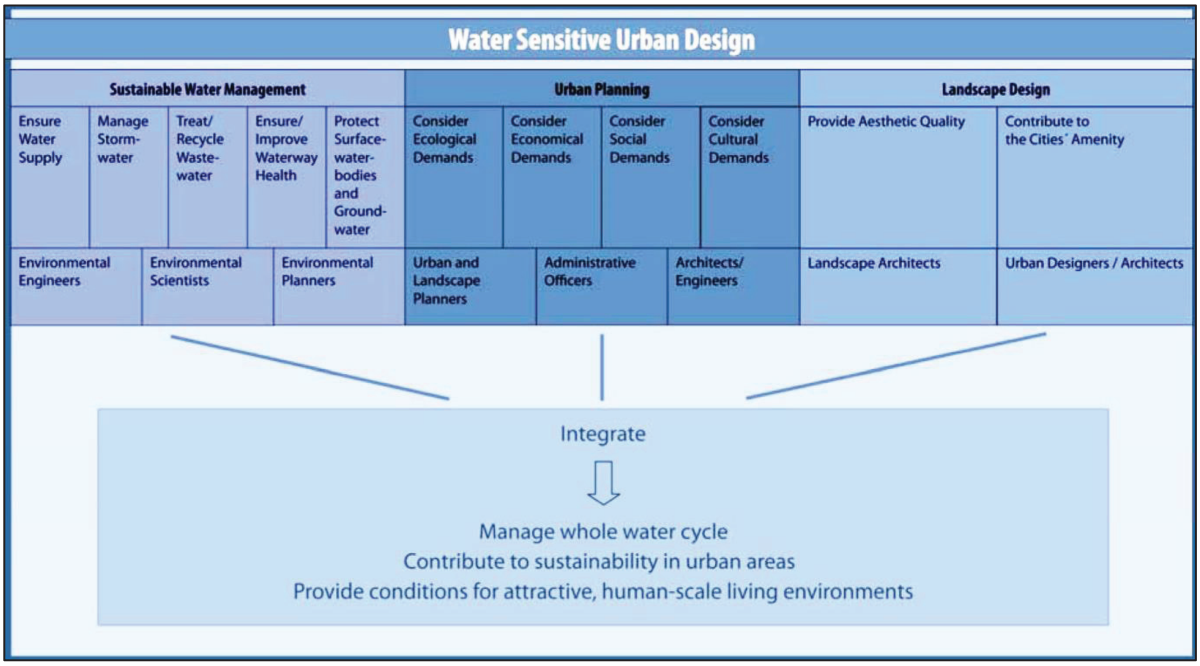

Figure 2-3. Components of Water Sensitive urban design.
Source (Hoyer et al., 2011)

WSUD is a broad concept and it can be related to several fields of urban water. In reviewing the background of what is known and discussed nowadays as WSUD; Carmon (2010) defines Water Sensitive Planning (WSP) as an approach to sustainable development that integrates water considerations into urban and regional planning. In his work, WSP'goals, domains and paradigms with special attention to stormwater management is presented. The paper starts from sustainable management of urban runoff,

moved to the larger space of the river catchment and to additional WSP subjects, including flood protection, streams rehabilitation, conservation of urban water and using alternative water resources.
Water Sensitive Urban Design Principles and Inspiration for Sustainable Stormwater Management in the City of the future was reviewed in the work of Hoyer (2011). First, the definition of the WSUD, technical elements, drivers and principles of successful water sensitive urban design were analysed through case studies in different scales. Then, for the success of decentralised stormwater management in combination with urban design, WSUD principles were defined, and these principles were checked for all case studies. These principals consist of: aesthetic, functionality, usability and public perception and acceptance. One of the large scale case studies was water plan in Rotterdam, Netherlands (Hoyer et al., 2011).

Urban Water Resources Centre' Report (2006) identified an effective WSUD measures and strategies, a study on a real catchment was undertaken and a range of WSUD options were assessed at varying scales. The study involved developing catchment models to review performance associated with water quality (MUSIC) and flooding (EPA SWMM). For determining the most effective strategy, a multi-criteria decision analysis was developed and measures were ranked based on performance with respect to a set of criteria, allowing the identification of the most effective options (Urban Water Resources Centre, 2006).

Although a significant amount of literatures has been done defining the WSUD and its principles, few analyses has been done to define a framework to adopt the WSUD concepts or integrate its principles. In the report of water by design (2001) a framework for the integration of water sensitive urban design elements into multiple use open spaces was developed. The framework has been proposed detailing key factors and criteria that should be considered while integrating floods and stormwater management into open space. This framework was a complex interrelationship between design standards and approaches to achieve acceptable outcomes for integrating of WSUD within public open space. Last, requirements for effective implementation of the framework were mentioned (Water by Design, 2011).

However, mainstreaming innovations in urban water management was done with comparing two case studies in Melbourne and the Netherlands in the work of Rijke (2007). In this thesis, enabling factors and obstacles for mainstreaming innovations that aim for a transition towards more sustainable urban water management were reviewed. This research constructed the four steps theoretical framework to analyse transition toward more sustainable urban water management. First step was based on literature study, field trips and discussions with people from the water sector. Then the set of criteria and case studies in Netherlands and Australia were selected. Last, these case studies were analysed and compared in order to outline similarities between innovations in Melbourne and the Netherlands which both aim to more sustainable practice.

2.5. Water sensitive city

Water sensitive cities are an illustration for other cities, as a transition toward more sustainable practices. Resilience to uncertain changing condition, liveability of the built environment and sustainability are the main characteristics of the water sensitive cities (CRC for Water Sensitive Cities, 2013). Table 2-2 illustrates the attributes of the water sensitive cities.

Increased complexity and aspects of the challenges in the cities, calls for a long term vision for the cities Hence, this framework can used as a tool to assist urban water strategies to identify the attributes of the more sustainable cities (Pahl-Wostl, Craps, et al., 2007). In the transition toward more sustainable approaches, cities have different states which have been presented in the Figure 2-4.

Table 2-2. The attributes of a Water Sensitive City, compared with conventional approach.
Source (CRC for Water Sensitive Cities, 2013).

Attributes	Traditional Regime	Water Sensitive Regime
System Boundary	Water supply, sewerage and flood control for economic and population growth and public health protection	Multiple purposes for water considered over long-term timeframes including waterway health and other sectoral needs i.e. transport, recreation/amenity, micro-climate, energy etc.
Management Approach	Compartmentalisation and optimisation of single components of the water cycle	Adaptive, integrated, sustainable management of the total water cycle (including land-use)
Expertise	Narrow technical and economic focussed disciplines	Interdisciplinary, multi-stakeholder learning across social, technical, economic, design, ecological spheres etc
Service delivery	Centralised, linear and predominantly technologically and economically based	Diverse, flexible solutions at multiple scales via a suite of approaches (technical, social, economic, ecological etc)
Role of public	Water managed by government on behalf of communities	Co-management of water between government, business and communities
Risk	Risk regulated and controlled by government	Risk shared and diversified via private and public instrument

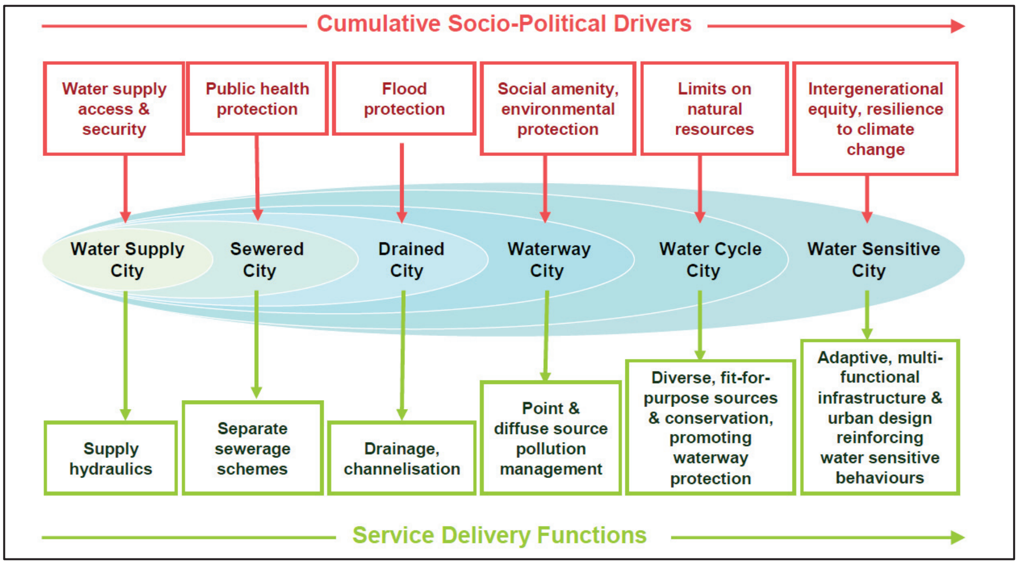

Figure 2-4. Urban water management transition framework.
Source (Brown, Keath, & Wong, 2008).

2.6. Overview of Australian policy framework

In Australia, state and local government authorities has realised that the traditional urban water paradigm is not sustainable and this led to a range of policy framework for WSUD implementation support. The emergence of policy frameworks has been supported by a wide range of Australian research that has revealed the highly degraded state of Australian waterways and the previously "hidden" opportunities for significant water conservation. The development of a large number of sustainable developments was the evidence of the emerging view that more sustainable water policy was needed. These events have led to national policies to support WSUD. Importantly, WSUD approaches are also seen as an opportunity to repair the impacts of previous planning and infrastructure designs on natural environments and human settlements (P. Coombes, 2011).

2.7. Overview of "best planning and best management practices"

Joint Steering Committee for Water Sensitive Cities (2009) presented evaluating options for Water Sensitive Urban Design in a national guide. In this guideline Best Planning practices (BPC) and Best Management Practices (BMP).

The term BPP is referred to the best practical planning approach to achieve management objectives. Site analysis, planning the WSUD measures, integrating water and WSUD measures in the landscape are components of the BPP. WSUD project with different scale applies a wide range of these measures.

A BMP appertain to the design elements in the site to manage the stormwater discharges (Zhiliang, 2012). This management practice has been divided to the structural and non-structural design elements. Structural elements refer to the construction of the measure in the site in order to collect, treat, convey and store and reuse the stormwater (Joint Steering Committee for Water Sensitive Cities, 2009). While, none-structural elements refers to the practices which increase the public awareness and stakeholder's participation (Zhiliang, 2012).

BMP consist of two general categories of "stormwater management practice" and "potable water demand reduction" techniques. Ponds, lakes, green roofs, sediments basins are number of stormwater management techniques while rainwater harvesting tanks and grey water treatment and reuse are examples of the potable water demand reduction techniques (Joint Steering Committee for Water Sensitive Cities, 2009). In this report all the techniques were reviewed and for each of them a comprehensive description of that technique was provided. Last, a descriptive evaluation framework for urban stormwater projects was proposed and site layout options through identified WSUD objectives were evaluated. The comprehensive list of these techniques has been provided in the Appendix C.

2.8. Cost Implications

Since the economic aspect is one of the determinant factors in the water management techniques, the cost implication of the greenfield and retrofit measures has been examined in the several studies. In the evaluating options for WSUD national guide (2009) it is explained that in the greenfield application in the Melbourne, the initial cost of implementing WSUD measures were higher than other conventional methods. But, the cost become comparable after the staff was familiar with the requirements of the implementation methods (Joint Steering Committee for Water Sensitive Cities, 2009).

In addition, it was expressed that implementing the WSUD measures and managing water locally, decreases the cost of drainage infrastructure development by replacing the reticulated network with localized solutions (Melbourne Water, n.d.).

2.9. Simulation models

In the context of quantification of the WSUD concept, the MUSIC model is implemented for the WSUD concept widely. MUSIC is a tool for simulating urban stormwater treatment trains to estimate their performance. This tool can model a wide range of treatment devices to find the best way to capture and reuse stormwater runoff, remove its contaminants, and reduce the frequency of runoff. MUSIC helps to evaluate these treatment devices until the best combination of cost, hydrology and water quality improvement is achieved (eWater, 2012). SWITCH, R.WIN, AQUALM-XP are example of models used for this purpose.

2.10. Water sensitive urban design principles

Main principles of the WSUD obtained from the literature are to protect natural systems, integrates stormwater treatment into the landscape, protect water quality, reduce run-off and peak flow and add value while minimising development costs. The description of each WSUD principle as well as number of sustainable water management principles are discussed as follows. It is remarkable that some principles such as public participation overlap in both concepts. Hence, categorizing these principles based on the related concept was not completely achievable.

Protect natural systems

It includes retaining and protecting natural features and creating more healthy ecosystem in the urban environment (Melbourne Water, 2013). As these features are valuable community assets, they enhance liveability of urban development and support the ecosystem (Melbourne Water, n.d.).

Integrates stormwater treatment into the landscape

Integrating and managing stormwater in the landscape reduces volume and rate of the catchment run off that reaches waterways (Melbourne Water, n.d.). Using stormwater in the landscape through incorporating multiple use corridors improve the visual characteristics of the developments (LANDCOM, 2009).

Protect water quality

Protecting water quality of surface and groundwater through WSUD treatment measures and improving the quality of drained water from urban developments into receiving environment (LANDCOM, 2009).

Reduce run-off and peak flow

This principle focus on reducing runoff in urban developments by increasing local detention and minimising impervious areas (Melbourne Water, 2013). Using and retaining stormwater in the catchment can reduce the amount of stormwater reaching waterways and reduce the frequency and severity of surface floods.

Add value while minimising development costs

Minimising drainage infrastructure costs of development due to reduced runoff, peak flows, pipe sizes and potentially, replacing large scale reticulated water systems with local solutions. Also, enhancing liveability of the built environment by enhancing natural features such as rivers and lakes has been focused (Melbourne Water, 2013).

Integration:

Due to the increasing complexity of the water management systems around the world, a more integrated approach is needed rather than only one technical solution (Rijke, 2007). Horbach (2005) defines the integration as managing water in context to other environmental media and integrating it with social, economic and ecological demands. Furthermore, integration plays a significant role in the WSUD concept to the extent that water sensitive urban design is defined as the integration of urban design, site layout and building design, with implementing WSUD measures (Bayside City Council Corporate Centre, n.d.).

In other words, WSUD design means integration that occurs in the different levels which is as follows:

- The integration between all water facets in the urban area including drinking water, groundwater, waste water and stormwater is one level of this integration.
- Integration between different scales of the project, such as regional and precincts.
- Integration between different disciplines ("Introduction to WSUD," 2009).

Participation:
Public participation is essential in decision making which provides an opportunity to incorporate stakeholder's values in this process (Horbach, 2005). According to Pahl-Wostl (2007) tackling the integrated management approaches without stakeholders participation is not possible (Pahl-Wostl, Craps, et al., 2007).

Reversibility:
Based on the sustainable water management, reversibility means consequence of measure should be reversible where possible (Horbach, 2005).

Precautionary or prevention principles:
This principle discusses about damage and risk of the system and asserts that measures with high potential of damage or risk should be possibly avoided. This principle has implementation and post implementation aspects.

Minimisation of resource use principle:
It emphasizes on the reduction of resource use and in particular potable water demand and increase on regeneration natural resources (Horbach, 2005).

Adaptability:
Based on the adaptive water management system, more adaptable built environment is needed to response to the uncertain and changing basic condition (Horbach, 2005).

Time of implementation
Giving priority to those alternatives and options that can be implemented immediately and those practices that yield results quickly. This principle and timing of the various options is an important factor in the crisis period (Lloyd, Wong, & Chesterfield, 2002).

2.11. Conclusion of the literature review

Number of remarks has been concluded from the literature review which are discussed as follows:

First, the WSUD objective is to develop solutions which are customized with the local context. Hence implementing the schematics solutions and proposing the specific measures for the water management in different context is not desirable. Therefore, in this research the proposed solutions and principles of the WSUD regard to the local condition were considered. The water management characteristics, site specification, morphology of the area, project's scale, specifications of the groundwater and surface water are examples of this consideration.

Second, it was concluded that an integrated solution and approach is needed for a multi-dimensional challenges in the water management systems. The integration between social, economic, built environment and ecological aspects. Hence the abovementioned dimensions and integration between them was considered in the proposed WSUD framework.

3. CASE STUDY

3.1. Location of Enschede

Enschede is located in the eastern part of the Overijssel province. With 157,797 inhabitants, it is the 14th largest municipality in the Netherlands and the largest city in the Twente region. One of the main characteristics of this region is the highly diverse nature of its spatial physical elements, such as soil types and depth of ground water level (Van Dijk, 2010).

Enschede can be considered to be source of several water systems (Gemeente Enschede, 2012b). The city has 44 meters elevation difference, with the East showing the highest elevation, so in the current water management situation, much water flows to the West and discharges toward the Twente canal, from thereon continuing toward Hengelo. Figure 3-1 illustrates Enschede's elevation and the Twente canal.
The red to blue colour range shows the elevation differences from high to low. The highest and lowest elevations are 68 MAMSL and 24 MAMSL. The area has a highly variable soil structure with low infiltration rates, sandy soils and boulder clay lenses in the subsoil (Van Dijk, 2010).

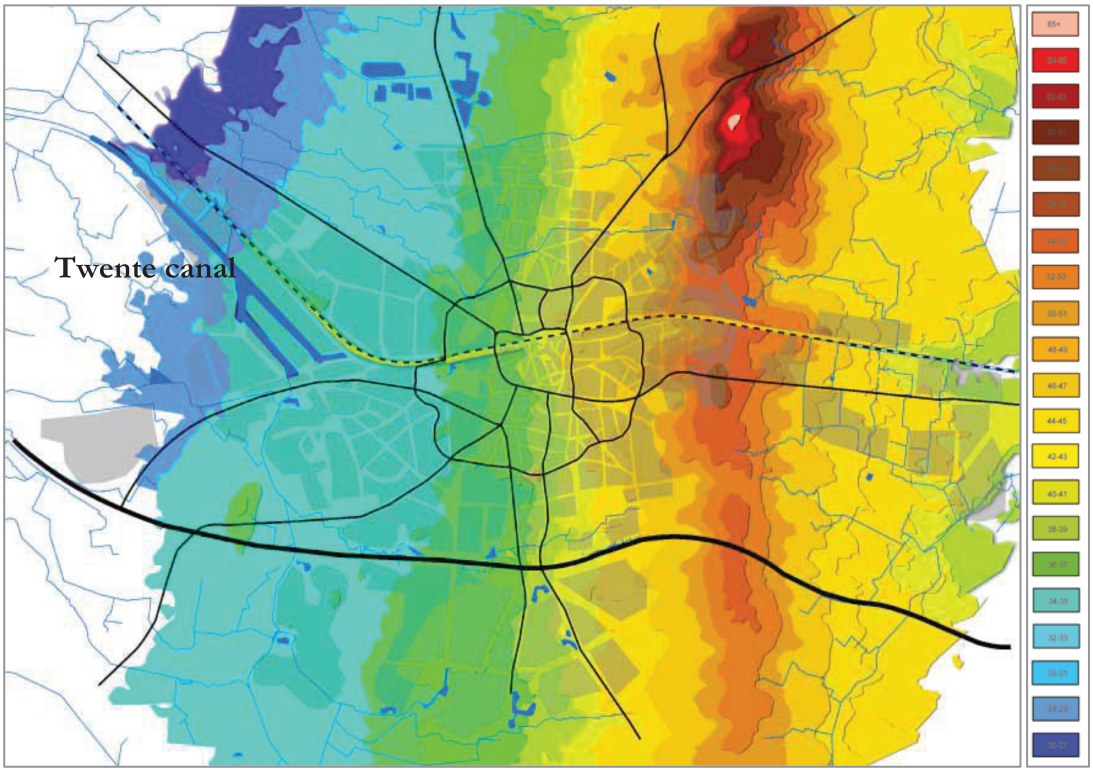

Figure 3-1. Enschede's elevation difference.
Source (Gemeente Enschede, 2012b).

3.2. Development of the city

Around 1850, the city of Enschede and streams belonged together and the city had number of brooks. Before the people's influence on the water system, water was flowing in a natural way. In that time, the impervious area was limited so the water was largely infiltrated into the ground.

In 1900, the textile industry came into Enschede since plenty of clean groundwater was available there. This industry pumped lots of groundwater which resulted in depletion of groundwater table in the area. Around 1930, the textile industry had expanded and was consuming increasing amounts of groundwater, resulting in lower levels of the water table. However as a result of these industrial activities, the shallow groundwater was also polluted so the textile industry started to pump and use water from deeper layers. With the growth of industry, some neighbourhoods were constructed for the working class population in the lower and wetter parts of the city, such as Pathmos. To improve accessibility of the textile industry, the Twente canal was dug as a water way between Hengelo and Enschede in 1930. This canal drains the water as well. Thus, in general, water consumption and physical interventions during the early 19th century, resulted in a lower water table in the city.

With the construction of sewer and as a partial consequence of the low level of ground water, many small streams lost their drainage function. In some cases, they were used as drainage of the factories which carried unhygienic water. In 1938 several streams were converted into sewers and the rest disappeared.
Due to Second World War a considerable part of the city was damaged by bombing. After the war, as a response to the need for new developments to substitute the destroyed areas and accommodate the displaced population, the city grew rapidly.

With the end of the textile industry in the late 1970s, however, water demand drastically decreased, pumping was stopped and the water table rose again. In addition, more impervious surface had been added in the intervening years. As a consequence, several districts in Enschede, such as Pathmos, received a considerable load of surface water that often exceeded the sewer capacity.
As of 2010, the ground water level in the lower parts of Enschede has increased, flooding is more frequent and, during some flood events, water overflows, impacting houses and shops. Additionally, because of climate change, the frequency of extreme rainfall events has increased, and both droughts and wet periods have also become more severe. Figure 3-2 illustrates how streams disappeared in the city along the time.

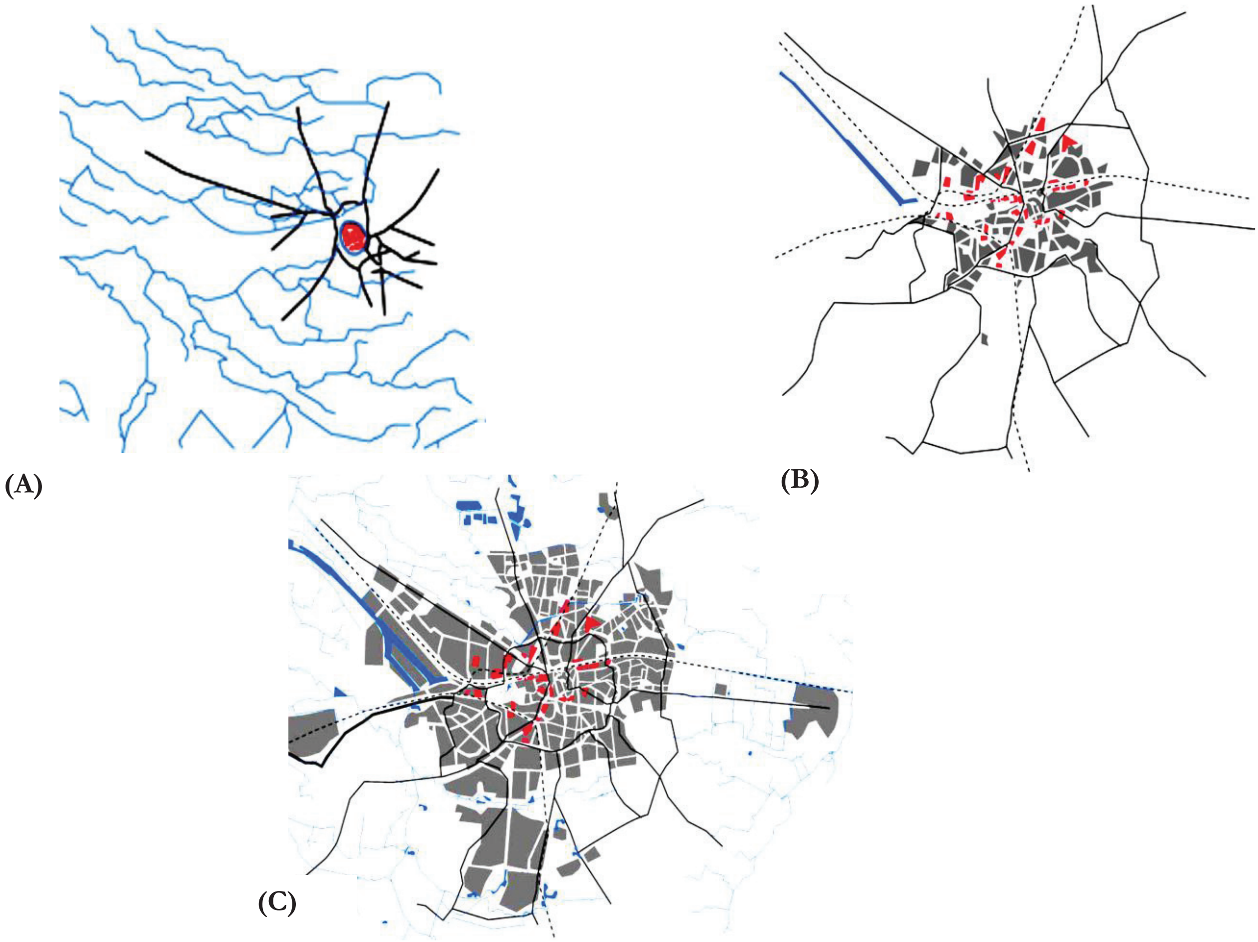

Figure 3-2. (A) Enschede's roads, rivers and centre in the year1850;
(B) Enschede city, 1930
(C) Enschede's urban area, roads and the Twente Canal, 2010.
Source (Gemeente Enschede, 2012b).

3.3. Current water management in Enschede

The channelization of the streams in the suburban area, the disappearance of streams in the city, increased impervious surfaces and pollution of the groundwater, are all the result of human impacts on the water cycle in Enschede.

In addition to the human impacts on the water cycle and soil characteristic of the area, climate change impact and increasing rainfall event intensify the situation (Van Dijk, 2010). Effects of climate change are long term (20-40 years) but they are inevitable. Since space in the city is scarce, it is important to anticipate these changes now. In this context, current water system management practices face number of challenges which will be discussed in this chapter.

3.3.1. Current water related problems in the city

Groundwater problems

In the lower western part of Enschede, the level of the ground water is high; there is also considerable fluctuation in the groundwater levels of these neighbourhoods. Due to this fluctuation, groundwater levels, even in nearby points, show considerable variations and modelling the groundwater is very difficult, if not impossible, to achieve (Gemeente Enschede, 2012b).

After the decline of the textile industry the ground water quality has generally improved significantly. Nonetheless, in some spots in the city, the water quality is still poor; and these spots are mainly places which have mixed sewer systems (i.e. storm water is mixed with sewage in one pipe network). During the heavy rainfalls, contaminated discharges overflow into surface water and flow in the streets.

This contamination can pose a risk to the citizen's health via water-borne diseases. The effects of water pollution are not just problematic for people, but also for the ecosystem. If the water quality is not acceptable, it might cause various problems such as high algae growth in the ponds and water bodies, odour and the death of fishes.

Enschede has groundwater contamination because of its industrial history. The most common contaminations are solvents. It is expected that contaminations may be in different depth and extent underground. Solvents are heavier than water in the aquifers, so they flow to the bottom of the aquifers (Gemeente Enschede, 2012a). Figure 3-3 shows the bottlenecks in the water quality, run off and high groundwater level. From the map it can be observed that problems place mainly in the west part of the city, near the Twente canal.

Storm water problems

Many of the same areas have experienced several surface flood events that are due to: increased impervious surfaces due to urbanisation, soil characteristics and low infiltration rate of the soil; the morphology of the city and its slopes, influence the volume, spatial accumulation and velocity of the run off.

The speed and amount of water in the sewer system increases during heavy rainfalls and this leads to pressure on the sewage system (water is conducted as a pipe flow). If the sewer's drainage capacity is exceeded it overflows onto the roads. This causes considerable inconvenience, problems in people's movement, traffic congestion by cutting off streets and even damages to some shops or houses.

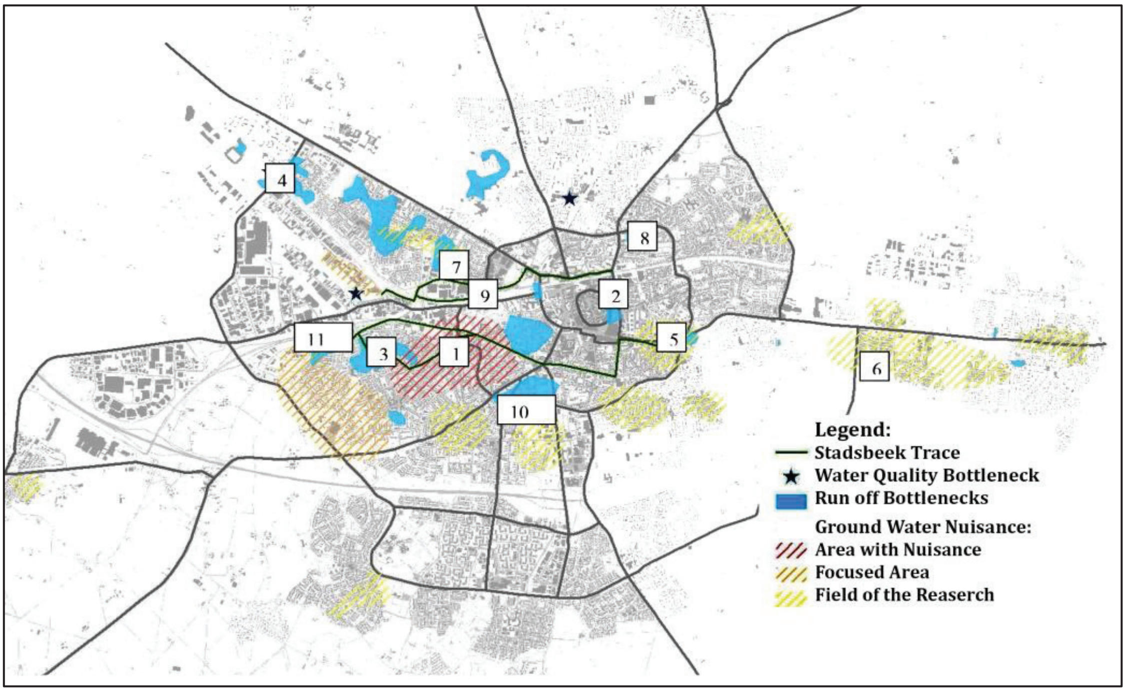

Figure 3-3. Current water management bottlenecks in Enschede.
Source(Gemeente Enschede, 2012b).

Strategies of the current water management:
Current water management authorities have implemented a number of strategies and are developing number of concepts, toward more sustainable water management. Among them, some strategies have been selected to discuss further:

- WADI concept
- Separate sewage system
- Kristalbad, multifunctional water complex
- Streams in the city

WADI concept:
The word WADI stands for "water afvoer door infiltratie " (evacuation of water by infiltration).
The WADI concept has been implemented in some neighbourhoods in which open space was available, such as the two neighbourhoods Oikos and Ruwenbos (The Danish Architeture Centre, 2012).

Enschede's Ruwenbos neighbourhood was the first example of implementation of this concept in the Netherlands. More permeable surfaces are found throughout the whole area so a significant amount of runoff water infiltrates before flowing into the ditches where it can either flow away or also infiltrate. Collected run off from roofs, roads and other impervious surfaces is transported via ditches to the WADI and then the retention pond in the local park. Figure 3-4 illustrates the drainage system in the Ruwenbos.

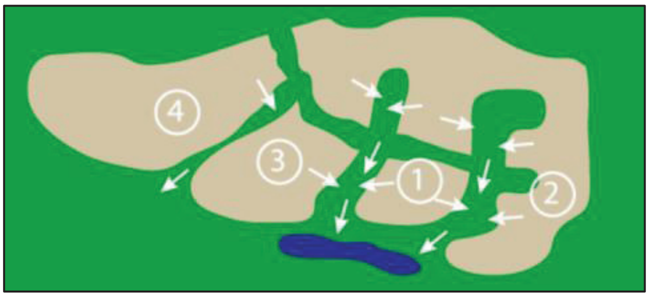

Figure 3-4. Sketch of the drainage system and design phases of the Rouwenbos neighbourhood.
Source (Birch, Bergman, Backhaus, Fryd, & Toft Ingvertsen, 2008).

Drainage and sewer systems:
Enschede has about 1400 hectare paved surfaces, of which 800 ha is served by a mixed sewage system and 600 ha has separated storm water and sewer systems. Figure 3-5 shows the 60% mixed and 40% separate sewage system in the city. The disconnecting of the storm water and grey water in the sewage system is a considerable improvement of recent years. In general, new developments have separated sewage systems and old parts of the city have a mixed sewage system, which is not completely able to cope with the run off during extreme precipitation.

Mixed sewage system:
In this system, rainwater and sewage are mixed and drained together.
Advantage:

- Simple and straightforward system.
- Lower infrastructure costs (one single set of sewage system is needed for the evacuation of both grey and run off waters).

Disadvantage:

- Water load for purification is much more whereas (up to 2/3) of the water is actually clean and this decreases the efficiency of the purification.
- If it rains heavily, the sewer system can’t drain the run off completely, so the contaminated water overflows on the street.
- Water quality problems because of contamination of overflow from sewage are possible.

Separate sewage system:
This system is designed to convey storm water from impervious areas directly to the water bodies, streams, rivers and lakes and waste water to the sewage system. So rainwater and waste water are carried separately.
Advantage:

- The purification centre will only receive the dirty water.
- In the case of heavy rainfalls, excess run off will not overflow from sewage system to the street.

Disadvantage:

- Risk of wrong connections during construction.
- Higher costs due to dual networks.

Separate system including storage
Separated sewer system with storage drains wastewater and rainwater separately. Waste water goes to sewage treatment. Rainwater is stored and delayed discharged to groundwater or surface water
Advantage:

- The water is locally stored and the amount of the run off which causes the nuisance in the lower area is reduced.
- Drainage prevents excessive groundwater level in the winter.

Disadvantage:

- The establishment of a storage area needs additional space for water to be preserved (Gemeente Enschede, 2012b).

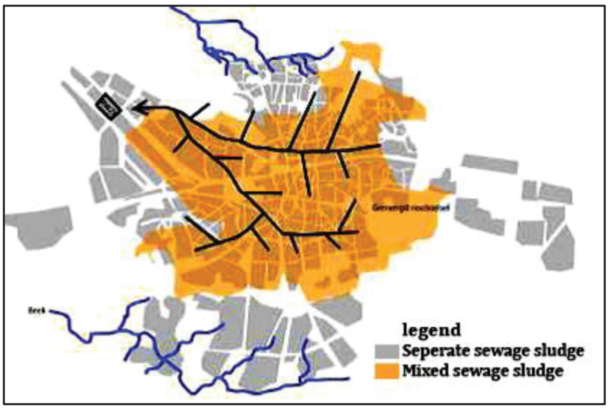

Figure 3-5. Sewage system in Enschede.
Source (Gemeente Enschede, 2011).

Kristalbad:
Kristalbad is a complex of 4000 hectare between Hengelo and Enschede, which consists of three major compartments. Water flows in these compartments successively, discharges slowly to next compartment and dries. Simultaneously, the water is filtered through dense vegetation. The remaining organic pollution during the drying phase is in contact with oxygen and will be naturally removed. Because of this process, bacteria and viruses are removed and converted to the fertilizers. Kristalbad is a multifunctional complex, it has various functions such as:

1. Water storage: The Water storage capacity is around 187.000 m3. It consists of sewage farm, swamp strip, stony strip and marsh pond.
2. Purification: Purifying water through vegetation cover.
3. Optimization ecological corridor: It is a habitat for birds and other spices.
4. Recreational buffer: Finally Kristalbad acts as a natural green buffer between the two fast-growing cities of Hengelo and Enschede (Water Board Regge and Dinkel, n.d.).

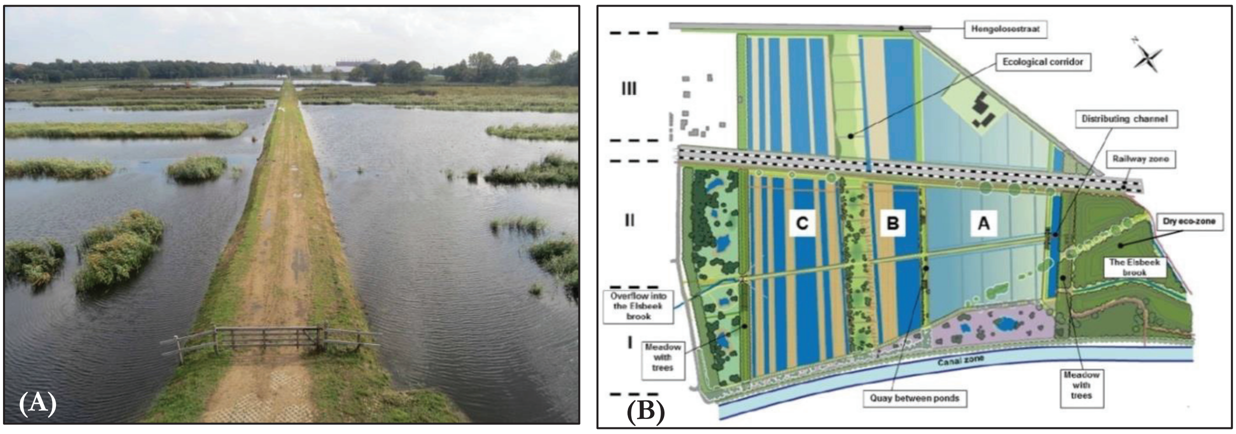

Figure 3-6. Kristalbad
(A) Kristalbad top view. *(Photograph by author).*
(B) Kristalbad plan. *source (Water Board Regge and Dinkel, n.d.).*

Case Study Analysis

This study is focused on a part of Enschede that includes the neighbourhoods Stadsveld and parts of Pathmos. The site area is highly developed consisting of around 40 hectares of land with a high density of buildings and population. The site is located in the lower part of Enschede in the west. Figure 3-7 shows the study area. A number of water related problems exists in the area as elaborated below.

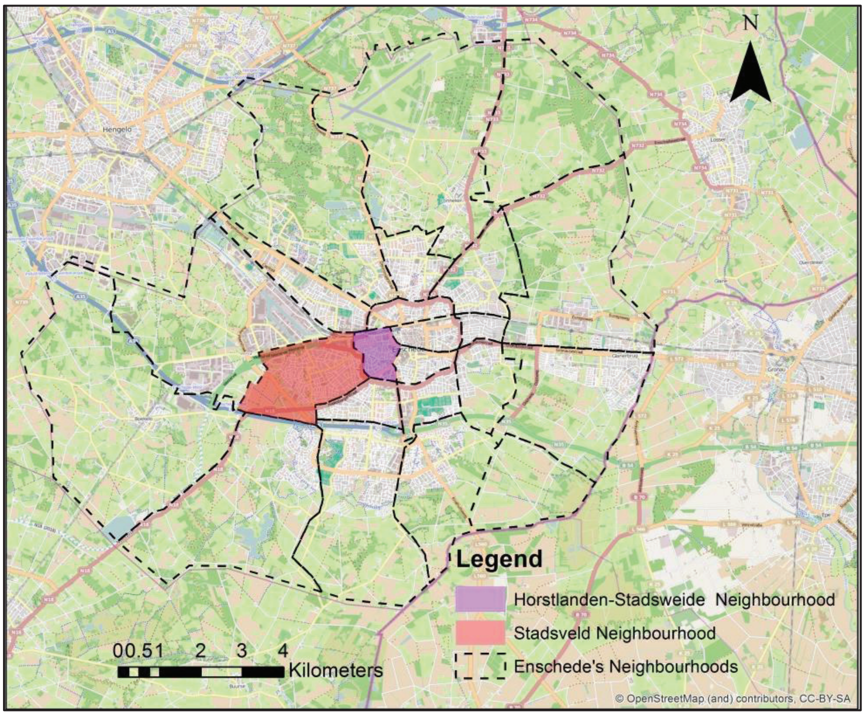

Figure 3-7. Study Area.
Source: Retrieved from the Open street map.

Storm water issues (quality and quantity):

In the event of heavy rainfall, in general when the precipitation is more than 10 millimetres per hour, the mixed sewage system is in the central part of the city, cannot adequately contain all of the water. This leads to an overflow of the sewer and the water (runoff and sewage) flows towards the study area and causes flooding and water-logging in the case study area.

It has been observed that during heavy rainfalls, the water overflows from the sewage system onto the roads. This overflow of polluted storm water, accumulates downstream and ends up in a basin, hence polluting it. Figure 3-8 shows the water quality problem that exists in the downstream basin of the study area.

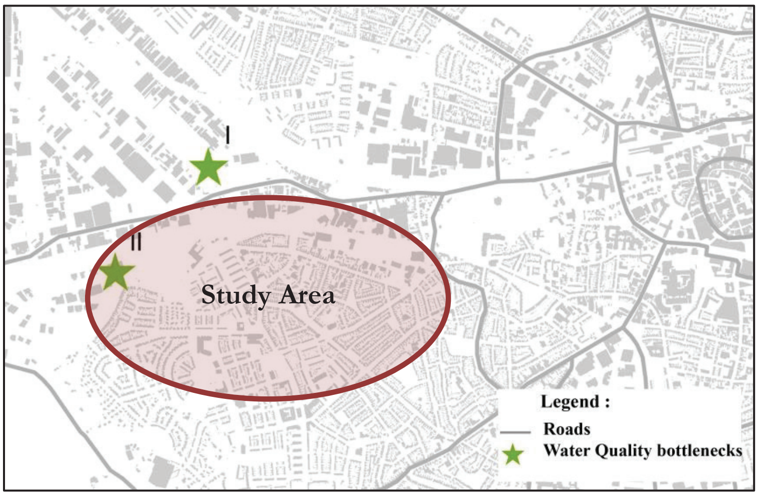

Figure 3-8. Water quality bottleneck in the study area.
Source (Gemeente Enschede, 2012b).

Groundwater issues (quality and quantity):

As a result of textile factory activities, lower west parts of Enschede such as Pathmos district have groundwater contamination. But, according to the municipality planners this pollution level is present only from a depth level of approximately 5- 7 meters. In addition, groundwater of this area contains naturally existing dissolved iron which causes noticeably red-orange coloured water.

Above mentioned discussion, the level of ground water in the study area especially in the Pathmos neighbourhood is high and this causes nuisance in these neighbourhoods, especially flooded basements in houses. Figure 3-9 shows bottlenecks in the ground water level and surface flood.

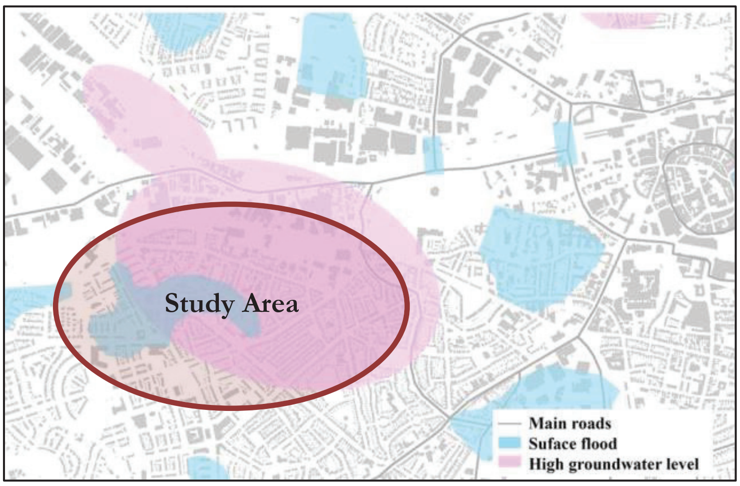

Figure 3-9. Ground water level and surface flood bottlenecks in the study area.
Source (Gemeente Enschede, 2013a).

3.4. Alternatives description:

To solve the aforementioned problems in the study area, in particular to remedy the street flooding and high groundwater level problems, four alternative solutions have been proposed which are described as follow:

3.4.1. Pumping the groundwater

First alternative is the pumping strategy of the groundwater flow which affects water levels. Pumping the groundwater can quickly draw down the water table and solve the high level of the groundwater table. This can be accomplished by means of drilling wells. Having Aforementioned that, the level of the groundwater is high in this area and is rising more when rainfall adds run off to the ground. This has been led to groundwater inundation and nuisance in the basement of the houses, therefore an alternative of pumping was proposed as one of the possible solutions. In the current situation, in order to lower the water table in the mentioned areas, water is being pumped out frequently in number of locations.

3.4.2. Increasing drainage capacity

This alternative undertakes the expansion, replacement or improvement on the existing drainage system. The current existing infrastructure system in the area doesn't have the sufficient capacity to cope with the run-off and high level of the ground water. Hence, to increase the flow capacity and facilitate the more effective collection of run-off, additional drains are proposed. This can be obtained through changing the old infrastructure or adding new one. Implementation aspects such as constructing and providing available space for the added or replaced sewage pipes, are the major challenges in this alternative.

3.4.3. Stadsbeek

Constructing a stream in the city was proposed by the municipality of Enschede through Stadsbeek project proposal. High ground water level in the lower part of the city of Enschede, overflow of the rainfall run off in the streets, water quality problems in some areas etc., were motivating factors toward an idea of the creating a new stream that flows through the city. In addition, expected warmer summers and more extreme rainfalls as a result of climate change, could not be ignored.

The main goal of the Stadsbeek project is a long term solution to the current problems, specifically high groundwater level and storm water run-off. Although this alternative focus on other urban design aspects such as enhancing the quality of the life, adding value to the neighbourhoods and increasing the liveability of the area as well.

Figure 3-10 illustrates the whole project area and proposed streams in the city. In this project, water in the stream will be drained from this area with a natural slope and will be discharge through the Twente canal. It is worth mentioning that, Twente canal is a good opportunity to drain the stormwater.

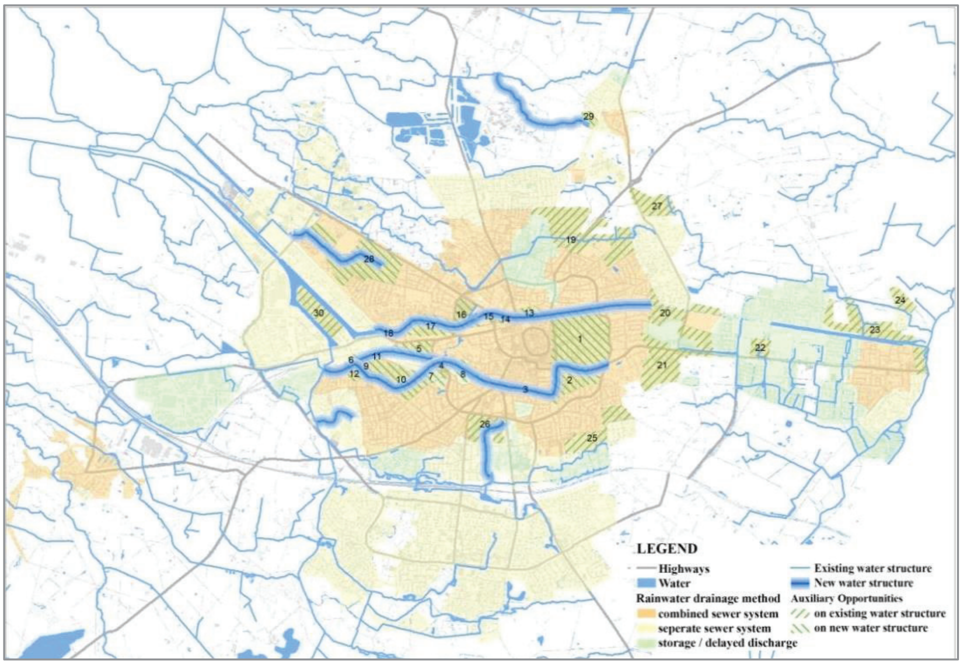

Figure 3-10. Water Vision in Enschede.
Source(Gemeente Enschede, 2012a).

The Stadsbeek project has different construction phases. Based on analysis done by the municipality, completing the whole project and constructing number of streams in Enschede will take approximately 20 to 40 years (Gemeente Enschede, 2013b). It can be observed in the Figure 3-11, that in some areas of the city, groundwater quality and storm water discharge bottlenecks overlap. Prioritizing the bottlenecks, this area is selected for the first phase of the project. Also, this area is mainly the dense residential neighbourhood known as Pathmos, which was built for working class of the textile industry.

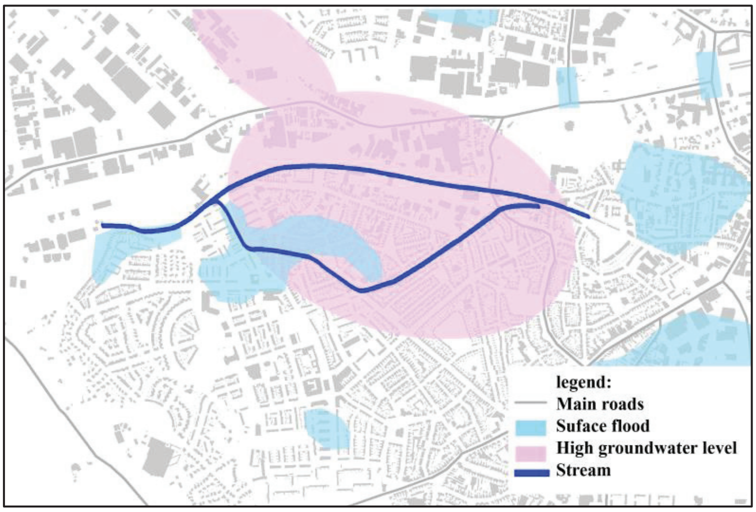

Figure 3-11. Stadsbeek project-Ground water level and Surface flood problems.
Source (Gemeente Enschede, 2013a).

As discussed earlier, the municipality proposes to construct a stream (the Stadsbeek) in this area to remedy the flooding and high groundwater table problems. To this end, two possible trajectories have been worked out. Figure 3-12 illustrates these two possible trajectories for the proposed Stadsbeek. The starting point, the Pathmos neighbourhood is a relatively low lying area with high density development and a high groundwater table. The end point Usselerstroom has more open spaces; the main issue in this area is a high stormwater discharge load and surface flooding in the adjacent streets.

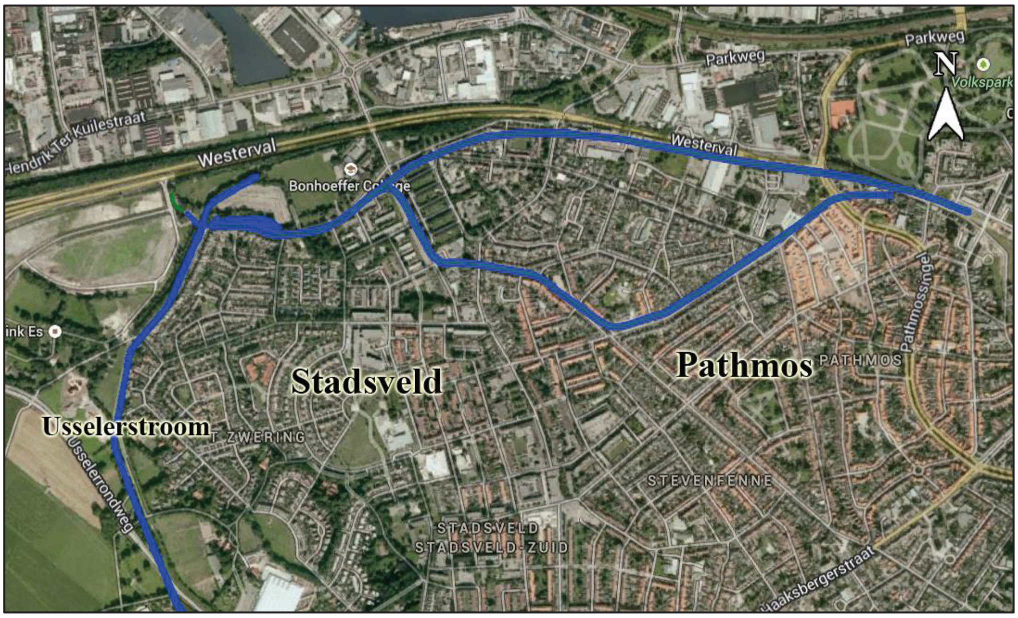

Figure 3-12. Orthographic photo of the proposed trajectory of the Stadsbeek in Enschede.

According to the municipality proposal, it is expected that constructing a stream will:

- Decrease the groundwater level:
  It is proposed that the construction of the stream will lead to a decrease in nuisance caused due to high ground water in the neighbouring areas. Although, accurate modelling or predictions to stimulate groundwater level after constructing the stream is very difficult if not possible.

- Decrease the street run off:
  In the heavy rainfall events, the excess run-off will be drained through the stream and it will not overflow from the sewage system to the street. Consequently, the sewage purification plant will receive only the dirty water.

- Increase the water quality:
  Due to reduced flooding the load of pollutants in the run-off and surface water channels and bodies will be reduced.

As previously mentioned, in the current situation, in order to lower the water table in the study area, groundwater is being pumped out frequently. According to the municipality proposal, there is an opportunity to connect this pumped underground water as a water source to the proposed streams, ensuring that a minimal flow is maintained throughout the year, even in relatively dry periods. Although existing pollution in the groundwater might not be desirable or the pumped groundwater might need initial purification process.

3.4.4. WSUD option proposal

Based on the WSUD concept for the success of any system, an appropriate selection of methods is important. In fact, the ideal solution is often the application of several methods that are appropriately linked (Hoyer et al., 2011). Therefore, in this alternative, along with the construction of streams, a number of interventions and measures were proposed. The WSUD measures specifically for this study area, are proposed in section5.6.

4. METHODOLOGY

4.1. Defining a framework to assess the applicability of WSUD principles

The holistic WSUD framework is necessary to assess the applicability of the WSUD principles and to evaluate different options for the study area. This framework should be broad enough to detect the applicability of the WSUD concept and includes the entire requirements for the water sensitive design. Although integration is one of the proposed principles in this framework, the framework itself establishes the connection between different principles by embedding the components. This holistic framework acts as a yardstick to evaluate the applicability of WSUD concept and serves as a bridge between different disciplines. Table 4-1 illustrates existing concepts and their principles in the framework.

A vision for the WSUD in Enschede and particularly for this case study is dependent on the local conditions. Therefore in this framework, a modified set of WSUD principles based on the water management goals in the neighbourhood is presented. The framework embeds the main WSUD principles obtained from the guidelines, as well as the required principles obtained from the case study analysis such as reversibility.

Table 4-1. Proposed WSUD Framework.
Own source.

Source	Principles
Main WSUD principles in the Australia	• WSUD Protect natural systems • Integrates stormwater treatment into the landscape • Protect water quality • Reduce run-off and peak flow • Add value while minimise development costs
Obtained WSUD principles from the literature *and* the case study specifications	• Reversibility • Precautionary or prevention principles • Minimisation of resource use principle • Adaptability • Participation • Integration

The proposed framework has been established in different stages:

- Identifying desired objectives in this project
- Integrating the principles of the WSUD that obtained from the guidelines and results of case study analysis
- Identifying criteria for the above mentioned principles
- Defining different dimensions to categorize criteria
- Determining different alternatives
- Assessing the WSUD of each alternatives

In the proposed framework, five main principles of WSUD were presented. Later, based on the project conditions and characteristics of the current water management in Enschede, a number of principles have been added. The idea of adding the related components in terms of principles such as precautionary and prevention or minimisation of resources, arose from the literature about principles of sustainable water management (Horbach, 2005).

On one hand, some of these added principles were mentioned in the WSUD concept, but as an approach or a component rather than a principle. For example, although stakeholder's participation in the planning process is fundamental part of the WSUD and its importance has been mentioned in the guidelines, but it was not explicitly considered as the principle. In this framework, participation is considered as a principle. Also, among influential factors to select an appropriate WSUD measure, components of the precautionary and prevention principle are highlighted. But the collection of these components under a distinct principle doesn't exist. Due to the importance of the implementation and post implementation risks and analysis in this research, these components were considered as a distinct principle.

On the other hand, some principles were added to the framework which was not mentioned in the WSUD concept. These principles were obtained from the characteristics of Enschede's water management system and in particular the study area specification. For instance, as a result of case study analysis, the importance of reversibility principle was revived and was added to the framework. The discussion with the municipality planners and importance of this principle is discussed in the section 5.1.

Lastly, the integration was added to the framework which focuses on the integration of each measure in the natural water cycle. The definitions of the presented principles in the framework have been provided in the section 2.10. Although it was attempted to present a distinct set of principles in the framework, in some cases these principles overlap each other to some extent. Adaptability and integrating stormwater treatment into the landscape principle are examples of this overlap.

4.2. Taking the framework forward, Matrix

Performance of each alternative is judged based on what may be called multidimensional matrix.
In this matrix, for each principle a number of practical criteria have been presented. Mainly, above mentioned principles were derived from the WSUD guidelines and the literatures. As an example, for protecting natural system's principle, presented criteria were obtained from the Melbourne Water guidelines. Also, some criteria were presented based on the project conditions, the results of the case study analysis and the stakeholder's participation. For instance, the importance of the consistency of proposed measures with the cultural characteristics of the area was understood after the discussion with the residents and this principle was added to the framework. Table 4-2 illustrates the presented criteria for each principle.

In the selection of the criteria for each principle number of considerations were taken into account as listed below:

- Selecting criteria with an appropriate scale.
- Defining the precise criteria
- Selecting preferably quantifiable criteria if possible.
- Avoiding redundancy or double counting, although integration between principles causes overlap between criteria.
- Selection of the best option based on the project condition in case of conflict between two criteria.

A fundamental part of this matrix is the establishment of the set of criteria divided into different dimensions. Categorising the abovementioned criteria gives us the opportunity to evaluate them based on the five different dimensions. Therefore a certain aspect of a given criterion can be quantified. Furthermore, multidimensional matrix emphasizes that economic costs and benefit are no longer sufficient in decision making and other aspects have to be incorporated in the planning process (Hellström, Jeppsson, & Kärrman, 2000).

Table 4-2. The WSUD proposed framework and the proposed criteria.
Own source.

Principle	Dimension	Selected Criteria for each principle
Protect natural systems	Environmental	1. Retaining existing natural features 2. Protecting environmental values 3. Creating more healthy natural ecosystem in urban environments 4. Supporting wildlife habitats
Integrates stormwater treatment into the landscape	Built-Environmental	5. Managing flood risk through landscape design strategies
	Technical	6. Using stormwater in the urban landscape
Protect water quality	Environmental	7. Pollution prevention through run off reduction 8. Removal or reduction of stormwater pollutant by vegetation or sand filtering.
Reduce run-off and peak flow	Technical	9. Disconnection of impervious surfaces 10. Using temporary rainfall storage 11. Conveyance stormwater from houses into the local stormwater treatment feature
Add value while minimise development costs	Economic	12. Reducing the costs of the treatment 13. Increasing the value of the sub-divisions 14. Reasonable construction cost 15. Reasonable maintenance and operation costs 16. Reasonable cost of the technology 17. Reasonable cost of the accessories
	Built-Environmental	18. Improving aesthetics characteristics(Improving the visual appearance of an area) 19. Creating long term value for the area 20. Minimising heat island effect 21. Creating more open spaces for recreational activity. 22. Enhancing linkages (pedestrian, bicycle, vehicular) across measures
Integration of the whole water cycle	Environmental	23. Single WSUD measure deliver multiple water related benefits 24. Single WSUD measure integrate in natural water cycle
Co-operation and participation	Social- cultural	25. Informing and involving the entire community in the planning process 26. Considering the demands of all stakeholders in the planning process 27. Commitment to community awareness raising 28. Addressing public safety 29. Addressing public health 30. Consistency with the current cultural characteristics of the area 31. Improving cultural heritage value of the neighbourhood
Reversibility	Technical	32. Consequence of measure is reversible where possible
Precautionary or prevention principles	Technical	33. Less implementation risks 34. Measures with low potential of damage 35. Required monitoring , performance assessment and post construction analysis 36. Required maintenance techniques and frequency 37. Durability
Minimisation of the resource use	Technical	38. Reducing potable water demand 39. Waste water generation minimisation
Adaptability	Technical	40. Adaptable built environment to uncertain and changing basic conditions
Time of the implementation	Technical	41. Shortest implementation time 42. Resulting Quickly

4.3. **Assessment aim**

To select a best alternative and to find an optimum solution using the existing knowledge in an effective way is a highly challenging task. Goal conflicts, uncertainty, different group of stakeholders, different preferences are among the challenges in this project. Goal conflict exists between socio-economic goals and ecological goals on one hand and between socio-economic goals itself on the other hand.

Hence, purposeful selection among a set of alternatives, in light of a given objective is desired. In other words, the purpose of the assessment is to identify alternative or alternatives through which the project objectives can be achieved from different perspectives such as economic, social and technical dimension and so on. On achieving the results of this assessment, comparison between their performances can be made. The matrix gives the unique opportunity to compare different dimensions of each alternative together or with other options.

As one of the alternatives is WSUD option, the applicability of WSUD in this project will be assessed and scored. This will facilitate to observe which dimension gets the higher score and which one doesn't fulfil the study goal. Correspondingly, it will be possible to compare WSUD option with the current municipality plan for the project to identify the similarity or possible conflict between them.

Assumptions in the assessment:
Alternatives which do not suit the hydrological objectives with regard to groundwater problem are not considered in the assessment.

Alternatives to be assessed:
As it was discussed in section 3.4, alternatives to be assessed through this framework are as follow,

- To pump the groundwater level
- Undertake the expansion, replacement or improvement of the existing drainage system
- To construct the stream
- A number of proposed WSUD measures in addition to constructing the stream. This alternative has been discussed comprehensively in the section 05.6.

4.4. Assessment process and selected decision support system:

4.4.1. Multi Criteria Analysis and justification of the use of the MCA:

Basically, MCA are used when there is inability to effectively analyse multiple streams of dissimilar information. In a complex situation with multiple aspect of planning and diverse groups of stakeholders, such as this research, MCA facilitates the decision making process. In this method, detailed information about the set of alternatives and insight to the logical structure of the problem is essential (Delft & Nijkamp, 1977). Therefore, in this research MCA was applied to cover broad interest between different aspects of the water management system and its interaction with other planning fields.

4.4.2. Multi-objective optimization method

Based on the different theoretical foundations, a number of MCDA methods have been developed. Optimization, goal aspiration, outranking, or a combination of these, are instances of this method. The method of MCA, which is applied in this research, is Multi-objective optimization. In this model, numerical scores are used to communicate the merit of one option in comparison to others. Above mentioned scores are obtained from the performance of the alternatives related to an individual criterion and aggregated into an overall score. In this research scores are averaged (Zhiliang, 2012).

4.4.3. Ranking the matrix:

In previous sections, the process which the matrix has established was described. Following, the matrix was used for each alternative to be ranked in five different classes. These classes present state of fulfilment of the criteria. From doesn't fulfil the objective but it doesn't have a negative impact with 0 score to completely fulfil the objective with score 1. Table 4-4 and Table 4-3 shows the matrix and the classes. After ranking each alternative's criteria, scoring different dimensions was the next step which is discussed in the following section.

Table 4-3. Different classes for ranking the matrix.
Own source.

1	Completely fulfils the objective
0.75	Highly fulfils the objective
0.5	Partially fulfils the objective
0.25	Fulfils the objectives meekly
0	Doesn't fulfil the objective but it doesn't have a negative impact

Table 4-4. Ranked matrix for each alternatives.
Own source.

	Pumping	Drainage Capacity	Stream	WSUD
Protect natural systems				
1. Retaining existing natural features	0.75	0.75	1	1
2. Protecting environmental values	0	0	1	1
3. More healthy natural ecosystem in urban environments;	0	0.25	1	1
4. Supporting wildlife habitats	0	0	1	1
Integrates stormwater treatment into the landscape				
5. Managing flood risk through landscape strategies	0	0	0.75	1
6. Using stormwater in the urban landscape	0	0	0.5	1
Protect water quality				
7. Pollution prevention through run off reduction	0	0.5	0.75	1
8. Removal or reduction of stormwater pollutants by vegetation or sand filtering	0	0	0.25	1
Reduce run-off and peak flow				
9. Disconnection of impervious areas	0	0	0.5	1
10.Using temporary rainfall storage	0	0	0.25	1
11.Conveyance stormwater from houses into the local stormwater treatment feature	0	0	0.5	1
Add value while minimise development costs				
12. Reducing the costs of the treatment	0	0	0.25	0.5
13. Increasing the value of the sub-divisions	0	0	0.5	0.75
14. Cost of cunstruction	1	0.75	0.25	0
15. Cost of operation and maintenance	0.75	1	0.25	0
16. Cost of technology	1	1	0.5	0
17. Cost of accessories	1	0.5	0.5	0
18. Improve aesthetics characteristics	0	0	0.75	1
19.Creating long term value for the area	0	0	1	1
20. Minimising heat island effect	0	0	1	1
21. Creating more green open spaces for recreational activities	0	0	0.5	1
22. Enhance linkages (pedestrian, bicycle, vehicular) across measures	0	0	0.25	0.5
Integration of the whole water cycle				
23. Single measure deliver multiple water related benefits	0	0	0.5	1
24. Single measure integrate in natural water cycle	0	0	0.5	1
Co-operation and participation principle				
25. Informing the entire community in the planning process	0	0	1	1
26. Considering the demands of all stakeholders and involve them in the planning process	0	0	1	1
27. Commitment to community awarness raising or education	0	0	1	1
28. Addressing public safety	1	1	1	1
29. Addressing public health	0.25	0.5	1	1
30. Consistency with the current cultural characteristics of the area	0.5	0.5	1	0.5
31 Improve cultral heritage value	0	0	0.5	0
Reversibility				
32. Consequence of measure is reversible where possible	0	0	0.5	0
Precationary (Implementation and post implementation aspects)				
33. less implementation risks	1	0.75	0.5	0.25
34. measures with low potential of damage	0	1	0.5	0.5
35. Required monitoring, performance assessment and post construction analysis	0.25	1	0.5	0.25
36. Required maintenance techniques and ferequancy	0.25	1	0.5	0.25
37. Durability	0.25	0.75	1	1
Minimisation of the resource use(Demand Management)				
38. Reducing potable water demand	0	0	0	1
39. Waste water generation minimisation	0	0	0.5	1
Adaptibility				
40. Adaptable built -environment to uncertain and changing basic conditions.	0	0	0.75	1
Time of the implementation				
41. Less implementation time	1	0.75	0.5	0
42. Resulting Quickly	1	1	0.75	0.75

4.4.4. Ranking different dimension

Weighing was done based on the ranking of different dimensions through three different groups. First, ranking was done based on the stakeholder's opinion about importance of these dimensions. Second, it was obtained from the planners in the municipality of Enschede. Third, it was done by the author based on the project condition.

4.4.5. Calculating a weighted Index

Based on the above-mentioned ranking preference of three different groups, the weight of each dimension was obtained in ILWIS software. Next, the obtained weight was divided equally between existing criteria in each dimension (Equal weighing). Using the calculated weight for criteria and the matrix of each alternative, the index value of each dimension was calculated. Last, by adding the value of all alternatives, the overall index value was obtained which illustrates the final value of each alternative. Comparing index value of each alternative with the value of the conceptual WSUD option, the level of the water sensitivity of that alternative will be achieved.

Summary of the steps taken in the assessment is illustrated in the Figure 4-1. These steps are listed as follow:

1. Number of WSUD principles has been proposed based on the guidelines and case study analysis.
2. Presenting the numbers of practical criteria for each principle.
3. Categorizing above mentioned criteria in different dimensions.
4. Ranking the matrix into 5 classes for each alternative.
5. Acquiring the stakeholders' choice of preference about ranking of the dimensions.
6. Calculating the dimension weights based on the obtained ranking.
7. Assigning the weights to the dimensions.
8. Equal weighing for existing criteria in each dimension.
9. Calculating index value for each dimension and
10. Calculating the overall index value by adding all dimensions' index value.

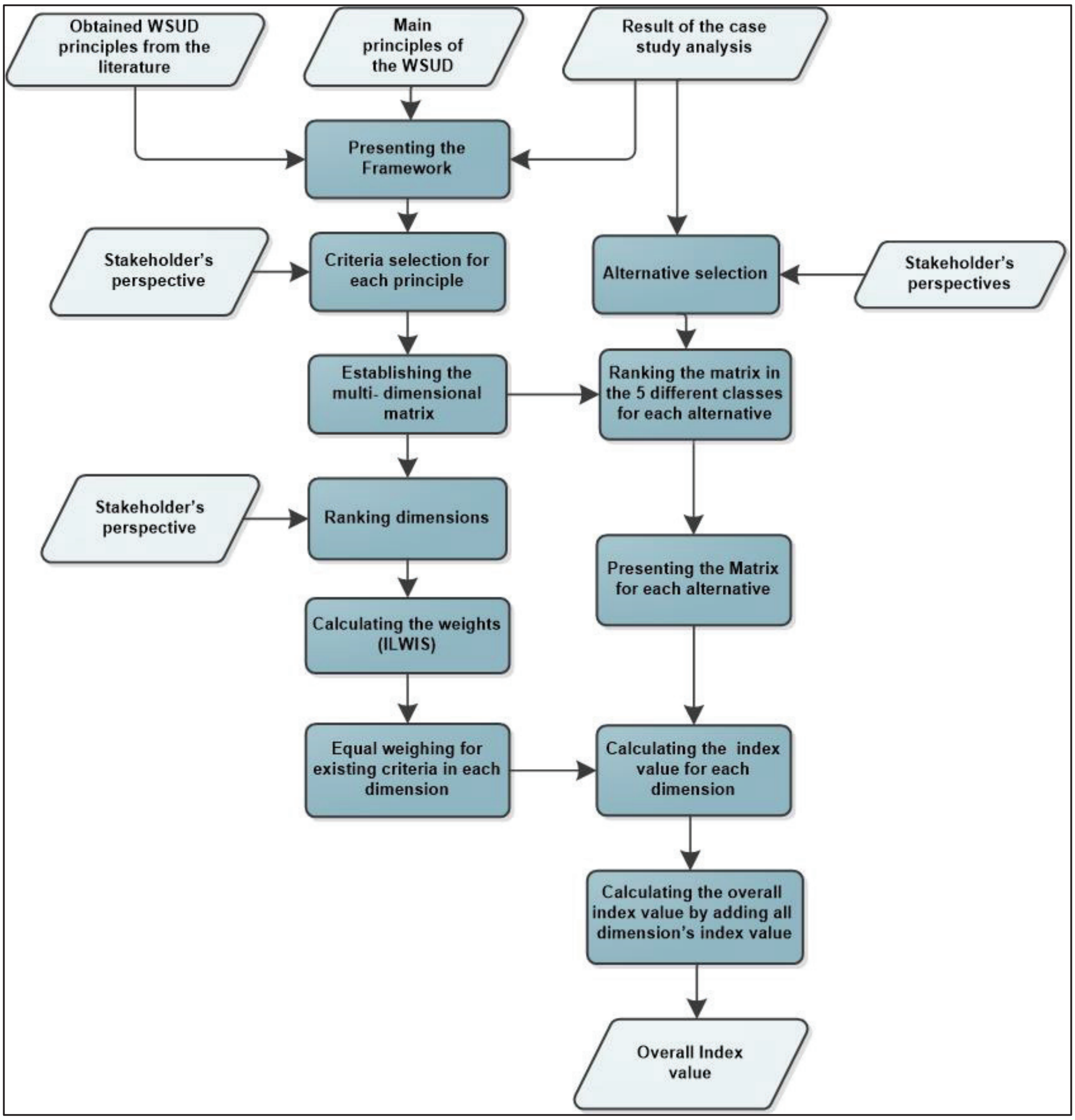

Figure 4-1. Steps taken in the assessment.
Own source.

4.5. Stakeholders in decision making process

4.5.1. Identifying the stakeholders

It is not possible to tackle the integrated management approaches without stakeholders' participation and collaboration in the planning process. The opportunity should be given to the people who are influenced by the decisions to express their information and perspective (Pahl-Wostl, Craps, et al., 2007). Till the date, only the municipality planner were involved in the process, but during this research residents of the Pathmos neighbourhood were involved in the decision making process. In total, around three month of collaboration with the municipality was done and 10 meetings with the municipality planner were carried out.

4.5.2. Approaching the stakeholders:

The municipality:

In the municipality of Enschede, a group of planners are working on the Stadsbeek project. The specialists of different domains such as water designer, transport planner, urban planner and so on are focused on the different aspects of the project. The project analysis has been started since 2012 and the first implementation phase of the project will start in 2014. This first phase includes construction of one or two possible stream trajectories from Pathmos to Usselerstroom neighbourhoods. In order to find the best solution for the existing problems in the area, a number of analyses have been done which mainly concentrate on the financial perspective. Cost benefit analysis is an example of these analyses which was done to evaluate a best solution in the area. But due to limitation of this analysis to target qualitative goals such as improving the visual characteristics of the area or added value to the neighbourhoods and lack of standard ways to assign monetary values to some qualitative goals, the outcome of this analysis is not sufficient to conclude which option is the best alternative for this project.

Since, this research focuses on establishing a holistic framework which includes all aspects of the water management system, municipality of Enschede showed a clear interest in the topic and collaboration with the municipality was devised. This collaboration consisted of different levels.

First, in order to increase the interaction with the planners and use the maximum available resources in the municipality, a working place in the municipality was provided. This opportunity increased the access to the available data in the municipality and facilitated the process of the transferring the information.

Second, in order to gain insight into the project and exchange the information, regular meeting with the team members took place. The meetings were convened in the municipality in presence of the project manager, water designer, urban planner, supervisors from ITC and the author. Before every meeting, an agenda was set and communicated to the meeting members and according to the proposed agenda, numbers of topics were discussed.

A number of the discussed topics have been listed as below:

- New water management in Enschede
- WSUD concept
- Stadsbeek Project
- Possible stream trajectories

Third, the municipality facilitated and arranged the meeting with the residents. In general, collaboration with the municipality has been central to accomplishment of the project.

The residents

Focus group discussion method was used to approach the residents. For this purpose, the meeting was arranged through the municipality. In this focus group discussion, 18 resident representatives of the Pathmos neighbourhood and a representative of the municipality were in attendance. Appendix A provides more detail information about the FGD.

In this approach, first the information was provided for the stakeholders through the presentations to effectively participate in the discussion. This approach provides a general understating among all participants involve in the planning. Next, stakeholders shared comments and their concerns.

Summarizing the dissection, topics discussed in the focus group discussion are listed below:

1. Stakeholder's perspective, Values, Beliefs, Interests, and Concerns
2. The importance of water issues for you, in your area
3. Ranking different dimensions of the criteria.
4. Dimension prioritisation
5. WSUD principles and options such as rainwater harvesting techniques
6. Trajectory choice preference

The presentation about WSUD concept was done in which the role of water in the urban area, WSUD, its principles and options were described. It is worth to mention that in July 2013, the municipality of Enschede conducted the survey from the residents of the Pathmos neighbourhood. The summary report of this survey has been attached in the Appendix C.

5. RESULTS AND DISCUSSION

This chapter demonstrates the result and discussion on this research. First, the divergent and similar issues discussed with stakeholders are presented. Section 5.3 and 5.4 illustrates the results of the alternatives' assessment and comparison between WSUD and current water vision in Enschede. Following, section 5.5 and 5.6 shows the field visits observations and implementation results. Last, discussion on the obtained results, applicability of the WSUD principles, research methodology, applied MCA method and integration is presented.

5.1. Divergent issues of the stakeholders

Residents

In the group discussions, all residents expressed common issues related to water problems in their neighbourhood. From their point of view, the main existing problem is the high level of the groundwater in the neighbourhood. Wet basement was expressed as the dominant problem which causes disturbance in houses. Their main concern is that the municipality should take actions about ground water problem in a short time horizon and solve the problem completely. Also, they believe that from the architectural perspective, the neighbourhood has a cultural heritage value that should be considered in all stages of the planning process and plans should not conflict with the socio-cultural characteristics of the area.

Residents gave their opinions about different alternatives to control ground water level, but the focus was on the construction of a stream. Residents expressed both interests and concerns about constructing a stream to control the ground water level. Interest focused on the potential of improving the environment, adding value to the neighbourhood by integrating the water as a visual enhancement of the urban environment, and increasing open green spaces along the stream bed. Their most pressing concern is the safety of children due to the depth of the water in the stream. Another concern was to what extent the stream will lower the groundwater table to resolve the issues related to it.

Participants also gave their opinion about the trajectory of the stream and the principles of WSUD. After presenting two possible trajectories for the construction of a stream to control water levels, residents' preference was 'trajectory 1'. Residents noted that due to the fact that 'trajectory 2' is located farther away from the neighbourhood, it will not contribute to control the groundwater level. Rain water harvesting techniques, such as rainwater tanks caused interest and a good response from the participants. Nonetheless, they foresaw high expenses from implementing water harvesting as the main obstacle. Though, they believe this can be solved by financial support of the municipality or other incentives such as indirect subsidies and grants for implementing these measures.

The Municipality planners

During the regular meetings with the municipality planners, a number of topics were discussed and the results of the discussions are described as follows:

Planners identified budget restrictions as a limitation to implement WSUD measures. They expressed that construction of any additional measure rather than stream is a trade-off between expenses on one hand and attainment of sustainability goals on the other hand. Considering that these sustainability goals will be mainly achieved by constructing the stream, additional costs to implement other measure seems difficult to justify.

The cost estimates to solve the current water related problems in traditional way and stream are 11 and 4.3 million Euros respectively. It is likely that an additional WSUD cost makes this cost gap bigger. Table 5-1 shows the cost summary of different alternatives to solve the current problems and to anticipate additional drainage capacity for the future. The construction of a stream is a cheaper option rather than traditional ways, when considering the costs for additional capacity to drain run- off and ground water in the future.

Table 5-1. Comparison between costs of different alternatives
to solve water related problems and anticipate additional drain for the future.
Source (Gemeente Enschede, 2013b).

	Solving current problems	**Additional drain in future**	**Total**
Traditional	€ 4.3 m	€ 6.0 m. (Traditional) € 3.0 m. (Stadsbeek)	€ 10.3 m. (traditional/traditional) € 7.3 m. (traditional/Stadsbeek)
Stream	€ 6.5 m (€ 4.5 m Co-financing)		€ 6.5 m. (Stadsbeek)

Another important point about construction of the stream is importance of the reversibility principle that arose from the step by step procedure in the implementation plan. According to this scheme, first the lower part of the stream near the Twente canal will be dug and the behaviour of the water in the stream will be observed. Then, based on the performance of the system the next construction phases will be started. This procedure aims to reduce the risk of implementation and any failure in the system due to unexpected conditions. And in case of unexpected implementation failure, the consequence of the measure is reversible. As result of discussion the importance of the reversibility principle in this project was revived and this principle was added to the framework.

5.2. Stakeholders' opinions on criteria ranking

Residenst

In order to have the same understanding of different dimensions of the project criteria, between the residents and the author, dimensions were explained to the residents. Thereafter, they were asked to rank these dimensions in the order of importance from their perspective. Ranking dimensions, the socio-cultural dimension ranked first, environmental dimension is second last and economic and technical dimensions are the last in importance for the residents. Table 5-2 illustrates the dimension choice of preferences.

In the multi-dimensional ranking, rank 1 has been assigned to the most important dimension and rank 3 to the least important one. Using the given ranks, related weights were obtained in ILWIS. The obtained weights were used in the multi criteria analysis.

The Municipality planners

Expressing the dimension preferences, municipality planners believed that technical and socio-cultural dimensions have the highest priority rather than other dimensions. Surprisingly economic dimension got the least ranking preferences. This indicates that, the economic factors are no longer the most influential factors in the planning process in the water management systems. Giving the highest rank to the socio-cultural and technical dimensions imply the direction of the water policy in the municipality of Enschede. Table 5-3 illustrates this choice of preferences. Using the given ranking, related weights were obtained in ILWIS.

The Author

Based on the insight gained during the research, two important elements, as in, the built-environment and technical dimensions of the presented framework was revealed. Through the study, the technical dimension ranked the highest followed by environmental and socio-cultural dimensions and then economic dimension. Technical dimension was highest importance since it focuses on the storm water flood which is the dominant problem in the neighbourhood parallel to the high level of the groundwater. Also, the main objective of the WSUD concept is to add value to the build environment and to enhance the visual amenity of it. Hence, built-environment was also equally important. Using the rank preferences of the dimensions, the weights were calculated. Table 5-4 contains the obtained weights.

Table 5-2. Resident's dimension ranking and weights in ILWIS SMCE.
Own source.

Dimensions	Ranking	Obtained weights in ILWIS SMCE
Economic	3	0.100
Technical	3	0.100
Built-environment	1	0.300
Environmental	2	0.200
Socio-Cultural	1	0.300

Table 5-3. Municipality planner's dimension ranking and obtained weights in ILWIS SMCE.
Own source.

Dimensions	Ranking	Obtained weights in ILWIS SMCE
Economic	3	0.067
Technical	1	0.300
Built-environment	2	0.167
Environmental	2	0.167
Socio-Cultural	1	0.300

Table 5-4. The author's dimension ranking and obtained weights in ILWIS SMCE.
Own source.

Dimensions	Ranking	Obtained weights in ILWIS SMCE
Economic	3	0.067
Technical	1	0.300
Built-environment	1	0.300
Environmental	2	0.167
Socio-Cultural	2	0.167

5.3. Result of the assessment of different alternatives

As mentioned in the chapter 4, the framework was presented based on the WSUD principles and the selected criteria. Then the framework was categorized based on the different dimensions and matrix was created. This matrix was scored in 5 different classes for each proposed alternative. Using the scored matrix, three multi criteria analysis were developed based on each stakeholder's dimensions choice of the preference and one from the author.

Table 5-5 illustrates the result of MCA with stakeholder's dimensions ranking. As a result, alternatives 4 and 1 obtained the highest and lowest scores respectively. Figure 5-1 illustrates the importance of built environment, environmental and socio-cultural dimensions in resident choice of preference.

Table 5-6 contains the result of the assessment based on the municipality planner's choice of preferences. This table shows although alternative 4 still got the highest overall score, but the differences with alternative 3 has been reduced. Figure 5-2 shows the relatively equally distributed importance between dimensions rather than stakeholders choice of preferences.

Table 5-7 contains the results of the assessment based on the author's dimensions choice of preference. It can be observed that the proposed weight didn't change the result of the assessment, however the score gap between different alternatives has been increased. Figure 5-3 illustrates the significance of built environment aspects in comparison with other dimensions.
The proposed alternatives as discussed in section 3.4 are as follows,

- To pump the groundwater level
- Undertake the expansion, replacement or improvement of the existing drainage system
- To construct the stream
- A number of proposed WSUD measures in addition to constructing the stream.

Table 5-5. Result of the assessment based on residents dimension's preference.
Own source.

	Economic	Technical	Built Environment	Environmental	Socio-Cultural	Overall index value
Alternative 1	0.063	0.027	0.000	0.019	0.075	**0.183**
Alternative 2	0.079	0.044	0.000	0.044	0.075	**0.243**
Alternative 3	0.038	0.051	0.203	0.150	0.279	**0.721**
Alternative 4	0.021	0.064	0.278	0.200	0.236	**0.799**

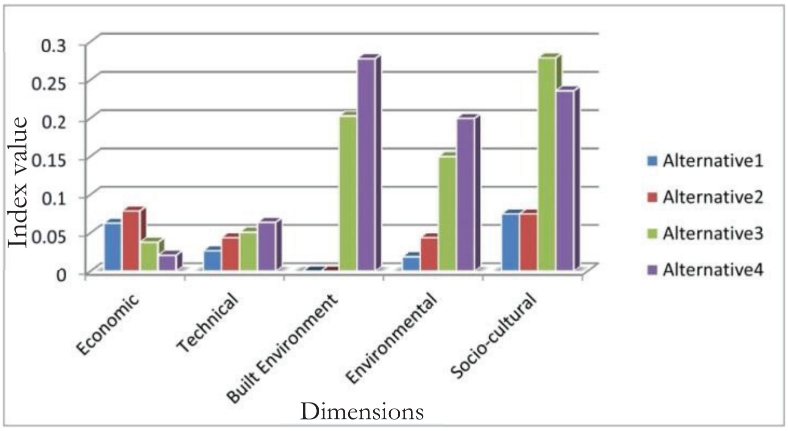

Figure 5-1. Result of the assessment based on residents dimension's preference.
Own source.

Table 5-6. Result of the assessment based on municipality planners dimension's preference.
Own source.

	Economic	Technical	Built Environment	Environmental	Socio-Cultural	Overall index value
Alternative 1	0.042	0.080	0.000	0.016	0.075	**0.213**
Alternative 2	0.053	0.133	0.000	0.037	0.075	**0.299**
Alternative 3	0.025	0.155	0.113	0.125	0.279	**0.698**
Alternative 4	0.014	0.192	0.155	0.167	0.236	**0.765**

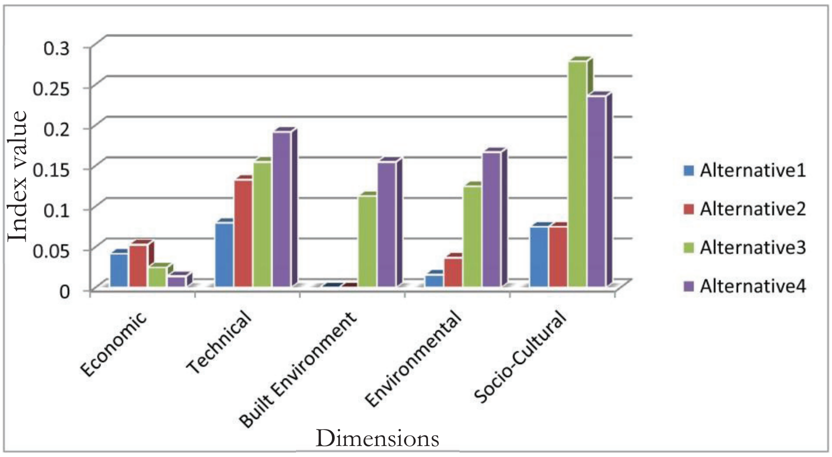

Figure 5-2. Result of the assessment based on municipality planners dimension's preference.
Own source.

Table 5-7. Result of the assessment based on the author dimension's preference.

	Economic	Technical	Built Environment	Environmental	Socio-Cultural	Overall index value
Alternative 1	0.042	0.080	0.000	0.016	0.042	**0.180**
Alternative 2	0.053	0.133	0.000	0.037	0.042	**0.265**
Alternative 3	0.025	0.155	0.203	0.125	0.155	**0.664**
Alternative 4	0.014	0.192	0.275	0.167	0.131	**0.784**

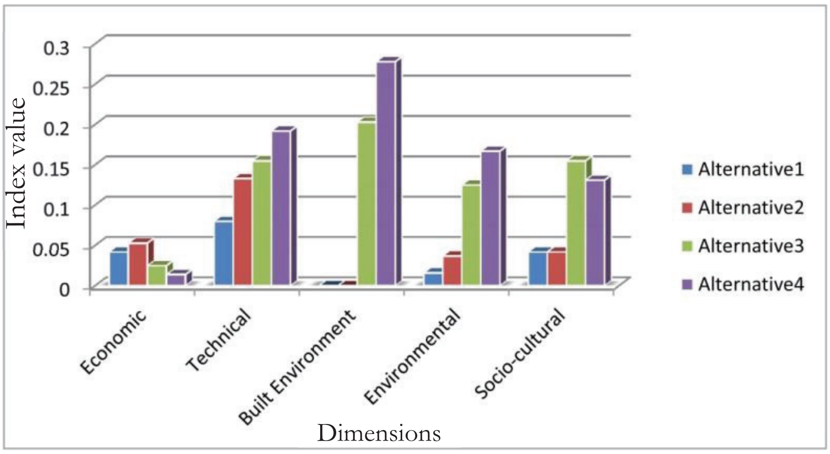

Figure 5-3. Result of the assessment based on the author dimension's preference.
Own source.

A number of common overall observations are apparent from the assessment which are listed as follow: First, "alternative 4" constructing a stream with additional measures and "alternative 1" pumping the groundwater obtained the highest and lowest score respectively. Basically, the different proposed weighs for dimensions didn't change the results of the assessment. Table 5-8 illustrates that alternative 4 was superior regardless of the ranking preferences. Thus, final alternative ranking provided by the matrix was unchangeable not matter what values were assigned to the weights.

It was observed that two extreme groups of index values exists between alternatives 1 and 2 on one hand and alternatives 3 and 4 on another hand. Basically, new water management approaches to solve the problem in the area got higher ranks with a considerable differences rather than traditional alternatives. Also, in comparison between the two traditional alternatives, the alternative of increasing the drainage capacity obtained a better index value. Thus, this emphasizes the importance of a long term solution for both groundwater table and run-off discharge rather than just solving the groundwater problem temporarily.

Furthermore, while comparison between dimensions, although alternative 4 got the highest overall rank but in two economic and socio-cultural dimensions other alternatives got better scores. In the social cultural aspect Stadsbeek got the highest rank which indicates that municipality proposal for the Stadsbeek was based on the local condition while in WSUD concept less emphasize has been given to cultural aspect of the planning. In the economic perspective, alternative 2 and alternative 4 got the highest and lowest score respectively. This indicates the higher costs of the construction and maintenance of the stream and proposed measures rather than traditional alternatives.

Table 5-8. Comparison of overall index values by stakeholders perspective.
Own source.

Perspective	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Residents	0.183	0.243	0.721	0.799
Municipality planners	0.213	0.299	0.698	0.765
The author	0.180	0.265	0.664	0.784

5.4. Result of comparison between WSUD and current water vision in Enschede

The current water management in Enschede is transforming from the traditional water management toward a more sustainable one. A number of case studies in Enschede described in sub-section 3.3 pointed out implemented examples toward more sustainable approaches. In Enschede's current water vision 2013-2025, a strong emphasis on bringing the water back to the urban environment is apparent (Gemeente Enschede, 2012b). Based on this research, Enschede has the potential to become more water sensitive. In this transition phase toward more water sensitive design, the stream and applying some WSUD measure are potential proposals to achieve it.

Whether or not the current water management in Enschede can manage the whole water cycle is debatable. The reason for that is a less emphasis on some aspects of water management such as improving the quality of the run-off and minimising reticulated water demand. Instead, managing the surface run-off and the high level of the ground water have been highlighted. However, it should be considered that even in Australia, most applications are related to manage run off rather than managing the whole water cycle (Ashley et al., 2013). As a result, it seems logical that motives to undertake an approach toward more water sensitive designs are highly related to solving the local contexts problems.

Although the shift is taking place more towards sustainable water management approach in Enschede, but lack of practical guidelines and localized detailed plans are some of the obstacles to the way forward. Nonetheless, there are a number of contributing factors which facilitate the transition towards more water sensitive city. Among these factors, there is a common understanding of emerging need towards a new water management system between different groups of stakeholders. Another influential factor is the new direction in the water policy and giving more importance to the water in the built-environment.

In Australia, based on the existing situation and dominant problems such as drought and population growth, the WSUD concept has focused on water supply, run –off quality and quantity. Supporting this concept, a number of guidelines have been provided. These guidelines are proposing practical measures and ways to operationalize the concept. In addition to these guidelines, cost estimation for implementing each measure is given. Supporting new technologies, institutional capacity, regulatory process, detailed action plans and development of a total water cycle management policy (Edwards, Holt, & Francey, 2006) are factors which are used to accelerate the transformation from a concept to effective implementation interventions.

During this research, it was observed that the WSUD concept and the current water management in Enschede have common goals and their proposal for achieving these goals overlap to some extent.
Although Enschede's approach toward more sustainable water management, is still more an aim for an ideal situation guided by a set of principles rather than a practical structured tool box.

5.5. Observations based on field visits

After 4 field visits spread over months from September 2013-November 2013, some observations have been made. Figure 5-4 illustrates these two stream trajectories. The main characteristics of the area between two possible trajectories, was highly developed residential neighbourhood. Due to the slope in the area towards the Twente canal, there is an opportunity to connect the stream to the Twente canal. In addition, existence of a number of open green spaces indicate as an opportunity to increase the interaction between water and landscape.

It was observed, the southern trajectory of the stream crosses the dense residential area and passes Tweede Emmastraat , Elferinksweg, Benjamin Willem Ter Kuilestraat, Rembrandtlaan and Bruggertstraat. In this area, the number of educational building such as schools and kindergarten was considerable. Besides, playground could be observed frequently, and these imply the neighbourhood with young families and Childs. Another observation was existence of few heterogeneous land-uses in the area such as garage. Figure 5-5 shows pictures of this stream trajectory.

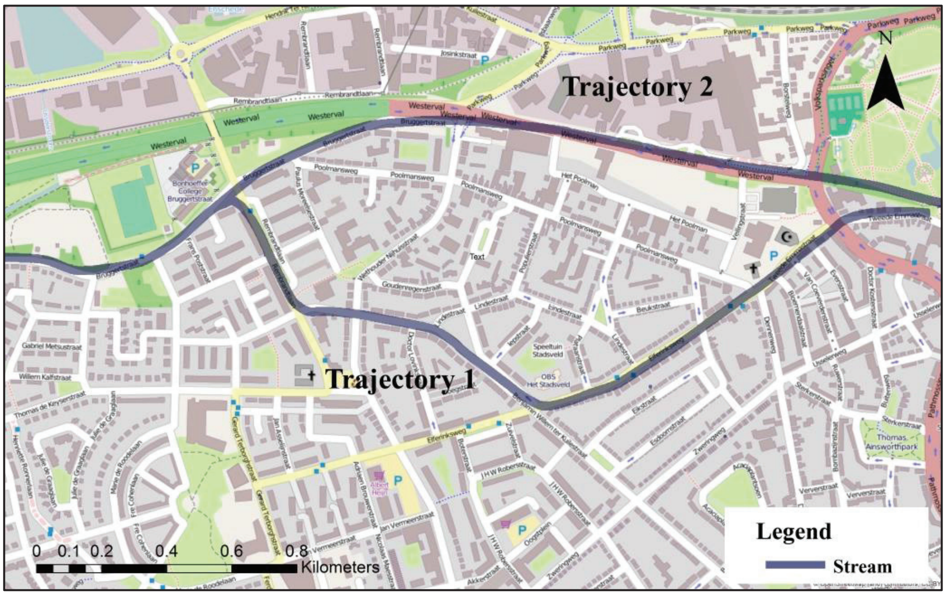

Figure 5-4. Two trajectories of the streams.
Source: Retrieved from the Open street map.

Figure 5-5. First stream trajectory,
(A,B) Current situation of Elferinksweg
(C,D) Benjamin Willem Ter Kuilestraat
(E,F,G) Rembrandtlaan)
(H) Bruggertstraat (Photograph by author).

Despite the first trajectory, the second trajectory has more spaces along its pathway and crosses Westerval, Bruggertstraat. AS the overview of the zoning plan illustrated, business is the dominant land use along this stream (Figure 5-6). It is notable that most of these business lots are vacant. Figure 5-7 shows picture of some of these lands. These two possible stream's trajectories join each other in Bruggertstraat and flows toward the Twente canal.

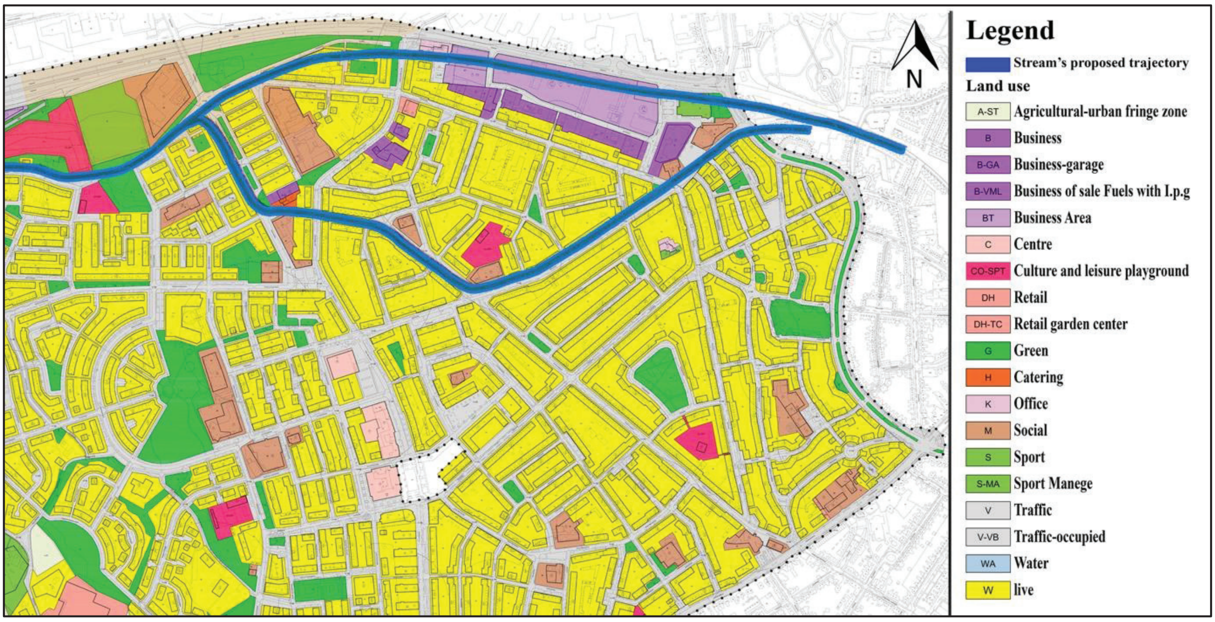

Figure 5-6. Overview of the zoning plan. Stadsveld and Pathmos neighbourhoods.

Figure 5-7. Northern stream trajectory pictures.
(A) vacant lot along the path of the northern stream trajectory.
(B) more open spaces along the northern stream trajectory, street Westerval.
(Photograph by author).

5.6. Implementation results, proposed WSUD option

Based on the results of the study area analysis, a number of WSUD measures and interventions have been selected and suggested. In the selection of these measures, several considerations have been taken into account as discussed as follow.

First, due to the high level of the groundwater, measures that increase the groundwater table were not selected. Therefore, measures such as infiltration trench, rain gardens and vegetated filter strips were excluded as well. For other cases where there was partly increase in ground water, retrofit collection pipe was considered in order to convey the storm water discharge to the stream or retention measures.

Second, required space for the proposed measures was one of the main limitations. Although limited number of green open spaces, vacant lands and heterogeneous land uses were identified, relatively dense residential neighbourhood in the study area and lack of required space was a determinant factor.

Third, according to the guidelines, performance of some measures such as sand filter in the cold climate was not still clear. Hence, this was mentioned in the design consideration.

The proposed measures are described as follow.

a) Rain water harvesting tanks

Rain water harvesting tanks act as a detention system which stores rainfall water and can reduce peak flow at the site. The collected water is an additional source of non-potable water which could be otherwise drained as a run off discharge. The water is appropriate for internal toilet flushing and for external uses such as irrigation and car washing (Bayside City Council Corporate Centre, n.d.). Financial incentive proposed from the municipality and other responsible organization and increasing local resident awareness might encourage residents about using these techniques. Figure 5-8 shows the example of rain water harvesting tank.

Figure 5-8. Rainwater harvesting tanks.
Source (LANDCOM, 2009).

Advantages:

- Reduce peak flow rates and retain rainfall on-site.
- low risk measure

Disadvantage:

- Considering the location of the study area in the downstream and the volume of discharge flowing toward the study area, rain water harvesting tank techniques might not help to reduce the peak flow.
- It may take up valuable space around the house.

Possible sites:

Although implementation of storm water harvesting techniques and on-site retention measures such as rainwater tanks don't have the specific site selection limitation but it might be more practical to implement these measures in area with the run-off problem such as Bruggertstraat and Weth. Nijhuisstraat. Figure 5-9 illustrates these sites.

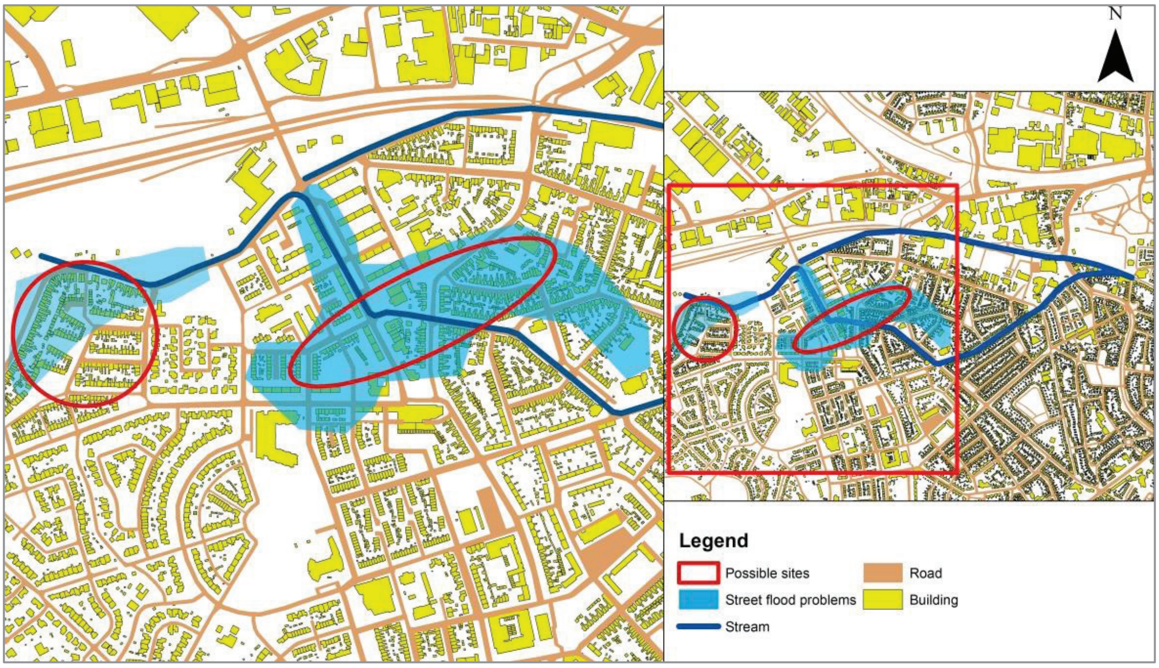

Figure 5-9. Possible sites for rain water harvesting tanks.
Own source.

Swales:

Swales are vegetated or grassed channel to collect and convey the stormwater flow. These broad channels reduce peak flow, increase infiltration and remove sediments (Government of Western Australia, 2011). Figure 5-10 contains the detail of this measure.

Advantages:

- Grassed or vegetated swales remove coarse and medium sediment.
- Below the swale the perforated pipe can collect the storm-water discharge and prevent the infiltration process.

Disadvantages:

- Wet swales may become a nuisance due to smell.

Possible sites:

In the dense area where the open channel is not possible and because of high groundwater level infiltration is not suitable, vegetated swales can be the potential measures for the site. Figure 5-11 demonstrations an example of possible sites for this measure.

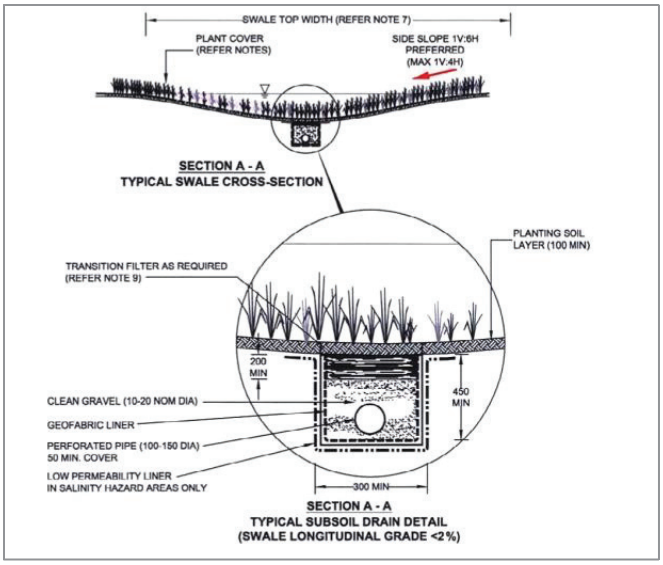

Figure 5-10. Detail of the swale cross section.
Source (Upper Parramatta River Catchment Trust, 2004).

Figure 5-11. Vegetated swales
(A) Example of the vegetated swales.Source (Water Sensitive Urban Design in Sydney, 2014).
(B) Potential site for this measure, Elferinksweg street. *(Photograph by author).*

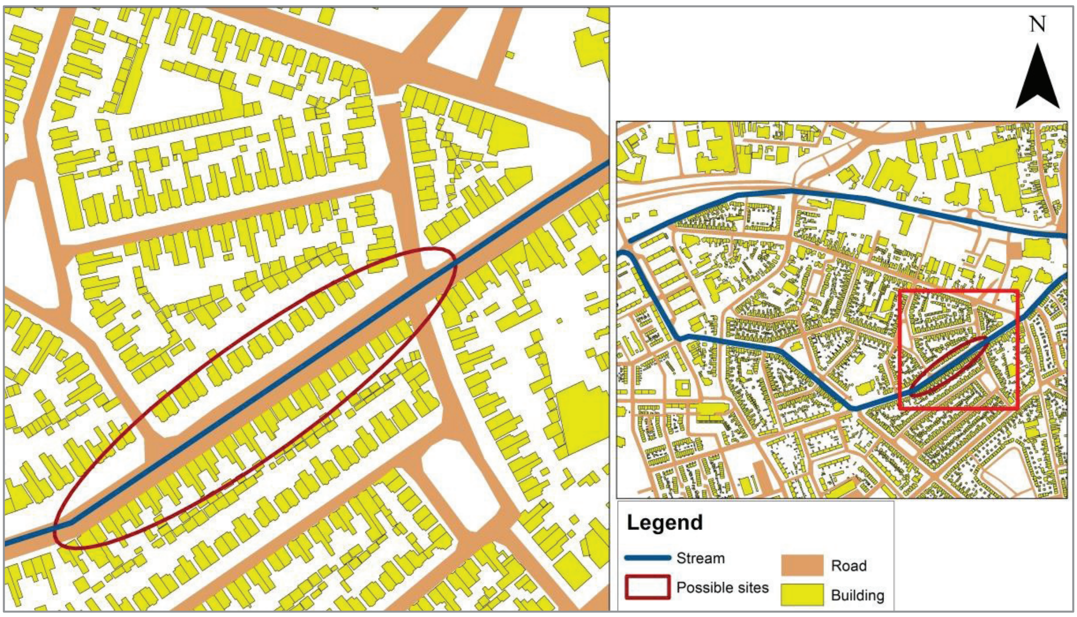

Figure 5-12. Possible sites for vegetated or grassed swales.
Own source.

b) Sand Filters:

Sand filters are generally water quality enhancement end of pipe techniques that remove pollutant from stormwater run off. They can be constructed either above or below the ground. The percolated water into the sand filter will be collected through pervious pipe. The collected water will be drained to the outlet eventually. Figure 5-13 shows the design detail of the sand filter section profile.

Advantages:

- This measure doesn't have a considerable land availability limitation, so it is a suitable measure for the dense residential neighbourhood.

Disadvantages:

- Regular maintenance is required.
- Sand filter performance and operation in the cold climate is not clear.

Design consideration:

- This measure is effective for area less than 5 ha (Alberta Government, 2013).

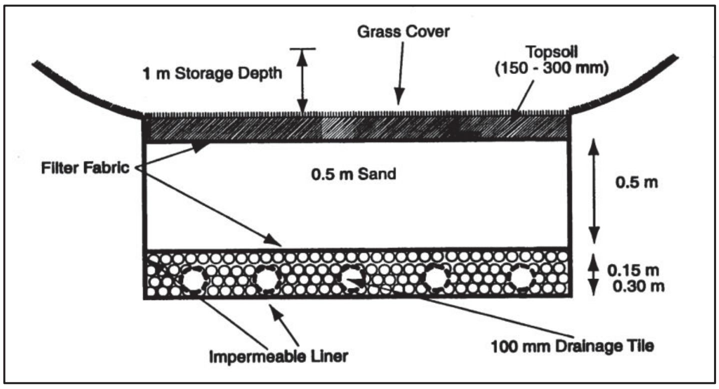

Figure 5-13. Sand filter section profile.
Source (Alberta Government, 2013).

c) Wetland

Wetlands are shallow water bodies with vegetation cover. This end of line treatment measures improve the run off quality and filter pollutants when run off passes through the dense vegetation cover. Furthermore, wetlands can be used as a detention basin which plays the role of flood protection for large residential or industrial sub-divisions. Figure 5-14 illustrates examples of the wetlands.

Figure 5-14. Picture of wetland.
Source (Water Sensitive Urban Design in Sydney, 2012).

d) Designing the roads layout

Roads include significant percentage of the impervious area in the urban development, so design of the roads and the way they convey the run-off is considerable. Along with the construction of the stream, appropriate design of the road layout can help to drain the run-off towards stream and prevent convey of the contaminated discharge on the streets. One way roads with single slope gives more space for the stream and only one side of the road needs a gutter to be connected to the stream. Figure 5-15 illustrates the road design with storm water feeding into a stream beside to the road.

In some parts of the neighbourhoods, where construction of the streams is impossible, storm water can be collected from the road sides through the pipe under the road, Figure 5-16 illustrates this system. Also, with design considerations, steep roads can carry the storm water toward WSUD measure or stream (Figure 5-17).

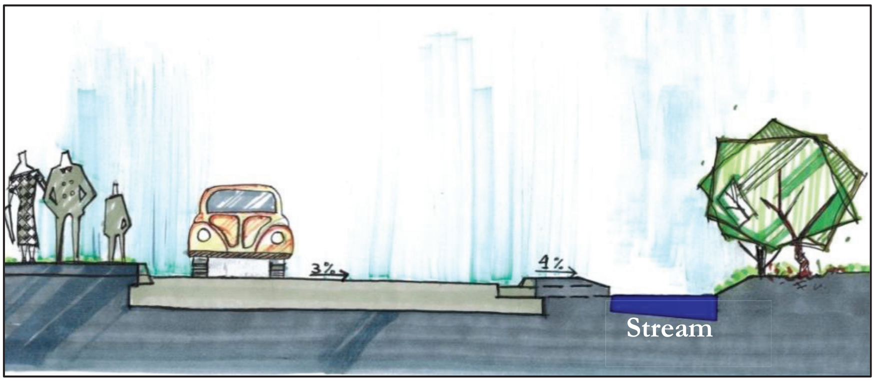

Figure 5-15. Road design with stormwater feeding into a stream.
Adopted from (LANDCOM, 2009).

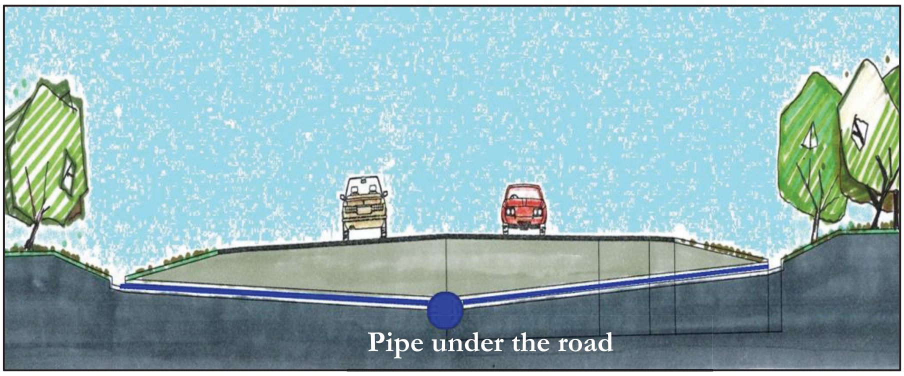

Figure 5-16. The collection pipe below the road.
Own source.

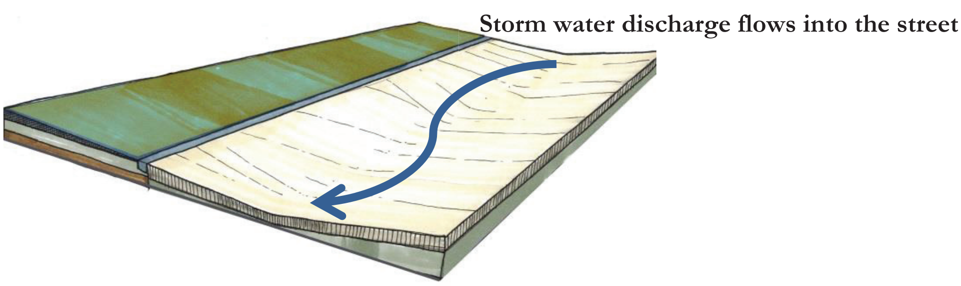

Figure 5-17. Road convey the storm water discharge.
Own source.

e) Matching public open space with the storm water features

Public open spaces are appropriate places for WSUD measures. They are potential sites for convey, store and treatment of the stromwater, and therefore reducing the peak flow. In addition, these measures and elements can strength the recreational activity. Stormwater can be integrating with the landscape into the open public spaces by number of elements and measure such as detention ponds, waterstepes, water squares. Figure 5-18 shows number of integrated elements and measures into the landscape.

Figure 5-18. Matching public open space with the storm water features.
(A) Water steps, Victoria Park.
(B) Integrating treated water into the landscape.
(C) Down, Detention pond integrated into parkland.
Source (LANDCOM, 2009).

Innovative designs and unconventional solutions are a key design aspect of integrating open public spaces with storm water features. Designing a multi-purpose features for dry and rainy season such as water plaza is an example of these innovative solutions. In the rainy season this measures can be used as storm water retention while during dry period it can be used as an open public spaces and playground. Figure 5-19 illustrates the design of pilot water plaza in the Rotterdam and its function during two dry and wet periods

Figure 5-19. The water plaza during the wet and dry seasons.
Source (Hoyer, Dickhaut, Kronawitter, & Weber, 2011).

Possible sites: Volkspark, and number of small open spaces in the study area are the potential sites for these measures. Figure 5-20 shows example of the potential sites in the study area.

Figure 5-20. Public open spaces in the study area, Benjamin Willem Ter Kuilestraat
(Photograph by author).

f) Considering land-use planning in the water management system

Improving the linkage between land use planning and water management, puts water a central element in the urban planning process. The integration between land use planning and water management in the future developments assists water management system to achieve its goals. For this study, considering land use planning in the water management can be achieved through different strategies as follows:

Finding the space in the study area

The vacant lands in the Stadsveld and Pathmos neighbourhoods should be identified, the corresponding land uses and site specification should be investigated and the possibility of using these lands for WSUD measures should be considered. These plots can be used as water retention area.

Possible sites: The vacant lands along the northern stream trajectory with business land-uses are example for sites.

Changing the land use

Existing heterogeneous land use in the site are the potential locations where land use plans can be revised. In order to do that, the heterogeneous land uses should be identified and the possibility to implement WSUD measures in that site should be investigated. The possibility to move these land-uses out from the study area should be considered.

Possible sites: During the field visits, some heterogeneous land uses in the study area observed such as the garage.

Optimum use of the space

The idea behind the multi-functional land use is "getting more for less"(Ashley et al., 2013). In order achieve these, potential land plots for a multi-functional land use should be identified. Water plaza is a design example for the multi-functional land use as described earlier.

Possible sites: The playground of the existing schools in the study area and the yard of the mosque are example of these potential sites.

5.7. Discussion about applicability of WSUD principles

WSUD measures were designed in response to the Australian challenges in the current water management system which are mainly droughts, floods and the health of waterways. Hence, most of the measures such as infiltration trench, rain gardens and vegetated filter strips in addition to improving the run-off quality, increase the infiltration process and recharge the ground water level. Nevertheless, in the context of Enschede, where dominant site characteristics such as high level of groundwater exists, proposing these techniques find number of limitations.

Different climate conditions between Australia and Netherlands causes difference in their water management problems and approaches. Specifically about WSUD, the performance of some measures such as sand filter in the cold climate is not known, so the local condition has an important role in the selecting and implementing measures in WSUD.

While presenting a framework, it was observed that WSUD principles were not focused at aspects such as socio cultural aspects and some technical aspects such as reversibility. Hence, based on the project's condition these principles have been added to WSUD framework. This indicates that although WSUD is a successful water management concept in Australia, the application of this concept in other locations in highly related to the local context. Although, the importance of the local context, has been already mentioned in WSUD concept.

5.8. Methodological discussion

A main challenge in this research was confronting and incorporating the inherent conflicts that exist between the goals and objectives of the project. The noticeable example of this conflict was between economic and other objectives. From the economic perspective, due to the higher construction costs of the proposed WSUD options and stream, traditional approaches are more suitable, while from other perspectives new approaches fits their objectives the best. These conflicts also exist even in intra-dimensions, for instance, conflict between high level of the ground water in the area and some of the criteria such as increasing the impermeable surfaces which increase the infiltration process and might accelerate the problem. The dominant approach to manage these conflicting goals constructively was to establish a trade-offs between them. Thus, MCA was used to find the best alternative in the existing situation with different group of stakeholders and relatively different set off concerns and interests was done.

A multidisciplinary framework to approach the problem reviled the need for a multidisciplinary solution. The need for managing the urban water system in integration with other disciplines was notable in this research. Hence, to evaluate the best option for the study area, water management was integrated with principles urban design and landscape architecture. Managing water systems in isolation from other disciplines such as traditional way are no longer applicable and this research can be a practical indication for this claim.

Due to the number of limitations, the assessment was done qualitatively. These limitations includes:

- Lack of surface run-off model to simulate the run-off in the urban area after construction of the stream or implementing the WSUD intervention.
- Lack of detailed economic assessment of WSUD options.

It is remarkable that, proposed framework in this study was established based on the specific case study analysis. Hence, the scale was a determinant factor in presenting these principles. For other case studies with different scale and different site specifications, other water sensitive principle can be added to the framework.

5.9. Discussion on the applied MCA method

From the literature review it was observed that in the number of researches to identify the best water sensitive measure and approaches, MCA is used to evaluate different single measures for specific sites. In these studies, MCA is done between number of different single measures such as constructing a wetland and the rainwater harvesting tanks. The limitation of such an assessment is that in this method, measures are evaluated separately and integration between them is ignored.

In order to solve this shortcoming, in this research instead of a single measure, alternatives consists of numbers of measures have been proposed. Even more, for Alternative 3 and 4, in addition to just technical measures, social cultural aspects has been considered. So, it was tried that the integration between the components of each alternative will be considered.

Another shortcoming of the qualitative analysis and in particular MCA is the subjective nature of these analyses. In order to reduce the inherent existing uncertainty, different groups of the stakeholders were involved in the assessment process. Examples of the stakeholder's participation are presented as follow:

- Stakeholders' dimension ranking which was discussed in the section 5.2.
- Discussion with the stakeholders about the alternatives to be assessed.
- Consultants with the municipality planners about the given ranks in the matrix for different proposed alternatives.

5.10. Discussion on the Integration

As integration is an important component in the WSUD concept, one of the research questions proposed in this study was how to achieve the integration. Hence, based on the definition and levels of the integration discussed in the literature, the research tried to respond the integration in different levels as follows:

Integration between different dimensions:

Presence of different influential dimensions of the water management was identified as a dominant attribute of this case study. Hence, it was necessary to consider the integration between these dimensions. Hence the proposed framework was established based on the different dimensions. In this context, linking different principles was achieved by embedding them in the framework.

Integration between different streams of water in the city

In this sense, integration means considering all facets of the water in the urban area together. In this case study, due to the specific site characteristics, groundwater and stormwater problems were highly influencing each other. Therefore, integration was establishing a trade-off between groundwater and stormwater which posed the number of design considerations in the planning process. Selecting measures for the WSUD option proposal was an example of this design. There, it was tried to avoid the measures which increase the infiltration process and reduce the run-off but on another hand they might intensify the high level of the ground water problem.

It is remarkable that in this research, only two streams of the groundwater and storm water were considered. The scale of the analysis which was neighbourhood level and site specification are the main reasons for this selection. Whereas, in the large scale analysis such as city and national level, all streams of the water should be taken in to consideration.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion from case study

The aim of this research was to provide a framework to assess the applicability of WSUD principles in two neighbourhoods of Enschede. In order to do that, different principles of WSUD were presented as the components of the framework which were obtained from the literature review and the project specification. This chapter summarized the findings of the research sub-objectives followed by the recommendations for future work.

1. *To analyse the WSUD concept and it's principles.*
From the literature it was observed that, WSUD is a concept towards managing urban water system in an integrated way with urban planning and landscape architecture. This concept aims to mitigate the negative impacts on the water cycle and bring it closer to the natural one. The main principles proposed for WSUD in Australia include the need to protect the natural water system, integrate the stormwater in the landscape and to improve the run-off quality. These principles are established based on the water management challenges in the Australian context which are mainly drought and flood. WSUD integrates urban water system and urban planning through these principles. The integration as a key component of this concept exists between number of principles as well as different urban water components.

2. *To analyse the current situation of Enschede toward WSUD.*
This was fulfilled during the collaboration with the municipality of Enschede, by investigating the current water management in Enschede, analysing its shortcomings, water problem hotspots in the city and finally, selecting two neighbourhoods for more detailed analysis. This was followed by deeper investigation through running the focused group discussion with the residents and filed visits.

Analysing the current water management in Enschede and particularly in the Pathmos and Usselerstroom, the high level of the groundwater and the storm-water runoff are recognized as the dominant challenges in the water system. Hence, the main principles of the WSUD which are the most relevant in Enschede are related to reducing the run-off, integrating the stormwater treatment into the landscape and adding value to the neighbourhoods. It can be observed, compared to WSUD in Australia, less focus has been given to the quality of the run-off. Instead, based on the local condition, reducing the ground water level is an important concern.

In the Stadsbeek project, as a remedy to the street flooding and high groundwater level problems in the Pathmos and Usselerstroom neighbourhoods, municipality planners were considering number of alternatives from the traditional approaches to more sustainable one. Considering new solutions illustrates that urban planners and water managers are realising that occurrences of the water can be a potential opportunity in the neighbourhoods.

In general, it can be concluded that current water management in Enschede is in the transition phase from the more traditional approach toward more sustainable one. A number of interventions such as Kristalbad, implementing the WADI concept, disconnection of the sewage system and the proposal for construction of the stream are indications of this transition.

3. *To define a framework to adopt WSUD principles in Enschede.*
A holistic multi-disciplinary framework was required to evaluate the applicability of different alternatives. Thus, a comprehensive analysis was done to incorporate all principles and objectives of WSUD in the framework. The framework acts as a bridge between urban planning, water management and landscape architecture. The components of this framework were the WSUD principles and number of principles based on the project condition. For each principle, a number of criteria were presented which were divided into different dimensions and formed the so called matrix.

4. *To assess the applicability of the framework.*
Multi criteria analysis was used to manage the multi-dimensional goals of the project and to find the optimum solution for the current and future problems in the study area. In order to do that, different groups of stakeholders expressed their choice of preference toward different alternatives and according to the given choice of preference, the dimension weights were obtained.

Four alternatives consist of traditional approaches and two more sustainable ones were selected and assessed through this framework. The proposed WSUD option was one of these alternatives. The result of the assessment illustrates that WSUD proposed option and construction of the stream respectively got the higher rank. The robustness of the assessment was evaluated through different dimension rankings for different group of stakeholders. The result of the ranking was unchangeable irrespective of the values assigned to the dimensions.

General conclusion:
It can be concluded that, the need for a multidisciplinary framework to approach the problem revealed the need for a multidisciplinary solution in the current water management in Enschede. Also, it was observed that the WSUD concept and the current water management in Enschede have common goals and their proposal for achieving these goals overlap. Although some of the principles to achieve these objectives, varies based on the local conditions. The Stadsbeek project is an indication of the transition towards more sustainable approach in the current water management of Enschede, although a number of challenges are on the way forward.

The main limitation for taking up the WSUD approach in Enschede is the economically centralized solution toward water issues in the city which approaches urban planning, water management and landscape architecture separately.

Considering different levels of the integration in the planning process is the step forward toward more water sensitive cities. This integration in one level exits between different domains of landscape architecture, water management and land use planning and in another level between different components of the water management system. Comparing the WSUD concept and Enschede’s water management, revealed some remarkable points. First, some components of the water in the Enschede consisting of ground water, stormwater are integrated and managed together. At this level, integration exists between different streams of the water in the city partially. But, the water system in Enschede doesn’t benefit from higher level of integration with land use planning or landscape architecture. This is due to the components of the system related to this integration, being fragmented.

6.2. Recommendation

In the view of this research there are some directions for further research as followed:

Quantitative analysis for a number of criteria in the proposed framework is recommended. This increases the accuracy of the assessment and reduces the existing uncertainty in the subjective nature of the qualitative analysis such as MCA. Cost estimation and economic assessment of the proposed WSUD measures is one example of this analysis. From the technical point of view, investigating the effect of WSUD measures and construction of the stream on the run-off discharges, through accurate simulation models is recommended.

From the social point of view, an effort should be made to identify and approach the other groups of stakeholders such as water board, related organizations and development companies. More detailed analyse of the socio-demographic characteristics of the residents is also recommended.

One of the main objectives of the WSUD is to integrate the land-use planning and water management. Hence, a detailed investigation in the land-use plans and its influence on the water system is recommended. This can be followed by defining future land-use change scenarios and investigating its impact on the water system.

Finally, in this study the general overview of the current situation of Enschede toward WSUD concept was investigated, but the unit of detailed analysis was neighbourhood level. By considering the larger spatial scale, the concise overview of the whole water management system in the city will be possible. The similarity between the units of analysis, facilitate the comparison between other aspects of the water management system rather than implementation measures. Institutional and regulatory processes in the water management system are example of these aspects.

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APPENDIX A: FOCUS GROUP DISCUSSION

Description

The focus group discussion (FGD) was held on Wednesday the 11th of December 2013 from 20.30 to 21.30 in the school in the Pathmose district, Spinnerstraat 27. The FGD was held after the regular meeting of the municipality representative and 18 representatives of the residents. The municipality representative, Peter Dijkstra translated the discussion and facilitated the meeting. The meeting was audio tapped.

The purpose of the focus group discussion

The purpose of the focus group discussion was to gain an understanding of the stakeholder's perspective, concerns and interests. FCD provided a general understating among all participants and involve thir perspectives in the planning.

How the FCD was held

In this approach, first the information was provided for the stakeholders through the presentations to effectively participate in the discussion. The presentation about WSUD concept was done in which the role of water in the urban area, WSUD, its principles and option were described. For this purpose, the municipality representative facilitates delivering the presentation. Next, stakeholders discussed their opinion and their concerns together. Then two representatives of them expressed the resident's common opinion which was not instant and took some time.

Summarizing the dissection, topics discussed in the focus group discussion are listed below:

1. Stakeholder's perspective, Values, Beliefs, Interests, and Concerns
2. The importance of water issues for you, in your area
3. Ranking different dimensions of the criteria.
4. Dimension prioritisation
5. WSUD principles and options such as rainwater harvesting techniques
6. Trajectory choice preference

Snapshots of the FGD:

Figure 0-1. Snapshots of the FGD.
Photograph by author.

APPENDIX B: THE LIST OF THE COLLECTED DATA:

Table 0-1. Primary and secondary data collections.

List of used data	Data type	Year	Source
Overview of zoning plan for Stadsveld-Pathmos neighbourhoods	PDF	2009	Municipality of Enschede
Aerial photo of the stream's trajectories	JPG	n.d	Municipality of Enschede
Stadsbeek's existing sewer system	DWG	n.d	Municipality of Enschede
Roads, Buildings, Rivers, Green space	Shapefile	n.d	ITC
WARECO Groundwater report *(Project Title: Does the construction of stream solve the groundwater problem in Enschede)*	PDF	2013	Municipality of Enschede
WARCO Groundwater report *(Report title: balancing measures)*	PDF	2013	Municipality of Enschede
Enschede water vision 2012-2015	PDF	2012	Municipality of Enschede
Overview of the water related bottlenecks in Enschede	PDF	n.d	Municipality of Enschede

APPENDIX C: SURVEY OF THE MUNICIPLAITY

Datum : 5 juli 2013
Aan : Stadsdeelcommissie West en fractiewoordvoerders
Van : Hans van Agteren
Afschrift: Patrick Welman, Hans Koning ter Heege, Huib Rietveld, Peter Dijkstra, Hendrikjan Teekens, Patrick Spijker
Onderwerp: Resultaten enquête wateroverlast Pathmos-Stadsveld

Inleiding

Om een beter beeld te krijgen van de wateroverlast in Pathmos en Stadsveld is hierover onder de woningeigenaren in mei 2013 een enquête gehouden.

Naast de inhoudelijke vragen is ook gevraagd of er interesse bestaat voor een huisbezoek van de gemeente om de situatie met betrekking tot de wateroverlast ter plekke te bekijken.

Resultaten van de enquête wateroverlast Pathmos-Stadveld

We hebben een erg hoge respons gehad op de enquête van 34 %. In totaal hebben 819 van de 2395 aangeschreven woningeigenaren deelgenomen.

Maar liefst 250 deelnemers hebben aangegeven interesse te hebben in een huisbezoek van de gemeente. Gezien dit grote aantal zullen we wel een selectie moeten maken. We zullen hierbij rekening houden met de mate van overlast, maar ook met de spreiding in het gebied. Na de bouwvakvakantie zal communicatie over de selectie en zullen deze huisbezoeken plaatsvinden.

De enquête geeft een goed beeld hoe de particuliere woningeigenaren al dan niet wateroverlast ervaren.

- Ongeveer 2/3 van de deelnemers ervaart enige vorm van wateroverlast. Van deze groep ervaart 1/3 deel al langer dan 10 jaar vochtproblemen in de woning (muren, kruipruimte en/of kelder). Dit uit zich het meest door vochtige muren.
- Een kwart van de deelnemers geeft aan weleens water in de kruipruimte te hebben. Hierbij valt op dat er onderscheid is te maken tussen wateroverlast als gevolg van hoosbuien en de overlast tijdens de winterperiode waarin over een langere periode neerslag valt. Van de mensen met water in de kruipruimte geeft een kwart aan dat dit door hoosbuien wordt veroorzaakt en de helft geeft aan dat dit bij langdurige regen het geval is. 15 % (27 deelnemers) heeft het hele jaar water in de kruipruimte.
- Wanneer maatregelen worden getroffen wordt dit voor het overgrote deel door de mensen zelf gedaan, circa 75%. Een veel toegepaste maatregel is het aanbrengen van ventilatieroosters voor de kruipruimte. Daarnaast zijn ook diverse andere maatregelen toegepast, zoals het plaatsen van een pomp of het aanbrengen van schelpen in de kruipruimte. De getroffen maatregelen werken niet of ten dele. Slechts in enkele gevallen is het vochtprobleem volledig opgelost.
- De meeste wateroverlast wordt ervaren in het noordelijk deel van het gebied. Desondanks zijn er in dit gebied ook woningeigenaren die geen wateroverlast ervaren.
- Op basis van de enquête ontstaat het beeld dat de wateroverlast in het noordwestelijke deel vooral te relateren is aan hoosbuien. De wateroverlast in het noordoostelijke deel wordt door zowel hoosbuien, als ook door langdurige regen en dus door een verhoogde grondwaterstand in met name voor en najaar veroorzaakt.

De volledige enquête is te vinden op: www.enschede.nl/enquetewateroverlas

APPENDIX D: ROLE AND FUNCTION OF THE WSUD MEASURES

Table 0-1. Role and function of the WSUD measures.
Source(Upper Parramatta River Catchment Trust, 2004).

Number	WSUD Measure	Water Quality Treatment	Flow Attenuation*	Reduction in Runoff Volume*
DS1	Vegetated Swales	H	M	L
DS2	Vegetated Filter Strips	H	M	L
DS3	Sand Filters	H	M	L
DS4	Bioretention Systems	H	M	L
DS5	Permeable Pavements	M	H	H
DS6	Infiltration Trenches	H	H	H
DS7	Infiltration Basins	H	H	H
DS8	Rainwater Tanks	L	H	H
DS9	Landscape Developments	M	M	L

Key: H – High level role; M – Medium level role; L – Low level role
* Applies to frequent events.

Table 0-2. Best Management Practices techniques
Source (Joint Steering Committee for Water Sensitive Cities, 2009).

Potable Water Demand Reduction Techniques	***Stormwater Management Techniques***
Rainwater Tanks Stormwater Harvesting and Reuse Greywater Treatment and Reuse Changing Landscape Form Water Use Education Programs Aquifer Storage and Recovery Water Quality Education Programs.	Sediment Basins Swales and Buffer Strips Bioretention Swales Bioretention Basins Sand Filters Constructed Wetlands Ponds and Lakes Infiltration Systems Aquifer Storage and Recovery Porous Pavements Retarding Basins Green Roofs/Roof Gardens Stream and Riparian Vegetation Rehabilitation