BALTIC FLOWS

D3.3 Analysis of Potential Regions for Mentoring in Urban Stormwater Management

Hamburg University of Applied Sciences (HAWH)

31st December 2014

European Commission 7th Framework Workprogramme
Regions of Knowledge, Call: REGIONS-2012-2013-1
Project no. 319923 BalticFlows
"Monitoring and management of flowing rain water in Baltic Sea catchment areas"

Table of Contents

Introduction

Background

At urban level, floods usually are caused by extreme rainfall events or rising of water bodies. This especially applies for cities located nearby water bodies. If urban stormwater events are not adequately managed, they may exert a threat to the infrastructure of the city and its economy. Thereby, reducing the resilience of urban ecosystems. The traditional way to manage urban stormwater includes the disposal of stormwater as quickly as possible to adjacent water bodies. Conventionally, stormwater may be handled by either a combined or separate sewerage system. In a combined system, wastewater and stormwater are collected in one pipe network which is sent to a wastewater treatment plant and subsequently into a water body. A separate system collects wastewater and stormwater separately in order to discharge stormwater directly to water bodies. The environmental impacts of these conventional approaches are highlighted by the degradation of riparian ecosystems which are caused by severe changes in catchment hydrology and runoff quality. Urbanization increases the variety and amount of pollutants (sediments, toxic chemicals from motor vehicles, heavy metals, organic micro-pollutants, pathogenic microorganisms etc.) carried into running and ground waters (EPA, 2014). Urbanisation also causes changes to catchment behaviour due to an increase in the impervious area and the reduction in catchment storage because waterways become channelled and piped. In urban and sub-urban areas, most of the land surface is covered by buildings, pavement and compacted landscapes with impaired drainage. These surfaces do not allow rain and snowmelt to soak into the ground. As a consequence, the volume and velocity of stormwater runoff may increase greatly (EPA, 2014). According to Marlow, et al. (2013), some of the main problems with the conventional urban stormwater management approach can be summarized as it follows:

- Reduction of groundwater infiltration
- Reduction of water infiltration and evaporation which has a negative impact on local climate (e.g. Heat Island effect)
- Risk of overflow in conventional systems may cause flooding during heavy rainfall periods. Especially in a conventional systems which receive more runoff than its design capacity.
- Conventional systems are designed to perform only under certain specific conditions

The issues highlighted above may indicate the need to shift from the conventional urban stormwater management to more sustainable solutions. Several concepts have recently been developed. Among them, Integrated Urban Water Management[1] (Coombes and Kuczera, 2002; Mitchell, 2006; Maheepala, et al., 2010; Burn, et al., 2012); Total Water Cycle Management (Chanan and Woods, 2006; Najia and Lustig, 2006; Grant, et al., 2010); Water Sensitive Urban Design[2] (Wong, 2006; Yu et al., 2012); Best Management Practice (Stahre and Urbonas, 1992). Despite the different terms used to describe more sustainable ways to manage water at urban level, three key benefits are associated to all of them: (1) a more natural water cycle; (2) enhanced water security through local source diversification; (3) resource efficiency.

Goals and objectives

The Baltic Flows project concerns rainwater monitoring and management in Baltic Sea catchment areas. This project is focused to lay the foundations for development of new capacities and policies for effective monitoring and managing the quality and quantities of rainwater. Work Package 3 of this project ("Urban Stormwater Management") is focused on decentralized urban stormwater management solutions in order to improve existing centralized systems. Those decentralized solutions are: roof stormwater detention/harvesting system (e.g. green roofs); street stormwater detention/harvesting system (e.g. permeable pavements); and green space stormwater detention/harvesting system (e.g. bioretention/bioswales). These technologies are accepted as best management practices (BMPs) for a more sustainable stormwater management practices (EPA, 2014). Since the project aim is to gather and analyse the best practices in urban stormwater management, one of its key objectives focused on evaluating the transferability of techniques by means of identifying the success factors and working principles of the best urban stormwater management practices. Therefore, the main aim of this study is to evaluate successful strategies used in the Baltic Sea Region (BSR) and other regions (countries outside BSR), and recommend which countries should be mentored.

---

[1] Integrated urban resource management

[2] This approach aims to integrate sustainable water management, practically decentralised stormwater management, into urban design.

The specific objectives of this study can be summarized as it follows:

- To evaluate and identify the key working principles of the main types of urban decentralised stormwater management systems
- To identify relevant parameters for adoption and transferability for these systems
- To analysis the transferability potential of these systems and potential mentoring regions in the European Region with a special focus on the Baltic Sea Region
- To analysis the transferability potential of these systems and potential mentoring regions at worldwide level

Methodology

Regional data for all the partner countries of the Baltic Flows project was collected from D2.1 and D3.2. In addition, a comprehensive and exhaustive desktop research was carried out to complement the data collected in these reports. Subsequently, the data was further analysed in order to identify the key working principles of the urban decentralised stormwater management practices evaluated (part I) and their transferability potential to other European and international regions (part II).

References

Burn, S., Maheepala, S., Sharma, A., 2012. Utilising integrated urban water management to assess the viability of decentralised water solutions. Water Sci. Technol. 66 (1), 113-121.

Chanan, A., Woods, P., 2006. Introducing total water cycle management in Sydney: a Kogarah council initiative. Desalination 187 (1-3), 11-16.

Coombes, P.J., Kuczera, G., 2002. Integrated urban water cycle management: moving towards system understanding. In: 2nd National Conference on Water Sensitive Urban Design.

Grant, B., Ramilo, N., Weber, T., 2010. Total water cycle management strategy for Moreton Bay regional council. BMT WBM, Brisbane, Australia.

EPA (2014). United States Environmental Protection Agency: Managing Urban Runoff. Retrieved on 13th of November 2014 from: http://water.epa.gov/polwaste/nps/urban.cfm.

Maheepala, S., Blackmore, J., Diaper, C., Moglia, M., Sharma, A., Kenway, S., 2010. Integrated Urban Water Management Planning Manual. Water Research Foundation, Denver, CO.

Marlow D. R., Moglia M., Cook S., Beale D.J.,(2013), Towards sustainable water management: A critical reassessment, Water Research 47 pp. 7150-7161.

Mitchell, V.G., 2006. Applying integrated urban water management concepts: a review of Australian experience. Environ. Manage. 37 (5), 598-605.

Najia, F., Lustig, T., 2006. On-site water recycling - a total water cycle management approach. Desalination 188 (1-3), 195-202.

Stahre P., Urbonas, B. (1992), Stormwater: Best Management Practices and Detention for Water Quality, Drainage, and CSO Management, Prentice Hall

Yu, C., Farrelly, M., Brown, R., 2012. Revealing the variables in the management of decentralised water systems in Australia. In: WSUD 2012-7th International Conference on Water Sensitive Urban Design: Building the Water Sensitive Community, Final Program and Abstract Book. Centre for Water Sensitive Cities, Melbourne, Australia.

Wong, T.H.F., 2006. Australian Runoff Quality: A Guide to Water Sensitive Urban Design.

Part I: Working Principles of Decentralised Urban Stormwater Management Systems

In this chapter, the key working principles of the three main types of decentralised urban stormwater management systems (i.e. permeable pavements, green roofs and bioretention systems) evaluated in this study will be presented. A special focus on relevant transferability factors such as hydrological performance, pollution removal performance, costs, and operation and maintenance aspects will be exerted.

1. Permeable pavements

Permeable pavements are regarded as an effective tool in managing stormwater (LLDGM, 2008). When compared to traditional, impervious asphalt, permeable pavements can reduce runoff quantity, lower runoff peak rates and delay peak flows. This is due to high surface infiltration rates (Pratt, et al., 1989; Hunt, et al., 2002; Brattebo and Booth, 2003; Bean, et al., 2007). Pavement for vehicular and pedestrian travel (i.e. street land use) has the potential to generate at least twice the impervious surface cover of buildings (EWLIDGM, 2013). The term permeable pavement describes basically three types of paved surfaces which are designed to minimize surface runoff: (1) Porous asphalt pavement[3], (2) Porous concrete[4] and (3) Modular permeable pavement.

Porous asphalt and porous concrete pavements are similar to conventional pavements but the sand and finer fractions of the aggregate are left out of the pavement mix. In addition, the pavement is generally placed on top of a layer of granular base. The gravel may provide 20-30% of its space as temporary storage for stormwater. In some cases, open joint tile is used to distribute stormwater through a thick gravel layer underneath the paving. A thick rock sub-base is usually provided in order to avoid the settlement of the pavement and its subsequent deterioration under the influence of water and/or frost heave (Stahre and Urbonas, 1992). Figure 1.1 illustrates the conventional configuration of porous asphalt systems.

---

[3] Consists of an open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water.
[4] Consists of specially formulated mixtures of Portland cement, uniform and open-graded coarse aggregate, and water.

Another type of permeable pavement is usually constructed alternating modular interlocking concrete block with open cells. The blocks are placed over a deep layer of coarse gravel. Porous geotextile filter fabric is then placed under the coarse granular base in order to prevent the underlying soils for migrating into the granular base. The voids of the pavers are subsequently filled with sand, gravel or sod. According to Whipple (1982), modular interlocking concrete block systems generally include:

- Poured-in-place reinforced concrete paving units. These are precast and placed on the ground and covered with special forms which are used to shape the voids.
- Precast concrete grids units. These are precast and placed on the ground. Two type are common (see Figure 1.2):
  - Lattice pavers: Generally flat/grid-like in surface configuration. The exposed paved surface is continuous and more than 50% of the finished area is exposed.
  - Castellated pavers: A pedestal type of surface configuration. The pedestals or "*merlons*" are exposed but surrounded by pervious material, usually sod. Only about 25% of the surface is exposed concrete.

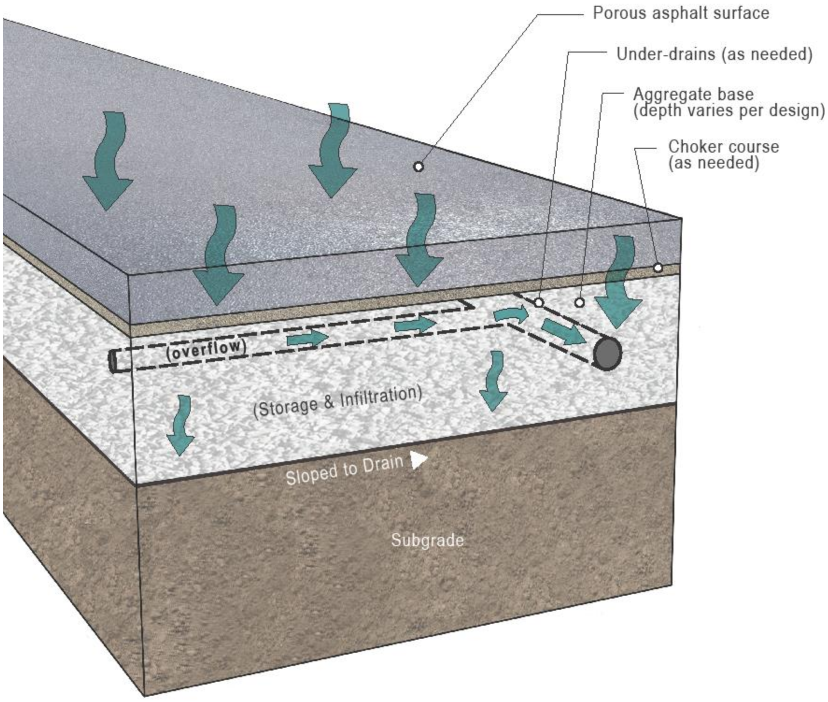

Figure 1.1: Typical porous asphalt system configuration. Source: (PSBMM, 2006)

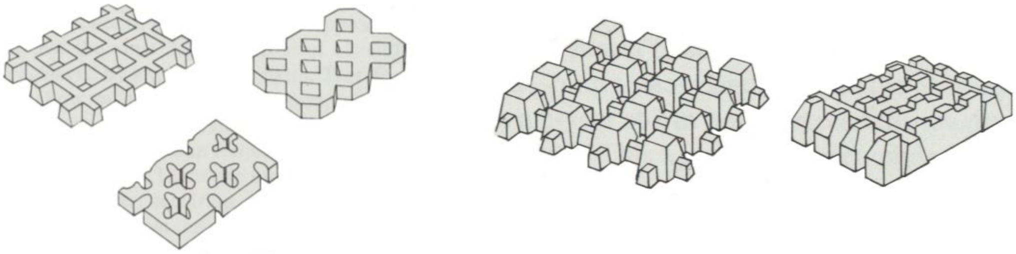

Figure 1.2: Typical Modular permeable pavement design: lattice type (left) and castellated type (right). Source: Whipple (1982)

Figure 1.3: Typical street view of modular permeable pavement. Source: Whipple (1982)

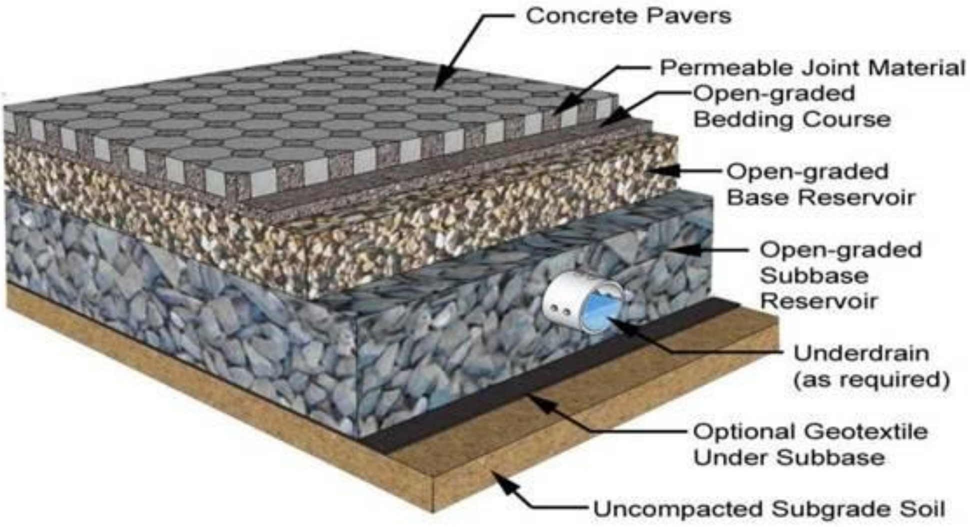

Figure 1.4: Typical cross section of modular permeable pavement system. Source: Smith, 2006

1.1 Advantages

According to EPA (1999); Legret, et al. (1999); Dreelin, et al. (2006); Shackel & Pearson (2006) and Roseen, et al. (2012), the main advantages of porous pavements are highlighted as it follows:

- Potential recharge of local aquifers
- Water protection by active pollution removal
- Improvement of water quality by preventing pollutants to enter water bodies
- Improvement of the frictional resistance of wet pavements
- Reduction of hydroplaning
- Reduction of splash and spray
- Reduction of night-time glare
- Improvement of the marking visibility of the pavement during night-time
- Reduction of the pavement noise
- Improvement of road safety because of better skid resistance

1.2 Disadvantages

According to Van Heystraeten & Moraux, (1990); Köster (1991); Daines, 1992; Stahre and Urbonas (1992); JPC (1994); Nicholls (1996); Dierkes & Geiger (1999); EPA (1999); Legret, et al. (1999) and SN (2001), the main disadvantages of porous pavements are listed below.

- The pavement is usually not applicable for high-traffic areas or for use of heavy vehicles
- The use may be restricted in cold regions and arid regions, and on top of sole-source aquifers[5].
- The use of porous pavement requires deep permeable soils
- Porous pavement has a tendency to become clogged if improperly installed or maintained
- Many pavement engineers and contractors lack expertise with this technology
- Risk of contaminating groundwater
- Lower thermal conductivity
- Potential long-term soil pollution with heavy metal and mineral oil

---

[5] An aquifer that supplies at least 50% of the drinking water consumed in the area overlying the aquifer. These areas may have no alternative drinking water source(s) that could physically, legally and economically supply all those who depend on the aquifer for drinking water. For convenience, all designated sole or principal source aquifers are referred to as "sole source aquifers" (SSAs).

- Shorter life span compared to impermeable pavement

1.3 Hydrological performance

The hydrological performance is generally accepted to be high (see table 1.1).

Table1.1: Hydrological Performance

Runoff volume reduction	Place	Reference
50–81% (Annual)	Sweden	(Stenmark, 1995)
97%(Annual)	Reze, France	(Legret and Colandini, 1999)
100%(Annual)	Pennsylvania, USA	(Dempsey and Swisher, 2003)
70% - 80%(Annual)	Massachusetts, USA	(GoM, 2014)
55%	Laboratory conditions	(Andersen *et al.,* 1999)
70%	Laboratory conditions	(Pratt *et al.*, 1989)
Mean: 75%		

1.4 Pollution removal performance

The pollution removal performance is generally accepted to be medium to high (see table 1.2).

Table1.2: Pollution Removal Performance

Parameters	Removal rate	Comments	Reference
Total Suspended Solids (TSS)	95%	First year; Water-quality treatment performance of snowmelt	(Hogland et al., 1987)

	82-95%	Two long-term monitoring studies conducted in Rockville, MD, and Prince William, VA in	(EPA, 1999)
	64-79%	Rezé, France; from 30 rainfall events	(Legret et al., 1996)
	Up to 80%	Two sites in Bordeaux, France	(Baladès et al., 1995)
Nitrates	1,000.3% Increased	From 0.37 to 4.3 mg/L; Nitrate increases were attributed to the presence of residual fertilizers, decomposition of organic materials, and to nutrient leaching from the asphalt itself.	(Hogland et al., 1987)
Total Nitrogen (TN)	43% Increased		(Dreelin et al., 2006)
	80-85%	Two long-term monitoring studies conducted in Rockville, MD, and Prince William, VA in	(EPA, 1999)
Zinc	17%		(Hogland et al., 1987) (Dreelin et al., 2006)
Lead	79%		(Legret et al., 1996)
	90-95%	Two sites in Bordeaux, France	(Baladès et al., 1995)
Copper and Cadmium	57-85%		(Legret and Colandini, 1999)
Chemical Oxygen Demand (COD)	80-90%	Two sites in Bordeaux, France	(Baladès et al., 1995)

Total Phosphorous (TP)	80%		(Dreelin et al., 2006)
	65%	Two long-term monitoring studies conducted in Rockville, MD, and Prince William, VA in USA	(EPA, 1999)
Chloride	650% Increased	From 8 mg/L to 60 mg/L, Chloride increased, presumably because of winter de-icing operations.	(Hogland et al., 1987)

1.5 Operation and maintenance

According to EPA (1999) and FHWA (2000), the adequate implementation of the system requires high technical skills. In addition, the systems also requires high maintenance requirements. In this line, maintenance should include vacuum sweeping (see Fig. 1.5) at least four times a year (with proper disposal of removed material), followed by high-pressure hosing to avoid clogging. Also, the pavement should be inspected several times during the first few months following installation and annually thereafter. Annual inspections should take place after storm events.

Figure1.5: Vacuum Sweeper Service for Permeable Pavement. Source: FHWA (2000)

1.6 Cost considerations

Porous pavements have higher initial capital costs as compared to conventional impermeable pavements. However, their overall costs may actually be lower if the additional cost associated to drainage infrastructures (curb, catch basins, piping, and ponds) for conventional systems are considered (UNHSC, 2012). Several examples of the financial costs related to the implementation of porous pavements are highlighted:

- Germany: 10 - 18 EUR/m^2 (Gartenbau, 2012)
- USA: 6 – 108 USD/m^2 (4,82-86,76 EUR/m^2) (VDCR, 2011); 17,8 – 107,4 USD/m^2 (14,30-86,28 EUR/m^2) (Thurston, 2012); USD 30,14/m^2 (24,21 EUR/m^2) for porous asphalt pavement compared to USD 24,22/m^2 for standard asphalt (UNHSC, 2012)

Operational costs

According to EPA (1999), the annual average costs for porous pavements are approximately USD 4.94 (EUR 3,97) per hectare and year. This cost includes four inspections per year with jet hosing and vacuum sweeping treatments.

1.7 Technical recommendations

Porous pavements are especially suited for roads with low traffic and light vehicles (i.e. residential driveways, parking areas sidewalks, etc.). Even though it is generally reported high to medium hydrological performance, the filtration and water holding capacity of these systems may depend on site conditions, the intensity of stormwater and maintenance practices. EPA (1999) has reported that this type of technology may have high potential risk of failure.

Special operational considerations are required for cold climates if adequate durability and performance are to be expected (Kuosa and Holt, 2014). In addition, permeable pavement technology is not usually recommended in arid regions (i.e. high wind erosion). This is because dust and small particles tend to clog the pores of the system. Even though porous pavements may help to recharge groundwater, these systems may also have the potential to pollute groundwater and/or the soil because of leakage of toxic chemicals from the road. Even though these systems may be expected to present a relative high pollution removal performance, the actual effectivity may depend on adequate operational and maintenance practices. In addition, a drainage system may be required at the bottom of the permeable section (see Fig. 1.1 and 1.4) in order to control pollution and increase the life-span of the system.

The factors presented in this section may suggest that these systems have a high potential for a multifunctional application inside the city. Modular concrete block pavements show a better performance under all climate conditions (Stahre and Urbonas, 1992).

1.8 Potential in the Baltic Sea Region

In Germany, porous pavements have recently been implemented with increasing frequency. Van Diemen (2009) states that 18.000.000 m^2 of porous pavement were installed per year, which is more than any other country in the world. In addition, a parking area in Hanover is one of the largest porous pavement systems in the world. This system allows the majority of water to infiltrate and be stored in the sub-surface soil while excess water flows through a rubble filled swale trench system (van Diemen, 2009).Porous pavements are also commonly used in Sweden to reduce runoff to sewer systems, reducing overflow frequency and volumes. European legislation encourages the implementation of infiltration-based stormwater management systems, being porous pavement system a particular type of these systems.

1.9 References

Andersen, C.T, Foster, I.D.L., and Pratt, C.J. (1999), Role of urban surfaces (permeable pavements) in regulating drainage and evaporation: Development of a laboratory simulation experiment. *Hydrological Processes* 13(4): 597.

Baladès, J. D., Legret, M., and Madiec, H. (1995). “Permeable pavement: Pollution management tools.” Water Sci. Technol., 32(1), 49–56.

Bean, E. Z., Hunt, W.F., and Bidelspach, D.A. (2007). Field survey of permeable pavement surface infiltration rates*. Journal of Irrigation and Drainage Engineering*. 133 (3): 247-255.

Brattebo, B. O., and Booth, D. B. (2003). Long-term stormwater quantity and quality performance of permeablepavement systems. *Water Research* 37(18): 4369-4376.

Daines M.E. (1992), Trials of porous asphalt and rolled asphalt on the A38 at Burton, Department of transport TRRL Report RR323, Transport and Road research Laboratory, Crowthorne.

Dempsey, B. A., and Swisher, D. M. (2003). “Evaluation of porous pavement and infiltration in Centre County, PA.” World Water & Environmental Resources Congress, ASCE, Reston, VA.

Dierkes, C. and Geiger, W.F. (1999), “Pollution retention capabilities of roadside soils”, Innovative technologies in Urban Storm Drainage 1998 (Novatech '98) Selected Proceedings of the 3rd NOVATECH Conference on Innovative Technologies in Urban Storm Drainage, Vol. 39 No. 2, pp. 201–208.

Dreelin, E. A., Fowler, L., and Carroll, C. R. (2006). “A test of porous pavement effectiveness on clay soils during natural storm events.”Water Res., 40(4), 799–805.

EPA (1999). Environmental Protection Agency: Storm Water Technology. Fact Sheet Porous Pavement.

Eastern Washington low impact development guidance manual (EWLIDGM). 2013.

FHWA, 2000. Stormwater Best Management Practices in an Ultra-urban Setting: Selection and Monitoring.

Gartenbau (2012), “Wasserdurchlässige Pflastersteine lohnen sich für Natur und Geldbeutel”, available at: http://www.gartenbau.org/wasserdurchlaessige-pflastersteine 20124901 (accessed 30 October 2014).

GoM, 2014: Massachusetts Low Impact Development Toolkit—Fact Sheet #6 Permeable Paving. Metropolitan Area Planning Council. At http://www.mapc.org/sites/default/files/LID_Fact_Sheet_-_Permeable_Paving.pdf. Accessed September 2014.

Hogland, W., Niemczynowicz, J., and Wajlman, T. (1987). “The unit superstructure during the construction period.” Sci. Total Environ., 59, 411–424.

Hunt, B., Stevens, S., and Mayes, D. (2002). Permeable pavement use and research at two sites in Eastern North Carolina. Proc. *9th* Int. Conf. on Urban Drainage, G*lobal Solutions for Urban Drainage*. ASCE, Portland, Oregon, USA.

JPC (1994): Japan Highway Public Corporation, Design and Execution Manual for Porous Asphalt; Haisuiseihosou Sekkei Sekou Manual, Tokyo, 1994.

Köster H. (1991), Drainasphalt Beobachtungen des Verhaltens von hohlraumreichen Verschliessschichten unter Verkehr, Observation of the behavior of porous asphalt under traffic, 1991 VSS report Nr. 218.

Kuosa, H. and Holt, E. (2014), *Development of Durable Pervious Concrete for Finland’s Stormwater Management Needs*, Concrete Innovation Conference 2014, Oslo, Norway.

Legret, M., and Colandini, V. (1999). “Effects of a porous pavement with reservoir structure on runoff water: water quality and fate of heavy metals.” Water Sci. Technol., 39(2), 111–117.

Legret, M., Colandini, V., and LeMarc, C. (1996). “Effects of a porous pavement with reservoir structure on the quality of runoff water and soil.” Sci. Total Environ., 190, 335–340.

Legret, M., Nicollet, M., Miloda, P., Colandini, V., and Raimbault, G. (1999). “Simulation of heavy metal pollution from storm-water infiltration through a porous pavement with reservoir structure.” Water Sci. Technol., 39(2), 119–125.

LLDGM (2008): Low impact development for urban ecosystem and habitat protection guidance manual. America Society of Civil Engineers. International Low Impact Development Conference 2008 Seattle, Washington, United States. November 16-19, 2008.

Nicholls J.C (1996), Review of UK porous asphalt trials, TRL Report 264, Transport Research Laboratory, Crowthorne, 1996.

PSBMM, 2006: Pennsylvania Stormwater Best Management Manual December 363-0300-002 / December 30, 2006.

Pratt, C. J.; Mantle, J.D.G.; and Schofield, P.A. (1989), Urban stormwater reduction and quality improvement through the use of permeable pavements, *Water Science and Technology,* 21(8): 769-778.

Roseen R. M., Ballestero T. P., Houle J. J., Briggs J. F., Houle K. M.(2012), Water Quality and Hydrologic Performance of a Porous Asphalt Pavement as a Storm-Water Treatment Strategy in a Cold Climate, Journal of Environmental Engineering, pp.81-89.

Shackel, B. and Pearson, A. (2006), *Technologies and Opportunities for permeable segmental planning in Australia*, University of New South Wales, Australia.

Smith, D. 2006. *Permeable Interlocking Concrete Pavement-selection design, construction and maintenance. Third Edition*. Interlocking Concrete Pavement Institute. Herndon, VA.

SN (2001): Drainasphaltschichten, Konzeption Anforderung, Ausführung, Januar 2001. Swiss Standards for porous asphalt.

Stahre, P.; Urbonas, B. (1992). Stormwater: Best Management Practices and Detention for Water Quality, Drainage, and CSO Management, Prentice Hall; 2 Sub-edition.

Stenmark, C. (1995). “An alternative road construction for stormwater management in cold climates.” Water Sci. Technol., 32(1), 79–84.

Thurston, H.W. (2012), Economic incentives for stormwater control, Ecological economics, CRC Press, Boca Raton, FL.

UNHSC (2012), “University of New Hampshire Stormwater Center”, 2012 Biennial Report, available at:http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/docs/UNHSC.2012Report.10.10.12.pdf (accessed 12 November 2014).

Van Diemen, N. (2009), “Permeable Paving Systems”, available at: http://issinstitute.org.au/wp-content/media/2011/04/ISS-FEL-REPORT-van-Diemen-Low-Res.pdf (accessed 7 November 2014).

Van Heystraeten G and Moraux C. (1990), Ten Years' Experience of porous Asphalt in Belgium, Transportation Research Record 1265, pp. 34-40.

VDCR (2011). Virginia DCR Stormwater Design Specification No 7: At http://vwrrc.vt.edu/swc/NonPBMPSpecsMarch11/VASWMBMPSpec7PERMEABLEPAVEMENT.html. Accessed on July 2014.

Whipple (1982). Stormwater Management in Urbanizing Areas, Prentice Hall. First Edition edition (September 1982). 234 pp.

2. Working Principles of Green Roof Technology

Stormwater runoff from building roofs in urban areas generally has a significant impact on sewerage-derived flooding and urban water quality problems. In most cities of high-income economies, building roofs may account for approximately 40–50% of the impervious surface areas of cities. Green roofs incorporate vegetation into the design of roofing systems. They have been suggested as an effective method in order to reduce the area of impervious surface in a city (Scholz-Barth, 2001). Therefore, these types of technology may reduce the volume of runoff from building roofs and contribute to a more efficient stormwater management (Stovin, et al., 2012). Green roof systems are one of the BMPs for new construction and modernising existing building structures. There are very good experiences and a well-established industry in Germany (Oberndorfer, et al. 2007; Köhler, et al. 2002). In addition, there are comprehensive guidelines for planning, construction and maintenance of green roofing in Germany.

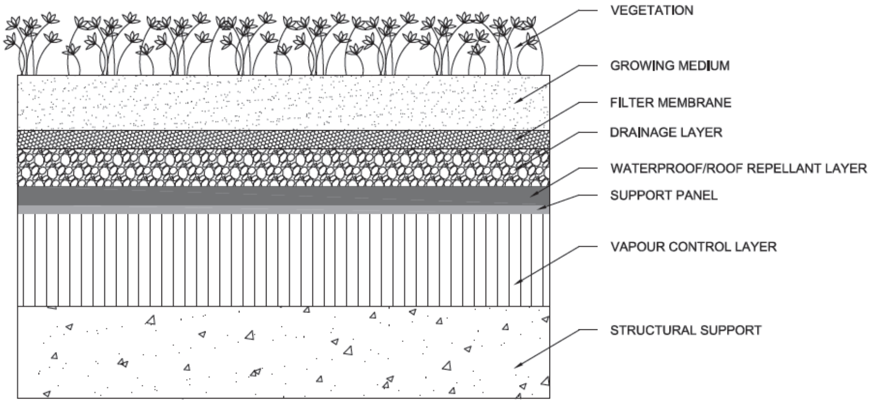

Figure 1.6: Schematic composition of green roof systems. Source: NRC, 2008

A green roof (also known as rooftop garden, vegetated roof or eco-roof) is a vegetative layer[6] which is grown on the top of a new or existing building roof. Figure 1.6 illustrates the schematic composition of green roof systems. There are four main types of green roofs: extensive, intensive, semi-intensive and elevated landscape.

---

[6] Includes a series of layers consisting of vegetation

The primary difference between the four types is the depth of the substrate, which has a direct effect on the runoff holding capacity of each system (GoSA, 2010):

- **Extensive roofs** are typically light systems with a low prostrate vegetation. These type of roofs are inaccessible and generally have between 50-150 millimetres of substrate depth.
- **Intensive roofs** have a substrate depth higher than 150 millimetres. They are usually accessible and provide good insulation properties.
- **Semi-intensive roofs** combine the best features of extensive and intensive roofs. They are partially accessible and have greater plant diversity. The depth of the substrate is about 150 millimetres.
- **Elevated landscape roofs** have at least 600 mm substrate depth and create a new ground plane.

2.1 Advantages

According to Liu & Baskaran (2003); Oberndorfer, et al. (2007); Santamouris, et al. (2007); Yang, et al. (2008); Molineux, et al. (2009); Berndtsson (2010); Currie and Bass (2010) and GoSA (2010), some of the main advantages of green roofs can be highlighted as it follows:

- Reduction of the runoff velocity during storm events
- Vegetation may act as a bio-filter in order to reduce the pollutants from the rainfall
- Reduction of the heat island effect
- Increase in the evapotranspiration
- Increase in the exchange of carbon dioxide/oxygen
- Reduction of the energy required for air conditioning
- Improvement of the air quality
- Replacement of displaced landscape
- Enhancement of biodiversity
- Reduction of the urban impervious surface
- Provision of recreational and agricultural spaces
- Sound insulation

2.2 Disadvantages

According to MSSC (2006) and GoSA (2010), there are two key disadvantages with regard to green roofs:

- Roof must be structurally capable of supporting the load of saturated soils
- Leakage for the roof can cause structural damage in buildings

2.3 Hydrological performance

There are several factors which may affect the hydrological performance of green roofs. These include the intensity of precipitation, slope, thickness and porosity of the soil medium, green roof age and level of vegetation coverage. Table 1.3 summarises the hydrological performance of green roof systems.

Table 1.3: Hydrological performance of green roofs

Performance	Comments	Reference
Up to 86%	Lightweight aggregate (LWA)	(Teemusk and Mander, 2007)
Limited capacity	Heavy rain storm	
38-54%	Depth of 8 cm	(Miller, 1998)
40%	Depth of 6.5 cm; 50-mm storm	(Scholz-Barth, 2001)
60 to 80%	Depth between 5 and 12 cm	(Köhler, et al. 2002)
64%		(Bengtsson, 2005), (Villarreal, 2007)

2.3.1 Effects of slope on hydrological performance

In Germany, Schade (2000) and Liesecke (1998) found no significant differences in retention across roofs with different slopes. However, other studies suggest that a higher slope causes a higher runoff (Villarreal, et al. 2004, Van Woert, et al., 2005). The discrepancies in these results may be caused by differences in the rainfall patterns. Van Woert, et al. (2205) investigated the influence of the rooftop slope on retention, as a function of the rainfall intensity. These authors found that during intense storm events, green roofs built on 2%-slopes retained the same quantity of rain than 6.5%-slopes (80%). However, during light rainfall events, 2%-slopes showed a higher performance.

2.3.2 Aging effects on hydrological performance

The vegetated substrate of green roofs undergoes various chemical and physical changes with time: soil particles may be lost, dissolvable substances may be washed away, organic content may increase and the porosity of the soil may change due to the development of roots. Therefore, it has been suggested that the age of green roofs may influence runoff dynamics (Berndtsson, 2010). Getter, et al. (2007) compared the organic matter content and physical properties of the soil in a 5-year old green roof. These authors found that the organic matter content and pore space doubled in that time period (from 2% to 4% and from 41% to 82%, respectively). The water holding capacity increased from 17% to 67%. However, Mentens, et al. (2006) found that the age of a green roof is not significantly correlated with annual runoff.

2.3.3 Season and weather effects on hydrological performance

The water retention capacity associated to green roofs is seasonal. Warmer temperatures may result in higher evapotranspiration and a higher regeneration capacity of the green roof system (Mentens, et al., 2006; Villarreal, 2007). Mentens, et al. (2006), showed that when three seasons were defined (i.e. warm, cold and in-between), no relationship was found between runoff and substrate depth for cold and in-between seasons. However, for the warm season, each 1-cm of substrate depth resulted in runoff reduction by additional 2,5 mm (Mentens et al., 2006). Villarreal and Bengtsson (2005) showed that weather conditions (dry or wet) affected the retention capacity of green roofs. This meant that whereas for dry conditions 6 to12 mm of rain were required in order to initiate runoff; for wet conditions the response was almost immediate. Teemusk and Mander (2007) studied the runoff of green roofs in winter conditions during snow melting and distinguished two melting periods: the melting of the snow cover (which took 1 day) and the melting of the frozen water in the substrate layer (which took 12 days). It has been suggested that more research is required in order to be able to quantify the performance of green roofs during the cold season.

2.3.4 Effects of type of vegetation cover on hydrological performance

The specific type of plants affects the performance of green roofs, with a variety of species significantly reducing runoff as compared to monoculture vegetation. Sedum is the commonly used plant for green roofs due to its higher survival rate on a roof top in harsh conditions (Villarreal and Bengtsson, 2005).

2.4 Pollutant removal performance in runoff

Table 1.4 shows the pollution removal performance for green roofs. According to Berndtsson (2010), the factors which may potentially influence the quality of runoff from roofs can be summarised as it follows:

- Type of green roofs materials
- Soil thickness
- Type of drainage
- Chemicals used for the maintenance
- Type of vegetation and season
- Dynamics of precipitation
- Wind direction
- Local pollution sources
- The chemical properties of pollutants

Table 1.4: Pollution removal performance of green roof system

Type of pollution	Performance	Comments	References
Phosphorus	26%, - 80%		(Köhler et al. 2002)
Nitrogen	-	Organic nitrogen may be released from vegetated roofs	(Berndtsson, et al., 2006)
	-	Increase of total Nitrogen in green roof runoff	(Teemusk and Mander, 2007); (Moran, et al., 2005)
Heavy metals	99% Pb, Zn, and Cu and 98% of Cd	semi-intensive systems	(Berndtsson et al., 2009)

	97% Cu, 96% Zn, 92% Cd and 99% Pb	Warm temperatures, extensive systems	(Berndtsson et al., 2009)
	68% Cu, 92% Zn, 88% Cd 94% Pb	Cold temperatures, semi-intensive roofs	
	44% Cu, 72% Zn, 62% Cd and 91% Pb	Cold temperatures, extensive roofs	
	61% of Cr, 24% of Mn, 93% of Pb, and 8% of Zn		(Berndtsson et al., 2006)

2.5 Energy performance

Derek (2007) states that green roofs may contribute to the insulation and energy efficiency of the building because they can trap air within the vegetation mass. This author also states that in this way the surface of the building can be cooled-up in summer time and warmed-up in winter time. In addition, vegetation of green roofs may act as a cooling agent by means of dissipating a portion of the heat of city via evapotranspiration. Thus, it has been argued that green roofs may alleviate the urban heat island effect. Peck, et al. (1999) stated that green roofs were able to reduce solar radiation by 90% as compared with conventional types of buildings. In addition, indoor temperatures for green roof's buildings were reported to be 3-4ºC lower as compared to outdoor temperature (Peck, et al., 1999). Currie and Bass (2010) showed that 6% green roof coverage over 10 years could result in a reduction of 1°C of the urban heat island effect in Toronto.

2.6 Operation and maintenance

According to GoSA, 2010 and GoM (2014), the main important aspects with regard to operation and maintenance can be summarized as it follows:

- High technical complexity
- Low maintenance requirements: Water for the weeding and soil fertilisation
- Regular irrigation in dry climates

2.7 Cost considerations

According to EFBGR (2014), the main factors related to the economic costs are as it follows:

- **Extended roof life:** Doubles roof life expectancy to last up to 60 years
- **Fuel Savings:** Green roofs have a positive effect in terms of thermal insulation through their ability to cool buildings and insulate them during the winter (dependent on daily conductance of the green roof)
- **Reduction in drainage costs**: Green roof installation could reduce the number of drainage outlets
- **Cost savings through the reuse of secondary aggregates:** The reuse of local or secondary aggregates can provide a cost saving during the construction of the roofs

Installation costs

The use of green roofs in Germany is widespread and has been promoted in many cities through financial incentives (Pedersen, 2001). Economies of scale, contractor experience, and specialized equipment have reduced the cost of installing a green roof in Germany and throughout Europe. In contrast, installing a green roof in the United States can be very expensive, adding from at least USD 6/ft^2 (USD 65/m^2), to more than USD 30-USD 40/ft^2 (USD 320-USD 430/m^2), to the cost of the roof. Therefore, high initial investment costs are required. However, these may be compensated with savings on energy. Some other reported investment costs in the literatures are listed as it follows:

- In Germany: extensive green roofs cost EUR 25-35/m^2
- In USA: USD 108 – USD 269 / m^2 ; USD 62,9 –USD 449/m^2 with lifetime of 50 years (Thurston, 2012)

2.8 Technical recommendations

This technology may be used for managing the rainfall of a significant share of the impervious surface area of the city. In addition, many environmental benefits such as a reduction of the heat island effects, air quality improvements, and building isolation are among the key additional benefits of this type of technology. If long-term benefits are considered, green roofs may have more desirable costs than conventional ones. However, higher investment costs can be considered as a limiting factor for applications in the absence of incentives.

Green roofs have a limited capacity for managing stormwater. The capacity of this system actually depend on several factors such as the type of growth media (i.e. intensive, semi-intensive, extensive and elevated landscape), roof slope, age of vegetation, weather and season, and type of vegetation cover. Due to the limited capacity of this system, runoff should be expected after the saturation of the system. In addition, green roofs may be a source of pollution especially for Nitrogen and Phosphorous. The performance for pollution removal depends on several factors such as precipitation, and maintenance and operation procedures. Heavy metal removal shows better performance with warmer temperatures.

Green roofs should be used as a supplementary stormwater management technology because of their limited carrying capacity. This technology can be useful to improve environmental conditions inside cities and mitigate the peak of storm events. This could actually be considered as a strategic advantage for conventional sewerage systems in terms of flooding prevention.

2.9 Potential in the Baltic Sea Region

Green roofs are especially common in Germany in the Baltic Sea Region. Germany is considered as the origin of modern day green roofs and the green roof industry is growing 10 to 15% annually (Getter, et al. 2007). An estimated 14% of all flat-roofed buildings in Germany are covered with green roofs (Köhler, et al. 2002). Germany is one of the three countries that established the European Federation of Green Associations, the other countries being Austria and Switzerland. The association currently consists of 10 member associations (EFBGR, 2014). In 2015 there will be a plan in Hamburg to cover at least 70% of newly constructed flats or low-pitched roofs with green roofs according to the city’s new green roof strategy. Also, direct financial incentives will be available for voluntary construction of green roofs which covers up to 50% of the total costs. Specific values for the different types of technologies are as it follows: intensive green roofing up to EUR 40/m², for simple-intensive green roofs up to EUR 20/m², and for extensive roofs up to EUR 15/m². Moreover, taxes associated to stormwater will be reduced by 50%.

2.10 References

Bengtsson, L., 2005. Peak flows from thin sedum-moss roof. Nordic Hydrol. 36 (3), 269–280.

Berndtsson, J.C., Bengtsson, L., Jinno, K., 2009. Runoff water quality from intensive and extensive vegetated roofs. Ecol. Eng. 30, 271–277.

Berndtsson, J.C, Emilsson, T., Bengtsson, L., 2006. The influence of extensive vegetated roofs on runoff quality. Sci. Total Environ. 355 (1–3), 48–63.

Berndtsson J.C, 2010; Green roof performance towards management of runoff water quantity and quality: A review; Ecological Engineering 36, 351–360.

Currie B., Bass B. Using green roofs to enhance biodiversity in the city of Toronto. Discussion paper for Toronto City Planning. Toronto 2010.

Derek Townshend. (2007). Study on Green Roof Application in Hong Kong, Final Report, pp 77-81, 100-104.

EFBGR (2014): European Federation of Green Roof Associations. At http://www.efb-greenroof.eu/. Accessed on July 2014.

EPA, 2007: US Environmental Protection Agency. Green Roofs. Heat Island Effect. At http://www.epa.gov/heatisland/mitigation/greenroofs.htm. Accessed on July 2014

Getter, K.L., Rowe, D.B., Andresen, J.A., 2007. Quantifying the effect of slope on extensive green roof stormwater retention. Ecol. Eng. 31, 225–231.

GoSA, 2010: Government of Southern Australia. Department of Planning and Local Government, 2010, Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region, Government of South Australia, Adelaide.

Köhler, M., Schmidt, M., Grimme, F.W., Laar, M., de Assunc¸ ão Paiva, V.L., Tavares, S., 2002. Green roofs in temperate climates and in the hot-humid tropics – far beyond the aesthetics. Environ. Manage. Health 13 (4), 382–391.

Liesecke HJ. Das retentionsvermögen von dachbegrünungen. Stadt Grün 1998;47:46-53.

Liu, K. and B. Baskaran. 2003. Thermal Performance of Green Roofs Through Field Evaluation. National Research Council of Canada. Report No. NRCC-46412.

Mentens, J., Raes, D., Hermy, M., 2006. Green roofs as a tool for solving the rainwater runoff problem in the urbanised 21st century. Landscape Urban Plan. 77, 217–226.

Miller, C. 1998. Vegetated Roof Covers: A new method for controlling runoff in urbanized areas. Proceedings: Pennsylvania Stormwater Management Symposium. Villanova University. Villanova, PA.

MSSC, 2006: Minnesota Stormwater Steering Committee (MSSC). Minnesota Stormwater Manual: Version 1.1. Available at: www.pca.state. mn.us/water/stormwater/stormwater-manual.html.

Molineux CJ, Fentiman CH, Gange AC. Characterising alternative recycled waste materials for use as green roof growing media in the U.K. Ecol Eng 2009;35(10):1507-13.

Moran, A., Hunt, B., Smith, J., 2005. Hydrological and water quality performance from greenroofs in Goldsboro and Raleigh, North Carolina. In: Green Roofs for Healthy Cities Conference, May 2005, Washington, DC.

NRC, 2008: National Research Council, Institute for Research in Construction. Principal Green Roof Technology. At *http://www.greenroofs.org/index.php?option=com_content&task=view&id=26&Itemid=40*.

Oberndorfer E, Lundholm J, Bass B, Coffman R, Doshi H, Dunnett N, et al. Green roofs as urban ecosystems: ecological structures, functions and services. BioScience 2007;57:823-33.

Peck, S.W., C. Callaghan, M.E. Kuhn., B. Bass. (1999). Greenbacks from Green RoofsL Forging a New Industry in Canada. Canada Mortgage and Housing Corporation, Ottawa, Canada.

Pedersen, K. 2001. Meadows in the sky: Contemporary applications for eco-roofs in the Vancouver Region. MS thesis. Vancouver, BC.: University of British Columbia,UBC School of Architecture.

Santamouris M, Pavlou C, Doukas P, Mihalakakou G, Synnefa A, Hatzibiros A, et al. Investigating and analysing the energy and environmental performance of an experimental green roof system installed in a nursery school building in Athens, Greece. Energy 2007;32(9):1781-8.

Schade C. Wasserrückhaltung und Abflußbeiwerte bei dünnschichtigen extensivbegrünungen. Stadt Grün 2000;49:95-100.

Scholz-Barth, K. 2001. Green roofs: Stormwater management from the top down. Environmental Design and Construction. January/February.

Stovin V., Vesuviano G., Kasmin H., The hydrological performance of a green roof test bed under UK climatic conditions, Journal of Hydrology 414–415 (2012) 148–161.

Teemusk, A., Mander, Ü., 2007. Rainwater runoff quantity and quality performance from a green roof: the effects of short-term events. Ecol. Eng. 30, 271–277.

Van Woert ND, Rowe DB, Andresen JA, Rugh CL, Fernandez RT, Xiao L. Green roof storm water retention: effects of roof surface, slope and media depth. J Environ Qual 2005;34(3):1036-44.

Villarreal EL, Semadeni-Davies A, Bengtsson L. Inner city storm water control using a combination of best management practices. Ecol Eng 2004;22 (4-5):279-98

Villarreal, E.L., Bengtsson, L., 2005. Response of a sedum green-roof to individual rain events. Ecol. Eng. 25, 1–7.

Villarreal, E., 2007. Runoff detention effect of a sedum green roof. Nordic Hydrol. 38 (1), 99–105.

Yang J, Yu Q, Gong P. Quantifying air pollution removal by green roofs in Chicago. Atmos Environ 2008;42(31):7266-73.

3. Working Principles of Bioretention Systems

Bioretention systems, also known as biofilters or rain gardens, are the most widely used stormwater practice in the USA (Davis, et al., 2009). These systems are widely promoted and used elsewhere for green space areas (Fujita, 1997; Wong, 2006; Woods-Ballard, et al., 2007). Bioretention systems consist of small areas which are excavated and backfilled with a mixture of soil of high-permeability soil and organic matter. Bioretention systems are designed to maximize infiltration and vegetative growth, and are usually covered with endogenous vegetation. The vegetation is selected to be resistant to environmental stresses and, depending on the size of the bioretention facility, they can range from small plants/shrubs to large trees. A layer of mulch is often added to cover the soil media and retain solids. An inlet structure is generally created in order to collect urban runoff from the surrounding area and transport it to the unit while an overflow structure bypasses flows above the ponding capacity of the unit. In regions having endogenous soils of low permeability, a subsurface structure to drain water can be installed at the bottom of the facility in order to prevent stagnant water for extended periods of time. Bioswales are a specific type of bioretention system. Figure 1.8 shows a cross-section of a typical bioretention system.

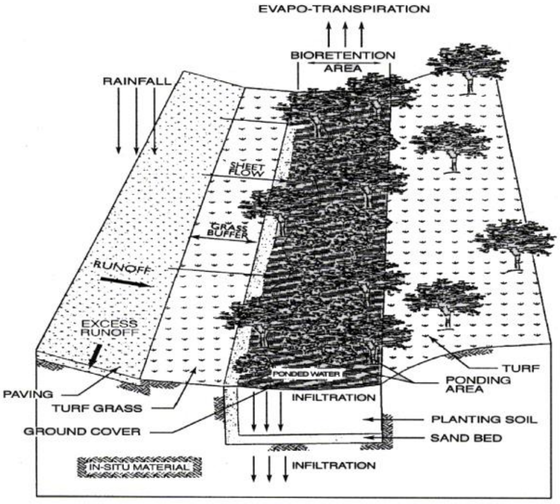

Figure 1.8: Typical schemes of Bioretention System. Source: (PGDER, 1993)

3.1 Advantages

Bioretention systems can be used in a wide variety of environments because the bioretention vegetation generally have a high tolerance to different hydrologic regimes (Coffman, et al. 1993$_b$). Another advantage of bioretention systems is their ability to significantly reduce stormwater volumes through infiltration and evapotranspiration[7]. The system can thus be used in urban areas to counteract the increase in the volume of stormwater which is generally associated to urban development. During dry periods, bioretention green spaces can be used for recreation. The key advantages of these systems include:

- Promotion of stormwater infiltration
- Reduction of pollutants
- Decrease in the peak flow rate and volume of the runoff
- Contribution to preserving base flow in streams
- Reduction of the temperature-related impacts of the runoff
- Enhancement of the quality of downstream water bodies
- Provision of shade and wind breaks
- Noise reduction
- Improvement of landscape.

3.2 Disadvantages

Bioretention systems may not be adequate in locations where the water table is higher than 1.8 m and/or where the soil stratum is unstable. In addition, the soil may freeze in cold climates. Thereby, preventing runoff from infiltrating into the soil. This type of systems are not recommended for areas with slopes higher than 20% and/or where mature tree may be required to be removed. Furthermore, clogging may pose a problem, particularly if the system receives runoff with high sediment loads (EPA, 1999). Other disadvantages for bioretention systems can include a limited capacity for heavy metal removal, a low suitability for building foundations[8] and high risk to be damaged by runoff with large amounts of salt-based deicers (Roy-Poirer, et al., 2010).

3.3 Hydrological performance

Davis (2008) stated that bioretention systems can effectively manage stormwater in urban areas. Significant reductions in stormwater volumes were reported by this author. In addition, 18% of the storm events monitored showed no outflow. The inflow was entirely captured by the bioretention

---

[7] Evapotranspiration (ET) is the sum of evaporation and plant transpiration from the Earth's land and ocean surface to the atmosphere.

8 An under-drain and impermeable liner can alleviate this problem

cells which showed reductions of the mean peak flow between 49% and 58%. Peak time was increased by an average factor between 5.8 and 7.2[9]. Hunt, et al. (2006) stated that the hydrologic performance of bioretention systems may be highly dependent on seasonal conditions. Higher outflow volume ratios are observed during cold months because the evapotranspiration rate is reduced at lower temperatures. Dietz and Clausen (2005) stated that infiltration can effectively occur in bioretention cells even under cyclical freeze-thaw soil conditions. However, further research is required to assess the behaviour of bioretention systems under frozen soil conditions.

3.4 Pollution removal performance

Table 1.5 shows the pollution removal performance associated to bioretention systems

Table 1.5: Performance of bioretention system for pollution control

		Removal rate	Comments	Reference
Nitrogen Removal (TKN)		45-80%	Aerobic conditions are required for nitrification, while ammonification can be carried out by both aerobes and anaerobes.	(Davis, et al., 2006); (Hunt et al., 2006); (Davis, et al., 1998)
Phosphorus Removal		70-85%		(Davis, et al., 2006); (Henderson, et al., 2007); (Bratieres, et al., 2008); (Davis, et al., 1998)
Ammonia removal		86%		(Hunt, et al., 2006)
Oil & Grease		96%-99%	Based on a synthetic influent oil and grease concentration of 20 mg/L	(Hsieh and Davis, 2005$_b$)
Heavy metal	Cu	36-93%	Limited capacity for heavy metal removal observed	(Glass and Bissouma, 2005); (Ermillio, 2005); (Davis, et al., 2006)
	Cd	66%		
	Zn	79%		

---

[9] Longer peaking times better mimic predevelopment hydrology in drainage basins

	Cr	53%		
	Pb	78%		
	Al	17%		
	As	11%		
	Fe	53%		
BOD		63%	From 8.54 mg/L to 4.18 mg/L	(Hunt, et al. 2008)
TSS		90-91%	During the first 6 h run	(Hsieh and Davis, 2005$_a$), (PGDER, 1993)
Pathogens removal		54.5-99.8%		(Rusciano and Obropta, 2007), (PGDER, 1993)
PAHs removal		90%	From 2.08 to 0.22	(Di-Blasi, et al., 2009)

3.5 Operation and maintenance

According to PGDER (1993), recommended maintenance for a bioretention system generally includes monitoring, repair and/or replacement of the components of the treatment area (See table 1.6). Trees and shrubs should be inspected twice per year in order to evaluate their health and remove any vegetation which is dead or with severe diseases. Pruning and weeding may also be necessary. Mulch replacement may be recommended when erosion is evident or when the site begins to look unattractive. Spot mulching may be adequate when there are random void areas but once every two to three years the entire area may require a replacement of the mulch. The application of an alkaline product, such as limestone, may be recommended one to two times per year to counteract soil acidity resulting from slightly acidic precipitation and runoff. If levels of pollutants reach toxic levels which can impair plant growth and the effectiveness of the system, the soil should be replaced.

Table 1.6: Maintenance Recommendations for Bioretention. Source: (VDEQ, 2011)

Required Action	Maintenance Objectives	Frequency
Inspection	Monitor detention area to determine if the sandy growth media is allowing acceptable infiltration Monitor trees and shrubs to evaluate their health and remove any dead or severely diseased vegetation	Routine – Annual inspection of hydraulic performance Routine – Twice per year for trees and shrubs inspection (EPA, 1999)
Lawn mowing and vegetative care	Occasional mowing of grasses and weed removal to limit unwanted vegetation. Maintain irrigated turf grass as 2 to 4 inches tall and non-irrigated native turf grasses at 4 to 6 inches	Routine – Depending on aesthetic requirements
Debris and litter removal	Remove debris and litter from detention area to minimize clogging of the sand media	Routine – Depending on aesthetic requirements
Landscaping removal and replacement	The sandy loam turf and landscaping layer will clog with time as materials accumulate on it. This layer will need to be removed and replaced to rehabilitate infiltration rates, along with all turf and other vegetation growing on the surface	Every 5 to 15 years, depending on infiltration rates needed to drain the WQCV in 12-hours or less. It may be required to do it more frequently if exfiltration rates are too low to achieve this goal

3.6 Cost considerations

Some of the reported bioretention construction costs are as it follows:

- 0.3 ha parking lot for USD 6.500 (Coffman, et al. 1993$_a$).
- A constructed bioretention area of 37,16 m^2 in US for USD 500. These units are rather small and their costs are low. The estimation of the costs includes excavating 0.6 to 1 meters and vegetating the site with 1 to 2 trees and 3 to 5 shrubs. The estimate does not include the cost for the planting soil, which increases the cost for a bioretention area. Retrofitting a site typically costs more, averaging USD 6.500 per bioretention area. The higher costs are attributed to the demolition of existing concrete, asphalt, existing structures and the replacement of fill material with planting soil.
- Costs for a constructed bioretention facility are USD 35 per ft^2.
- Drainage pipe costs may be reduced by 50% (PGDER, 1993).

Operation and maintenance costs

The operation and maintenance costs for a bioretention facility may be comparable to those of typical landscaping. Costs beyond the normal landscaping fees may include the cost for testing the soils, sand bed and planting the soil (EPA, 1999) (USD 1,10 per ft^2 for annual operation and maintenance costs).

3.7 Technical recommendations

In urban areas where space is at premium, bioretention systems can offer high versatility. These systems have been been used in commercial, institutional, and residential sites as a part of spaces that are traditionally pervious and landscaped. Typical locations for bioretention systems may include parking lots, and low and high density residential areas. These systems have multifunctional roles in urban environments such as recreational sites, wind breaks, or sites to reduce the pollution and promote the infiltration. It is important to highlight that areas with high water level (<2 m) and slopes higher than 20% are not recommended for the application of bioretention systems. This type of systems have a low heavy metal capacity removal. In addition, in cold climates the soil may freeze and prevent infiltration. This system should not be placed at the foundation of the buildings. This is especially the case for clayey soils.

Bioretention systems have a good potential for mitigation and controlling stormwater in green space areas. That could be considered as an opportunity in order to implement more sustainable practices at urban level. However, this system could not manage all the stormwater that a city may receive and should be used as a complement of other stormwater management systems.

3.8 Potential in the Baltic Sea Region

The potential in the Baltic Sea region could be summarized as it follows:

- The Water Framework Directive (WFD) 2000/60/EC (WFD) establishes an EU-wide regulatory framework for the protection of inland surface waters and groundwater (Baumgartner, 2008).
- Decentralized stormwater management practices are preferred methods in Germany and Sweden.
- In Germany, the Federal Nature Conservation Act (BNatSchG) establishes the general framework for the impact mitigation regulation on nature and landscape. This framework encourages the implementation of stormwater management practices that mimic natural flows (BNatSchG, 2009)

3.9 References

Baumgartner, G. (2008), “Wasserrecht”, in Baumann, S., Baumgartner, G., Feik, R., Giese, K.J., Jahnel, D. and Lienbacher, G. (Eds.), *Besonderes Verwaltungsrecht*, Springer, Wien.

BNatSchG, 2009: Act on Nature Conservation and Landscape Management (Federal Nature Conservation Act –BNatSchG) of 29 July 2009. At http://www.eui.eu/Projects/InternationalArtHeritageLaw/Documents/NationalLegislation/Germany/federalnatureconservation-act.pdf. Accessed on October 2014.

Bratieres, K., Fletcher, T. D., Deletic, A., and Zinger, Y, 2008. “Nutrient and sediment removal by storm water biofilters: A large-scale design optimization study.” *Water Res.*, 42(14), 3930–3940.

Coffman, L., Green, R., Clar, M., and Bitter, S, 1993a. “Design consideration associated with bioretention practices.” *Proc., 20th Anniversary Conf. on Water Management in the ’90s*, ASCE, Reston, Va., 130–133.

Coffman, L., Green, R., Clar, M., and Bitter, S.,1993b. “Development of bioretention practices for storm-water management.” *Proc., 20th Anniversary Conf. on Water Management in the ’90s*, ASCE, Reston, Va., 126–129.

Davis, A. P. (2008). “Field performance of bioretention: Hydrology impacts.” *J. Hydrol. Eng.*, 13(2), 90–95.

Davis, A. P., Shokouhian, M., Sharma, H., and Minami, C. (2006). “Water quality improvement through bioretention media: Nitrogen and phosphorus removal.” *Water Environ. Res.*, 78(3), 284–293.

Davis, A.P., Hunt, W.F., Traver, R.G., Clar, M., 2009. Bioretention technology: overview of current practice and future needs. Journal of Environmental Engineering 135, 109–117.

Davis, A.P., Shokouhian, M., Sharma, H., and Minani, C., 1998. *Optimization of Bioretention Design for Water Quality and Hydrologic Characteristics*.

Di-Blasi, C. J., Li, H., Davis, A. P., and Ghosh, U, 2009. “Removal and fate of polycyclic aromatic hydrocarbon pollutants in an urban storm water bioretention facility.” *Environ. Sci. Technol.*, 43(2), 494–502.

Dietz, M. E., and Clausen, J. C. (2005). “A field evaluation of rain garden flow and pollutant treatment.” *Water, Air, Soil Pollut.*, 167(1–4), 123– 138.

EPA (1999). Environmental Protection Agency. Storm Water Technology Fact Sheet Bioretention. At http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_biortn.pdf832-F-99. Accessed on September 2014.

Ermilio, J.R., 2005. Characterization Study of a Bio-Infiltration Stormwater BMP, a Thesis, Department of Civil and Environmental Engineering, Villanova University, October 2005.

Fujita, S., 1997. Measures to promote stormwater infiltration. Water Science and Technology 36, 289–293.

Glass, C., and Bissouma, S. _2005_. “Evaluation of a parking lot bioretention cell for removal of storm water pollutants.” *Ecosystems and sustainable development V*, WIT, Southampton, U.K., 699–708.

Henderson, C., Greenway, M., and Phillips, I. _2007_. “Removal of dissolved nitrogen, phosphorus and carbon from storm water by biofiltration mesocosms.” *Water Sci. Technol.*, 55(4), 183–191.

Hererra 2012 Draft (July 2). Federal Way SUSTAIN Model Draft Optimization Approach. Prepared for Hong, E., Seagren, E. A., and Davis, A. P, 2006. “Sustainable oil and grease removal from synthetic storm water runoff using bench-scale bioretention studies.” *Water Environ. Res.*, 78(2), 141–155.

Hsieh, C., and Davis, A. P, 2005a. “Multiple-event study of bioretention for treatment of urban storm water runoff.” *Water Sci. Technol.*, 51(3– 4), 177–181.

Hsieh, C., and Davis, A. P, 2005b. “Evaluation and optimization of bioretention media for treatment of urban storm-water runoff.” *J. Environ. Eng.*, 131(11), 1521–1531.

Hunt, W. F., Jarrett, A. R., Smith, J. T., and Sharkey, L. J. (2006). “Evaluating bioretention hydrology and nutrient removal at three field sites in North Carolina.” *J. Irrig. Drain. Eng.*, 132(6), 600–608.

Hunt, W. F., Smith, J. T., Jadlocki, S. J., Hathaway, J. M., and Eubanks, P. R, 2008. “Pollutant removal and peak flow mitigation by a bioretention cell in Urban Charlotte, N.C.” *J. Environ. Eng.*, 134(5), 403–408.

Prince George's County Department of Environmental Resources (PGDER), 1993. *Design Manual for Use of Bioretention in Storm water Management*. Division of Environmental Management, Watershed Protection Branch. Landover, MD.

Roy-Poirer A., Champagne P., ASCE A.M., Filion Y. 2010. Review of bioretention system and design Past, Present, and Future, Journal of Env. Eng., Vol.136, No.9, September 1.

Rusciano, G. M., and Obropta, C. C, 2007. "Bioretention column study: Fecal coliform and total suspended solids reductions." *Trans. ASABE*, 50(4), 1261–1269.

VDEQ, 2011: Virginia DEQ Stormwater Design Specification No. 9; 2011. At http://www.vwrrc.vt.edu/swc/april_22_2010_update/DCR_BMP_Spec_No_9_BIORETENTION_FinalDraft_v1-8_04132010.htm. Accessed July 2014

Wong, T.H.F., 2006. Australian Runoff Quality: A Guide to Water Sensitive Urban Design.

Woods-Ballard, B.K., Martin, P., Jefferies, C., Bray, R., Shaffer, P., 2007. The SUDS Manual. CIRIA (C697), London and Dundee.

Part II: Analysis of Mentoring Regions

2.1 Transferability

Roessner and Bean (1994) defined technology transfer as ‘‘the movement of know-how, technical knowledge, or technology from one organizational setting to another’’. This is the definition that is used in this report in order to illustrate the potential for mentoring other regions.

2.1.1 Importance of transferability for decentralised urban stormwater management

The traditional way to manage urban stormwater generally revolves around the disposal of stormwater as quickly as possible to nearby water bodies. The unsustainable nature of this traditional approach is highlighted by the environmental externalities exerted to the urban ecological system. Especially, the degradation and modification of riparian ecosystems which is basically caused by severe changes in the catchment hydrology and the quality of runoff (Marlow, et al. 2013). In addition, conventional systems are not flexible because they have been designed to exclusively perform under certain highly specific conditions. Thus, the design of traditional water and wastewater management systems are basically driven by the need to cater for peak demands. Mitigation of these peaks by means of the use of decentralised urban stormwater management systems may reduce investments and capital costs (Speers and Mitchell, 2000).

In this section, the term "decentralised urban stormwater management technology" comprises permeable pavement systems and bioswales, green roofs, and bioretention systems. After extensively and comprehensively reviewing relevant literature (see D3.2 and part I), it has been shown that these technologies can be considered best management practices (BMPs). Thus, it is proposed that decentralised urban stormwater management systems act as a part of BMPs at urban level.

Permeable pavement systems and bioswales, green roofs, and bioretention systems share basic and key working principles and impacts, especially increasing infiltration, storing rainwater and removing pollutants. Furthermore, another important and crucial common characteristic is that all the systems require a vegetation cover in order to adequately function (with the exception of some specific types of permeable pavements). Therefore, it is suggested a new categorisation of these technologies focusing on their catchment area and land use.

The categories are as it follows:

- Roof stormwater management systems
- Street stormwater management systems
- Green space stormwater management systems

The rationale behind the analysis of the transferability potential is to tap into existing know-how, technologies and experiences from the Baltic Sea Region and transfer them to other regions at European and worldwide level.

2.1.2 Relevant transferability factors

In order to effectively transfer decentralised urban stormwater technologies, it is convenient to identify relevant transferability factors which may have a key role in the transfer of these technologies to other areas. These factors are as it follows:

- **Geophysical factors**
- **Legislative and social factors**
- **Economic and technical factors**

2.1.2.1 Geophysical factors

- **Climate**: Decentralised urban stormwater management systems depend on the local climate. In fact, the patterns and intensity of the rainfall may exert a significant impact on their capacity to infiltrate and/or absorb water. If rainfall events are repeated in periodic cycles of relative short time, there may not be enough time for the soil to dry out completely before the next rainfall event. This may reduce the capacity of the system to store water. In addition, when the interval between rainfall events is relatively long, the system may not be able to store enough water to allow the vegetation to survive the drought period, especially in warmer climates. Finally, if the intensity of the rainfall is relatively high, the vegetation of the system may not be able to adequately slow down the runoff.
- **Soils**: The selection of the soil media is crucial. Storing water in the system can help to reduce the runoff volume and peak. Water stored in the system may help vegetation to survive between rainfall events. Soils with a high proportion of sand may provide higher infiltration and filtering rates, even with frequent rainfall events. However, some of these

soils shows a low capacity to sustain plant growth during drought periods. Sandy soils with moderate proportion of silt and clay may show higher water storage and holding capacities. Soils with high proportions of silt and clay do show very low infiltration rates. Therefore, these type of soils are not an effective solution to manage stormwater.

- **Vegetation**: The selection of the vegetation is directly dependent on the climate and type of soil. If the system is to be located in an area that receives frequent rainfall events throughout the year, vegetation is not expected to experience severe drought conditions. However, the vegetation may have to survive several days of inundation. On the contrary, if a system is located in a region that receives little rainfall, it is expected that the vegetation experiences drought conditions. In this case, the vegetation should be able to survive drought but also tolerate heavy rainfall periods. In any case, it is recommended to always focus on endogenous vegetation which is adapted to the local climate variability.

2.1.2.2 Legislative and social factors

Requirements from legislation generally define the boundaries for engineering solutions (Hvitved-Jacobsen, et al., 2010). In addition, they may also constitute the driving force for applied research solutions. The Clean Water Act (1972) of USA, and the Water Framework Directive (2000) in Europe are two good examples. The implementation of the EU Directive may strengthen the social perception of the challenges of stormwater management, contribute to a higher level of participation, and change the paradigms of related institutions and politicians. In order to adequately integrate the social dimension, decentralised urban stormwater management should take into account user acceptance and public participation.

2.1.2.3 Economic and technical Factors

The economic costs of stormwater management should be considered at an early stage of the decision process. FHWA (2000) points out the need to include not only the purchase of the land and the construction, operation, maintenance and monitoring costs, but also other expenses related to the effective life duration of the facility and the technical training of staff. Cost savings through application of the decentralised urban stormwater management systems should be considered. Technical factors are relevant because only technologies with adequate levels of performance can be cost-effectively transferred to other areas.

2.2 Analysis of European regions that could benefit from mentoring in the field of urban stormwater management

The working principles of the transferability potential in Europe are presented and discussed in this section.

2.2.1 Geophysical factors

Even though there are different climatic conditions in Europe, at a continental level the climate is considered to be mild, with cool summers and cold winters. In addition, climate shows a tendency to get colder towards Northern Europe and warmer towards Southern Europe on one hand, and wetter towards Western Europe and drier towards Eastern Europe on the other. The change from hot summer to cold winter is greatest in Eastern Europe. More specifically, in Southern Europe the Mediterranean Sea influences the climate of countries like Portugal, Spain, south of France, Italy, Croatia, Albania, Greece and Turkey. Temperate oceanic climate is generally found in Western Europe, in the area of the Atlantic Ocean. Countries with this type of climate include United Kingdom, France, north of Spain, and Germany. Temperate continental climate can be found in central and eastern Europe. Countries with this type of clime include Romania, Hungary, Ukraine, Bulgaria, Serbia, Bosnia and Montenegro. In the Baltic Sea Region, the climate is characterised by a marked seasonality with generally long and cold winters, and short warm summers. Countries in this region are Denmark, Estonia, Latvia, Finland, Germany, Lithuania, Poland, Russia and Sweden.

2.2.1.1 Current precipitations in Europe

Figure 2.1 provides annual precipitation trends from 1940-1995 in the European region. As it is shown in this figure, the central part of Europe (i.e. Montenegro, Slovenia, Austria, Bosnia and Croatia) and Norway received higher annual precipitation than other countries located at north (with the exception of Norway). If it is assumed that areas which have received higher rainfall have higher risk of floods, these cities show a transferability potential for decentralised urban stormwater management. This is especially caused by the low performance of conventional stormwater management systems during stormwater events. Based on this hypothesis, the following cities receiving at least 1.000 mm/year may show high transferability potential. Some examples are as it follows:

- Between 1.600-4.000 mm per year: Cork (Ireland), Cardiff (Wales), Plymouth (England); Lyon (France); Geneva and Zurich (Switzerland); Stuttgart and Munich (Germany); Salzburg (Austria); Sarajevo (Bosnia and Herzegovina); Zagreb (Croatia); Ljubljana (Slovenia); Tirana (Albania); Sofia (Bulgaria); Santiago de Compostela (Spain); Kristiansand (Norway)
- Between 1.000-1.600 mm per year: Barcelona and Valencia (Spain), Ioannina (Greece), Oporto (Portugal); Brighton (England); Bergen and Trondheim (Norway); Venice (Italy)

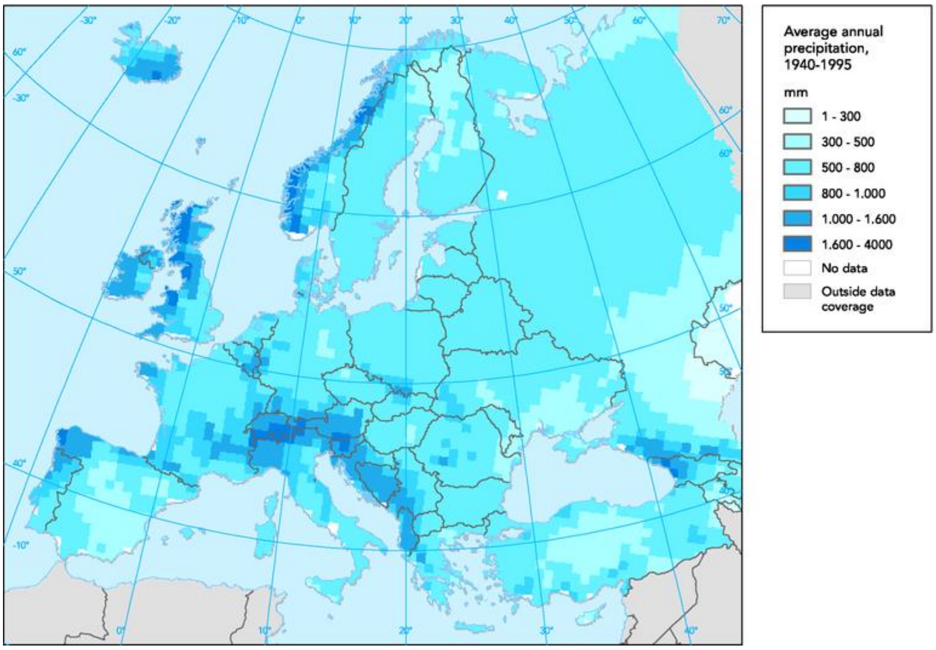

Figure 2.1: Precipitation trends in European countries. Source: EEA, 2003

Rainfall distribution also has a direct impact on the vegetation cover of some decentralised urban stormwater management systems. Countries with long and cold winters, as it generally happens in the Baltic Region and other central and Eastern Europe countries, are in principle less suited to facilitate the necessary conditions to support this. Therefore, the hydrological performance for green roofs, bioswales and bioretention systems may significantly decrease during winter time because the impacts of the cold temperatures on the vegetation cover.

Permeable asphalt pavements may have a higher potential in these countries because they do not require vegetation. However, it is necessary to take into account that heavy vehicles should be excluded during winter time. In addition, the use of chains for the snow may also damage this type of pavement. For instance, Switzerland does not allow the use of snow chains in permeable pavement roads. In any case, modular permeable pavements may have a high potential as a parking area in these countries.

A look into the future

According to EEA (2012$_a$), climate change and the associated increase in the frequency of flood events are one of the important parameters that may affect the performance of conventional water and wastewater systems in urban areas. The implementation of decentralised urban stormwater management systems may be a suitable option in order to increase the capacity of conventional systems. Current predictions by Roeckner and Kirk (2013) state that there might be a dramatic increase in rainfall in cities of Norway like Mode, Bergen, Stavanger and Kristiansand (from 5 to 13 times higher risk of heavy rainfall). Other European cities like Brussels (Belgium), Paris (France), London (England), Amsterdam (Netherlands), Copenhagen (Denmark), Dublin (Ireland), Warsaw (Poland), Riga (Latvia), Helsinki (Finland), and Stockholm (Sweden) have also been identified as cities with high risk of heavy rainfall (from 1 to 5 times higher risk of heavy rainfalls).

2.2.1.2 Soil

As soil-related factors can be modified in order to adapt them to the specifics needs of the systems and the specific geophysical factors at local level, soil may not be considered a limiting factor for the transferability potential. However, it is highly recommended to have a soil with high permeability and low rates of wind erosion. Wind erosion is considered to be a limiting factor for permeable pavement systems because it has the potential to reduce infiltration. With regard to the analysis of the permeability, Gleeson, et al. (2011) proposed a method in order to evaluate the permeability which was based on the use of satellite images. Figure 2.6 shows a map which presents an estimation of the permeability all over the world. Based on this map, countries like Sweden, Norway, England, Switzerland, southern Germany, northern Italy and Austria show low permeability indexes. In these areas, the implementation of additional infiltration systems may be required in order to successfully develop bioswales, bioretention systems and permeable pavements.

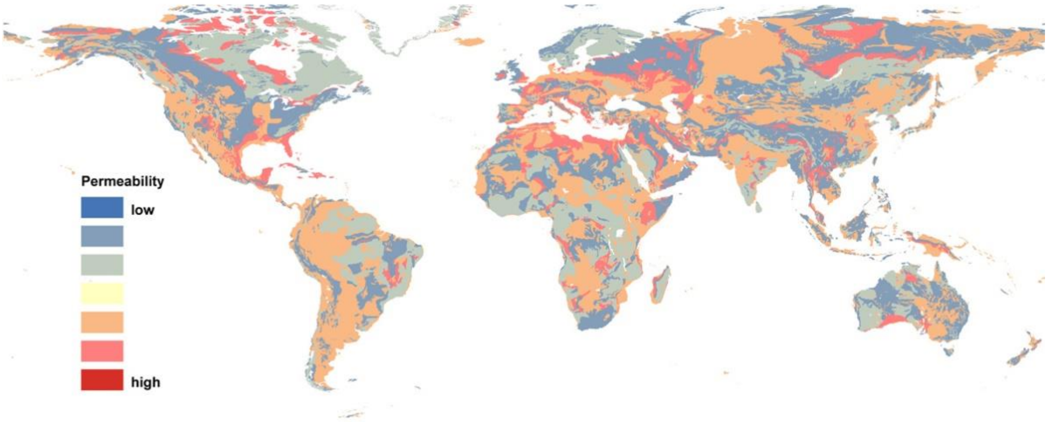

Figure 2.6: Earth's Permeability Map. Source: Gleeson et al. (2011)

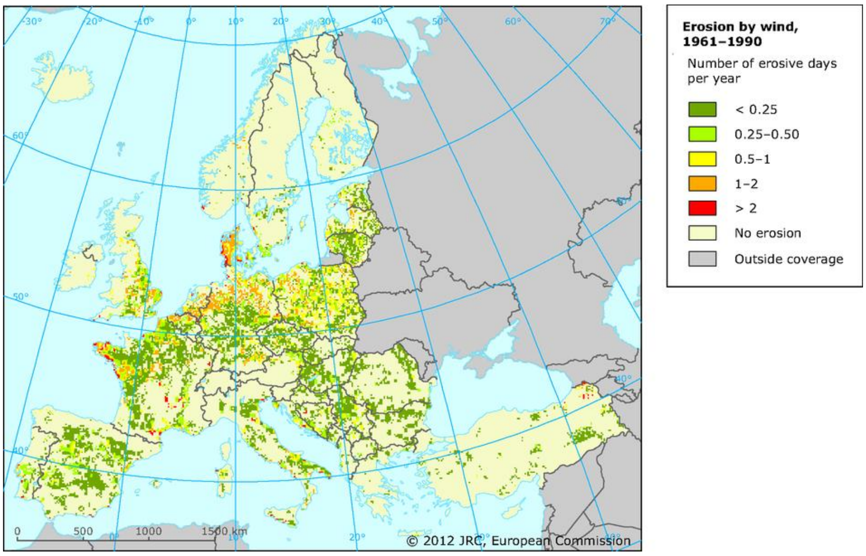

Figure 2.7: Recorded Wind Erosion in Europe. Source: (EEA, 2012b)

Wind erosion could bring dust and small particles into the system and block the pores. This is especially relevant for permeable asphalt pavements. Based on Figure 2.7, which is a map of the wind erosion published by European Environmental Agency in 2012, cities like Madrid (Spain), Venice (Italy), Leipzig and Dortmund (Germany), Paris and Caen (France), Esbjerg (Denmark) and Benevento (Italy) may show high rates of wind erosion. This may further complicate the implementation of porous asphalt pavements.

2.2.1.3 Slope

One of the factors which may be considered a limiting factor for bioswales is slope. Thus, bioswales are not recommended to be implemented in areas with slopes higher than 3% . Therefore, cities with overall slopes higher than 3%, like Zurich and Geneva (Switzerland), Salzburg (Austria), Lyon (France) and Turin (Italy), may not be suitable for the implementation of bioswales.

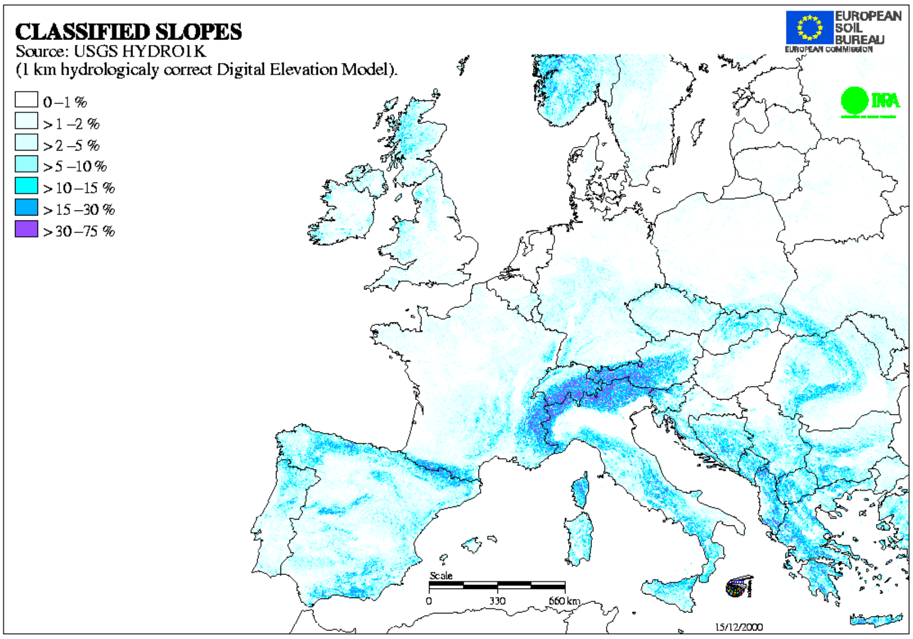

Figure 2.8: Slope classification in European countries. (Source: ESB, 2000)

2.2.2 Legislative and social factors

The use of BMPs varies greatly between countries (Revitt, et al., 2003), with developed countries generally demonstrating greatest usage. Simultaneously with development of the new technologies for upgrading urban stormwater management, it is necessary to improve the policies and directives for their implementation. In the EU, the following legal acts are relevant for urban rainwater management:

- Water Framework Directive (2000/60/EC)
- Floods Directive (2007/60/EC)
- Urban Wastewater Directive (91/271/EC)
- Environmental Quality Standards Directive (2008/105/EC)
- Bathing Waters Directive (2006/7/EC)
- Groundwater Directive (2006/118/EC)

In addition, a UK Water Industry Research (UKWIR) report (Ashley et al, 2006) suggested that in the short term up to 2020, both environmental legislation and energy use will be more important drivers for urban drainage than climate change. Therefore, the EU Action Programme on Flood Risk Management includes a proposal for a future Directive on the assessment and management of flood risk although a number of Member States have questioned the need for further legislation. This was on the grounds that flood management is indirectly addressed within the Water Framework Directive. In addition, the European Commission announced a strategy to promote green infrastructure throughout the European Union, making it a systematic part of spatial planning (Stormwater, 2013_a).

In some regions, the awareness of people regarding water management is strong and they initiate certain improvements and changes in that field. According to a BalticSTERN report released on 14th of March 2013, residents of Baltic Sea countries are willing to pay nearly EUR 3.8 Billion in order to restore water quality in the sea. BalticSTERN is an international research network with partners in all countries around the Baltic Sea and is hosted by the Stockholm Resilience Centre (Stormwater, 2013b).

User acceptance is considered to have especial relevance for green roof systems. Experiences in Germany shows that incentives can significantly improve rates of adoption. Other decentralised systems like bioretention systems, bioswales and permeable pavements, are generally implemented in public spaces and/or green areas. Therefore, it is considered that user acceptance may play a secondary role.

2.2.3 Economics and technical factors

Bioswales and bioretention systems can be considered a low-cost technology. Permeable pavements may show higher economic costs. However, a key advantage for porous pavements in cold climates is that they do not require vegetation cover. Therefore, this type of systems may show high suitability to countries with cold and long winters (Baltic Sea Region, Northern, Central and Eastern Europe). Among the technologies reviewed, porous pavements and green roofs may require higher capital investment, maintenance and technical skills. Even though the transferability of these systems may inherently show a higher complexity as compared to bioswales and bioretention systems, porous pavements and green roofs can be implemented in a significantly wider range of scenarios. More importantly, in scenarios where bioswales and bioretention systems cannot be implemented. It is necessary to highlight that the area allocated to streets and buildings generally cover more than 50% of European cities.

The countries of Central and Eastern Europe are currently in transition (the recovery process from the breakdown of the state-controlled economies after the political changes in the beginning of the 1990s to market-oriented economies). Now, after 10 years of transition, new legislation is approaching market economy requirements. However, in all transition countries the economy has priority over the environment, so there are only limited financial resources available for investment, modernisation or reconstruction of environmental protection facilities. This has happened to Croatia (see section 2.2.4.2), but also to other Central and Eastern European countries such as Serbia, Montenegro, Bosnia, etc. (United Nations Environment Programme, 2014). In short, there are big differences between single countries or country groups in this region regarding economic performances, social achievements and the realisation of environmental protection measures (United Nations Environment Programme, 2014). However, all of those countries poorly manage urban stormwater in cities and towns, and therefore they could benefit from developed countries by adapting their sustainable strategies for managing urban stormwater.

2.2.4 Case study: the Baltic Sea Region

There are differences in development and current management of urban stormwater between countries that have been included in the Baltic Flows project. For that reason, there is a need for evaluation of the current practices and policies on the national level with final aim to estimate the need for monitoring and collaboration among the countries involved in the project, as well as their potential to mentor the regions outside the Baltic Sea Region

Most of the more developed countries in the Baltic Sea Region (e.g. Germany, Sweden, Finland, Sweden, etc.) have highly developed strategies to manage urban stormwater, while less developed countries are generally characterizes by a rather outdated rainwater management (e.g. Latvia, Lithuania, Estonia, etc.). Nevertheless, the highly developed countries should still work on the improvement of their urban stormwater management and therefore could benefit from mentoring (Ashley et al., 2007).

2.2.4.1 Highly developed countries can mentor and benefit from mentoring

Strategies regarding decentralised urban stormwater management in some highly developed countries of the EU and Baltic Sea Region can be used as a model for improvement of USWM in the less developed countries. However they can also benefit from mentoring by other developed countries outside the EU, such as USA, Australia or Canada. In this case study, Germany and Finland has been presented as developed countries which could mentor and benefit from mentoring.

EU and Baltic Sea Region examples: Germany and Finland

As Germany is one of the first countries to include rainwater and stormwater management activities into its policies (Jin, 2005) and especially addresses decentralized solutions, and even incentivizes their application, the area of policy making is quite well equipped. As combined sewer networks are still the status quo, the runoff increases the amount of water that needs to be cleaned in a central sewage treatment plant. Other parts of the runoff on the other hand are not treated and end up in the receiving bodies that lead to the Baltic Sea, causing the water quality to worsen. Runoff quantity management, therefore, needs to be combined with water quality management.

Like other Baltic Flows partner regions can benefit from technology and knowledge transfer from the Hamburg regions, the Hamburg area can benefit from technology transfer from other regions (e.g. UK and USA). German stakeholders are interested in cooperation activities on either a local, regional, national, or even international level. They are mainly involved in the research and technological development (RTD) of rainwater management. In other partner regions of the Baltic Flows project, the private sector is much more present than RTD. The private sector could learn from the experiences and results that Hamburg has already gained and will gain through the many research pilot projects taking place in the city's region.

Something that other regions can definitely learn from Hamburg, and Germany in general, is designing and implementing multifunctional spaces that adjust to the surrounding infrastructure and image of the city. Public spaces like parks, green spaces or playgrounds that mainly serve purposes like recreation or sports can be designed to combine those purposes with rainwater/stormwater management (Nickel et al., 2014). In case of heavy rainfall events, those areas can temporarily store the water.

At present, urban runoff management in Finland is in a transient state. The Water Services Act (199/2001), which most directly regulates urban stormwater management, and other stormwater guidelines are currently being renewed. Therefore good practices and examples within Finland and from other countries are actively sought. Compared to other European countries, water service infrastructure in Finland is generally in a good condition (Sänkiaho et al., 2011). However, there are still some issues that should be regulated.

In Finland, the trend is towards Integrated Urban Water Management (IUWM) with the aim of taking into consideration all interactions of the urban water cycle, i.e. stormwater, water supply, wastewater, groundwater, and ecological and health aspects (Sänkiaho et al., 2011). However, the current municipal organisation structures, design guidelines and regulations do not support these long-term goals. In cold climate countries such as Finland, snowmelt also makes up a considerable part of annual stormwater runoff. Therefore, Finland should be mentored by the countries with similar climate such are Canada or Northern USA. The overall stormwater regulations and guidelines are considerably less conclusive in Finland compared to countries such as the USA and Australia (Ashley et al., 2007).

During the ongoing process of developing the new criteria for stormwater - in addition to the American and Australian guidelines - examples from Canada (Toronto Water, 2006), Germany (DWA, 2006) and Scotland (SEPA, 2008) have been studied. Therefore, Finland could benefit from mentoring by these countries. Currently, town and regional planning are considered as principal tools for comprehensive urban water management. Water companies consider stormwater management to be outside the main range of their duties, especially because they are seldom able to influence land-use and source areas. There are several economical issues which need to be considered, if the distribution of liabilities is changed. Water companies fund their operation with water bills and connection fees, whereas elsewhere the water management costs are generally covered by taxes. If the municipality is taking the sole responsibility for stormwater management they have to consider new ways of funding and re-evaluate the total value of drainage systems (Sänkiaho et al., 2011).

2.2.4.2 Poorly developed countries can mentor and benefit from mentoring

Some countries of the EU and Baltic Sea Region are less developed and relatively poor, still facing economical and financial problems. In those countries, decentralised urban stormwater management has received less attention and financing in comparison with other EU countries. Therefore, those countries could greatly benefit from lessons learned and strategies adapted from the neighbouring countries. This case study evaluates the need for mentoring in two countries: Latvia (is one of partner countries of the Baltic Flows project) and Croatia (is the newest member of the EU).

BSRs example: Latvia

Legislation and existing practice in rainwater management in Latvia can be considered relatively outdated due to lack of attention and financing for this issue during the last 20 years. The rainwater management is regulated by the national legislation in the field of environment, construction and land drainage, enforced at the local (municipal level) through construction control (mainly during the process of technical design). Maintenance of the rainwater management infrastructure is mainly ensured by local municipalities or municipal water companies.

Rainwater sewers are designed according to the Latvian Construction Norm LBN 223-99 “External networks and buildings of sewerage”, which is inherited from the Soviet construction norm SNIP. The main approach of the construction norm is ensuring necessary sewer dimensions for the maximum calculated runoff (maximum intensity method). Therefore, it does not explicitly consider rainwater retention and infiltration.

The competence and experience of Latvian institutions and companies acting in the field of rainwater management and monitoring will probably be of little interest to Western European markets, because the transfer of knowledge and technology is currently happening in the opposite direction (Latvian Ministry of Education and Science, 2014). Moreover, there is a lot to be done for capacity building in Latvia itself. However, expertise of the leading Latvian players in the rainwater management and monitoring field may be of interest to the immediate neighbours – Estonian and Lithuanian institutions and companies as well as other countries of the former USSR. This is due to common historical background, similar engineering practices and knowledge of the Russian language. The EU Eastern Partnership initiative in order to promote the relations of the EU with Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine, and in particular the European Neighbourhood Instrument 2014-2020, provides the ground for cooperation projects aimed at exporting the competence in this direction.

On the other hand, there are many fields where mentoring is needed in Latvia, as for example:

- Best practice on rainwater tariffs;
- Improvement of legislation and regulatory base for sustainable rainwater management;
- Construction and maintenance of sustainable rainwater management systems;
- Pollution reduction potential of different techniques, most cost-effective techniques for specific pollutants.

EU example: Croatia

Croatia is the newest member of the European Union (it became a member on 1st of July 2014), and as such there are many regulations and directives that should be respected. Water management in Croatia is far from sustainable and consists of redundant and very expensive hydrotechnical river regulations. This is typical old-fashioned water management which disregards EU institutions and its legislation. In addition, State agency for water management, Hrvatskevode, is accelerating all such activities to regulate as many rivers and streams as possible prior to accession (Water World, 2014).

In fact, when it came to the issue of access to EU, ecological issues were relatively low down on the agenda. Rather, the fight against organized crime and corruption in Croatia was always taking priority. Still, slowly but surely in the years prior to accession the government in Zagreb, with support and assistance from Brussels, was working away to ensure that water came to be seen as a valued natural resource - an integral part of the aquatic and terrestrial eco-system.

Regarding decentralised urban stormwater management, the use of sustainable drainage systems (SuDS) to manage urban runoff and contribute to environmental and landscape improvement is now widely known, but practical experience of its application and performance in Mediterranean countries in general and Croatia in particular is still limited (Jefferies et al., 2014).

The newest initiative in stormwater management in Croatia is a participation in the EU-MED Programme project E^{2}STORMED, the benefits of applying SuDS to manage stormwater in this region are being evaluated with a focus on possible system energy savings (Jefferies et al., 2014).

Therefore, Croatia (as a new EU country with poor stormwater management) should be considered as a good candidate for mentoring. In addition, Croatia is adequate potential candidate to be involved in further stormwater management projects.

2.2.5 Conclusion and recommendations for the European Region

It is argued that Europe as a geographical region shows a relatively high transferability potential for decentralised urban stormwater management systems because of the generalised high levels of annual precipitation. In addition, cities like Brussels (Belgium), Paris (France), London (England), Amsterdam (Netherlands), Copenhagen (Denmark), Dublin (Ireland), Warsaw (Poland), Riga (Latvia), Helsinki (Finland), and Stockholm (Sweden) may show high risk to present heavy rainfalls in the next 50 years. Furthermore, countries like Sweden, Norway, England, Switzerland, southern Germany, northern Italy and Austria show an overall low permeability. Therefore, this should entail difficulties to the implementation of infiltration systems for bioretention systems, bioswales and permeable pavements. Cities with more than 3-10% like Zurich and Geneva (Switzerland), Salzburg (Austria); Lyon (France) and Turin (Italy) show a low transferability potential for bioswales.

Bioswales and bioretention may show relatively low capital investment and operational costs. However, green roofs may show a higher potential to be socially accepted because of incentives and reduction of energy costs. Bioswales, green roofs and bioretention systems may show a relatively lower transfer potential to cold climates.

Although some countries of EU and Baltic Sea Region are developed and rich, they could still improve their stormwater management and benefit from mentoring. Countries such as Canada, Australia and USA have recently improved their urban stormwater management and could mentor and provide an encouraging example for other developed countries which still need to improve their urban stormwater management. On the other hand, some poor countries could benefit from the lessons learned in developed countries and also improve their urban stormwater management. As mentioned, some EU and countries from the Baltic Sea Region (e.g. Lithuania, Croatia, etc.) should improve their stormwater management. Therefore, they could benefit from other EU and Baltic Sea Region countries (as well as outside EU and Baltic Sea Region).

2.3 Analysis of international regions that could benefit from mentoring in the field of urban stormwater management

The working principles of the transferability potential mentoring at International level are presented and discussed in this section.

2.3.1 Geophysical factors

Regions with high rainfall may be considered to have a high transferability potential. Figure 2.9 shows areas with high annual precipitation. These areas are mainly located in South America (i.e. Brazil, Venezuela and Colombia), Eastern parts of USA, Central America, Western Canada, West Africa and south-eastern Asia and Melanesia.

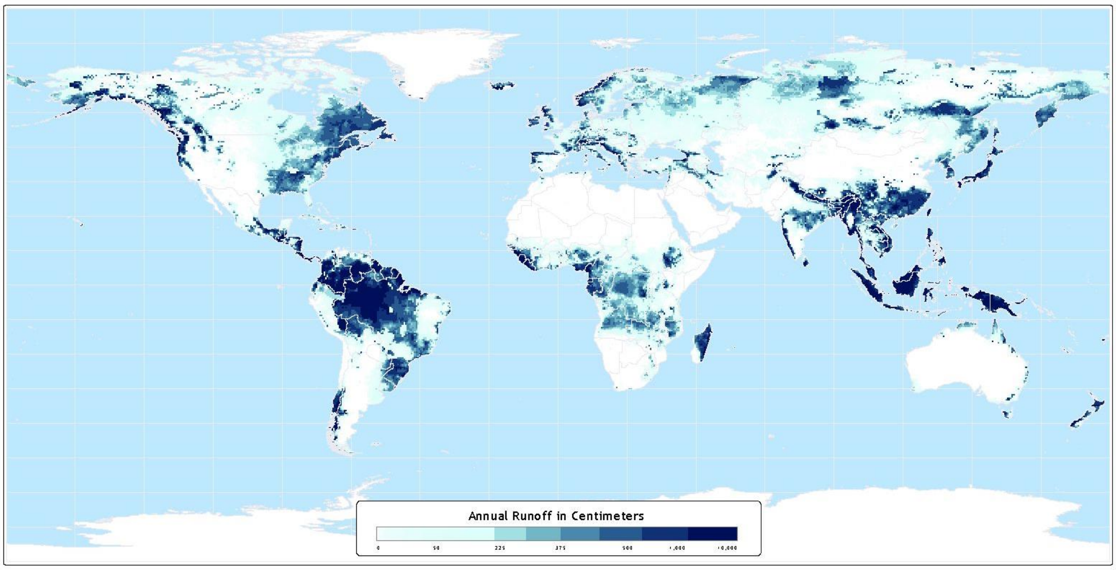

Figure 2.9: Annual runoff of the world. Source: Fetke, et al. (2000)

2.3.1.1 Groundwater stress

Recharge of local groundwater is one of the main functions of infiltration-based systems (i.e. bioretention, bioswales and permeable pavement system). Based on Figure 2.10, areas with relatively high stress of groundwater resources are Saudi Arabia, Pakistan, India, Mexico and Iran. It is argued that bioretention, bioswales and permeable pavements may have a high potential in these areas. In addition, other areas showing groundwater stress may also show high potential for these technologies.

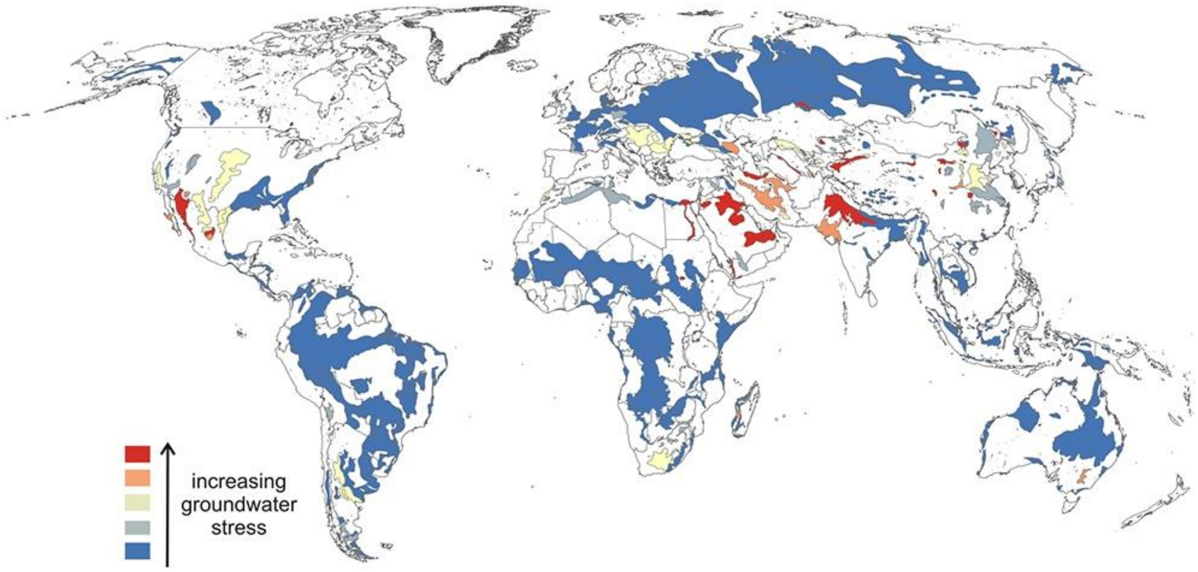

Figure 2.10: Groundwater Stress in the World. Source: Mascarelli (2012)

2.3.1.2 Soil

Surface soil can be replaced at the site of application, therefore soil permeability was not considered as a key factor for transferability (see also section 2.2.1.2).

2.3.2 Case study: Legislative and social Factors in South Korea

Decentralised urban stormwater management systems are considered an integral part of green urban infrastructures in South Korea. The main relevant legislative and social transferability factors are highlighted below. The text below is an excerpt of a study carried by OECD (2012).

The national government of South Korea promulgates various kinds of financial and tax incentive policies that can facilitate green infrastructure public-private partnerships (PPP) financing. This is in line with its First Five-Year Action Plan for Green Growth, which was initiated in 2009. More specifically, the government provides (i) construction subsidies, (ii) compensation for base cost, (iii) infrastructure credit guarantees via the Infrastructure Credit Guarantee Fund, and (iv) tax incentives.

- (i) Construction subsidies: According to the PPP Act, the government may grant a construction subsidy to the concessionaire, if it is required to maintain the user fee at an affordable level. The timing of the subsidy is determined in the course of the concession agreement and depends on the equity investment plan of the concessionaire. The timing of the distribution reflects the completion level of the project and the schedule and scope of equity investment. The amount of subsidy is determined in each individual concession agreement. When notifying about a project, the government first discloses an approximate ratio of the construction cost that it is willing to subsidise. The exact ratio of subsidy to construction costs is determined through consultation and is stipulated in the concession agreement. As a result, each project ends up with a different amount of subsidy. The government has set a subsidy guideline for road projects of 20% - 30% of the total project cost. It has set a subsidy guideline for railway projects of up to 50% of total project cost. The ratio of subsidy to construction cost for environmental projects is stipulated by law (50% to 80%) and included in the government’s public notification. Generally speaking, more green-oriented projects are eligible for larger subsidies than the other projects.

- Compensation for base cost: the government assumes a portion of investment risk. This risk is limited to what the government’s costs would have been in the case of a public-financed project. The government payment is made for the amount of shortfall in the actual operational revenue compared to the share of investment risks by the government. When the actual operational revenue exceeds the share of investment risks, government subsidies are redeemed on the basis of and within the limit of the amount previously paid. On the part of the private participant, subsidies are provided only when the actual operational revenue surpasses 50% of investment risk.
- Infrastructure credit guarantee fund (ICGF): Since 1994, the ICGF has provided credit guarantees to concessionaires who want to obtain loans from financial institutions for PPP projects. According to the PPP Act, the ICGF is managed by the Korea Credit Guarantee Fund. The ICGF consists of annual government subsidies, guarantee fees and investment returns. When the project guaranteed by the ICGF defaults, the ICGF subrogates on behalf of the project company. Additional government contribution can be granted if the funds are insufficient. The limit of the credit guarantee per concessionaire is KRW 100 billion, but in cases where the director of the management institution considers it necessary, the limit may be raised to KRW 200 billion. The guarantee fee will have a maximum annual fee rate of 1.5%.
- Tax incentives: To facilitate infrastructure financing, the government provides tax incentives that are stipulated in the PPP Act. Details of the tax incentives are also included in the PPP Basic Plan in four categories: special taxation, corporate tax, local tax and exceptions

from charges. The PPP Act directs the government to enact special taxation for infrastructure bond, value-added tax, foreign investment zone, and infrastructure fund. A separate taxation rate of 14% is applied to the interest revenue from infrastructure bonds. A 0% tax rate is applied for the value-added tax for infrastructure facilities or construction services. Reduction of an exemption from taxes, including corporate tax, income tax, acquisition tax, registration tax, and property tax, are applied to foreign investment in the foreign investment zone. With respect to the dividend income distributed for the infrastructure fund, a 5% tax rate is applied to the dividend income from the equity investment portion up to KRW 300 million and a 14% tax rate is applied to the dividend income from the equity investment portion exceeding KRW 300 million. Local tax exemptions for PPP projects, which include an exception for three times the registration tax within the capital region and an exemption from acquisition and registration tax are included as well.

2.3.3 Case study: Learning from previous urban stormwater management projects

Many international projects regarding stormwater management have been conducted and completed. Some of the important projects are listed in table below (Table 2.1) together with the benefits they have provided to the EU and other regions.

Table 2.1. Stormwater management projects

Project	Period	Objective	Partner - Countries	Benefits for SWM in the EU
DAYWATER	2003-2005	Development of an Adaptive Decision Support System (ADSS) for Stormwater Pollution Control	Germany, the UK, France, Netherlands, Denmark, Sweden, Greece, Slovakia	The research was focused on the functional behaviour of structural and non-structural best management practices (BMPs). Models were developed for simulating pollution fluxes and assessing their possible control and fate within BMPs, and for assessing risks and impacts related to urban stormwater.
NORIS	2005-2007	Innovative technologies for reducing storm water runoff in sewer systems.	Sweden, Belgium, Netherlands, Germany, UK	Led to interesting lessons about the applicability of assessment frameworks, the difficulty in comparing technologies out of context and the benefits of working in transnational partnerships.

SWITCH	2006-2011	The SWITCH Integrated Project aims at the development, application and demonstration of a range of tested scientific, technological and socio-economic solutions and approaches that contribute to the achievement of sustainable and effective urban water management schemes in 'The City of the future'.	Netherlands, Germany, the UK, Spain, Poland, Switzerland (+ Near East, Africa, South America, China)	Collaboration between many countries. One work package has been focused only on stormwater management. The main role was to support the development of cross-sectorial city learning in 9 cities towards more integrated urban water management. To link up stakeholders to interact productively and to create win-win solutions along the water chain; multiple-way learning.
RISA	2010-2013	The project focuses on the identification of technological requirements and the creation of conditions that enable a forward-looking and sustainable rainwater management.	Hamburg, Germany	Establishment of pilot projects, recommendations for changes / adaptations in regulations or new regulations etc. and structural plan developed.
BLUE-GREEN DREAM	2012-2015	Aims to develop the service infrastructure to implement the use of this adaptation solution.	UK, Netherlands, France, Germany	On-going project. Improving technologies for USWM, mainly focused on green roofs and other green areas within the cities.

2.3.4 Economic factors

In order to identify potential mentoring regions with regard to the economic dimension, it is assumed that a high GDP ratio at national level adequately reflects a high level of wealth at a national level. Thus, it is argued that with high GDP levels, the potential for transferability is high as well. Based on this hypothesis, countries with moderate to high levels of GDP have been classified to have high transferability potential. Figure 2.12 shows the GDP at international level in 2007.

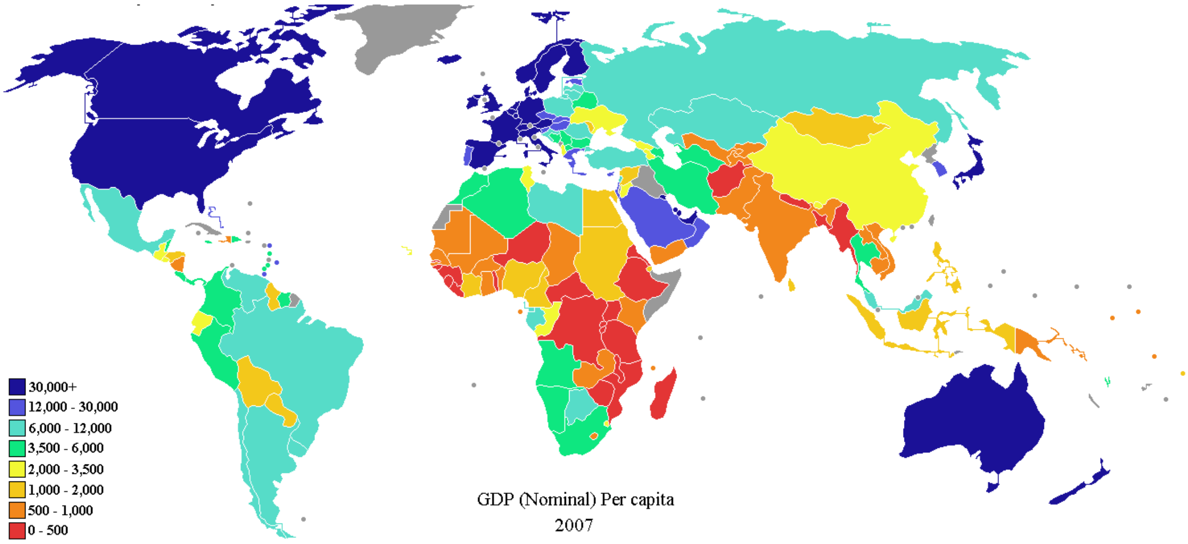

Figure 2.12: GPD (Nominal) Per Capital World Map in 2007. Source: IMF, 2008

North America, Europe and Australia can be clearly distinguished as areas with high GDP levels. Therefore, cities in these countries can be identified as areas with high transferability potential. Several decentralised urban stormwater management systems already exist in the USA. However, the installation costs for green roofs in Germany are two times less expensive than in the USA. Therefore, this may entail a good potential for transfer.

Emerging economies may actually show the highest potential for implementation at international level. These countries are especially China, Brazil and Russia, but also other relevant countries in Africa and South America like Chile, Mexico, Argentina, Botswana and Gabon. The rationale behind this revolves around the fact that these countries need to develop and/or modernize the water and wastewater management systems of large areas of their territories. Therefore, there is actually a high demand for the implementation of cost-efficient decentralised management practices.

2.3.5 Conclusions and recommendations

The main potential mentoring areas at international level are as it follows:

- South America, East of USA, West of Canada, western Africa, Central America, south-eastern Asia and Melanesia are identified as potential areas for transferability in terms of rainfall distribution.
- Saudi Arabia, Pakistan, some parts of India, Mexico and Iran are identified as potential regions for transferability in terms of reducing groundwater stress.
- Permeability of soil is not identified as a key parameter for transferability because the surface soil can be replaced in the site of application.
- No comprehensive data base for wind erosion monitoring exists at worldwide level
- Relevant legislation in South Korea has a high transferability potential to the Baltic Sea Region and other EU regions. This country is very advanced in term of cooperation with private sector to develop green infrastructures (i.e. urban stormwater system is defined as a part of green infrastructure). Their experiences may be transferred to other countries in order to promote decentralised urban stormwater management systems
- Green roofs show potential to be transferred to USA. More than 15 federal funding sources exist for supporting the implementation of green infrastructure.
- Based on GDP analysis, North America, Europe and Australia can be clearly distinguished as areas with high GDP levels. However, emerging economies may actually show the highest potential for implementation at international level.

2.4 References

Ashley, R., Jones, J., Ramella, S., Schofield, D., Munden, R., Zabatis, K., Rafelt, A., Stephenson, A.&Pallett, I. (2007) Delivering more effective stormwater management in the UK and Europe – lessons from the Clean Water Act in America *NOVATECH.*

Ashley, R M., Tair, S., Cashman, A., Saul, A J., Hurley, L and Blanksby, J, 2006. Sewer Design Parts 1 and 2. Report Project WM07, UKWIR, London. Retrieved from: www.ukwir.org.uk.

EEA, 2003: Average Annual Precipitation in Europe. At http://www.eea.europa.eu/data-and-maps/figures/average-annual-precipitation. Accessed on October 2014.

EEA, 2012_a: Challenges and opportunities for cities together with supportive national and European policies. Published by European Environmental Agency.

EEA, 2012_b: Erosion by Wind in Europe, 1961-1990. European Environmental Agency. At http://wwws3.eea.europa.eu/data-and-maps/figures/estimated-number-of-erosive-days/image_xlarge. Accessed on November 2014.

ESB, 2000: European Soil Bureau. Classified slopes in the European Union. At http://eu-soils.jrc.ec.europa.eu/ESDB_Archive/serae/GRIMM/erosion/inra/europe/analysis/maps_and_listings/web_erosion/maps_and_listings/slopeclass_a3.gif. Accessed on November 2014.

Fetke, Balazs M. et al (2000). Global Composite Runoff Fields Based on Observed River Discharge and Simulated Water Balances. Complex Systems Research Center, University of New Hampshire. UNH-GRDC Composite Runoff Fields v1.0.

FHWA, 2000. Stormwater Best Management Practices in an Ultra-urban Setting: Selection and Monitoring.

Gleeson T., Smith L., Moosdorf N., Jens Hartmann J., Dürr H., H. Manning A., Ludovicus P. H. van Beek L., Jellinek A. M. (2011), Mapping permeability over the surface of the Earth, Geophysical Research Letters , Vol. 38 Issue 2.

Hvitved-Jacobsen, T., Vollertsen, J., Nielsen, A.H., 2010. Urban and Highway Stormwater Pollution. Taylor & Francis Inc, 347 pp.

IMF, 2008: GPD (Nominal) Per Capital World Map in 2007. International Monetary Fund World Economic Outlook Database, April 2008

Jefferies, C., Escuder-Bueno, I., Andrés-Doménech, I., Perales-Momparler, S., Wade, R.&Morales-Torres, A. (2014) In *13th International Conference on Urban Drainage*Sarawak, Malaysia

Jin, Z. (2005) Development of a transparent knowledge-based spatial decision support system for decentralised stormwater management planning. PhD, University of Hannover, Germany, 2005.

Latvian Ministry of Education and Science (2014) Science. Retrieved on 25th of November 2014 from: http://www.izm.gov.lv/.

Marlow D. R., Moglia M., Cook S., Beale D.J.,(2013). Towards sustainable water management: A critical reassessment, Water Research 47 pp. 7150-7161.

Mascarelli A., (2012).Demand for water out strips supply. Nature. At http://www.nature.com/news/demand-for-water-outstrips-supply-1.11143. Accessed on December 2014.

Nickel, D., Schoenfelder, W., Medearis, D., Dolowitz, D. P., Keeley, M.&Shuster, W. (2014) German experience in managing stormwater with green infrastructure. *Journal of Environmental Planning and Management,* **57,** 403-423.

OECD, 2012: Financing Green Urban Infrastructure; OECD Regional Development Working Papers 2012/10.

Revitt, D M, Ellis, J B and Scholes, L, 2003. Review of the Use of Stormwater BMPs in Europe. Report 5.1. EU 5th Framework DayWater Project. Retrieved from: www.daywater.org.

Roeckner, E.; Kirk, A. (2013): What will the climate in Europe look like in the middle of the 21st century?. At http://www.mpimet.mpg.de/en/kommunikation/fragen-zu-klima-faq/what-will-the-climate-in-europe-look-like-in-the-middle-of-the-21st-century.html. Accessed on September 2014.

Roessner, D., Bean, A.S., 1994. Payoffs from industry interaction with federal laboratories. Journal of Technology Transfer 20 (4).

Sänkiaho, L., Sillanpää, N.&Setälä, H. (2011) In *Cities of the Future: Sustainable Urban Planning and Water Management.*

Speers, A., Mitchell, G., 2000. Integrated urban water cycle. In: National Conference on Water Sensitive Urban Design e Sustainable Drainage Systems for Urban Areas: Melbourne, Australia.

Stormwater (2013a) European Commission Launches Green Infrastructure Strategy. Retrieved on 26th of November 2014 from: http://stormwater.wef.org/2013/06/european-commission-launches-green-infrastructure-strategy/.

Stormwater (2013b) Baltic Sea Denizens Willing To Pay for Water Quality Improvements. Retrieved on 26th of November 2014 from: http://stormwater.wef.org/2013/04/baltic-sea/.

United Nations Environment Programme (2014) International Source Book On Environmentally Sound Technologies for Wastewater and Stormwater Management. Retrieved on 18th of November 2014 from: http://www.unep.or.jp/Ietc/Publications/TechPublications/Tech-Pub-15/3-7EuropeEast/7-0.asp.

Water World (2014) How Will Croatia Cope with New EU Water Responsibilities? Retrieved on 25th of November 2014 from: http://www.waterworld.com/articles/wwi/print/volume-28/issue-2/regional-spotlight-europe/how-will-croatia-cope-with-new.html.

Zoppou C. (2000), Review of urban storm water models, Environmental Modelling & Software 16: 195–231.