Irma Mäkelä & Tarja Palvi (eds.)

Lahti as an Urban Laboratory for Sustainable Environment

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LAHDEN AMMATTIKORKEAKOULU
Lahti University of Applied Sciences

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ABOUT THE AUTHORS

Aarrevaara Eeva, DSc (Arch.), has been principal lecturer at Lahti University of Applied Sciences in Degree programme of Environmental Technology since 2003. She is also responsible for the Master degree programme Sustainable Urban Planning and Climate Change (running since 2012) and is involved in several RDI projects.

Allen John, BSc, has a degree in geology from the University of Georgia. He worked in the City of Richmond, Virginia Wastewater and Stormwater Utilities as an Environmental Technician for three years. Currently he lives in Finland and participates in the LUAS Master study programme.

Carroll Paul, MSc (Env. Tech), is a teacher in environmental science subjects in Lahti University of Applied Sciences. He specialises in integrating practical cases from the public and private sectors into learning units, which is facilitated by relevant project participation.

Huttunen Jessica is a BEng, whose thesis deals with stormwater monitoring in Karisto and Kytölä areas in Lahti. The thesis was carried out under the ILKKA project for Lahti Environmental services.

Järveläinen Juhani works as a research technician at Helsinki University's Department of Environmental Sciences in Lahti. He is currently finishing his MSc (Tech.) degree in environmental engineering at Aalto University.

Kadlec Jiri is a PhD candidate and project employee at Aalto University. He is the developer of the Lahti Urban Water Laboratory web-based map application for capturing stormwater pollution sources in the changing city of Lahti. Jiri's research topics include the design of a reusable web map client framework for sharing environmental observations, Open GIS web services and spatial data infrastructure.

Koivusalo Harri, DSc (Tech), is a professor of water resources engineering at the Department of Civil and Environmental Engineering in the Aalto University School of Engineering. His research focuses on precipitation-runoff modelling, snow and canopy processes, solute transport, and hydrological impacts of land use changes.

Setälä Heikki is a professor in Urban Ecosystem Ecology at the Department of Environmental Sciences, University of Helsinki.

Sillanpää Nora, DSc (Tech.), works as a researcher in Aalto University School of Engineering and has ten years of experience on urban runoff related research on construction sites, residential areas, city centres, industrial sites and urban snow.

Suomalainen Sari, MSc, (The University of Helsinki) is a lecturer in the Degree Programme in Landscape Design at HAMK University of Applied Sciences. She has earlier served as a park manager in Pirkkala, Finland (1992-2010), as a member of the board for the Association of Park Managers (1998-2010) and has been a Commissioner in the International Federation of Park and Recreation IFPRA Administration since 2007.

Valtanen Marjo, MSc, is working as a doctoral student at the University of Helsinki in the Department of Environmental Sciences. Her main research areas are urban hydrology, urban runoff pollution and sustainable stormwater management.

Vesikko Ari, MEng, works as a lecturer in Lahti University of Applied Sciences, Faculty of Technology. Ari's teaching topic is in ICT and projects include the development and the implement of physical and virtual learning environments.

ABSTRACT

The project Urban Laboratory of Sustainable Environment started in the year 2012 and finished in late 2014. Aalto University acted as coordinator and the partners were Helsinki University and Lahti University of Applied Sciences. The project was based on earlier stormwater projects and in it data on stormwater in Lahti is combined with the development of a new kind of geographic information application, with which measuring results can be illustrated. In the project a modelling method for stormwater formation was developed, as well as an attempt being made to avail of stormwater research results in urban planning.

This publication consists of the combined writings of participants in the research project. In the introduction Eeva Aarrevaara gives an overview of the contents of the publication, tells of the general project situation and describes the project seminar that was held in April 2014. In the appendices is the programme of this seminar. In her own article Sari Suomalainen discusses the need for virtual learning in the future, this being a central element in the development project of the Niemi campus in Lahti. As part of the University of Applied Sciences Master thesis of Ari Vesikko a decision theatre was set up within the existing energy and environmental technology premises in Niemi. The facilities it contains also serve the geoinformatics part of the project. In his work Jiri Kadlec presents a new kind of geographic information system interface, with the aid of which existing geographic information material can be combined with future scenarios and environmental measurement material. In his Master's thesis Juhani Järveläinen created a stormwater model for the Lahti area by dividing the city area into different land use classes which typically have different amounts of permeable surfaces. In this work earlier stormwater models for Espoo and Lahti are integrated and a model is produced on the basis of which the quality and amount of stormwater in different types of area is estimated.

The final UAS project work of Jessica Huttunen was carried out under the City of Lahti's ILKKA-project and it deals with the results of stormwater measurements from both the Karisto and the Kytölä stormwater treatment areas. The opinions of residents of the stormwater areas were gathered by questionnaire. Huttunen has also compiled a list, contained in the appendix, of previously implemented waterway and stormwater research projects in the Lahti area. Paul Carroll in his part describes a student project that was carried out in cooperation with Lahti Region Environmental Services and dealing with an inventory of the land use of Lahti's lake shores. The project enabled students to become familiar with necessary land planning tasks and they were able to obtain useful advice while carrying it out.

John Allen answered a number of questions posed to him on the theme of stormwater management in Richmond, Virginia in the United States, where he earlier worked in a practical capacity. It transpired from the interview that in the US the legal requirements for stormwater management have long been made clear and that their implementation is becoming routine. Nora Sillanpää, together with Harri Koivusalo, Heikki Setälä and Marjo Valtanen, presents earlier Finnish stormwater projects prior to the Urban Laboratory of Sustainable Environment, and points out their main differences. Stormwater measurement methods and the challenges involved, especially in cold climates, are presented from many viewpoints. Graduate theses published during the project, as well as scientific articles are listed at the end of this section, while as an appendix 3 broad review of different previous stormwater research, and the associated theses and articles is included. At the end it can be concluded that it is hoped that stormwater measurements will become the practice in the public sector, where up to now they have been based on the results of university research projects. There is also a need to assess the formation of stormwater outside of residential area in the future, for example industrial areas, the vicinity of roads and green areas are crucial research sites.

Keywords: Urban hydrology, stormwater, monitoring, sustainable environment, sustainable development, GIS-based information systems, urban planning

TIIVISTELMÄ

Kestävän ympäristön kaupunkilaboratorio -hanke alkoi vuonna 2012 ja loppui kesäkuussa 2014. Hankekoordinaattorina toimi Aalto Yliopisto ja partnereina Helsingin yliopisto sekä Lahden ammattikorkeakoulu. Hanke pohjautuu aiempiin hulevesitutkimushankkeisiin ja siinä ovat yhdistyneet hulevesimittaukset Lahdessa sekä uudenlaisen paikkatietoliittymän kehittäminen, jonka kautta mittaustulosten seuranta on mahdollista. Hankkeessa on myös kehitetty hulevesien muodostumisen mallintamista sekä pyritty hyödyntämään yhdyskuntasuunnittelussa hulevesitutkimuksen tuloksia.

Tämä julkaisu on koottu tutkimushankkeeseen osallistuneiden kirjoituksista. Johdannossa Eeva Aarrevaara luo yleiskatsauksen julkaisun sisältöön, kertoo yleisesti hankkeen lähtökohdista sekä huhtikuussa 2014 järjestetystä hankkeen seminaarista. Julkaisun liitteenä on seminaarin ohjelma. Sari Suomalainen käsittelee omassa osuudessaan virtuaalisen opetuksen tarvetta tulevaisuudessa, mikä liittyy keskeisesti Lahden Niemen kampuksen kehittämisprojektiin. Niemessä jo olemassa oleviin ammattikorkeakoulun energia- ja ympäristötekniikan tiloihin toteutettiin osana Ari Vesikon ylemmän AMK-tutkinnon opinnäytetyönä ympäristötietoteatteri, jonka laitteisto palvelee myös projektin geoinformatiikan osuutta. Jiri Kadlec esittelee omassa osuudessaan uudenlaista paikkatietoliittymää, jonka avulla voidaan yhdistää olemassa olevia paikkatietoaineistoja, tulevaisuuden skenaarioita sekä ympäristömittausdataa. Juhani Järveläinen on diplomityössään laatinut Lahden alueen hulevesimallinnuksen jaottelemalla kaupungin alueen erilaisiin maankäyttöluokkiin, joille on tyypillistä erilainen imeytyvän pinnan osuus. Työssä yhdistetään luokitukseen aiemmin tehtyjä hulevesimittauksia Espoossa ja Lahdessa ja tuotetaan malli, jonka pohjalta arvioidaan hulevesien laatua ja määrää erityyppisillä alueilla.

Jessica Huttusen AMK-opinnäytetyö on tehty Lahden kaupungin ILKKA-hankkeelle ja siinä käsitellään hulevesimittausten tuloksia sekä Kariston että Kytölän hulevesien käsittelyalueilta. Alueiden asukkaiden mielipiteitä hulevesien käsittelyalueista on myös kartoitettu kyselyillä. Huttunen on myös koonnut julkaisun liitteenä olevan luettelon aiemmista Lahden seudulla toteutetuista vesistöihin ja hulevesiin liittyvistä tutkimushankkeista. Paul Carroll kuvaa osuudessaan opiskelijaprojektina yhteistyössä Lahden kaupungin ympäristöpalveluiden kanssa toteutettua Lahden järvien maankäytön kartoitusta. Projektin avulla opiskelijat ovat päässeet tutustumaan tarpeelliseen tehtävään ja saaneet käytännöllisiä neuvoja sen toteuttamisesta.

John Allen on vastannut hänelle asetettuihin kysymyksiin koskien hulevesien käsittelyä Yhdysvalloissa, Richmondin kaupungissa Virginiassa, jossa hän on aiemmin toiminut niihin liittyvissä käytännön tehtävissä. Haastattelusta ilmenee, että Yhdysvalloissa on jo varhain tiedostettu lainsäädännössä hulevesiin liittyvä ohjaustarve ja sen toteuttaminen on arkipäivää. Nora Sillanpää esittelee yhdessä Harri Koivusalon, Heikki Setälän ja Marjo Valtasen kanssa aiempia suomalaisia hulevesitutkimushankkeita ennen Kestävän ympäristön kaupunkilaboratoriota sekä tekee huomioita niiden keskinäisistä eroista. Hulevesien mittausmenetelmiä ja niihin liittyviä haasteita, erityisesti kylmässä ilmastossa, esitellään monipuolisesti. Hankkeen aikana julkaistut opinnäytetyöt ja tieteelliset artikkelit on luetteloitu osuuden loppuun, lisäksi on liitteenä laaja katsaus eri aikoina julkaistuihin hulevesitutkimuksiin ja niihin liittyviin opinnäytetöihin sekä artikkeleihin. Lopussa on todettu, että hulevesimittausten toivotaan muodostuvat julkisen sektorin käytänteiksi jatkossa, kun ne tähän asti ovat muodostuneet lähinnä yliopistojen tutkimushank-

keiden pohjalta saaduista tuloksista. Tarvetta on myös kartoittaa erityisesti muiden kuin asuinalueiden hulevesien muodostumista tulevaisuudessa, esimerkiksi teollisuusalueet, tieympäristöt ja viheralueet ovat keskeisiä tutkimuskohteita. Hulevesitutkimusta sovelletaan muun muassa yhdyskuntasuunnittelussa, johon on jo käytössä erilaisia mitoitusohjeita. Toivottavaa on, että hulevesitutkimus jatkuu ja laajenee tarkemman tutkimustiedon saamiseksi kaupungistumisesta ja ilmastonmuutoksesta johtuvien ympäristöongelmien ratkaisemisissa.

Avainsanat: taajamahydrologia, hulevesi, monitorointi, kestävä kehitys, kestävä ympäristö, paikkatietojärjestelmät, yhdyskuntasuunnittelu

INTRODUCTION

The research project Urban Laboratory of Sustainable Environment commenced in January 2012 with European Regional Development Fund (ERDF) funding. The coordinator of the project is Aalto University (AU), with The University of Helsinki (UH) and Lahti University of Applied Sciences (LUAS) as partners. The goal of this project has been to establish a long term research and development base/platform for the Lahti region. Multidisciplinary research is needed for nationally and scientifically challenging problems, which is being carried out by a larger group consisting of the following: the urban ecology research group (UH), the hydrology group and the environmental geoinformatics group (AU) and the degree programme in environmental technology (LUAS). The platform can include also new bodies in the future. This platform should also include the local decision makers and authorities who are responsible for the development of the urban environment, as well as enterprises operating in the environmental branch.

The goal of the research project

According to the project plan, the research goal has been to identify and describe activities in urban ecosystems, the impacts of building in ecosystems and develop databases connected to these subjects. The main activities in the project have been the planning and realisation of new experimental observation sites for stormwater measurements and an environmental geoinformatics laboratory, which will later be referred to as a decision theatre. The practical studies from these places have provided new environmental information to the project partners. The network of experimental locations has consisted of six different sites in the Lahti area and they represent different types of land use, from housing areas to the city centre. Measurements in these areas have provided data concerning water circulation and air quality in the urban ecosystem. Measurements have been input to the data infrastructure set up within the project. The geoinformatics based information has been connected with other databases, models and planning tools dealing with the same area. All these elements will provide a new research infrastructure for Lahti concerning urban environment, community development and environmental GIS based data. This platform will complete and strengthen existing regional environmental research.

The work packages covered management of the project, four different areas of research and one package deals with adaptation of the research results.

WP 6 Management /Aalto University
WP1 Hydrological cycle in the built environment/Aalto University
WP2 Impact of ecosystem services on hydrological cycle and air quality/The University of Helsinki
WP3 Building of infrastructure supporting decision making and research/Aalto University
WP4 Modelling and valuation of ecosystem services and their relationship with human activities/ Aalto University
WP5 Adaptation of research results in the use of urban planning and enterprises

The project has had a steering board consisting of several stakeholders in the Lahti region. Director Harri Kallio from the Centre for economic development, traffic and the environment acted as chairman up to 2013 and secretary general Senja Jouttimäki from Lahti University campus was elected as his successor for the last part of the project. Members of the board have been principal lecturer Eeva Aarrevaara/Lahti University of Applied Sciences (LUAS) (1.1.2013 -), managing director Markku Heikkonen/Lahti Aqua Ltd., professor Ari Jolma/Aalto University (AU), professor Harri Koivusalo/AU, principal lecturer Silja Kostia/LUAS (until 31.12.2012) head of water protection Ismo Malin/City of Lahti, account director Juha Määttä/Lahti Region Development LADEC Ltd. (LADEC), deputy head of unit Osmo Niiranen/Ramboll Ltd, professor Heikki Setälä/The University of Helsinki (UH). Regional development manager from Päijät-Häme regional council Juha Hertsi has acted as controller of the project. Researcher Nora Sillanpää from AU has acted as secretary of the board.

Seminar presenting the results

A seminar was arranged on 7th April 2014 in Niemi campus to present the results of the Urban laboratory project and over 50 participants attended it. An essential goal was also to invite representatives from enterprises and the public sector to comment on the results and their usability in working life, as well as on future needs in research concerning urban environments. Opinions concerning scientific and practical solutions were shared and the need for continuing environmental research and measurements was recognised, as was the urgent need to adapt new innovations in practice. Important contacts were made between different stakeholders. The programme of the seminar is presented as an appendix 1 of this publication. The chair of the seminar was Professor Harri Koivusalo while Nora Sillanpää and Hanna Vellonen from Aalto University were responsible of the arrangements. Part of the seminar was realised in the Decision Theatre where Ari Vesikko introduced the technical features of the concept and Jiri Kadlec presented demonstrations using the equipment.

Picture 1: Seminar on 7th April in Niemi campus (Päivi Kärnä 2014)

Cooperation between Master degree programmes

In the course of the project several thesis works have been produced at Bachelor and Master levels, and also Nora Sillanpää finished her doctoral thesis during the project. The University of Helsinki (UH) runs a Master programme in environmental ecology in Lahti and also an English-language Master programme called MURE has been arranged in Lahti. The newcomer is the Master programme in Sustainable urban planning and climate change, which started in Lahti University of Applied Sciences (LUAS) in 2012. The Master programme in LUAS differs from university programmes: the goal of this programme is to broaden the environmental perspective for professionals who need a new kind of environmental understanding in their working field in enterprises, consulting firms and the public sector. According to the present legislation master students in LUAS need to possess at least three years of working experience to be accepted into the programme. The goal of their master thesis is to either develop their organisations and its functions, or to adapt environmental research into practical urban situations and challenges. Attention is paid to urban and interactive planning, to climate change mitigation and adaptation in urban planning, to GIS as a tool in planning, with matters of environmental management, environmental research and Cleantech issues also included.

The Master's Degree Programme in Multidisciplinary Studies on Urban Environmental Issues (MURE) took on new students in the year 2012. The programme is focused on understanding and mitigating environmental problems due to urbanisation, such as human-induced impacts on the urban biota, changes to the hydrology and biogeochemistry of soil, terrestrial and aquatic ecosystems, as well as their socioeconomic impacts. Principal lecturer Eeva Aarrevaara and university lecturer Kirsi Kuoppamäki decided to plan common courses for both of the English Master programmes in autumn 2013. Previous experiences dealing with a common environmental course in the 2000s in cooperation between Helsinki University of Technology (HUT), UH and LUAS also encouraged this kind of experiment. The first cooperative course was Urban and Interactive Planning, where theoretical lectures were given concerning urban ecosystem services and urban planning. The students prepared a pre-course assignment and then, during the contact days, presented interesting urban development projects from all over the world. During these contact days students worked in five groups and evaluated the plans for the new Ranta-Kartano area in Lahti, paying attention to the spatial structure of the area, green surfaces and stormwater management. The group working was successful, although it was carried out over three days and the results were presented on the last day. Students were then given follow-up individual assignments to be carried out after the intensive period.

The second common course was Climate Change: Adaptation and Mitigation in Urban Areas. Topics of the lectures dealt with the interaction between climate change and urban areas, challenges to stormwater management in urban environment, as well as energy policy and climate change adaptation in the city of Lahti. Students again worked during contact days through searching for climate orientated development projects by which the cities and regions adapt and mitigate climate change impacts. In these courses lectures were given by Kirsi Kuoppamäki, Eeva Aarrevaara and Paul Carroll. Visiting lecturers were Tommi Ekholm (VTT Technical Research Centre of Finland), Johanna Palomäki (Lahti city planning), Timo Permanto (Lahti Region Environmental Services) and Kirsti Toivonen (City of Tampere, Vuores project). Pirkko-Leena Jakonen introduced the Ranta-Kartano area to the group and told about its current planning situation. Students were asked to give feedback for the courses and positive comments given referred to the international atmosphere and the lively discussions held. Also constructive comments were given regarding the arrangements and topics, with the overall impression being positive.

This kind of course arrangement represents the favourable use opportunities to increase cooperation between regional educational organisations, such as in this case UH and LUAS, which has also been one goal of the project.

Virtuality and environmental changes

Changing learning environments and methods, such as the growing share of eLearning are current topics in educational environments like Niemi campus, where all the partners of this project are working. Virtual information and online services are not only important for education but they also provide opportunities to adapt new environmental information to research, urban planning and decision making. They also offer a tool for environmental impact assessment, which is quite challenging in urban planning. Changes of land use are caused, for example, by changes in the quantity and quality of stormwater in a certain area, when an untouched area is turned into a built one and the share of impervious surfaces changes radically.

The role of eLearning in future education and new campus environment

Master of Science Sari Suomalainen is preparing her Master thesis in Lahti university of Applied Sciences (LUAS) concerning eLearning pedagogies and methods which are based on working life in a future campus environment. LUAS is cooperating with LADEC Ltd in a project of future campus design. LADEC is an actor which supports the right conditions for business growth in the Lahti Region, and strengthens the area's competitiveness and attractiveness (LADEC Ltd, 2014). According to the so-called campus theses, six different features have been presented concerning the future campus. Doing together is the first thesis, meaning a diversified way of working, joint uses of educational spaces, a sense of community and common services. Uniform campus refers to joint buildings and a built unity, which contains common public spaces like squares and streets or pathways. Everyday services means bringing service and entrepreneurship environments as a part of the future campus environment. Flexibility describes being able to change the uses of spaces or that an educational space is designed to serve different purposes. Open operational environment reflects easy accessibility and attractiveness of the educational environment, which should be serving its region. The last thesis, responsibility, describes a high utilisation rate, the use of clean technology and ecological principles in the area. (Hyökki, Kaikonen, 2013). A tangible goal for a new campus environment is to reduce the spaces used in education and special laboratories in LUAS. This means e.g. an increase in the amount of eLearning compared with the present situation. Although this principle is not without challenges, such as how to increase eLearning, what kind of learning can be realised virtually and when it is necessary to have contact lessons or meetings.

In her thesis, Sari Suomalainen will examine these limits with the help of interviews of eLearning professionals. She will use as an example the design process of a module which will be produced in cooperation between HAMK University of Applied Sciences (HAMK) and LUAS. Both of these, together with Laurea University of Applied Sciences (Laurea), form the so-called Federation of Universities of Applied Sciences (FUAS), inside of which efforts towards the production of common studies and RDI are shared goals. Both education and research are especially expected from so-called focus areas like energy and the environment. The module under planning is Traffic and Land Use Planning. The equal parts of the module will be Urban Planning, Traffic Planning and Traffic psychology and safety. Virtual learning and methods will play an essential role in the realisation of the module. Common virtual platforms enable teachers and students to share information and build and develop it together.

The concept of blended learning is often combined with virtual learning, because blended learning as a pedagogic principle allows learning to happen in different kind of environments, from traditional classrooms to virtual reality. According to Nordberg et al. (2011) there is a shift between synchronous and asynchronous elements in blended learning. Synchronous elements mean arrangements which concern the whole group, such as like deadlines and contact meetings, while asynchronous elements combine individual learning which is not bound to time and space. In her work, Suomalainen is places special emphasis on how working life orientated projects can be combined with virtual learning. The interviews with virtual learning experts have been carried out with the virtual meeting service Lync. The STEEP analysis has been used to structure the interviews. STEEP stand for Socio-cultural forces, Technological forces, Ecological forces, Economic forces and Political forces. The analysis is expected to produce working models to be utilised in future FUAS modules and create working life based project activity.

The Decision Theatre

MEng Ari Vesikko introduces the Niemi campus environmental information laboratory or Decision Theatre that was designed and built in association with his thesis work in LUAS. A prototype for the decision theatre has been constructed for example in Arizona State University (ASU), in which the theatre consists of eight different projectors. The decision theatre was built in the new premises of the Bachelor degree programme of Environmental Technology in Lahti Science Park in Niemenkatu. An audio matrix system controls two Full LED hybrid projectors, which enable a panoramic view to be shown (a screen of 32:9), or the use of different information in both of them (each screen of 16:9). The project was realised by funding of the Urban Laboratory of Sustainable Environment project. The purpose of the Decision Theatre is based on better opportunities to present environmental information, especially in GIS-based information, to illustrate environmental data and help scientists and planners to comprehend and connect different kinds of data. Theoretically it has been claimed (McCormick, DeFanti et al. 1987) that this kind of presentation will also help the decision making process. To verify this theory a survey was organised amongst LUAS faculty of technology staff, in which they were asked about data visualisation. The answers clearly support the claim that visualisation enables complex data to be understood better.

A new kind of user interface based on GIS

Jiri Kadlec has been working as a researcher and PhD candidate in the Aalto University geoinformatics unit. His task has concentrated on the design of a web based information platform and building a user interface by collecting and processing different types of environmental information obtainable in GIS format. Maps in GIS format and real time stormwater measurements are combined for the same interface, which will enable more diversified environmental information, for example for urban planning and decision making processes. Especial interest has been paid to effectively visualising urban runoff quantity and lake water quality by using a web based online information platform. The software platform of the project has been built by using open source software. Jiri Kadlec presents three application cases: 1. Experimental Catchments Visualisation and 2. Stormwater Runoff and Pollutant Load Forecasting Map and 3. Map Editing Functionality for Urban Planning. In the first one, three observation sites with real-time observation service are maintained in the Lahti area. Users can observe how these different catchment areas behave in different rainfall or snowmelt situations. In the second case the user can choose an interactive map of either the present or future situation in land use of the city area. The data sources include material of different character, official data bases, material collected by volunteers and research studies. The user can choose different situations concerning land use, rainfall, the receiving lake and different indicators of rainfall quality. The application enables testing of different situations and variables. The third case supports editing possible future land uses and their impacts in stormwater amounts. The new version can be saved and compared with the existing land use maps. This enables future scenarios in land use and its impacts to be compared.

Picture 2: Jiri Kadlec presenting GIS-based user interface demonstrations (Päivi Kärnä 2014).

Estimating stormwater pollutant loads in Lahti

Juhani Järveläinen, in his master thesis, has made a land use based stormwater model, in which stormwater quality is characterised and runoff based volumes estimated. A volume-concentration model has been used to estimate the annual pollutant load in stormwater in the Lahti area. The land use based division was made in the study with the help of most recent land use and aerial photographic data available in Lahti city Land Use Unit. The relative imperviousness in different land use classes was estimated by an imperviousness analysis.

The estimations are based on recent monitoring data in two stormwater studies in Lahti and Espoo. Pollutant concentrations have been calculated on behalf of them and in relationship with different land uses. In Lahti area the total annual stormwater runoff has been estimated as 13 million m3. According to FMI (2011) the annual rainfall in the Lahti region is 634 mm. Industrial areas, roads and green areas produce the largest part of the annual stormwater load when all pollutants are considered. However, roads, city centres and commercial or public areas are the largest sources of pollution compared with their size.

Järveläinen claims that unmanaged stormwater runoff can have severe impacts on the environment. Usually in stormwater management elements like retention pools, grass swales and permeable surfaces in urban areas are used. The natural hydrologic cycle is usually changed by urbanisation and stormwater management aims to minimize these impacts. According to Järveläinen this model can be used in other cities as well. The accuracy of estimations is improved if local monitoring data is available. Especially updated information from industrial, commercial and green areas would increase the accuracy in local conditions. Most of Finnish cities are lacking current monitoring data concerning stormwater quality.

Opportunities of natural stormwater management

Climate change, urbanisation, increase in impermeable surfaces and the current capacity of stormwater handling arrangements all demand new kinds of solutions in urban areas in the future. The natural hydrologic cycle is disrupted by urbanisation. Huttunen claims that by aspects of natural stormwater management these kinds of changes could be controlled and balanced. Annual precipitation is predicted to increase by 10-40 % in the future compared with the reference period 1971-2000. Also, it has been found that precipitation has increased in urban areas by at least 10 % because of the effect of air pollution, turbulence caused by buildings and warmer microclimates compared with rural areas. These phenomena together cause an increasing need for new means to manage stormwater in urban areas.

Natural stormwater management methods can serve several purposes at the same time: they can create more positive environmental effects, increase social interaction between the users and improve the biodiversity of the area. Stormwater quality management methods can be classified as follows: bio-filtration or bio-retention, retention pools, retention areas (with drying time of 48 hours max.), grass swales, green- or vegetation roofs, infiltration depressions, planting of natural plant species, permeable surfaces, rain gardens, wetlands and different storage methods. In certain urban areas there is not enough space to use natural stormwater management constructions. In those cases some combinations of natural and other arrangements should be considered, or only mechanical treatment applied. In planning of natural stormwater management areas one must also consider if there is enough space for treatment, that service road connections are arranged in the area and that there is access to the areas all year round.

Jessica Huttunen carried out her Bachelor thesis for Lahti Region Environmental Services in autumn 2013, and in association with the project Climate-Proof City– Tools for Planning (ILKKA). Monitoring data from two natural stormwater management areas, Kytölä and Karisto in Lahti, is also presented in the thesis. Regular samples were collected from in- and out-flowing stormwater systems and analysed in Ramboll Analytics Ltd. In Kytölä area the water was flowing in open surfaces and natural ditches where the infiltration was happening through coarse soil and vegetation. The effectiveness of the biofiltration system was observed to be very efficient. In Karisto area the reduction capacity of the two constructed wetlands varied a lot in different samples and this was caused by different factors. For example, the total nitrogen diminished in both areas, but several other nutrients and pollutants varied in samples. Both these wetlands are still relatively young and usually the retention capacity is not as efficient as it can be in natural wetlands. It was noticed that the effectiveness of biofiltration has not been examined during the winter period. Also the role and species of vegetation plays an important role in the effectiveness of biofiltration.

Sustainable development in urban ecosystem – course in environmental technology

MSc Paul Carroll describes an environmental learning project which was conceived based on discussions with staff members in Lahti Environmental Services and Urban Planning. In the Environmental Technology Degree programme there is a project course for the first year Bachelor students every spring, the one described was 2013. Mr. Timo Permanto and his colleagues agreed that an inventory project concerning the lakeshores in the Lahti area would entail useful work that the permanent staff has no time to implement, and that such a project would serve well the needs for environmental and urban planning. Students were divided into 5-6 person groups and they were given a special inventory document to fill in on site visits. One central purpose of the inventory was to find out what kind of differences there are between the official maps and the real land use of the shorelines. The students seemed to need quite a lot of instructions in the beginning and subsequent repetition of them, but understandably they were just beginning to get experiences from this kind of work. Rivers were left outside this inventory project, but with the intention that they might provide a target for the following year. Feedback for the student project from the city representatives was good and it was told that the material will serve their practical work well. The students were also asked to give feedback for the course, with one of the things stressed being how it was good getting involved in this kind of working life based project where a real need exists.

Experiences and practices on stormwater management in the city of Richmond, Virginia

John Allen has a degree in geology from the University of Georgia. His working experience led him to work for the Wastewater and Stormwater Utilities of the City of Richmond, Virginia as an Environmental Technician for three years. He recently moved to Finland and has been participating in the LUAS Master study programme in Spring 2014. Eeva Aarrevaara posed a list of questions to him concerning stormwater management experiences and practices in the US. Stormwater management has a long history in US legislation: the Clean Water Act in 1972 already considered the problems of urban stormwater quality, but particularly in the Water Quality Act of 1987 and with the establishment of the Municipal Separate Storm Sewer System (MS4) program these issues have been considered seriously. Allen also describes examples of monitoring depending on the character of the current project. Good housekeeping practises in public and private sites are needed to reduce pollution of stormwater. The aging infrastructure is also creating new risks to the environment, if for example there are leaks in the waste water system they usually adversely affect stormwater quality. Possible solutions to managing stormwater are rain harvesting and rain gardens, permeable pavements, sunken planter beds, retention and detention beds.

Urban hydrological monitoring in Finland: past experiences, recent results, and future directions

DSc (Tech.) Nora Sillanpää, together with professor Harri Koivusalo, professor Heikki Setälä and MSc Marjo Valtanen, summarises the background of Finnish stormwater research and recent results in various projects in different urban areas. The discussion concerning monitoring is introduced as well as the challenges for monitoring in a cold climate and snowfall effects. There seems to be little experience of monitoring snow affected conditions compared with rainfall-stormwater monitoring. Today the challenge seems to be to fit the monitoring needs to a realistic budget. The monitoring programme should include data from different seasons and from a range of event sizes. Hydrological monitoring has a long history in Finland: the first water level observations date back to the 19th century. The first stormwater research, Finnish Urban Storm Water took place in the late 1970s in Helsinki, Tampere, Oulu and Kajaani. It was based on monitoring of seven different urban catchment areas; both the quality and quantity of the stormwater were measured.

The next major research programme started only in the beginning of the 2000s and contained three urban runoff monitoring stations in Espoo. The areas represented low-density, medium-density and development areas. This research made up part of the RYVE-project (Urban Waters and Storm Water Management Practices in Finland 2001-2003). Measurements in Espoo concentrated on different kinds of residential areas under similar meteorological circumstances. The continuous year-round runoff and water quality measurements were in the focus of the study.

During the subsequent StormWater –research programme (2008-2011), three different monitoring stations were established in the city of Lahti. Water quality was sampled with automatic samplers year round, in the winter periods with a bit less frequency than in the summers. Analysis of pollutants played an important role in the monitoring programme. One monitoring station was also established in the city of Kouvola. The programme also performed the first experimental stormwater biofiltration experiments in Finland, at a lysimeter facility located in Jokimaa, Lahti, where the biofiltration with vegetated filtration structures is measured with eight lysimeters. The current project Urban Laboratory of Sustainable Development is based on the previous stormwater projects, but has also changed some practicalities like monitoring schemes in different stations. A new monitoring station was constructed in the future residential area in Kytölä, Lahti, where the impacts of the construction process can be measured.

Several publications have been published concerning the current project. The publications are listed in appendix 3 and they deal with the following areas: Impacts of urbanisation on runoff generation, impacts of urbanisation on urban runoff quality, the importance of urban runoff as a diffuse pollution source and urban runoff modelling. Nora Sillanpää´s dissertation, several Master Theses and scientific articles were published based on the previous and the current project´s stormwater monitoring results.

As a conclusion, some remarks concerning Finnish urban stormwater monitoring are presented in the article by Sillanpää & al. So far most of the monitoring data has been collected by universities in different research projects. In the future one would expect that at the national level the stormwater measurements could be included in the routine hydrological data monitoring systems connected with drainage systems. Successful monitoring should be based on year round working measurement stations and include both stormwater quantity and quality. Long datasets are needed also to eliminate the impact of exceptionally cold seasons, when problems can be caused by freezing. The recent monitoring projects have concentrated on residential and city centre areas, but in the future more monitoring data is needed especially from industrial and green areas, as well as from roads and their environments.

From the viewpoint of urban planning, there are already practises to estimate urban rainfall and stormwater and plan the management of the stormwater in urban areas according to these measures. So one could expect that research concerning real situations is needed in order to improve modelling of the future situations concerning stormwater treatment and flooding. Climate change adaptation and mitigation are required in the current and future urban planning and stormwater management is one of the essential tools in this process.

On behalf of the Lahti University of Applied Sciences I would like to express gratitude to all those who have participated in the writing and collection of this publication. In LUAS the main responsibility for the practical arrangements has been that of project manager Irma Mäkelä and project secretary Tarja Palvi. MSc Paul Carroll has examined and corrected all the English language texts as well as translating the abstract and the article and project compilation appendix by Jessica Huttunen.

Lahti 5th May 2014
Eeva Aarrevaara

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Sari Suomalainen

Abstract

The aim of this study is the development of work-related education in terms of virtual learning. In LUAS a development project has been going on for a couple of years now to design the future campus in the Niemi area, which will provide a collaboration platform for enterprises and education. Niemi will also be an object of urban development which will support the area in combining business, education, students, research and other stakeholders. The appropriate use of space for this purpose should be considered carefully in the new campus environment. In this study a case is examined concerning the FUAS module Traffic and Land Use Planning, developed jointly by LUAS and HAMK UAS in Hämeenlinna and Riihimäki. The module will include virtual lecturing, virtual presenting and commenting. Visualising belongs to planning processes and it will be used as a tool. Virtual learning is described as an Internet based learning environment which is connected to by teachers and students using computers and mobile devices. One pedagogical solution is to adapt blended learning which combines, with the help of technology and mobile devices, individual learning to community learning. In blended learning one must separate synchronous and asynchronous elements: A synchronous element means learning with deadlines, meeting-times and other issues in terms of community learning, while asynchronous steps are taken individually. The research question in this study is: what virtual techniques can be used in co-operation with working life actors? The method of the study has been interviews of responsible persons from different sectors of educational and organisational development in the FUAS organisation.

DEVELOPING eLEARNING IN NEW CAMPUS ENVIRONMENT

Introduction

Universities of Applied Sciences have a task to carry out research and development that is integrated into education. Project- and practice based innovation is in keeping with the strategy of Lahti University of Applied Sciences (LUAS), focused on the Lahti Region, and as a member of the Federation of Universities of Applied Sciences (FUAS), work-related research and development integration RDI covers the wider Helsinki metropolitan area (LAMK RDI Strategy 2013-2016, 2). The aim of this study is to develop work-related education in terms of virtual learning.

Niemi Campus has been developed strongly in the last few years. The aim is to provide concrete environment for collaboration between Lahti region stakeholders and education. Lahti Region Development LADEC Ltd. has had a leading role in introducing new development projects into the Niemi Campus concept. This concept is provided also for FUAS needs. (LAMK RDI Strategy 2013-2016, 11.)

The development of Niemi Campus also addresses current challenges in terms of urban planning. City of Lahti has made a commitment to reducing emissions and compacting the city structure. Furthermore, certain actions should be concentrated and both public traffic and connection network developed. These changes will release space for compact residential areas in the city centre, while the Niemi area enables new implementations in terms of energy efficiency solutions and combining business, students and education, research and other stakeholders (Niemi Campus 2013). Furthermore, the appropriate need of space for this use should be considered carefully. When virtual learning is already used in education, it is a solution also for educating people without the need for physical space.

This study will focus on the module case developed in co-operation with three educational units of FUAS and led by LUAS environmental technology. The case will present a project which will include methods of planning and co-operation of several areas of study. The co-operational virtual solutions will be based on working methods and common tools of both education and the labour market.

The conclusions and the concept will be launched by August 2014 in order to help the planning of work related project based modules.

The module

The FUAS module Traffic and Land Use Planning has been developed together with LUAS, HAMK University Applied Sciences (Hämeenlinna and Riihimäki) (HAMK). LUAS will be responsible for the area of environment planning, HAMK will contribute content of traffic planning, traffic safety and traffic psychology to the module. Each unit will dedicate an equal amount of resources. The specified themes steer the content of the module, and they are also considered when the know-how of students is evaluated. The objectives in terms of know-how are indicated at different levels and this makes the evaluation valid. The implementation of this module is scheduled to start in 2015. (Aarrevaara 2014.)

The pedagogical approach will combine the theory from each sector and students will work according to their own educational demands. This means that environmental planners (LUAS) will manage the planning process, while other partners for instance, have trained skills for performing inventories issuing and statements. The pedagogical approach is Learning by Doing. (Aarrevaara 2014.)

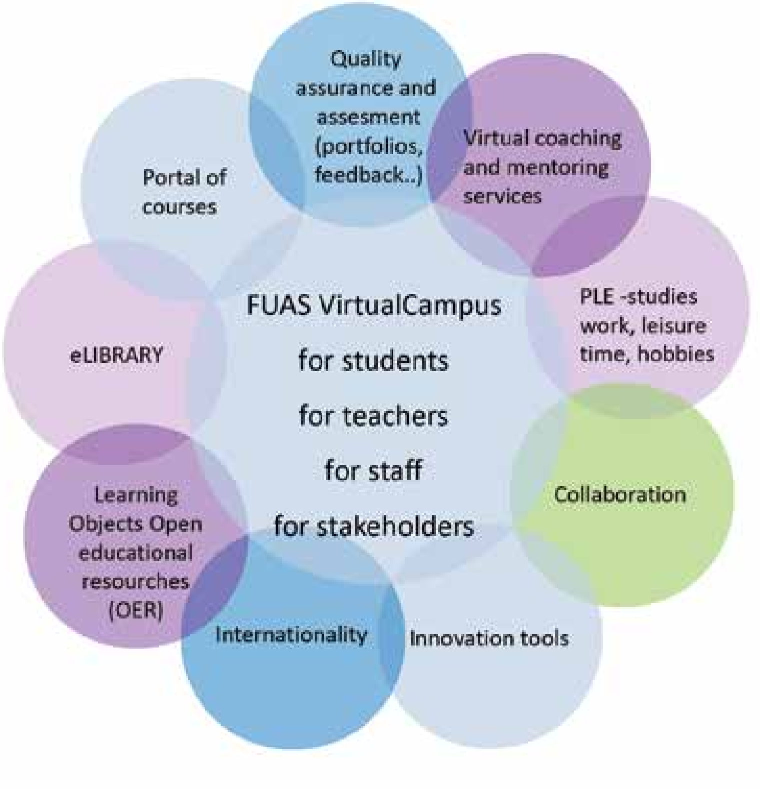
The module will include virtual lecturing, virtual presenting and commenting. Visualising belongs to planning processes and it will be used as a tool. Three dimensional space (3D) is suited to modelling and animating and in that way it promotes collaborative understanding. Stephen Sheppard, with his colleagues, has made studies in terms of visualising landscapes (CALP 2014). Vesikko (2014) studies interactive visualisation in his Master´s Thesis Decision Theatre in Decision Making and Urban Planning. These experiments will be utilised in this work.

Virtual Learning and pedagogy

The Ministry of Education and Culture finances the Virtual University of Applied Sciences and Virtual University in Finland. The Ministry promotes the use of digital learning environments and the development of communication technology skills from pre-school to professional studies. They are promoted as part of a lifelong learning process. Digital technology itself develops communication technology skills and furthermore enables learning and teaching methods, which will respond to challenges of changing work life in terms of broad knowledge, interaction and co-operation. (Ministry of Education and Culture 2013.)

Virtual learning means an Internet based learning environment which is connected to by teachers and students by using computers and mobile devices. Virtual learning can be independent of time and place. Silander (2009) describes a mobile approach by determining mobile pedagogy. Mobile devices in learning can promote for instance thinking and inquiry learning, on-demand learning and situated learning (Silander 2009).

Virtual learning includes social network which means that it is not only a question of passive technology (Picture 1). Development of social media used in education trails behind social media used in leisure time. Some steps have been taken lately to utilise social media more in the connection of studies and working life. This platform in Metropolia University of Applied Sciences connects students and professionals (Metropolia 2014). Social media is a process with a social network, which enables people to share information and create common meanings. In other words it is communal information which is built and developed together. Furthermore, communal learning in interaction activates individual apprehension. (Pönkä 2012, 4.)



Picture 1: The structure of the virtual learning (Kuusela 2012).

Blended learning has widened the concept of e-learning in the context of pedagogy. Vainio (2008) writes in her article traits of blended learning (Bonk et al. 2006, s. 549–567). Blended learning combines individual learning and community learning, with the help of technology and mobile devices. It can happen both in classrooms and in virtual environments or only in virtual environments. A teacher is seen as a supervisor, but new methods and a pedagogical structure is a challenging task and needs different kind of experts when blended learning is launched. (Vainio 2008.)

According to Nordberg, Dziuban & Moskal (2011, 211) there is a shift between synchronous and asynchronous elements in terms of blended learning. It is necessary to understand this when planning a course. A synchronous element means learning with deadlines, meeting times and other issues in terms of community learning, when asynchronous steps are taken individually. Classroom based courses are synchronous, but they have asynchronous elements included, such as reading and assignments before virtual learning times. Furthermore, asynchronous parts of the course can be supported by virtual tools, such as blogs, recorded lectures, while synchronous parts need less and less physical contact, but seek more and more learning interaction.

Pedagogy is a part of the course planning. When the course is work related, also the procedures of work life should be considered. These approaches can be examined from the viewpoint of Problem Based Learning (PBL). The problem or the task creates the basis for the content of the module. PBL is not necessarily connected to working life, but working life is at least imitated. Generally students work as a team and they are supervised by someone with authority (Boud & Feletti 1999, s. 16-20). Theoretical knowledge is not enough for the labour market, which is constantly addressed by fast changes. Changes can be economical, political, scientific, technological and other such influential world-scale phenomena. Adaptation to changes is related to a self-guided learning skill. Both of them need communication skills, critical thinking, a logical and an analytical approach, decision making skills and self-assessment skills. (Engel 1999, 33-34.)

A project is a common working method for education and the labour market. It is a working method where requirements for change are addressed. In other words the targets of the project should describe the change required. A project organisation and realistic schedules are needed and resources should be drawn for the planned project. In addition a project should learn from itself. This means that it is not reasonable to follow the project plan if the planned steps will not lead to results which cannot be applied. (Silfverberg 2009.)

Methods

This study aims to create a concept for work orientated modules for areas like urban planning, environmental planning and landscape planning. The research question is: what virtual techniques can be used in co-operation with labour market actors?

Holistic information is gathered from specialised experts for his quality study. Recommended methods are interviews and discursive analysis of documents and texts. The analysis will be reviewed in detail, the aim being to find out unexpected factors and phenomena. (Hirsijärvi et al. 2010, 164.)

The Delphi method is a structured communication technique for forecasting. Panellists are chosen for it and the first interview cycle consists of individual anonymous interviews. The report summary will be then sent to the panellists to be commented on and developed. (Kuusi 2013, 249). Forecasting is necessary in order to find out the definition policy of FUAS in terms of the development of the system.

The interviews took place in March 2014 and they have been done by using virtual connection Lynch, which enables an interviewee and an interviewer to connect regardless on the place. Furthermore, interviews can be recorded and saved by using the same system. The panellists are responsible for different sectors of educational and organisational development, and they come from the FUAS organisation.

STEEP- analysis structures the interviews and aims to find out the changing phenomena in the macro-environment connected to the organisation being studied. STEEP stand for Socio-cultural forces, Technological forces, Ecological forces, Economic forces and Political forces. The analysis will create the strategy of virtual environment techniques as well as producing collaborative forecasting for possible applications, which can be used in the FUAS organisation and in co-operation with the labour market.

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Picture 1. Kuusela, H. 2012.
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Ari Vesikko

Abstract

Ari Vesikko introduces the Niemi campus environmental information laboratory or Decision Theatre that was designed and built in association with his thesis work in LUAS. A prototype for the decision theatre has been constructed for example in Arizona State University (ASU), in which the theatre consists of eight different projectors. The decision theatre was built in the new premises of the Bachelor degree programme of Environmental Technology in Lahti Science Park in Niemenkatu. An audio matrix system controls two Full LED hybrid projectors, which enable a panoramic view to be shown (a screen of 32:9), or the use of different information in both of them (each screen of 16:9). The project was realised by funding of the Urban Laboratory of Sustainable Environment project. The purpose of the Decision Theatre is based on better opportunities to present environmental information, especially in GIS-based information, to illustrate environmental data and help scientists and planners to comprehend and connect different kinds of data.

DECISION THEATRE NIEMI CAMPUS

Background

Urban laboratory for sustainable environment is a co-operation project between Lahti University of Applied Sciences (LUAS), Aalto University (AU) and The University of Helsinki (UH). One of the project targets was that an environmental information laboratory will be set up in Niemi campus in Lahti. The focus in my Master degree thesis was to study the opportunities to implement the information laboratory within the given budget and also to build the laboratory. Laboratory is built with technology that supports decision making and scientific visualization.

In the Arizona State University (ASU), where the room was first built up, seven screens affixed along the wall offered a 260-degree panoramic display of graphics and visualizations (Picture 1). It is called the "drum." Advantage can be taken of a variety of tools to improve decision making including geospatial visualization, simulation models, system dynamics, and computer-assisted tools for collecting participant input and collaboration.

Picture 1: Decision Theatre ASU (Arizona State University 2013).

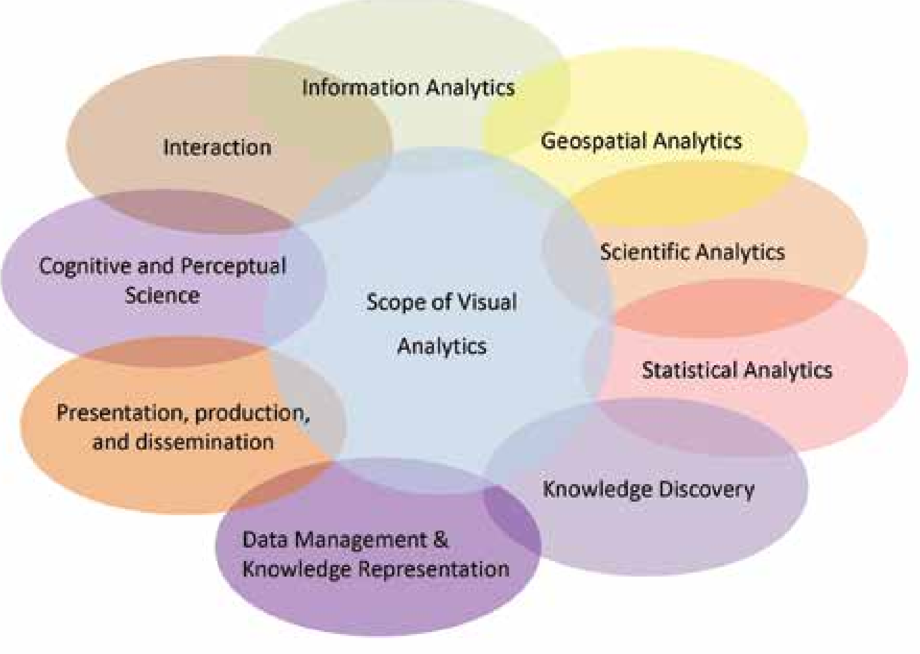
Some decision making theory

The ability to make good decisions is the defining attribute of a high performance organization. The challenge is to ensure that good decision-making practices are adopted in the entire organization. As organizations grow, employees make decisions in an increasingly complex, ambiguous, and uncertain environment. Formal practices enable employees to make decisions that are meaningful to the stakeholders and guide their behaviour to align with the strategic intent of the company as well as its values and norms. (Michel 2007.)

Decision makers may feel pressured and agitated. The time pressure means taking shortcuts and jumping to conclusions. Fortunately, decision-making is a skill that can be learned and grown into. Somewhere between instinct and over-analysis is a logical and practical approach to decision-making that does not require endless investigation, but helps you to estimate the options and impacts. (MindTools 2013.)

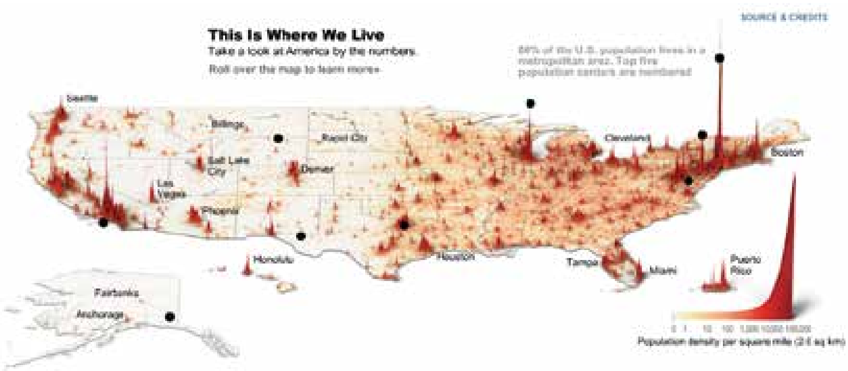
Scientific visualization helps decision making

Scientific visualization is to graphically illustrate scientific data to enable scientists to understand, illustrate, and get rare insight from their data. The emphasis is on realistic renderings of volumes, surfaces and illumination sources. (McCormick et al.1987.) Picture 2 shows a visualization field.



Picture 2: Visual analytics as a highly interdisciplinary field of research (Keim et al. 2006)

Almost everything can nowadays be visualized by computer applications. Computer applications or web applications can be evaluated as much as there are resources for that. Spatial data solutions are used in many fields from traditional city planning to developing a new commercial centre developing. Effective solutions to visualize data are always welcome to the many sectors to help decision makers to make better decisions. An example of interactive picture presents in Picture 3.



Picture 3: Where America Lives (Time 2013).

A survey to verify the theory

Visualization seems to have an impact of decision making. For this reason a survey was organized as part of this thesis to find necessary and important features to develop and build an inspirational environment to help decision making.

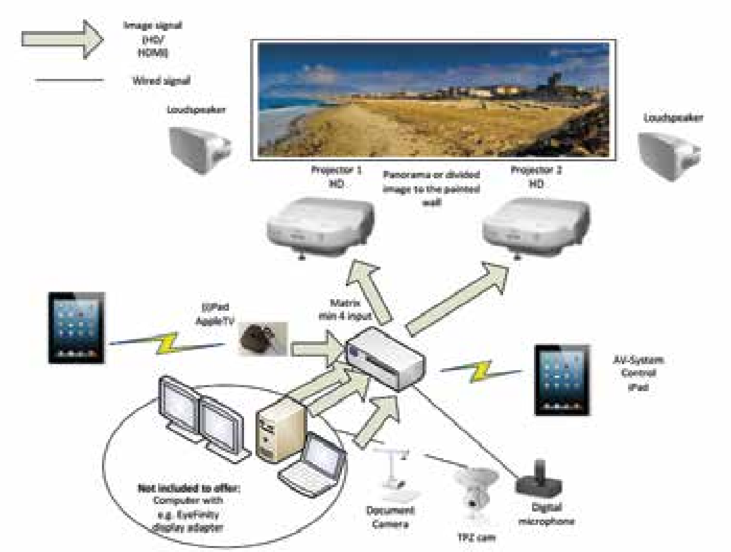
The survey about the impacts of visualization on decision making was made with Google Form Application for a limited group of people. Respondents were from LUAS, Faculty of Technology. Most respondents were teachers. Teachers are educating future decision makers and many of them are decision makers themselves, too. An invitation to answer was sent to 70 faculty members by an email distribution list. Seventeen (17) gave their opinions on the basis of 29 propositions that were asked in the survey.

Survey propositions were divided into two main fields: A) Visual Perspective and B) Information Context. Visual Perspective was divided to two subtasks: Interactivity and Depth of Field. Information Context had three subtasks: C) Vividness D) Evaluability and E) Framing. Respondents were asked to evaluate propositions in scale 1 to 5, where 5 is fully agree and 1 is disagree.

Survey result shows that all the introduced propositions in the survey support decision making process to make better decisions (28/29 counted averages are more than 3). All tools or applications to visualize data will help people to understand complex things better. It might be possible to manipulate decision makers to focus on visualization and some important things (text) might be hidden behind visualization.

Implementing the laboratory, Decision Theatre

Niemi Campus environmental information laboratory, also known as the Decision Theatre is built similar with Arizona State University Decision Theatre, but with more limited resources. Picture 4 shows the draft on the infrastructure.



Picture 4: DT Niemi-hardware (Ari Vesikko 2013).

Two LED-Laser Full HD hybrid projectors are controlled by audio matrix system. The user interface to control the matrix is implemented with a mini iPad. That makes it possible to project Full HD 32:9 wide screen images from a PC or two 16:9 screens to the wall from different sources. 32:9 wide screen images are really demonstrative in some planning or visualization cases.

Picture 5 shows people making decisions in Niemi Campus Decision Theatre.

Picture 5: Niemi campus dt-photo (Ari Vesikko 2013).

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Jiri Kadlec

Abstract

Jiri Kadlec´s task has concentrated on the design of a web based information platform and building a user interface by collecting and processing different types of environmental information obtainable in GIS format. Maps in GIS format and real time stormwater measurements are combined for the same interface, which will enable more diversified environmental information, for example for urban planning and decision making processes. Especial interest has been paid to effectively visualising urban runoff quantity and lake water quality by using a web based online information platform. The software platform of the project has been built by using open source software. Jiri Kadlec presents three application cases: 1. Experimental Catchments Visualisation and 2. Stormwater Runoff and Pollutant Load Forecasting Map and 3. Map Editing Functionality for Urban Planning.

DESIGN OF A WEB-BASED STORMWATER DECISION SUPPORT TOOL FOR URBAN PLANNING

Introduction

The hydrological cycle in urban areas is strongly affected by the urbanisation process. Urbanisation leads to an increase in impervious surfaces (such as asphalt roads or car parks) with high runoff to rainfall ratios. Water flowing from these impervious surfaces is known as stormwater runoff. In Finland, stormwater runoff is typically not treated by wastewater treatment plants. Instead, it flows through a separate network of pipes and culverts directly into receiving water bodies and lakes. By collecting heavy metals, suspended solids and other pollutants from the impervious surfaces, urban stormwater runoff may have harmful effects on water quality in receiving lakes.

Sustainable urban planning decisions require extensive online collaboration between urban planners, hydrologists, and public stakeholders. The hydrologist is responsible for developing and testing a mathematical model that is capable of predicting stormwater runoff and the transport of pollutants under varying land cover conditions. The urban planner is responsible for maintaining up-to-date spatial data, including future land cover change scenarios. Finally, the public is concerned about such features of their environment as urban forests, streams, rivers and lakes.

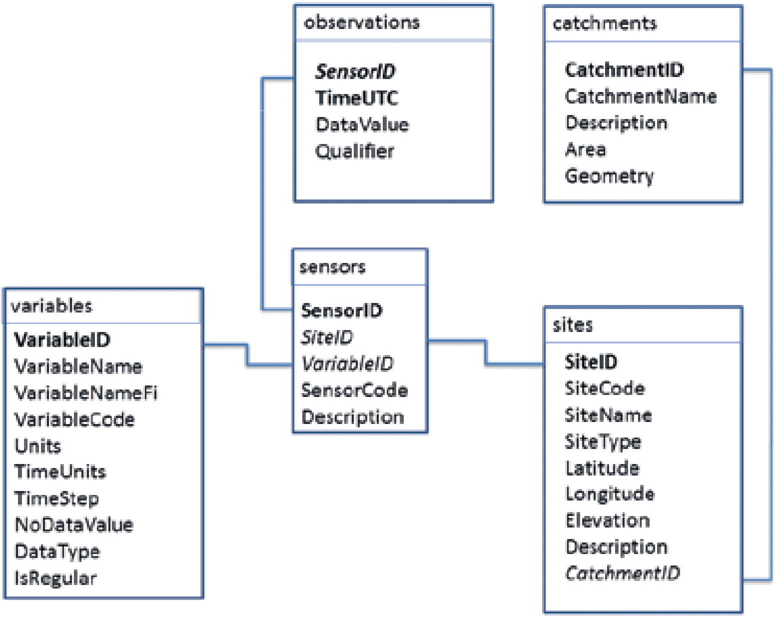
Despite the rapidly increasing availability of geographic information on the web, traditional desktop-based geographic information systems (GIS) and specialised hydrological model software tools are predominantly used in the hydrological model setup, often requiring the time-consuming exchange of large datasets between the urban planner, GIS expert and hydrologist, and resulting in information loss. The limitation of desktop GIS can be overcome by moving the system to a distributed web-based information platform.

This paper explores options of how to efficiently visualise the effects of urban planning decisions on stormwater runoff quantity and lake water quality using a web-based online information platform. The demonstration has been implemented in the city of Lahti. The whole software platform was built using free and open source software.

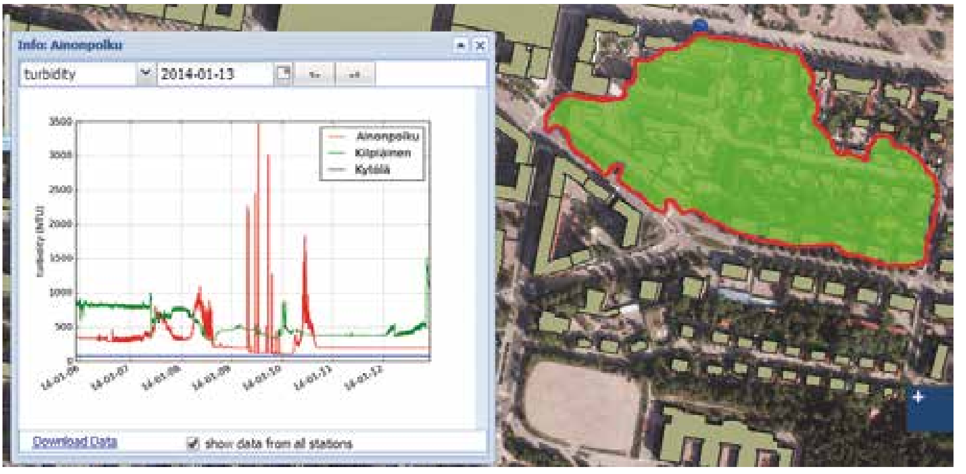
Application Use Cases

1. Experimental Catchments Visualisation

As part of hydrological research in Lahti, three experimental observation sites with real-time observations are maintained. The first site is located in a natural forest area where construction is planned. The second site is in a suburban residential area. The third site is in a city centre residential area. The time series data from field sensors are transmitted to a relational database and served using the Sensor Observation Service (SOS) or Javascript Object Notification (JSON) format. The open-source Flot Javascript toolkit is then used to display the one, two or three time series of precipitation, discharge or turbidity in a dynamic interactive chart. Users can visually compare how three small catchments behave in different types of recent rainfall or snowmelt events. Picture 1 shows the database schema for archiving the experimental catchments observation data. Picture 2 shows an example turbidity time series chart in the map from the city centre (Ainonpolku) experimental station.



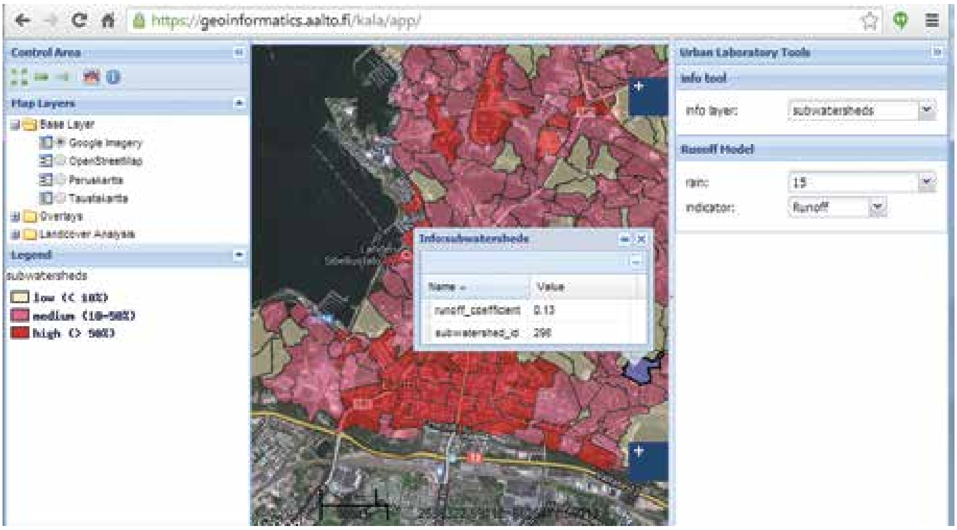
Picture 1: Database schema for archiving observation data from the experimental watersheds (Jiri Kadlec 2014).



Picture 2: Example time series chart – one week of turbidity measurements at the Ainonpolku and Kilpiäinen sites (Jiri Kadlec 2014).

2. Stormwater Runoff and Pollutant Load Forecasting Map

In this website, the user can select an interactive map of present or future land use in the Lahti region. The data sources include official data sources (Finnish surveying office's map, Lahti city official map), volunteered geographic information (OpenStreetMap), data collected by researchers (Land cover map created by interpreting air photographs), and urban planning documents (Strategic plan and detailed area plans), and a map of lakes and their drainage catchments. The user selects the land use dataset, rainfall amount, receiving lake and indicator: runoff volume, sediments, nutrients, or heavy metals. The land use map data from external data sources is accessed through the Web Feature Service (WFS) or Web Map Service (WMS) protocols. In the case of WFS, the data must be "polygon" geometry type. In case of WMS, the "GetFeatureInfo" operation must be supported to enable listing of attributes for each land use polygon. Land use map data collected internally by Lahti researchers is stored in a PostGIS database. For each data source, a lookup table is created. The lookup table links each land use category with an "impervious area percentage" value and an "event mean concentration" factor. The "impervious area percentage" is the estimated percentage of asphalted roads, roofs, car parks and other impervious surfaces within the polygon. The "event mean concentration" is specified separately for each pollutant and it characterises the pollutant's typical concentration during a stormwater event. A hydrology expert can edit the lookup table according to local knowledge. The actual runoff coefficient (runoff volume/rainfall volume ratio) is then calculated as a function of rainfall height and the stormwater runoff factor (Picture 3). For rainfall, the rain can be assumed as uniform for the whole region, or as spatially varying. If the rainfall map is spatially varying, then a runoff raster is created by overlaying the rainfall map and the runoff coefficient map. Next, a pollutant loading raster is created for each pollutant indicator (heavy metals, nutrients, suspended solids) by overlaying the runoff raster and the land use polygons. Finally, the runoff raster and pollutant load rasters are overlaid with the drainage catchments map to calculate total runoff volume and total pollutant loading (mass) for each catchment. Additional indicators are also displayed for each catchment, for example the percentage of impervious area. The resulting maps are made available as a dynamic Web Map Service (WMS). The MapServer open source software is used for handling the WMS service. An interactive map client displays the map in a web browser. The client was created using the Javascript and OpenLayers tools.



Picture 3: Calculated stormwater runoff coefficient in the urban sub-watersheds of Lahti (Jiri Kadlec 2014).

3. Map Editing Functionality for Urban Planning

In urban planning, it is important to be able to rapidly compare the impacts of a land use change decision on the environment, including stormwater runoff quantity and quality. The services-oriented architecture of the Lahti Urban Laboratory platform supports interactive editing of all land use maps that are stored as internal data sources. It also supports the creation of new land use maps and their combination with the original maps. The simultaneous editing of maps is enabled using the WFS Transactional (WFS-T) protocol. Let us consider a use case, where a part of an urban forest is planned to be replaced by a low-density residential area. Multiple users can edit the "future land use" map simultaneously over the internet. Both the polygon areas (geometry) and the polygon attributes (land use class) may be edited (Picture 4). After completing map edits, the expected stormwater runoff map and the pollutant loading maps are recalculated and these maps become available as a new WMS service and a new "map layer" in the interactive map client. The user can switch between the old and the new land use scenarios and decide which scenario has lesser impact on stormwater runoff and on lake water quality.

Picture 4: Example of using the online map editing tool (Jiri Kadlec 2014).

By using a web-based interactive map application, the interface is readily available in any location with Internet access. The up-to-date geographical information (urban plans, land cover maps, drainage network) is maintained by respective stakeholders, reducing the need to exchange large datasets. Hydrologists can easily modify the simulation model parameters using the latest results from field experimental sites. The interactive web map application is used to present alternatives for urban development and rapidly compare and contrast the impact of urban planning decisions on the water environment. In contrast with other similar applications, the "Lahti urban water laboratory" is built completely based on open source software. In particular, the Apache server, PostGIS, MapServer, TinyOWS and OpenLayers technologies are utilised. In addition, the components of the system are loosely coupled using services-oriented architecture closely following the Open Geospatial Consortium (OGC) standards. With continuing interest in providing standards-compliant geospatial data (including the INSPIRE initiative), it is expected that the stormwater runoff forecasting web platform presented here will become available as a part of the public spatial data infrastructure of other cities in Finland and northern Europe.

Juhani Järveläinen

Abstract

Urban stormwater runoff can potentially have severe negative impacts on the environment if unmanaged. Stormwater management aims to minimise changes to the natural hydrologic cycle caused by urbanisation, usually by integrating elements like retention pools, grass swales and permeable surface materials into urban areas. Detailed information on the stormwater being formed in urban areas is, however, a prerequisite for effective stormwater management. In this study the annual stormwater pollutant load from the area of Lahti city, Finland was estimated using a volume-concentration model. A land-use based approach was used for the characterisation of stormwater quality and estimation of stormwater runoff volumes. Monitoring data from two recent Finnish stormwater studies in Lahti and Espoo was analysed to assess average stormwater pollutant concentrations in urban areas with different land uses. Additionally, variables needed for the design of a city-wide stormwater monitoring effort were determined.

The total annual stormwater runoff from the Lahti city area was estimated to be approximately 13 million m3. Different land use classes contributed varying amounts of different pollutants. Uncertainty estimates in total pollutant load estimations ranged from approximately 11 % to 26 %, respectively, for suspended solids and lead. Industrial areas, roads and green/undeveloped areas produced the largest portion of the total estimated annual pollutant load in Lahti, when all studied pollutants were considered. Roads, city centre areas and commercial/public areas were the largest sources of stormwater pollution relative to their size.

The methods used in the study can be applied for estimating stormwater loads in other cities as well. The average stormwater pollutant concentrations determined for different land use classes can be used for stormwater pollutant load assessment if local data on stormwater quality is unavailable. In order to provide reliable results, the volume-concentration model used in the study requires inputs that accurately characterise local conditions. Updated information on the quality of stormwater runoff from industrial, commercial/public and urban green land use areas would increase the accuracy of pollutant load estimations.

ESTIMATING STORMWATER POLLUTANT LOADS IN LAHTI

Introduction

Unmanaged urban stormwater discharges have numerous and well documented negative impacts on both human well-being and the natural environment (e.g. Marsalek 1978; Melanen 1981; U.S. EPA 1983; Driscoll et al. 1990; Bingham 1993; Mikkelsen et al. 1994; Pitt et al. 1995). Stormwater carries harmful substances from urban areas into the environment in addition to potentially causing flooding during intense rain incidents, as well as having other negative impacts resulting from the change in the natural hydrologic cycle. An increase in urban construction, its density and climate change are all expected to increase future stormwater-related problems in urban areas (Semadeni-Davies et al. 2008; Rosenberg et al. 2010).

Traditionally stormwater management entailed the implementation of drainage systems that could efficiently channel stormwater runoff into receiving waters, usually without any treatment (Burns et al. 2012). The increasing understanding of the scope and severity of stormwater-related negative impacts has led to the supplanting of these traditional stormwater management practices with more sustainable urban drainage systems focused on minimizing or preventing excess stormwater generation, by keeping the changes to the natural hydrologic cycle to a minimum. Components such as bioretention pools and grass swales, intended to infiltrate any rainfall to the maximum extent possible, are now increasingly included in new construction. The use of such measures is collectively known as Low Impact Development or LID. (U.S. EPA 2000.)

To address the problem of stormwater pollution, many governments have enacted legislation and cities, Lahti included, have drafted stormwater programmes aimed at reducing negative stormwater impacts. Efficient stormwater management cannot, however, be realized without sufficient knowledge of the amount, quality and distribution of local stormwater discharges (Fletcher and Deletic 2007). This article briefly outlines a study estimating the annual stormwater pollutant load from the city of Lahti, Finland. The study was carried out as a part of the project 'Urban laboratory for sustainable built environment – Water cycle and ecosystem services in an urban environment'. Stormwater monitoring efforts in Lahti have also been established as part of the project, the results of which will be published elsewhere.

Stormwater pollutant load estimation methods and limitations

Stormwater pollutant loads can be estimated using various methods. Marsalek (1990) for example divided urban diffuse pollution calculation methods into three categories: i) transfer of runoff quality data to other, unmonitored sites, ii) runoff monitoring, and iii) runoff quality simulation. Of these approaches, the latter two have severe limitations when applied on a larger scale. These include limited reliability, high costs and large implementation requirements in time, human resources and/or input data (Mitchell 2005). The first method, the transfer of runoff quality data to other sites, however, has been widely employed for city-scale estimation of stormwater pollutant loads (e.g. Charbeneau and Barrett 1998; Wu et al. 1998; Mitchell 2005). Models using such an approach are referred to as empirical, or volume-concentration models, and rely heavily upon having access to accurate land use, imperviousness and pollutant concentration data to produce reliable results (Schiff 1996). For most areas, these are not readily available. Using various reference datasets, or other studies from similar locations, as sources for missing quality data can sometimes be necessary for certain parameters when local observations are unavailable, but can lead to significant biases if the suitability of used data is not verified. Even assessments made for the same area using similar approaches (Stenstrom and Strecker 1993; Psomas 2005; Susilo et al. 2006; Stein et al. 2007; Ha and Stenstrom 2008) have been shown to produce highly variable results due to differences in the study area characterisation (Park et al. 2009), highlighting the need for the formulation of new methodologies to assess stormwater discharges in a unified and comparable manner.

The northern climate and the accompanying seasonality present in Finland also pose several unique challenges for stormwater modelling and pollutant load estimation. The effects of urbanisation on hydrologic processes under cold climate conditions, and the accumulation and release of pollutants from snow are not very well understood at present (Hvitved-Jacobsen et al. 2010). Snow acts as a form of temporary storage for both water and pollutants during the cold season; from an urban planning perspective, for example, the handling of snow within urban catchments affects the design, effectiveness and maintenance requirements of LID solutions (Oberts et al. 2000). Thus, year-round monitoring of urban catchments located in areas with distinct seasonal differences is required for the development of stormwater pollutant load estimation methods (Bartošová and Novotny 1999) and the effective design and implementation of stormwater management practices (Sillanpää 2013). Indeed, several researchers (Semádeni-Davies and Bengtsson 1999; Westerstrom and Singh 2000; Matheussen 2004; Oberts et al. 2000) have recognised the need to obtain monitoring data from urban catchments during wintertime conditions.

An update to existing stormwater quality data is also needed, as several researchers (e.g. Park et al. 2009; Langeveld et al. 2012; Sillanpää 2013) have noted that some of the average pollutant concentrations presented in reference texts, based on measurements made in the late 1970s and early 1980s are higher than those based on more recent local observations from urban study catchments. The recently published results of two multi-year stormwater monitoring efforts in Espoo (Sillanpää 2013) and Lahti (Valtanen et al. 2013) have made it possible to estimate the amount, quality and distribution of stormwater from the study area of Lahti city, Finland (Figure 1).

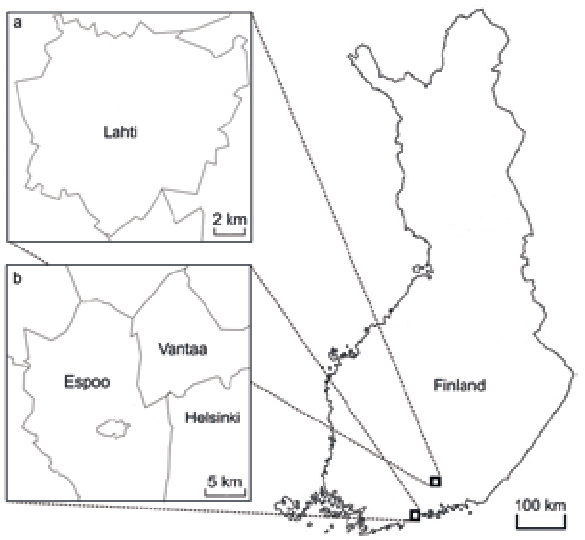


Figure 1: The location of Lahti (a) and Espoo (b). (Juhani Järveläinen 2014).

Stormwater pollutant load estimation in Lahti

Lahti is a city and municipality located in southern Finland (60°59′00″N, 25°39′20″E) on the southern end of Lake Vesijärvi, about 100 kilometres northeast of the capital Helsinki (Figure 1). It is the capital of the Päijänne Tavastia region, and with a population of 103 000 is the ninth largest city in Finland. The total land area of the Lahti municipality is approximately 135 square kilometres. Winter usually begins in November and lasts for about 100 days. Permanent snow covers all open ground about two weeks after winter begins, with the deepest snow cover of 20 to 30 cm being typically observed in mid-March. The mean temperature mostly remains below 0°C during wintertime, with the coldest temperatures of -35°C to -45°C usually occurring well after perihelion, at the end of January. During springtime, which begins in early April and lasts about 45 to 65 days, daily mean temperatures rise to 10°C. The time it takes for the accumulated snow to melt depends on the amount of snow as well as on the prevailing weather. On average the period of melting lasts two to three weeks in open areas and an additional two weeks in forested areas. The 30-year average annual rainfall in the Lahti region is 634 mm (FMI 2011).

In this study the annual stormwater pollutant load from the Lahti city area was estimated based on stormwater monitoring data from the recent Finnish Sillanpää (2013) and Valtanen et al. (2013) stormwater studies as well as on literature sources. Additional objectives for the study included: i) the comparison of pollutant load estimations calculated using different input datasets, ii) the determination, based on these estimates, of the key variables needed for the design of a city-wide stormwater monitoring programme and, iii) the production of data on average stormwater quality parameters, study area characterisation methodologies and monitoring system design tools that can be used for practical planning applications in other locations.

To realise these objectives, an established method used for stormwater monitoring system design (see Burton and Pitt 2001) was applied with modifications to account for the availability of local stormwater monitoring data. A graphical representation of the study process is presented in Figure 2.

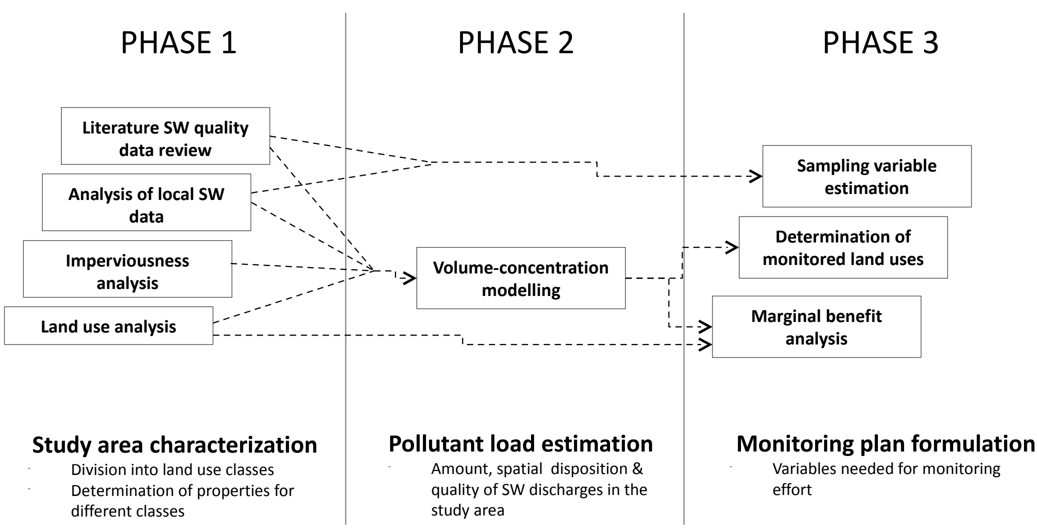


Figure 2: The main phases and component analyses of the study. SW is an abbreviation for stormwater. A dashed line indicates that the results of a particular component analysis are used as inputs in other phases. (Juhani Järveläinen 2014).

In the first phase the study area was divided into several land use categories, for which distinct characteristics influencing stormwater generation were determined. A land-use based categorisation was feasible as the quality of stormwater runoff from a given catchment has been shown to be highly related to its land use and accompanying human activity (e.g. Marsalek 1978; Novotny 2002; Park et al. 2009). The land use division was made based on the most recent land use- and aerial photographic data available from the city of Lahti Land Use Unit. The average amount of imperviousness of the urban land use classes was evaluated based on an imperviousness analysis (after Burton and Pitt 2001). The quality of stormwater from most urban land use classes was estimated based on an analysis of stormwater monitoring data collected by Sillanpää (2013) and Valtanen et al. (2013) as well as literature sources for other land use classes. Average stormwater pollutant concentrations were determined for suspended solids, nutrients (tot-P and tot-N), chemical oxygen depletion and the most common metals (Pb, Zn, Cu, Cr, Ni). Additionally, three reference stormwater quality datasets were compiled based on average land use type pollutant concentrations published in literature (Melanen 1981; Nordeidet et al. 2004; Mitchell 2005).

The second phase of the study was the estimation of annual stormwater pollutant loads by pollutant and land use type from the city of Lahti area. The volume-concentration method was used for the estimation. This approach was selected for several reasons; if applied with sufficient data regarding local conditions, volume-concentration methods give results comparable or, in some cases, more accurate than complex build-up and wash-off models at a significantly lower cost (e.g. Mourad et al. 2005; Park et al. 2009). Pollutant load estimates were calculated with different input variables from the compiled stormwater pollutant concentration datasets. The average uncertainties in the pollutant load estimates were also assessed based on the statistical properties of the analysed stormwater quality data and the results of the imperviousness analysis.

The third phase of the study involved the conceptual planning of stormwater monitoring in the Lahti area based on the results of the annual stormwater pollutant load estimates. Marginal benefit analysis (after Stenstrom and Strecker 1993) followed by a numerical index ranking of the land use classes (Bingham 1993) was used to determine the type and number of land use classes that would need to be monitored to obtain 80% coverage of the total amount of annual stormwater pollutant load in the city area. Additionally, the number of rainfall-runoff events that would need to be sampled to obtain reliable estimates of average pollutant concentrations was determined based on the analysed stormwater quality data. If desired, these key variables make it possible to design and implement a city-wide stormwater monitoring effort for Lahti in the most cost-effective way possible, while still meeting any monitoring targets.

Results and practical applications

Estimates of the amount and spatial disposition of the stormwater runoff volumes and pollutant loads in the Lahti area were successfully produced. The total annual stormwater runoff from the Lahti city area was estimated to be approximately 13 million m3. The volume-concentration estimation method used in the study was straightforward to implement and also allowed for easy revision of the pollutant load estimations as new information became available. As such it can be recommended for other studies where large-scale stormwater loads are being estimated.

The volume-concentration method did, however, prove to be quite sensitive to input data. This sensitivity was evident in the pollutant load estimates calculated with different input datasets, which varied depending on the dataset used. In particular, estimates based on average stormwater pollutant concentrations measured in Finnish urban areas in the 1970s (Melanen 1981) were significantly higher than estimates based on more recent stormwater quality observations for all studied pollutants with the exception of total nitrogen. The uncertainties in annual pollutant load estimates ranged from 10,9 % to 25,7 % for suspended solids and lead, respectively. The quantification of the uncertainty related to the land use class delineation phase, while outside the scope of this study, could benefit further studies. The industrial, commercial/public and urban green land use classes were identified as potential candidates for additional stormwater monitoring studies.

While the distribution patterns of the estimated annual pollutant load from the Lahti city area varied between the different pollutants, some patterns were noted. The runoff from the transportation land uses (roads and highways) was notable considering the limited area they occupied in the study area, 1,28 % and 1,30 %, respectively, of the total. Agricultural and green/undeveloped areas were major sources of the estimated nutrient load. When the land use classes were ranked based on their relative estimated stormwater pollutant load (Figure 3) the top-ranked land uses were the industrial, green and roads land use classes. The transportation land use classes, city centre areas and commercial/public areas were the largest stormwater pollution sources relative to their size.

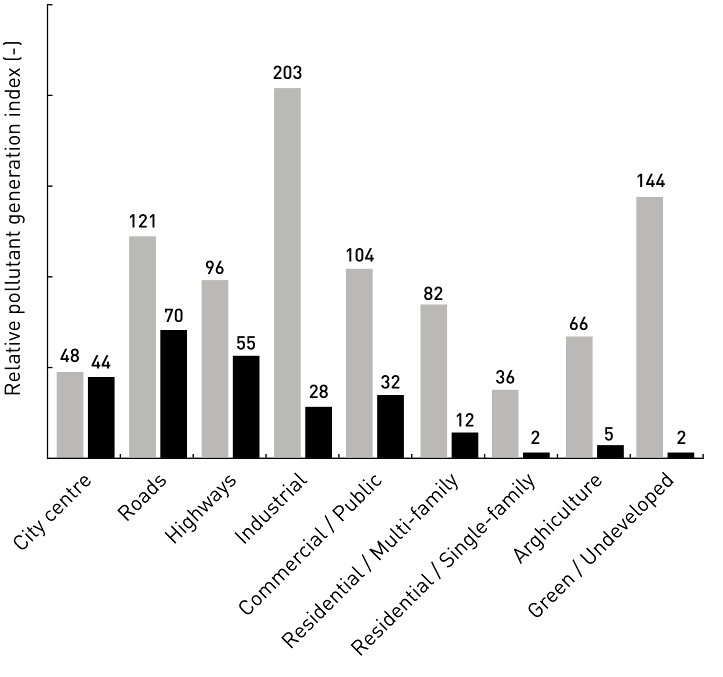


Figure 3: The relative pollutant generation indexes for the land use classes in the study area, calculated based on the distribution of the estimated annual pollutant load (grey) and annual pollutant load relative to total land use class area (shaded) (Juhani Järveläinen 2014).

The top-ranked land uses should be selected for stormwater monitoring, assuming the estimated annual stormwater load as the only criterion for monitoring location selection. The relative pollutant generation index used to rank the land use classes can be adapted to accommodate other criteria in addition to the relative pollutant load. For example, land use classes or pollutants considered particularly important could be weighted accordingly. Great care should, however, be taken to ensure that the land use ranking criteria used accurately represent the concerns and priorities in local stormwater policy, as well as any monitoring targets. The total number of monitored land uses will depend on local monitoring targets as well as available resources. The variation in the estimated sampling counts required between different pollutants was high, ranging from a handful of samples (total nitrogen) to several hundred (lead). Most sampling counts were, however, in the range of approximately 15-100 samples.

In addition to the planning of stormwater monitoring efforts, the estimation of stormwater pollutant loads is critical for minimising the costs associated with stormwater management (Park et al. 2009). Other practical applications include the prediction of impacts from LID implementation (Wong and Strecker 1997), the evaluation of the need for and siting of urban runoff treatment (Nordeidet et al. 2004) and the identification of sites with significant potential loads and impacts on receiving waters (Mitchell 2005).

The methods applied in this study are applicable for stormwater pollutant load assessment in other locations as well. The average pollutant concentrations for different land uses determined in the stormwater data analysis can be used to characterise stormwater quality if local data is unavailable, as is currently the case for the majority of Finnish cities. For a more in-depth look at the methods and results outlined in this article refer to the author's M.Sc. thesis, titled "*Land-use based stormwater pollutant load estimation and monitoring system design: Case of Lahti city, Finland*". It is available in digital form from Aalto University's publication archive.

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Jessica Huttunen, Paula Salomäki, Paul Carroll

Abstract

The effects of climate change, urbanisation, the increasing amount of impermeable surfaces and the handling capacity of the present stormwater infrastructure no longer correspond to anticipated needs in the coming decades. In addition to the increasing amount of stormwater, a challenge for the handling of stormwater which should be mentioned is the increase in extreme rain incidents and the question of the quality of the stormwater formed. Elements of the built environment disrupt the natural water cycle, with the result that the local water economy becomes imbalanced.

By availing of the positive aspects of natural stormwater management, however, the climate influenced side-effects of stormwater in the built environment can be controlled. Among other things, natural stormwater management systems balance the natural water cycle, remove pollutants and suspended solids from the stormwater and regulate peaks in flow, something which is usually lacking in traditional stormwater systems. Natural stormwater management systems also, for example, create more positive environmental psychological effects, increase social interaction among users of the area, purify the microclimate, promote biodiversity and invigorate the built environment in many ways.

NATURAL STORMWATER MANAGEMENT IN THE NEW RESIDENTIAL AREAS KARISTO AND KYTÖLÄ

The effects of climate change and human activity changes on the hydrologic cycle

Climate change has been proven to cause a range of influences in Finland and these can be scientifically substantiated, for example through changes in snow, ice, evaporation, soil moisture and in drainage. (Veijalainen et al. 2012, 21). Based on the estimated development patterns of climate change total precipitation at least will increase by 10 - 40 % in comparison with the reference period 1971 - 2000 (Ilmasto-opas 2013). Also typical features of the different seasons will be evened out and the growth period will be extended in Finland, in this case it has the exceptional characteristic of even being a useful thing for increasing efficiency in agriculture. As a rule, however, there are more negative aspects to climate change than positive ones, with the likes of an increase in extreme climatic conditions and flood risks occurring much more frequently in the future (Hakola 2012).

In addition to this, it has been found that urbanisation increases precipitation locally by as much as about 10 %, and in certain cases by even more. This is due to the concentrating effect of pollution in the air, air current turbulence due to buildings and to the warmer urban climate compared to rural areas. (Vakkilainen, Kotola & Nurminen 2005, 12.) Nevertheless, building is perhaps still not seen as a great threat in Finland, because over two thirds of the surface area of the country consists of forest. (Aalto-yliopisto 2013.)

There is a need, however, to have increasingly more attention attached to the effects of construction. The compact and efficient building trend is undoubtedly sound from the ecological viewpoint, but it also has other effects on the environment, with changes in vegetation, fauna, air quality, local micro-climates and hydrological cycle processes being caused (Hakola 2012). This kind of building demands considerations at the planning stage for stormwater treatment, taking the drainage area and the surround natural environment into account (Aalto-yliopisto 2013).

An increase in precipitation is, however, not the only challenge for urban planning. Climate change and climate-inducted side-effects together change the hydrological cycle in the built environment, which in turn leads to an increase in the amount of stormwater. For example, the formation of surface runoff appears to have a clear and direct correlation with the amount of impermeable surfaces in the build environment (Eskola & Tahvonen 2010, 13). An urban structure with the absence of-, or with an inadequate amount of green areas, and when there are compact, extensive and numerous impermeable surfaces there are negative effects on hydrologic cycle processes, with the result that the entire natural water balance of the local environment is disrupted (Hakola 2012).

Stormwater in the built environment

Stormwater is usually defined as water from rain or melting snow and ice being led away from the ground area, from the roofs of buildings and other comparable surfaces in the built environment, including drainage water from the foundations of buildings. In addition stormwater includes snow that has fallen on built areas and that which is later transported elsewhere. Stormwater does not, however, include surface flow in fields and forest areas. Other water resulting from human activity, such as fire-fighting water from fires or street washing water, can exceptionally also end up in the stormwater system. (Malin et al. 2010, 7.)

As well as the problem of the increasing amounts of stormwater there is that of the quality of stormwater. Factors affecting the quality of stormwater are, for example, atmospheric deposition (Melanen & Tähtelä 1981, Valtanen et al. 2010, 5), particular characteristics of the drainage area, the land-use type and activities in the area, as well as seasonal variation (Eskola & Tahvonen 2010, 13). Existing drainage facilities do not have sufficient capacity to effectively deal with increasing amounts of stormwater received, nor do they usually have properties for improving the quality of the stormwater.

Traditionally stormwater is lead away from the source in urban areas through mixed- or separate drains. Mixed drainage can represent challenges to waterway protection, particularly in association with heavy rain incidents when unpurified mixed water can exceed the flood threshold and end up in waterways. (Aaltonen et al. 2008, 11.) While it is traditionally attempted to lead stormwater quickly into drains, evaporation is then not able to occur with the same intensity as outside urban areas. When evaporation is low the total amount of draining water is presumed to increase, but on the other hand the surface-level- and ground water runoff is reduced as the amount of covered surface area increases, which in turn negatively affects the groundwater level and decreases flow into channels. (Hakola 2012.)

The amount, significance and use of natural stormwater in urban planning

Fortunately, about twenty years ago attention started to be paid to availing of natural solutions in the treatment of stormwater. According to Ahponen (2003, 45), in natural stormwater management the hydrological processes of nature itself are taken advantage of. In contrast to traditional drainage treatment methods the stormwater is in contact with the air, the soil, with vegetation and micro-organisms. By improving the quality of stormwater the state of the water is regulated so as to correspond as much as possible to the natural state of the water. (Ahponen 2003, 45.)

Malin et al. (2010, 20 - 21) point out that natural stormwater treatment methods serve many tasks simultaneously. There are extensively developed natural stormwater management methods available internationally, the dimensions and other characteristics of which are mostly determined by factors particular to the location in question. At best the treatment methods correspond with the natural situation where contaminants, nutrients and solid matter are filtered out and removed from the water, where water flow peaks are reduced, the retention time is increased and ground- and surface water reserves remain undamaged (Ahponen 2003, 45).

Komulainen (2012, 25) classifies stormwater quality management methods as follows: bio-filtration or bio-retention, retention pools, retention areas (with drying time of 48 hours max.), grass swales, green- or vegetation roofs, infiltration depressions, planting of natural plant species, permeable surfaces, rain gardens, wetlands and different storage methods. Some management methods are still little used in Finland, but new research is being carried out all the time. Some uses and adaptations of management methods are being investigated for the cold climate conditions of Finland.

There are several side benefits to using natural stormwater management methods, which are lacking in traditional stormwater management practices. Correct and locally-adapted methods can meet many stormwater management challenges. Some natural stormwater management methods are more adaptable, as regards their structure, dimensions and form, to planning areas than others. For example in road areas a narrow and efficient water purifying bio-filtration system can be installed, while the slowing down wetland method can be better suited to stormwater treatment for a residential area. Different stormwater management methods can also be combined and a sort of route network can be constructed, that can then serve to maximise the advantage to be obtained from the system.

Natural management systems do not only regulate the amount and quality of stormwater, but also promote biodiversity and balance the hydrologic cycle. The main purpose of intentionally planning biodiversity in association with stormwater management systems is to holistically reduce the environmental load caused by stormwater in drainage areas and discharge waterways. Salminen (2008, 1) adds that through naturally planned approaches and techniques the formation of stormwater flow can be minimised, the flow and flooding can be evened out and constrained, so as to reduce erosion and the burden of contaminants passing into discharge waterways.

Water elements and the associated green areas also have positive environmental psychological impacts (Jalkanen et al. 2004, 154), increase social interaction (Järvenpään kaupunki 2009, 9) and invigorate the built environment in many ways. Fortunately in Finland many towns have implemented stormwater programmes and guidelines and have started to avail of water elements as a part of the urban environment, whereby the positive influences brought about by natural solutions can be seen in the environment of the area in question, and among the user population.

Availing of natural stormwater management methods is, however, not possible in all locations. Depending on the form of land use, the activity in the area may demand a lot of covered and impregnable surfaces for example, in which case some other stormwater management methods, such as a mechanical system or a combination of different management methods may suit the area better. Natural stormwater management also imposes many demands, such as the need for space due to the dimensions of the system and maintenance, as well as demands for operability throughout all seasons of the year. (Jormola 2005.)

There is a strong legal guideline basis with regard to stormwater issues. Several directives, laws and decrees refer to stormwater management. Such matters as waterway protection, flood risk evaluation and management, as well as general stormwater-related issues are controlled by directives. The directives are adapted on the Finnish state level e.g. through laws and decrees, which in turn form the based for stormwater programmes and guidelines in cities. The degree of positive attitudes to environmental issues in different towns and cities, as well as the focus of budgets varies within the national level, and natural stormwater management methods are not necessarily availed of, even though in cases the potential for their implementation may exist. In addition, some natural stormwater treatment methods can be challenging to construct in an already built-up environment, although on the other hand such methods as bio-filtration can easily be installed in sites being renovated (Komulainen 2012, 34).

The significance of vegetation of soil type on natural stormwater management

Vegetation and the land type have an important role in effective natural stormwater management methods. Water evaporates from the surfaces of plants and they also use it for respiration and photosynthesis. Lush and varied vegetation slows down stormwater effectively, protects the soil and surfaces from the eroding effect of water and reduces erosion in the channel network. In addition, plants clean stormwater biologically, for example by retaining and binding nutrients contained in the water and indirectly enhancing the physical and chemical purification processes in the stormwater structures. The vegetation of wetlands, with its corresponding microbes and bio-filtration areas, binds and consumes the nutrients and contaminants in the stormwater, as well as retaining solid material well. (Suomen kuntaliitto 2012, 217.)

Through stormwater management the soil acts as a medium for the filtration of contaminants and nutrients. The physical and chemical properties of the soil have an effect on the detention and transportation of contaminants and nutrients. (Valtanen et al. 2010, 22.) Coarse soil types filter water excellently. Sandy soils and coarser ones aid the passage of water, so that the groundwater level is usually higher (Fischer 2003, Valtanen et al. 2010, 22). The effective permeability of soil partly prevents the reactivity of substances with the soil structural material, enabling these substances to penetrate through to the groundwater. For this reason, the properties of contaminants are more visible in soil types through which water penetrates poorly, as compared with coarse soil types. (Yoon et al. 2009, Valtanen et al. 2010, 22 - 23.)

The more clay-like or the higher in humus content the bottom soil is, the greater its ability to detain the nutrients and contaminants contained in the stormwater. Also vice versa: the detention properties of less clay-like and low humus content bottom soils are poorer. Nevertheless, Ficher (2003) states that coarse soils that are highly permeable to water, and the effective filtration of water may lead to the risk of contaminating the soil and reducing the quality of the groundwater, in which case the risk of leaching of contaminants into the groundwater is greater than with clay-like soil. (Valtanen et al. 2010, 22 - 23.) The iron and aluminium oxides contained in clayey soil, as well as humus, are bound from stormwater, e.g. metals and nutrients with the aid of the so-called cation exchanges mechanism. Also a part of the nitrogen compounds in soil are broken down in the de-nitrification process and are removed in the form of gaseous nitrogen and nitrogen dioxide into the air. (Ahponen 2003, 47 - 48.)

A case study of bio-filtration in Kytölä

This thesis was carried out under commission from Lahti Region Environmental Services in autumn 2013, and in association with the project Climate-Proof City (ILKKA) – Tools for Planning. The City of Lahti is partial implementer of the project (2012 - 2014), which aims at creating city planning that can better cope with climate change. (Lahden kaupunki 2013.) The main objective of the work was to research the effectiveness of stormwater management methods in the new Lahti residential areas of Karisto and Kytölä, with the aid of load reduction studies. In order to carry out efficiency calculations, regular water samples from the in-and out-flowing stormwater system were taken from drain points in Karisto and Kytölä. The environmental laboratory Ramboll Analytics analysed the samples and on the basis of this the reductions in nutrient and contaminant levels were calculated.

The bio-filtration system of the Kytölä case-study corresponded totally with the natural system, with the purification efficiency of stormwater being estimated in this exceptional case only on the basis of surface transportation of water and material. Stormwater flowed along the so-called visible surface along ditches, while at the same time passing through coarse soil and varied vegetation cover. Usually, however, the basic idea of bio-filtration is the filtering of stormwater into a depression with the aid of selected vegetation and a bio-filtration structure built into the ground, in which case the stormwater accumulates in a shallow depression and is absorbed further into underground structural layers (Vantaan kaupunki 2013).

In addition to environmental factors, the soil layers and plant species of the bio-filtration structure are significant in terms of the retention efficiency of different matter and the transportation speed of water. The plant species chosen in Finland for bio-filtration purposes need to be very tolerant of water and cold conditions. In addition, the risk of freezing of the structures needs to be taken into account at the planning phase.

In the Kytölä case also surface-level bio-filtration was observed to be a very efficient and functional purification method for stormwater, although the structures already present in the ground were not availed of in the research. Samples were gathered six times during the course of autumn 2013. On the basis of the results obtained a surprisingly large reduction in nutrients and heavy metals from the stormwater was observed to occur via the natural stormwater management method, as compared with the test results for the constructed system.

Taking advantage of the wetland method in Karisto

The reduction of material in the Karisto wetlands varied a lot regardless of the season. Particularly the total nitrogen dropped best in the case of both wetlands, while the amounts of other materials varied for other reasons. However, wetland samples were taken over the observation period only several times a year, in spring and autumn. For this reason, certain details e.g. peak loads caused by spring melting are not necessarily visible in the results.

The sample results may have been influenced by many factors. The possible influence of forest and land disturbances by soil cultivators on the high levels of total nitrogen arose, as well as the negative influence in Karisto of the dense residential building structure being generally responsible for the quality of the stormwater arising in the area. On the other hand, both wetland areas are rather young and usually the retention capacity of newly-installed wetlands is not as efficient as established constructed-, or totally natural wetlands are at their best.

Picture 1. An upstream view of the Karisto stormwater system (Eeva Aarrevaara 2014).

Picture 2. Stormwater retention pond, Karisto (Eeva Aarrevaara 2014).

Many factors affect the efficiency of natural wetlands. During the planning phase predictions can be made regarding the influences of existing conditions and dimensional factors. The correct plant types, soil types and structural choices can also optimise the filtration speed and the retention of materials in vegetation and in soil particles.

It should be possible to improve the treatment ability of wetlands e.g. by choosing plant species with retention ability and by minimising the release of nutrients from sediments, as well as from the degradation of vegetation, back into circulation. The release of nutrients can be balanced by controlling the inflow and the residence time in wetlands and by preventing the re-release of nutrients due to the disintegration process of wetland vegetation. On the other hand, also the quality of inflowing stormwater needs to be monitored, possible sources of large loads need to be investigated and thereby the original load caused to the stormwater can be minimised. Possible load sources can usually be predicted as early as at the stormwater planning stage.

Considering the above-mentioned factors, in any follow-up research a comparison could be made between the efficiency of natural stormwater management methods and mechanical ones. In the comparison it could be ascertained whether mechanical methods are better suited to certain types of target areas than natural methods. In the case of bio-filtration, availing of the method in cold conditions has been investigated very little and there is still a need for research into this area. In addition, the retention ability of plant species suited to wetlands may need to be investigated in order to be able to maximise the efficiency of new constructed wetlands.

On the express wish of the commissioner of this thesis work a questionnaire survey was carried out on residents in December 2013. The intention of the questionnaire was to record the experiences and opinions of the residents of the Karisto area to natural stormwater management methods. On the basis of the answers received it was found that residents had some previous knowledge of the main purpose of the pools and ditches, and regarded natural stormwater management as a factor in increasing the value and desirability of the area. On the negative side, some of the residents found the open systems dangerous for children and mentioned neglect of their upkeep, especially as regards cleanliness. Many respondents expressed the wish that the area should be changed to be more park-like and for the green area management category to be raised, and thereby for the potential of the area to be maximised.

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Paul Carroll

Abstract

Paul Carroll describes an environmental learning project which was conceived based on discussions with staff members in Lahti Environmental Services and Urban Planning. In the Environmental Technology Degree programme there is a project course for the first year Bachelor students in spring 2013. Students were divided into 5-6 person groups and they were given a special inventory document to fill in on site visits. One central purpose of the inventory was to find out what kind of differences there are between the official maps and the real land use of the shorelines.

SUSTAINABLE DEVELOPMENT IN THE URBAN ECOSYSTEM –COURSE IN ENVIRONMENTAL TECHNOLOGY

A practical study unit for first year Lahti University of Applied Sciences (LUAS) students under the Urban Laboratory for Sustainable Environment project.

Introduction

For the final study period of the academic year 2012-13 it was decided to implement the annual study unit (of 3 credits in scope) entitled *Urban sustainable development project to encompass the objectives of the Urban Laboratory for Sustainable Environment project*. Although the matching of this study unit with the project was based on a conscious choice it was by no means a forced coupling, but rather a natural choice for a topic for the implementation of this particular project-based-learning activity. In fact, a course for the equivalent group of students was carried out the previous spring and it dealt with a completely different aspect of urban sustainable development, namely developing a system for providing bicycle borrowing facilities.

The more specific nature of the work carried out by the undergraduate students this time was defined according to a request of the author and course lecturer from Lahti Region Environment Services (henceforth LSYP –based on the acronym of the Finnish-language name) for a practical case related to the urban environment, that perhaps needed field investigation, but for which they would not have the workforce resources to carry out themselves. After some deliberation and discussion between different divisions of Lahti Technical Services the contact person got back in touch with an issue that had come up involving both LSYP and Lahti City Planning office. This took the form of a detailed survey of the shoreline of all waterways in the municipality of Lahti, emphasising existing land use as compared with the mapped and documented shoreline land use at present.

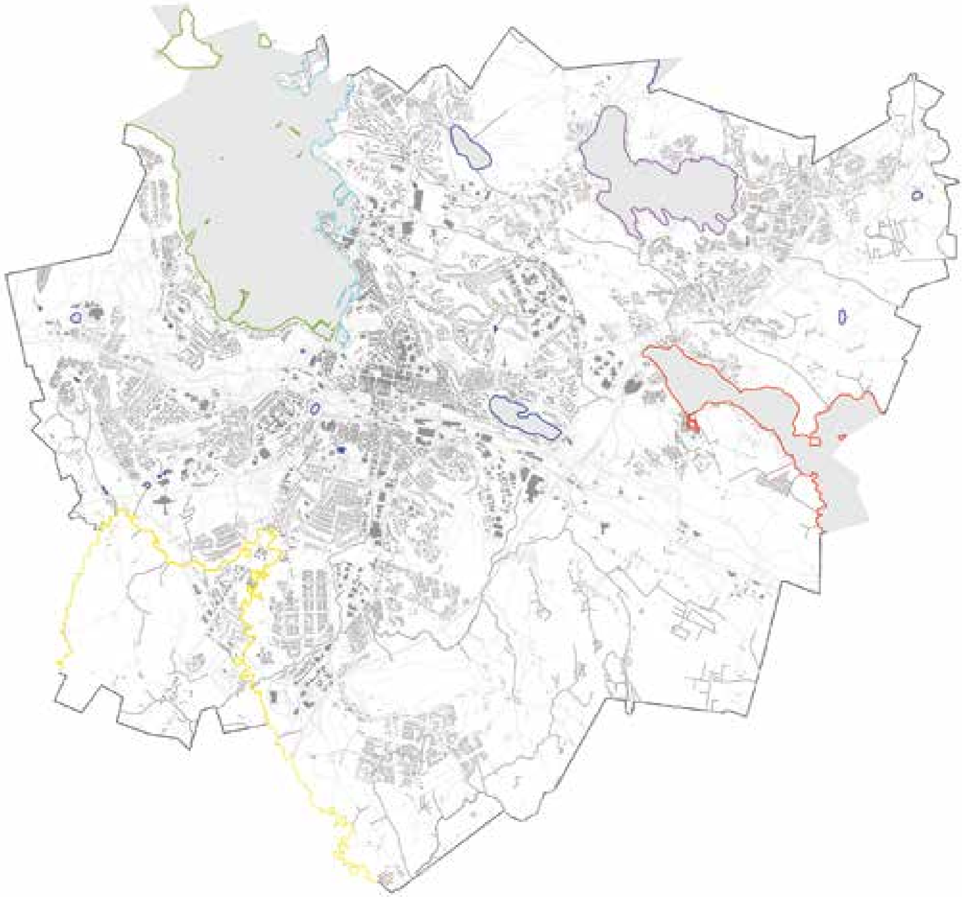

Figure 1. The entire map of lakes and ponds in the study area (shorelines are marked in colour) (Paul Carroll 2013).

The task

In order to explain the need for the agreed course tasks, and to explain the methodology necessary for its successful completion, an introductory class was held in April 2013 attended by all involved. Two representatives of LSYP and one of Lahti City Planning office were present. They provided all the students with detailed city maps as well as giving the teacher electronic versions of detailed maps of the lakes and ponds involved. There was one general map made (Figure 1) available showing the entirety of lakes and ponds in the whole city area. A basic inventory card was provided to the students (Figure 2) and this provided them with a starting point for what to look out for on their field visits. As well as the group work tasks each individual student had the obligation to write a personal field diary, recording observations and experiences and documenting their own level of participation in the whole exercise. Being first year students, the teacher stressed the ability to make observations and to critically describe their own experiences and performance as an importance skill that needs to be developed at this stage.

Relevance

An explanation was given by the municipality representatives of the benefits to be gained from the information from their findings after this exercise. The students learned that the land use as marked on the maps does not in all cases correspond to the real present situation. Updates could then be made to the maps and the city planning and the environmental authorities would be able to look into cases where lakeside cottages or other buildings exist in places where they should not, at least according to the land use records.

Inventory card/Inventointikortti

Figure 2: The inventory cards used by the students both directly in the field & for later completion (Paul Carroll 2013).

Identification of feature/Kohteen tunnus	
Name of feature/Kohteen nimi	
Feature of map scale/Kohde kartalla 1:5000 - 1:20000	
Length of shoreline/Rantaviivan pituus	
Land ownership/Leisure use Maanomistus/ virkistyskäyttö	
Land use/Maankäyttö	
Description/Kuvaus	
Nature/Luonto	
Ground type, Geological survey /Maaperä, GTK	
Shore type/Rantatyypit.	
Classification/Luokitus	
Photographs/Valokuvat	
Field visit/Maastokäynti	

Implementation and support

Considering the wide scope of this work, it was decided in further negotiations between the City of Lahti employees and the teacher from LUAS to restrict the waterways to lakes and ponds on this occasion, then on some further date to involve the shorelines of rivers and streams. Also, the question arose of how to deal with the larger lakes with shorelines in more than one municipality, such as Vesijärvi (Lahti and Hollola) and Kymijärvi (Lahti and Nastola). This is indeed a pertinent question, considering that for administrative issues the three municipalities of Lahti, Hollola and Nastola have a common governing committee and come under the jurisdiction of LSYP. The municipal partners responded to this with the practical solution of confining the study in this case to the limits of Lahti municipality, which means only carrying out the inventory on the parts of the lakeshores in question occurring on the Lahti side. The remaining shoreline segments of those lakes could well provide study material for a future course.

The class was divided up into groups of 5-6 students approx. and each was allocated a certain number of small lakes and ponds, or one or two larger ones, while a couple of the larger lakes, such as the dominant Lake Vesijärvi, around which Lahti city is built, were divided into two shoreline sections, because of the long total shoreline (in the case of Lake Vesijärvi it was western and eastern sections. The intention was that each group would in total have approximately the same length of shoreline to deal with. Paper printouts of the relevant maps were distributed to each group and it was made sure that before starting that the breakdown of lakes and ponds and their section was clear between the groups. They were then encouraged to get together and clarify the division of tasks within the groups, regarding field visiting dates and times, who would take photographs etc., then who would prepare the presentations and reports later.

A small boat was made available for investigating the islands on Lake Vesijärvi, when they were visited a member of LSYP went along to assist. All necessary background information that was given by the municipality partners was made available by the teacher on the Moodle platform which is used by LUAS. There was an introductory day as well as a full briefing day given before the students were sent to first plan their group work and then go out into the field to carry out the inventory.

Obstacles encountered

It was found that for a couple of the other lakes, Lake Kymijärvi and Lake Alasenjärvi, the use of a boat would also have been necessary, since areas of the shoreline were inaccessible but foot from the shore, either due to features of the landscape or fences preventing access. Although due to “everyman’s rights” it is not a typical aspect of Finnish natural areas to be denied access, in some otherwise public places questionable No Trespassing signs were encountered. There were some other landscape obstacles such as wetlands area preventing immediate access to the shoreline itself, as well as buildings directly on the lakesides which had to be circumnavigated. A typical section of shoreline in this regard is illustrated in Picture 1; in the corresponding inventory card it was accompanied by the description: Reed-covered shore, steep mixed forest, tree cover near the shoreline, damp and difficult to access by foot in the field. Lake Mytäjärvi is situated beside a major crossroads near central Lahti and represents the typical land use challenges met in this course (Picture 2).

Picture 1: A section of the shore of Lake Kymijärvi as recorded by one student group.

Feedback from Students

Written feedback was requested from the students after this course, as with other courses in LUAS. While this was given to a certain extent, there was much more learned from the field logs or diaries submission that was required of each individual student. Course feedback was voluntary, while writing the diaries was a necessary task to prove active individual participation, encourage the reflective process and not least to assist the teacher in grading.

As a whole the exercise (held in the month of May) was well received and praised as being a welcome "hands-on" task after much of the first year theory classes necessarily being held indoors over the winter months. It was also welcomed in terms of dealing with a real need of the public authority and thereby representing a genuine working life case.

Some of the feedback contained the criticism that there was not sufficient information about the tasks expected of the students during the inventory, which proved surprising both to the teaching staff and to the municipality partners, since also an extra briefing was given a week or two after the start of the exercise. The attendance at this was voluntary, but it was hoped that any outstanding issues or methodology questions, such as how to interpret field observations, could then be clarified. Some availed of this opportunity to ensure that they had started the inventory and the recording if data which it involved correctly, but others did not. At the briefings all the required information was made available, as well as the opportunity being made available to ask the teacher and city planning partners for more instructions via e-mail and the Moodle platform. However, these were first year students and many had still to learn to take on new tasks with the more patient methodical approach demanded by working life, where the responsibility of the employee it is to obtain all necessary information about a new project from the employer or customer before commencing the task.

Feedback from the municipal partners

On completion of the whole exercise the main contact and representative of Lahti municipality Mr. Timo Permanto from LSYP gave the following statement on the usefulness of what was obtained (translated by the author).

"The information obtained from the shore area inventory can be availed of in land-use planning to estimate the suitability for leisure use and for different potential construction purposes. It can be used to interpret their landscape value and suitability, among other things, as a green area involved in stormwater management. Also the quality of shore areas for waterway-based leisure use can be estimated on the basis of the inventory. As regards the analysis of vegetation contained in the inventory, this represented help in making plans to ensure the protection of biodiversity."

Picture 2. Lake Mytäjärvi represents the typical land use challenges met in this course (Matti Heikkinen 2013).

Discussion and further Study

As a choice of theme for the first year environmental students' course *Urban sustainable development project* the inventory of lakes and ponds in the Lahti area provided a good opportunity to deal first hand with the challenges of combining and accommodating the pressures for different, and often competing, uses of urban waterways. From the point of view of the larger *Urban laboratory of sustainable environment* project students were obliged to consider the impact of construction and other land use changes on drainage issues and had the opportunity to appreciate the value of wetland areas in the urban context, among other things as buffer zones and storm water receptacles. Although it was limited during a short course how deeply these issues could be expanded on in the time available, it is hoped that the appreciation process will have been instilled in the minds of many of the students to be developed further in subsequent studies and for application in practical periods and later working life in different aspects of the urban environmental sector.

The issues which remained open after the present study were as follows: The rivers and streams in the area, which it was initially agreed would be omitted this time round, notable the River Porvoonjoki. This is being carried out at the time of writing as a central part of the same course in the spring of 2014. In addition to these there remained the lake shorelines of the lakes, in particular Lake Vesijärvi and Lake Kymijärvi, which are situated in two other municipalities, namely Hollola and Nastola respectively. Then there were the above mentioned lakeshore areas which proved to be poorly accessible to the surveying teams, whether for topological reasons or because of being marked (legally or illegally) as private property.

John Allen, Eeva Aarrevaara

Abstract

John Allen´s work experience includes five years in the mining industry for Iluka Resources, and most recently, three years with the Wastewater and Stormwater Utilities of the City of Richmond, Virginia as an Environmental Technician. He recently moved to Finland and has been participating in the LUAS Master study programme in Spring 2014. Eeva Aarrevaara posed a list of questions to him concerning stormwater management experiences and practices in the US. Stormwater management has a long history in US legislation: the Clean Water Act in 1972 already considered the problems of urban stormwater quality, but particularly in the Water Quality Act of 1987 and with the establishment of the Municipal Separate Storm Sewer System (MS4) program these issues have been considered seriously. Allen also describes examples of monitoring depending on the character of the current project. Good housekeeping practises in public and private sites are needed to reduce pollution of stormwater. Aging infrastructure is also creating new risks to the environment, if for example there are leaks in the waste water system they usually adversely affect the stormwater quality. Possible solutions to managing stormwater are rain harvesting and rain gardens, permeable pavements, sunken planter beds, retention and detention beds.

EXPERIENCES FROM STORMWATER MANAGEMENT IN RICHMOND, US.

Among the interview there are a few pictures. All of these photographs are from Richmond, Virginia.

1. What kind of working experience do you have concerning stormwater management? Where did you work in the US?

Stormwater management and compliance issues were a central part of my work, both in the mining industry and for the City of Richmond. Iluka operated under several different permits that required strict controls on discharges of stormwater from the mines and the processing sites. At Richmond I worked with both the industrial wastewater pretreatment and stormwater programs. My work with stormwater was focused mainly on sampling and inspections to ensure that the City was in compliance with the requirements of its MS4 permit. This work included inventorying and inspecting all stormwater outfalls within the City and conducting illicit discharge detection and elimination (IDDE) investigations. I also developed, distributed, and presented training programs to City employees and worked with citizens and environmental groups to address pollution concerns.

Picture 1: Vince Revene (right) and John Allen installing sampling equipment as part of an IDDE investigation

2. Did you study stormwater management in the university, or did you get your experience in practical work?

My studies in the University of Georgia were focused on geology, so I learned a great deal about hydrology, erosion, and sediment transport. My primary education in stormwater issues came from practical work and on-the-job training.

3. Is stormwater management taken into consideration in urban planning, and what kind of regulations and instructions are there? What kind of planning documents are usual concerning stormwater management?

This is a bit outside of my current experience, but the basic answer is “yes”. Planning for stormwater infrastructure is certainly conducted as part of the urban planning process, and is required by the NPDES MS4 permits that most cities have. The primary regulatory vehicle for municipal stormwater management is the MS4 permitting program, which sets various monitoring, reporting, and educational goals and requirements for the city. Cities also must review and approve Erosion and Sediment control plans for new construction projects or for projects that disturb a certain amount of land area.

4. Are there long term plans and strategies concerning stormwater management?

Stormwater and other environmental plans are typically included as aspects of the City’s master or district plans. Additionally, the City’s MS4 permit will set goals for the City to reach during the permit term, which is generally 5 years.

5. Did you cooperate with other authorities in stormwater management – if so, which ones?

My program worked closely with other City Departments, the Virginia Department of Environmental Quality, the Virginia General Services Office, the Science Museum of Virginia, as well as the US Environmental Protection Agency and various nonprofit groups.

Picture 2: Volunteers with the Reedy Creek Coalition preparing to conduct a stream walk, an assessment of outfalls and creek channel condition, along Reedy Creek.

6. What kind of measurements are made concerning stormwater and how often are they carried out? Who takes care of the research in the city?

The types of measurements and frequency of samples that were taken depended on the sort of project. For illicit discharge investigations, we would typically test a sample for pH, conductivity, E. coli, total suspended solids (TSS), ammonia, nitrate and nitrite, total phosphorus, turbidity, temperature, total petroleum hydrocarbons (TPH) and detergents. The exact parameters chosen would depend on what contaminant we suspected. For outfall screening we would sample for turbidity, nutrients, E. coli, temp, pH, and conductivity. These samples were collected at least once from each outfall found to have flow during dry weather, and additional samples were taken if a contaminant was detected. For monitoring of green infrastructure projects, we would sample for TSS, nutrients, E. coli, and pH. I tried to collect these samples after nearly every rain event. If possible, I would go to the site to collect pH and E. coli samples during the first 30 mins of a rain event. My partner and I were the only two people charged with these jobs. Analysis of samples was conducted by the DPU laboratories and contract labs. My partner, I, and the Environmental Compliance Officer were primarily responsible for handling the data collected and issued reports based on it.

7. What are the main problems in dealing with rainfall and stormwater?

Pollution from poorly kept sites, erosion, blockages of storm drains from leaves and trash, educating the public about litter and pet waste

8. What kind of circumstances have you worked with? How often were there heavy rainfall events compared with lighter rainfall?

During the summers in Virginia there would be fairly frequent thunderstorms that could produce very heavy rain. It was not uncommon to have a rain event that would produce 2 to 3 cm of rain in less than one hour. During the spring, fall, and winter, rains tend to be lighter and longer in duration.

9. What kind of practical solutions have you come across in the environment concerning stormwater management? What kind of maintenance did they need?

At private residences I saw: Rainwater harvesting, which, in the US suburbs anyway, is an old idea that is new again. I conducted a rain barrel building demonstration for the Richmond Schools science teachers.

Other practical solutions were:

- Rain gardens, where you divert water that would normally run off of your property toward a shallow garden basin, which retains the water and allows it to infiltrate into the soil.
- Permeable pavers and pavements
- Using mulch to help stabilize bare and eroding soils

These, of course, require some maintenance. The rain barrels for rainwater harvesting should be drained, cleaned out, and stored at the end of autumn. Rain gardens should be tended like any garden bed. Permeable pavers should be swept to remove debris that will clog the material's pores. Mulch has to be replenished and kept from moving off site with stormwater.

On streets the City was installing and monitoring several different projects. One was a series of sunken planter beds which took in stormwater runoff from the street and allowed it to infiltrate through a sand bed before entering the collection system. We also monitored a permeable concrete parking area at the Science Museum of Virginia. I don't really know much about the maintenance on these. I understand that the permeable pavement can actually be vacuumed to remove debris that is blocking the pores.

Retention and detention basins are the primary method of dealing with stormwater at industrial, commercial sites, large residential areas and roads. These of course have to be kept clear of debris and trash to work properly.

10. For how long have stormwater challenges been observed and paid attention to in the US?

Urban stormwater has been considered as a source of pollution since at least the passage of the Clean Water Act in 1972, but it was 15 years later, with the adoption of the Water Quality Act of 1987 and the establishment of the Municipal Separate Storm Sewer System (MS4) that these issues really began to be addressed.

Pictures 3-4: Dr. Charles Gowan and students from Randolf Macon College conducting outfall screening for pollution sources along Reedy Creek.

11. What could we learn in Finland about your experiences concerning stormwater management?

I'm hoping to learn from you! In Finland you have the benefit of having a population that seems to truly value the quality of the country's land, air, and water. Given that, I think that stormwater professionals in Finland have a great opportunity to begin educating the public on the importance of implementing practices that will protect the quality of the environment. Things like good housekeeping practices at industrial and municipal sites and at farms, as well as picking up dog waste and litter can make a huge difference in the quality of stormwater. Another thing that is gaining popularity in US cities are Illicit Discharge Detection and Elimination programs (IDDE). As the infrastructure of cities ages and degrades, more leaks occur from failing and damaged sewer systems and these commonly impact storm sewer systems. IDDE programs can help to find and correct these pollution sources, along with those from illegal dumping, and leaking underground storage tanks. Conducting these investigations was one of my favorite duties while working for the City of Richmond.

Nora Sillanpää, Harri Koivusalo, Heikki Setälä, Marjo Valtanen

Abstract

Nora Sillanpää together with Harri Koivusalo, Heikki Setälä and Marjo Valtanen summarises the background of Finnish stormwater research and recent results in various projects in different urban areas. The monitoring requirements are introduced as well as the challenges for monitoring in cold climate conditions. There seems to be little experience of monitoring snow affected conditions compared with rainfall-runoff monitoring. Monitoring programmes should include data from different seasons and from a range of event sizes. Today the challenge is often to fit the monitoring needs to a realistic budget. Hydrological monitoring has a long history in Finland: the first water level observations date back to the 19th century. The first urban stormwater research, Finnish Urban Storm Water took place in the late 1970s in Helsinki, Tampere, Oulu and Kajaani. Since then, extensive urban runoff monitoring studies have been conducted by Aalto University and the University of Helsinki starting from the year 2001. The following chapter introduces the main outcomes of the previous and current monitoring projects and discusses the following topics: the impacts of urbanisation on runoff generation, the impacts of urbanisation on urban runoff quality, the importance of urban runoff as a diffuse pollution source and urban runoff modelling. In appendix 3, several publications published in the current and previous Finnish stormwater studies are presented.

URBAN HYDROLOGICAL MONITORING IN FINLAND: PAST EXPERIENCES, RECENT RESULTS, AND FUTURE DIRECTIONS

1. Introduction

Urbanization leads to changes in natural catchment characteristics by increasing impervious coverage and drainage efficiency, which enhance flooding, erosion and water quality problems in the receiving waters. Urbanization is a rather recent phenomenon in Finland - one third of densely populated urban regions were built during the years 1980-2000 (Ristimäki, Oinonen, Pitkäranta & Harju 2003, 187). Although these urban areas cover only two per cent of the total area within Finland, they are home to over 80% of Finns. Therefore, the majority of Finns are directly affected by the management decisions made regarding urban water resources (Sillanpää 2013, 24). During the recent decade, several Finnish cities have prepared stormwater strategies where, instead of the conventional drainage-oriented approach, urban runoff management is understood as a larger phenomenon including goals for maintaining predevelopment hydrological conditions and improving water quality and ecology. The inclusion of sustainable urban runoff management principles to the national stormwater manual by the Association of Finnish Local and Regional Authorities (2012) is a promising step forward towards renewed urban runoff management guidelines at the national level (Sillanpää 2013, 25). Yet, without extensive research on urban runoff in the local cold climate conditions, practitioners have to adopt new ideas without proper guidelines and understanding of urban rainfall-runoff process in cold climate conditions.

The main objective of this chapter is to briefly describe the data requirements for urban runoff monitoring, to provide a summary of recent monitoring studies conducted in Finland, and to give an overview of the main results. With this review, we hope that the outcomes of the recent research work would more easily reach authorities and practitioners working with urban stormwater issues in climatic conditions similar to Finland.

2. General requirements for urban runoff monitoring

For researchers, plenty of guidance on hydrological monitoring of urban catchments is available, e.g. WMO (1996), Burton & Pitt (2002) and CWP (2008). It is well known that urban stormwater flow rates are highly variable in both time and space. Hence, a higher temporal and spatial resolution is required for hydrological monitoring in urban catchments than in rural ones. A rule of thumb "1-1-0.1" for optimal precipitation data (Niemczynowicz 1996) describes the high resolution needed: one rain gauge per 1 km2, a 1 minute time resolution and a 0.1 mm volume resolution. Maksimović (1996) lists typical data requirements that range from one to five minutes for time series analysis, modelling, real time control and flood mitigation. Daily and seasonal values are adequate for general planning purposes. For the urban hydrological calculations of pollutant transport, temporal resolution of 10 - 20 minutes for rainfall is required (Krejci & Schilling 1989, according to Niemczynowicz 1996). In addition to these general guidelines, also the catchment characteristics affect the required measurement resolution.

The high temporal and spatial variability of urban runoff also concerns pollutant concentrations and, therefore, reliable monitoring requires extensive field measurements. Generally, few quality parameters can be measured continuously on-site and the quality analyses for most pollutants have to be done at a laboratory based on water samples. In a typical case, the flow is measured continuously and water quality is sampled for a number of events (Marsalek 1996), yet the most extensive sampling may require sampling intervals of ten seconds, as in a study of the first flush phenomenon by Deletic (1998). Another common task is to use measurements for a calibration of an urban rainfall-runoff model; however, the difficulties in using physically based formulas for urban runoff quality simulations have led to a preference for statistical approaches (Van Buren, Watt & Marsalek 1997, 95). Today the question is often not how to collect enough data, but how to limit the data collected to fit within a realistic budget (Terstriep 1986, 128). Ideally, the monitoring programme should gather data from different seasons and from a range of event sizes. Appropriate experimental setup depends on the objectives of the water quality study: comprehensible example study designs can be found e.g. in CWP (2008).

Thorolfsson (2000) discussed issues related to the successful operation of urban hydrological stations in cold climate. Yet there seems to be no monitoring manuals that would provide guidance on topics specific for cold climate observations, such as the monitoring of snow properties, snowmelt runoff, and snowfall in urban environment. Even though knowledge on urban snow accumulation, redistribution, melt and meltwater routing is crucial to informed decision making, still little work has been done with snow affected conditions compared with rainfall-runoff events (Semádeni-Davies & Bengtsson 1999, 1871).

3. Urban hydrological monitoring studies in Finland

Hydrological monitoring has a long tradition in Finland. For instance water levels have been observed since 1847. National water quality monitoring of rivers was launched in 1962 and monitoring of lakes in 1965. (Niemi & Heinonen 2003, 106) In addition to national monitoring of larger water bodies and rivers, already at the beginning of 1930s the National Board of Agriculture established a hydrological station network of small rural catchments intended primarily for drainage planning purposes (Järvinen & Vakkilainen 1982). The data collected since have been used for studies e.g. of snowmelt, high and low flows, and areal evapotranspiration. At present, the network, now operated by the Finnish Environment Institute, provides runoff data from 35 catchments, with catchment areas ranging from 0.07-122 km2 (Linjama 2009, 24). In 14 catchments water quality is measured for diffuse load assessment for rural land uses such as agriculture, forestry, and sparsely populated areas (Granlund 2009, 40).

Monitoring study	Monitoring period	Study catchments	Location	Area (h)	Impervious-ness (%)	Land use
Finnish Urban Storm Water Project[1]	1977-1979	Herttoniemi	Helsinki	14.2-15.1	33-37	traffic
		Kontula	Helsinki	22.9	40	residential
		Pakila	Helsinki	20.2	29	residential
		Nekala	Tampere	14.1-14.3	40-41	industrial
		Hämeenpuisto	Tampere	13.2	67	city centre
		Kajaani	Kajaani	18.5	64	city centre
		Kaukovainio	Oulu	40.5	30	residential
Espoo stations (several projects)[2]	2001-2006	Laaksolahti	Espoo	31	20	residential
		Vallikallio	Espoo	13	50	residential
		Saunalahdenranta	Espoo	8.5-13.4	1.5-37	construction
Storm-Water[3]	2008-2010	Kilpiäinen	Lahti	12.6	19	residential
		Ainonpolku	Lahti	6.5	62	city centre
		Taapelipolku	Lahti	6.1	89	city centre
		Kouvola	Kouvola	6.6[4]	~70-80[5]	city centre
Urban laboratory for sustainable environment	2013 onwards	Kytölä[6]	Lahti	51.6	~0	rural
		Kilpiäinen	Lahti	12.6	19	residential
		Ainonpolku	Lahti	6.5	62	city centre

Table 1. Summary of the previous urban hydrological studies in Finland.

Sources for the catchment information:

1)Melanen & Laukkanen (1981)

2)Sillanpää (2013)

3)Valtanen, Sillanpää & Setälä (2014a): Lahti catchments

4)Hujanen & Sänkiaho (2012)

5)Hujanen & Sänkiaho (2012): the value is given as a theoretical runoff coefficient, not as imperviousness-%

6)J. Järveläinen, personal communication, 21 March 2014

Despite the diverse environmental monitoring on national level, only few monitoring programs of urban catchments have yet been conducted. In the following, the monitoring studies with extensive urban runoff monitoring at small urban catchments in Finland are described (Table1). Results from monitoring studies of urban streams (e.g. Ruth 2004; Sänkiaho, Huth & Krebs 2011) and reports on stormwater runoff and quality with limited monitoring are also available, but here the studies of small urban catchments with uniform land use are emphasized. Such study catchments are essential when the purpose of the research is to investigate surface runoff generation and pollutant transport, e.g. for evaluating diffuse pollution or developing means for runoff management. Table 1 does not include three urban monitoring stations currently operated by the University of Helsinki within the Helsinki region; research results from these stations will be available in the near future.

3.1 Finnish Urban Storm Water Project 1977-1979 (Valtakunnallinen hulevesitutkimus 1977-1979)

The Finnish Urban Storm Water Project 1977-1979 was the first research programme in Finland with extensive hydrological monitoring in urban catchments (e.g. Melanen 1980, 1981, 1982; Melanen & Laukkanen 1980, 1981). The seven study catchments (Table 1) across the country represented a range of land uses from residential to city centre/commercial. Monitoring programme included flow and rainfall measurements with five-minute temporal resolution. Water quality during the warm season was sampled with flow-proportional composite samples, each sample representing one runoff event. During the snowmelt period in 1978, runoff quality was sampled with time-based composite samples and during the snowmelt period in 1979 with flow-proportional composite samples. Several water quality parameters were analysed: total/volatile/suspended solids, total organic carbon, biochemical/chemical oxygen demand, total phosphorus, total nitrogen, chloride, sulphate, vanadium, zinc, copper, lead, pH, and conductivity. Based on the monitoring results, both stormwater quantity and quality were analysed. The study objectives included examination of rainfall-runoff relationships (i.e. runoff coefficients), stormwater quality, pollutant loads and atmospheric deposition, and their dependence on meteorological conditions and catchment characteristics (Melanen 1981; Melanen & Laukkanen 1981). Even today, the Finnish Urban Storm Water Project remains an important reference for stormwater studies.

3.2 Urban runoff monitoring stations in Espoo (2001-2006)

After the Finnish Urban Storm Water Project, the next major experimental research program was not launched until in 2001. As a part of the RYVE-project (Urban Waters and Storm Water Management Practices in Finland 2001-2003), a field study carried out by the Helsinki University of Technology (TKK, now Aalto University) began in three study catchments, all located within the city of Espoo, in southern Finland (Kotola & Nurminen 2003; Vakkilainen, Kotola & Nurminen 2005). The measurement activities continued with a series of research funding from different national sources (e.g. the Academy of Finland, Maa- ja vesitekniikan tuki ry.), aiming to provide several years of monitoring data. The three study catchments (Table 1) included a low-density residential catchment (Laaksolahti), a medium-density residential catchment (Vallikallio) and a developing catchment (Saunalahdenranta). When the monitoring study began in 2001, the Saunalahdenranta catchment was predominantly a forested area. Within the five-year monitoring period, it was transformed into a medium-density residential area. In the Espoo study catchments, monitoring started with 10 min temporal resolution that was changed into 2 minutes starting from September 2005 to increase the accuracy of the measurements and to better observe the flashy runoff response to rainfall due to the changed catchment conditions in Saunalahdenranta (Sillanpää 2013, 109). The RYVE-study reported results from the first year of the monitoring study, when the building construction in Saunalahdenranta had not started yet, but logging and earth-moving works had already changed the catchment characteristics (Kotola & Nurminen 2003; Vakkilainen, Kotola & Nurminen 2005). Some extended results were later reported by Metsäranta, Kotola & Nurminen (2005) and Sillanpää (2007) from the years 2001-2006.

Compared with the Finnish Urban Storm Water Project in the 1970s, the monitoring studies in Espoo focused on one land use (residential land use and its construction phase) with closely located study catchments ensuring similar meteorological conditions between the catchments. A special emphasis was given to continuous year-round runoff and water quality measurements. In contrast to the earlier Finnish Urban Storm Water Project, which covered geographic areas outside southern Finland and included a large selection of the water quality variables, the RYVE-project enabled better comparison between seasons and catchments representing different degrees of urbanization.

Towards the year 2006, the water quality sampling in Espoo was more and more aimed at analyzing pollutographs within events, instead of composite samples. This led to high amounts of analyzed samples (in total 4100 samples) and, consequently, only selected water quality variables were analyzed (total suspended solids, total phosphorus, total nitrogen, and chemical oxygen demand). Additionally, a detailed survey of urban snow properties and snow quality was conducted during winter/spring 2006 in two residential catchments. Presently, the three urban hydrological stations operated in 2001-2006 provide the longest continuous urban hydrological data series in Finland.

3.3 STORMWATER –programme (2008-2010)

StormWater –research programme was funded for a period of 2008-2011 by the European Regional Development Fund, ERDF (Päijät-Häme Regional Council as the funding authority), and by partner municipalities (the city of Kouvola, Hollola municipality, Lahti Aqua Ltd). During the study, the University of Helsinki established three new stormwater monitoring stations within the city of Lahti: the low-density residential area Kilpiäinen and two city centre catchments, Ainonpolku and Taapelipolku (Table 1). The monitoring stations gathered rainfall and runoff data between December 2008 and August 2010 with 1-min temporal resolution (Valtanen, Sillanpää & Setälä 2014a, 2641). During cold winter periods without measurable runoff, the monitoring resolution was 2-3 minutes. Water quality was sampled with automatic samplers using discrete flow-proportional samples, several samples per runoff event (Valtanen, Sillanpää & Setälä 2012, 5). The studied water quality variables included suspended solids, total phosphorus, total nitrogen, total organic carbon and metals (Cr, Mn, Co, Ni, Zn, Cu, Pb, Al).

Additionally, the study programme included a stormwater monitoring station in the city centre of Kouvola (operated and owned by the Kouvola Water company), where rainfall and runoff was observed with one-minute temporal resolution and flow-proportional composite samples were analysed for suspended solids, total nitrogen, total phosphorus, lead, cadmium, copper, zinc, nickel and chromium between the period from June 2009 to November 2010 (Hujanen & Sänkiaho 2011, 23).

Stormwater pollutants were also studied by soil sampling conducted in industrial plots in Hollola, a small municipality neighbouring Lahti (Hätinen 2010; Pouta, Tiainen, Sillanpää & Setälä 2011; Hätinen, Pouta & Sillanpää 2012). A variety of common stormwater pollutants added with industrial pollutants were sampled from infiltration wells and drainage channels within industrial plots from different soil depths and from undisturbed forest soil. It was observed that urban runoff transported mainly oil hydrocarbons and metals (zinc and copper, in particular). Other pollutants such as a variety of PAH and VOC compounds were also present in the soil samples, but these concentrations were low and did not exceed criteria indicating an increased risk for groundwater contamination (Hätinen 2010, 44). Occasionally, an industrial chemical such as toluene was observed. Based on the results, the largest risk of groundwater contamination was associated with zinc and toluene as pollutants, and the use of bottomless sewer manholes as infiltration wells within the industrial plots (Hätinen, Pouta & Sillanpää 2012, 16).

One possible solution for on-site stormwater treatment is biofiltration with vegetated filtration structures for stormwater treatment, retention, and detention. The StormWater-programme conducted the first experimental stormwater biofiltration experiments in Finland, in a lysimeter facility located in Jokimaa, Lahti (Valtanen, Sillanpää & Setälä 2011, 2012). In Jokimaa, stormwater runoff through constructed "raingarden lysimeters" was monitored during summer, winter, and spring seasons. Considering the scale of the lysimeter experiments (8 lysimeters with an approximate volume of 2 m3/lysimeter) these experiments represented an advanced example of cold climate specific stormwater research.

3.4 Urban laboratory for sustainable environment (2012-2014) (Kestävän ympäristön kaupunkilaboratorio)

The ongoing Urban laboratory for sustainable environment -project builds on the foundations created in the Stormwater -programme and the previous monitoring studies in Espoo. The funding is received from ERDF through Päijät-Häme Regional Council and the project co-funding was granted by the city of Lahti and the Lahti University Campus. The project partners, Aalto University, the University of Helsinki, and Lahti University of Applied Sciences (LUAS), aim to establish a research network to strengthen the environmental and engineering research focusing on urban areas.

Within the Urban laboratory -project, the University of Helsinki established a new monitoring station in Lahti: the Kytölä catchment is at the moment a predominantly rural catchment that will undergo residential construction works during the future years (Table 1). As a reference for the Kytölä catchment, the University of Helsinki also resumed monitoring at two of the previous study catchments – the residential Kilpiäinen catchment and the city centre Ainonpolku catchment. The monitoring scheme adopted in the current project differs from the previous studies. In addition to the continuous precipitation, runoff and turbidity monitoring, water quality sampling focuses on two-week flow-proportional composite sampling (i.e. one sample represents an average flow-weighted concentration). This approach enables the comparability of the samples collected simultaneously from rural and urban study catchments, for which the temporal occurrence and the magnitude of runoff are completely different. At the same time, the cost of monitoring can be reduced in order to maintain monitoring for several years during the urbanization process in Kytölä. Additional monitoring campaigns with more frequent water quality sampling can be organized to supplement the long-term monitoring programme.

During the Urban laboratory -project, several publications have been prepared and published, which utilize the data collected in Espoo (Section 3.2) and in Lahti during the Stormwater -programme (Section 3.3). These results are shortly summarized in the following, with reference to the publications from previous Finnish studies. Complete references for the publications discussed here and other publications discussing the monitoring data from the previous Finnish studies are presented in Appendix 3.

3.5 Summary of the recent publications within the Urban laboratory -project (2012-2014)

Impacts of urbanization on runoff generation

The results from the monitoring stations both in Espoo (Sillanpää 2013, 89) and Lahti (Valtanen, Sillanpää & Setälä 2014a, 2648) show that the impacts of urbanization on runoff generation depend on the catchment imperviousness, season, and meteorological conditions. The runoff changes associated with urbanization, such as the increased runoff volumes, peak flow rates and runoff coefficients, were clear during summer rainfall-runoff events. More specifically, Sillanpää (2013, 176) noted that urbanization causes larger (relative) increase in runoff generation during frequently occurring small storms than during infrequent, large storms. Additionally, urbanization reduced the event-to-event variations in the shape of the direct runoff hydrographs and the catchment lag (Sillanpää 2013, 180).

Both studies (Sillanpää 2013, 70; Valtanen, Sillanpää & Setälä 2014a, 2647) concluded that the differences between urban catchments in runoff generation diminish during the cold season. Hence, the impacts of urbanization on the cold season runoff are not as distinct as during the warm season. In the residential catchments studied by Sillanpää (2013, 206), urbanization did not cause notable changes in long-term total runoff generation during the cold season despite the observed changes in the areal distribution of snow. In the highly impervious city centre catchments studied by Valtanen, Sillanpää & Setälä (2014a, 2647), the transport of snow away from the catchment area likely affected the accumulated runoff volumes. Valtanen, Sillanpää & Setälä (2014a, 2639) concluded that the spring snowmelt occurred a few weeks earlier in city centre catchments than in a low-density residential catchment and that spring snowmelt yielded smaller runoff rates in the city centre catchment than summer storms. Both in Espoo and Lahti, urbanization increased the number of wintertime runoff events (Sillanpää 2013, 151; Valtanen, Setälä & Sillanpää 2014a, 2645) and decreased the duration of runoff events during the cold season (Sillanpää 2013, 177; Valtanen, Sillanpää & Setälä 2014a, 2646). Hence, the main consequence of urbanization on runoff generation was the changed temporal occurrence of runoff during the cold season: the snowmelt period became separated into more numerous events of a shorter duration and with smaller event runoff volumes. From the water balance point of view the cold season evapotranspiration demand is low and precipitation generates runoff more effectively, and therefore the total accumulated volume of runoff during the cold season tends to be less sensitive to urbanisation than during the warm season.

Based on the monitoring studies it is clear that the highest peak flows occur during summer storms even at a rather low level of catchment imperviousness (the low-density catchments in Espoo and Lahti with imperviousness of 19-20%), yet the snowmelt period still produces high runoff volumes. At the catchment imperviousness of approximately 50%, the earlier snowmelt and the increased runoff generation during the warm period caused a shift towards an evenly distributed monthly runoff pattern throughout the year (Sillanpää 2013, 93). In the Lahti city centre catchment with the imperviousness of 89%, the warm period produced even larger runoff volumes in relation to precipitation than the cold period (Valtanen, Sillanpää & Setälä 2014a, 2643).

Infiltration and treatment of common small storms seem to be a promising approach to maintaining the predevelopment hydrology of urban catchments, because urbanization causes the greatest increases in the runoff generation during frequently occurring summer storms (Sillanpää 2013, 209). The intense summer downpours are appropriate design events for sizing pipe sewers as the highest peak flow rates occur during warm season rainfall events. Yet, snowmelt may be a critical event in stormwater management planning (Valtanen, Sillanpää & Setälä 2014a, 2649), especially in the detention of larger runoff volumes (Sillanpää 2013, 211).

Impacts of urbanization on urban runoff quality

The results from Espoo and Lahti show that urbanization increases both pollutant concentrations and export rates. Valtanen, Sillanpää & Setälä (2014b) observed that the catchment imperviousness and the land use type affected the concentration differences between the studied catchments: for total phosphorus, aluminium, chromium, zinc and lead, concentrations varied between land use types (city centre vs. low-density residential), whereas for suspended solids, total nitrogen, nickel, copper, and manganese, the concentrations correlated with imperviousness. The impact of urbanization is most visible in terms of pollutant loads which are directly affected by the enhanced runoff generation during the warm season, caused by constructed impervious surfaces (Valtanen, Sillanpää & Setälä 2014b). Based on snow quality measurements in the Espoo catchments, Sillanpää & Koivusalo (2013, 2164) showed that urbanization increased pollutant accumulation into snow: the pollutant mass stored in snow in a medium-density residential catchment was two- to four-fold larger than in a low-density residential catchment.

Urban runoff quality showed large seasonal variations. Sillanpää (2013, 102) demonstrated that a statistically significant seasonal pattern can be observed for suspended solids, total phosphorus and nitrogen concentrations in residential catchments: these patterns indicated that the highest seasonal concentrations are observed during summer in low-density residential areas and in spring at medium-density residential areas. These results are supported by the findings of Melanen (1981, 184), who concluded that the quality of snowmelt in city centres was poorer than the quality of stormwater during the summer season, and by Kotola & Nurminen (2003), who suggested that in small urban catchments with at least 40% of imperviousness, the water quality was poorer for snowmelt than for stormwater during summer season. The snow study conducted in Espoo indicated that the larger proportion of untouched, cleaner snow diluted the pollutant concentrations in the low-density residential catchment in comparison to the medium-density residential catchment (Sillanpää & Koivusalo 2013, 2168). The results from the study catchments in Lahti also exhibited similar seasonal concentration variations based on the land use type (Valtanen, Sillanpää & Setälä 2014b). Yet, it should be noted that not all studied pollutants yielded similar results. Additionally, both studies emphasize that the spring snowmelt yields large pollutant loads regardless of the observed seasonal concentration pattern owing to large runoff volumes during the cold season.

The impact of construction works on water quality in the developing study catchment in Espoo was so strong that seasonality explained only part of the temporal variations in pollutant concentrations. The export peaks of suspended solids occurred together with the periods of greatest soil disturbance starting already during the initial earth-moving works, but the peaks in total nitrogen export occurred later during the construction works, particularly during the building construction period. (Sillanpää 2013, 104.)

Importance of urban runoff as a diffuse pollution source

The severity of urban runoff as a diffuse pollution source can be evaluated based on concentrations or pollutant loads. Valtanen, Sillanpää & Setälä (2014b) and Sillanpää (2013, 105) compared the observed runoff concentrations to the stormwater quality criteria developed by the local water company in Stockholm, Sweden (Stocholm Vatten 2001). In Espoo, the concentration thresholds indicating treatment need were exceeded particularly in summer or spring depending on the pollutant (suspended solids, total phosphorus and nitrogen) and catchment type, during all phases of construction works and in winter for ploughed snow. In Lahti, the median concentrations exceeded these thresholds for total nitrogen, copper and zinc at all studied catchments, and for suspended solids, chromium and lead in the city centre catchments. Valtanen, Sillanpää & Setälä (2014b) also compared metal concentrations to the receiving water thresholds set by the Swedish Environmental Protection Agency (2000). The comparisons indicated an increased risk to the aquatic biota and their functions in surface water courses for chromium and lead in the city centre catchments and for zinc and copper at all studied catchments.

Based on average annual export rates, Sillanpää (2013, 107) concluded that urban catchments often produce much higher pollutant loads than forested catchments and that the pollutant export from city centres and construction sites may equal or even exceed the pollutant export from agricultural catchments. Both Sillanpää (2013, 108) and Valtanen, Sillanpää & Setälä (2014b) noted that, instead of comparing annual pollutant loads between land uses, the greatest concern related to the urban runoff diffuse pollution may be the increased pollutant transport during growing season and the fact that, along with urbanization, pollutant loads are produced all-year round in comparison to rural land uses that often produce the majority of the pollutant export outside the growing season. Sillanpää (2013, 210) also emphasized that the pollutant transport related to construction activities should be included in controlled activities in order to protect the environment and water resources.

Urban runoff modelling

The urban hydrological data gathered from the catchments in Espoo and Lahti provide a promising basis for tests and applications of mathematical rainfall-runoff models. Krebs, Kokkonen, Valtanen, Koivusalo & Setälä (2013) calibrated the Stormwater Management model (SWMM, Rossman 2010) using the high resolution data of the Lahti catchments. The data were useful for demonstrating how short-term runoff response to storm events can be simulated and what the sensitive parameters of the model are, when a detailed parameterisation of different surface types of the catchment was implemented. Krebs, Kokkonen, Valtanen, Setälä & Koivusalo (2014) further extended the SWMM model applications in Lahti to find out how model parameters can be calibrated to support regionalisation of the parameters to areas larger than the small study catchments. The key solution was the use of high-resolution representation of surface types. Tikkanen (2013) presented the first application to produce a hydrological simulation of a large urban area in Lahti. Tikkanen (2013) compiled available spatial data on topography, stormwater collection systems, and land surface types to delineate subcatchments and determine their parameter values. The work outlined the data requirements and data processing methodology that is necessary to implement SWMM model in the city area of about 2.6 km2. In the end, Tikkanen (2013) realised SWMM a simulation of about four years using hourly precipitation input data. Guan, Sillanpää & Koivusalo (2014) implemented the SWMM model with data from Espoo to study construction impacts on runoff in the Saunalahdenranta catchment.

The gathered data are valuable for demonstrating the performance of urban hydrological models in cold climate conditions. The modelling exercises cited above were based on the use of SWMM as the modelling platform. SWMM is currently used in Finland by consultant companies and cities. Also, the model is available as an open source package, which allows the modification and tailoring of the model for different purposes. The case studies reveal that SWMM has potential for producing scenarios how urban hydrological processes respond to stormwater management and changing climatic conditions.

4. Concluding remarks

A prerequisite for successful design and analysis of urban drainage systems is the access to reliable and relevant data (Thorolfsson 2000). Evidently, due to the importance of well-designed sustainable urban drainage systems to the society, authorities responsible for routine data collection should include urban hydrological stations in their monitoring networks. These stations should conduct year-round monitoring of stormwater quantity and quality. Long datasets are also prerequisites for frequency analyses, such as the determination of stormwater design events. In cold climate conditions, problems caused by freezing and frost lift may easily interrupt monitoring during spring snowmelt and, hence, more years with favourable conditions may be needed for successful monitoring in cold climate conditions compared with more temperate climates. So far, monitoring data from urban catchments in Finland have mainly been acquired by universities; yet, universities cannot be responsible for routine monitoring at the national level.

In terms of monitoring, the absence of valid data in Finland concerns particular urban land use types, stormwater management practices and systems. Land use types such as industrial, commercial and traffic areas have been less studied, whereas most data are available from residential areas. Construction sites require special attention as other urban hot spots, such as golf courses or other land use types, which may produce runoff that deviates from "average" stormwater runoff. It should also be noted that the role of urban "green" as a sink or a source of stormwater pollution has not been thoroughly studied in Finland. Urban runoff quality monitoring has so far concentrated on more conventional quality parameters, such as nutrients, oxygen demand, suspended solids and conductivity, and heavy metals have been studied to some extent. There is enormous amount of substances and chemicals still unexplored. In the future, monitoring data are needed about the performance of individual urban runoff management structures and sustainable urban drainage systems in the local climate conditions. The combination of experimental efforts with development and application of simulation models provides promising approach for explaining the hydrologic functions and load generation mechanisms as well as their response to changing conditions in urban areas. The possibilities for future research in Finland are evidently substantial if appropriate resources are available, including educated staff and sufficient funding for monitoring studies with high temporal resolution required for urban runoff studies.

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APPENDIX 1.

The programme of the project seminar held 7th April, 2014

9.30	Aamukahvit ja ilmoittautuminen
9.50	Tilaisuuden avaus
10.00	Hydrologiset muutokset rakennettavalla kaupunkialueella: eväitä hulevesien hallinnan ja mitoituksen uudistamiseen Nora Sillanpää (Aalto)
10.25	Kaupunkialuetyypin huomioiminen hulevesikuormituksessa ja käsittelyn suunnittelussa Marjo Valtanen (HY)
10.50	Hulevesikuormitusten arviointi ja käytännön sovellukset kaupunkimittakaavassa Juhani Järveläinen (HY, Aalto)
11.15	Kysymyksiä ja keskustelua aamupäivän esityksistä
11.20	Välipala- ja kahvitauko sekä jakaantuminen kahteen tilaan (Auditorio ja DT-tila)

Auditorio:

12.10-12.30	Kokemuksia Helsingin yliopiston ja Lahden ammattikorkeakoulun master-ohjelmien opetusyhteístyöstä Kirsi Kuoppamäki (HY) ja Eeva Aarrevaara (LAMK)
12.30-12.45	Automaattisten hulevesimittausten laadunvarmennus Johanna Pajari (Aalto)
12.45-13.10	Rainfall-runoff modelling in a large-scale urban watershed (esitys englanniksi) Gerald Krebs (Aalto)

Tilojen vaihto (n. 13:15-13:30)

DT-tila:

12.00-12.15	Ympäristötietolaboratorion tekniset mahdollisuudet Ari Vesikko (LAMK)
12.15-13.15	Paikkatietodemonstraatioita ympäristötietoteatterissa Jiri Kadlec (Aalto)

Auditorio:

13.35-13.55	Kokemuksia Helsingin yliopiston ja Lahden ammattikorkeakoulun master-ohjelmien opetusyhteístyöstä Kirsi Kuoppamäki (HY) ja Eeva Aarrevaara (LAMK)
13.55-14.10	Automaattisten hulevesimittausten laadunvarmennus Johanna Pajari (Aalto)
14.10-14.35	Rainfall-runoff modelling in a large-scale urban watershed (esitys englanniksi) Gerald Krebs (Aalto)

13.25-13.40	Ympäristötietolaboratorion tekniset mahdollisuudet Ari Vesikko (LAMK)
13.45-14.40	Paikkatietodemonstraatioita ympäristötietoteatterissa Jiri Kadlec (Aalto)

<u>Tilaisuuden päätös</u> (Auditorio)

14.45	Kysymyksiä ja keskustelua päivän aiheista
15.15	Tilaisuuden päätös

APPENDIX 2.

Jessica Huttunen has collected a list dealing of previous research projects dealing with Lake Vesijärvi and stormwater management in Lahti area. The wish to this kind of collection was expressed in a steering board meeting of the project.

RESEARCH, PROJECTS, PUBLICATIONS AND PROGRAMMES RELATED TO STORMWATER, AS WELL AS LAND USE AND PLANNING RELATED STORMWATER STUDIES IN LAHTI FROM 1994-2014

2013 - 2016 Uusimaa Regional Council, Päijät-Häme Regional Council Häme Regional Council, Uusimaa & Häme Centres for Economic Development, Transport and the Environment (ELY Centres):
South Finland WATERS Project/Etelä-Suomen VEDET-hanke
The aim of the WATERS project is to support common efforts of various stakeholders for the innovative project development regarding the improvement of water quality status of all water body types in Southern Finland, including groundwater, stormwater management and wastewater management for sparsely populated area.

2013 - The City of Lahti (Lahti Region Environmental Services):
Research on stormwater loads with regard to Lake Vesijärvi
The stormwater from Lahti municipal area is led by rainwater drains into Lake Vesijärvi. In order to determine the quality of water being channelled into Lake Vesijärvi there are now regular samples taken to measure phosphorus- and nitrogen concentrations, solid matter, conductivity, turbidity, pH and faecal bacteria. Water quality is also monitored by automatic continuous sampling stations, which measure the water temperature, conductivity and turbidity. In order to determine flow rates and suspended solid load there are continuous monitored flow metres installed in stormwater drains.

2013 The University of Helsinki:
Fifth Dimension –Green roofs in Urban Areas–project
The common objective of the researchers involved is to determine what kind of green roofs are suitable as part of the Finnish urban structure and building, so that they offer sufficient eco-system services, protect biodiversity and support the development of urban areas according to economic and social. For example various meadow and mossy roofs offer a potential living environment for endanger species. In Jokimaa in Lahti 20 test green roofs, each of 2 m^2 in area have been built for research purposes. Rainfall, runoff, temperature and the moisture content of the growing area are constantly monitored.

2013 Finnish Consulting Group Ltd:
UPM Niemi Stormwater Evaluation
In this work a stormwater evaluation general and stormwater management plan was carried out for United Paper Mills Niemi built-up area (A-2518). The objective of the stormwater management plan is to improve the quality of stormwater and the reduce the amount of stormwater going into Lake Vesijärvi Primarily methods to improve the quality of stormwater as well as the delaying and filtering of the stormwater before it flows into the waterway are investigated, then secondarily the infiltration of stormwater. The aim is to plan sufficient management and channelling solutions at the general management level and to give directions for future plans.

2013 Ramboll Finland Oy:
Päijät-Häme Central Hospital area - Stormwater Investigation
This evaluation is connected with land planning changes which are aimed at developing and further building up the Päijät-Häme Central Hospital area. The objective of the work was to draw up directions for a stormwater management plan.

2012 - 2014 Häme Centre for Economic Development, Transport and the Environment (ELY Centre): The City of Lahti, Hollola Municipality & the Lake Vesijärvi Foundation:
Mechanical and chemical restoration methods for improving the condition of a lake (MELLI) -project

In this project different lesser-used methods for restoring a lake are tested, with the result that the ability of the water area in question to cope with eutrophication and oxygen loss in the lake bottom improves. The methods being tested include the chemical binding of phosphorus in the sediment and in stormwater entering the lake. There are 2-4 test locations planned for Lake Vesijärvi and its catchment area.

2012 - 2014 City of Lahti, City of Turku, City of Vantaa, Helsinki Region Environmental Services Authority, Finnish Meteorological Institute & Turku University:
Climate-Proof City– Tools for Planning (ILKKA)
This project promotes climate-proof urban planning. The purpose is to create planning tools and guidelines for town planners and for enterprises in the construction and landscaping business to consider climate change in their plans. As well as the tools the project reviews the best practices for climate change adaptation in Finland and internationally. Research is carried out during the project on rainwater drains entering Lake Vesijärvi and on the composition of the stormwater entering them.

2012 - 2014 Aalto University, Helsinki University & Lahti University of Applied Sciences :
The Urban Laboratory for Sustainable Environment Project –management of the hydrologic cycle and ecosystem services in the urban environment
The main result of this project is the setting up of a long-term common platform for studying the processes of urbanisation, and as a support for research, analyses and management. The platform to be built enables multi-disciplined, nationally and scientifically significant research and development. At the core of the platform is the urban ecosystem, water technology, environmental informatics and on-going research, development and innovation in environmental technology.

2012 - 2017 Helsinki University & Aalto University:
Research on city floods and the amounts and quality of stormwater in Lahti and Helsinki
As research targets five catchment areas each of about ten hectares are selected from each of the two cities. The stormwater from each research area is tested for at least the water flow rate, temperature and turbidity. Samples are also gathered for laboratory analysis.

2012 FCG Finnish Consulting Group Ltd:
Ranta-Kartano planning area storm water general plan
In this work a general stormwater management plan is drawn up for the area, which includes management method principles, a general plan for locations and amounts. In particular, attention is paid to the promotion of the natural management of stormwater and on methods for reducing the load on waterways.

2011 Ramboll Finland Ltd:
City of Lahti - Karistonportti planning area stormwater investigation
This investigation is linked to land planning for the new office- and residential zone situated in the Yrjölänpelto area. In the stormwater investigation the impact of the land use plan on the flow directions of stormwater and on the proposed drainage system for the area is researched. In addition, an estimate of the amounts of stormwater and the adequacy of the system for dealing with it was carried out.

2010 Malin, I., Värttö, H., Jänis, R., Sillanpää, N., Horppila, P., Lastikka, M., Neuvonen, H., Kujala, K., Salminen, T., Rope, A. M., Uurtamo, J., Siikanen, K., Karu-Hanski, T., Simonen, A., Lipponen, M., Heikkonen, M., Hiltunen, J., Mäkinen, H. & Jormola, J.:
City of Lahti stormwater programme
A stormwater programme is drawn up with the purpose of developing a clear action model for managing stormwater. With the aid of the programme it is aimed to clarify and reinforce the cooperation between authorities dealing with stormwater and to convey information on the importance of stormwater to all stakeholders in the city planning process, including decision makers and residents.

2010 Autio, M. (Lahti Region Environmental Services reports)
Investigation of the quality of the stormwater in the Lahti's largest stormwater drains discharging into Lake Vesijärvi

The stormwater reception area contained busy traffic streets, parking areas, businesses, administrative- and residential buildings, as well as green areas. The sample collection covers the whole period from spring melting through the whole non-frozen water period until October. Nutrient load levels were measured for stormwater drain flow models and with the aid of point samples.

2008 - The City of Lahti (Lahti Region Environmental Services):
Monitoring information of the stormwater in ditches discharging into Lakes Vesijärvi, Kymijärvi and Alasenjärvi

2008 - 2011 Helsinki University & Aalto University, Lahti Aqua, City of Kouvola, Kouvola Water, Hollola Municipality & Lahti Science and Business Park Ltd.:
STORMWATER-Project
In this project solutions were sought for the management of stormwater –the rainwater and waters from melted snow of built up areas. Measurements of the amount and quality of stormwater were carried out at least in the Lahti city area. The study area consisted of various different catchment areas. Biofiltration tests were also carried out in the lysimetric facility at Jokimaa in Lahti.

2008 - 2011 Helsinki University:
The concentrations and toxicity of oil hydrocarbons in Lahti's stormwater street gullies and in the sediments Lake Vesijärvi
The objective of this research is to evaluate the amount and composition of oil hydrocarbons in the sediments of Lake Vesijärvi and in stormwater drains, to measure the ecotoxicity of precipitated sediment and to investigate the toxicity caused by stormwater pollutants, as well as to assess the need for treatment of water before it is released into natural waterways.

2008 - 2011 The Lake Vesijärvi Foundation:
The Lake Vesijärvi Programme
The objective of the Lake Vesijärvi programme was to promote the treatment of the waters of Lake Vesijärvi and other waterways in the Lahti region. In the Lake Vesijärvi programme water- management and protection –related research and public awareness raising activities were arranged involving interested organisations. The programme was targeted at the waterway protection in the greater Lahti area and acted as support for the activities and decision making of the Lake Vesijärvi Foundation.
It is a central aim of the programme is to prevent nutrient loads entering Lake Vesijärvi. A check of the wastewater solutions for the entire catchment area was systematically carried out. Cultivation was terminated in the case of the steepest lakeshore meadows and many new protection strips were added, as were settling basins and wetlands. In addition, it was demonstrated that a reduction in the amount of forestry and soil cultivation activity in the catchment area was important in terms of reducing loads. It was also the purpose to increase the amount of wetlands and basins in the future, as well as to continue management and maintenance activities in the future.

2008 Niukkanen, H. (Helsinki University Environmental Ecology unit research and reports)
The stormwater load on the Enonselkä part of Lake Vesijärvi caused by the city centre area of Lahti

2006 Lammi, P. (Lahti University of Applied Sciences final thesis):
The influence of the stormwater load on Lake Joutjärvi in Lahti
The objective of this final thesis was to determine the influence of the stormwater lead into Lake Joutjärvi in Lahti on the quality of the water.

2002 - 2007 The City of Lahti, the Municipalities of Hollola, Asikkala & others:
Vesijärvi-project 2
This was a Lake Vesijärvi protection and restoration project, where the monitoring of the condition and nutrient load was further developed. The loads entering Lake Vesijärvi from different channels was reduced and wastewater treatment for sparsely populated areas and for diffuse sources in build-up areas was improved. Wastewater treatment systems for the properties in at least a thousand sparsely populated areas were investigated. Sedimentation basins and wetlands were planned and implemented, restoration plans were improved and the restoration of shorelines was intensified.

1987 - 1994 The City of Lahti, the Municipalities of Hollola Asikkala & others:
Vesijärvi-project 1
Lake Vesijärvi protection and restoration project.

OTHERS:

2009 - 2012 Aalto University& Lahti University of Applied Sciences :
Local action to combat climate change (IMMU) -project
The objective of the Local action to combat climate change (IMMU) –project was to determine and adapt concrete means to reduce the effects of climate change in the Lahti region. The project supported the drawing up and development of a regional climate programme. In addition up to date information was produced for decision makers, citizens and enterprises about the factors which influence climate change.

1999 - 2001 Technology Center Neopoli Ltd. (since 2004 Lahti Science and Business Park, now part of LADEC Ltd)
Big Lakes

1996 - 1998 The City of Lahti:
Life of Lake Vesijärvi

APPENDIX 3.

The appendix includes a list of selected publications that use monitoring data from the urban monitoring projects presented in the chapter. The list includes the main reports, journal articles and selected articles in Finnish. Also a list of Master's theses is included. The publication list is not complete, e.g. additional material can be found from several conference proceedings.

Publications the years 1970-1999:

Melanen, M. 1980. Taajamien hule- ja sulamisvedet, Osa I: Laadun tarkastelu. Report 197. Helsinki: National Board of Waters.

Melanen, M. & Laukkanen, R. 1980. Urban storm runoff quality and its dependence on some rainfall and catchment characteristics. Publications of the Water Research Institute 38. Helsinki: National Board of Waters, 29-41.

Melanen, M. 1981. Quality of runoff water in urban areas. Publications of the Water Research Institute 42. Helsinki: National Board of Waters, 123-188.

Melanen, M. & Laukkanen, R. 1981. Quantity of storm runoff water in urban areas. Publications of the Water Research Institute 42. Helsinki: National Board of Waters, 3-39.

Melanen, M., Laukkanen, R. 1981. Taajamien pintavalunnan määrän arviointi. Vesitalous 3/1981, 8-17.

Melanen, M. & Tähtelä, H. 1981. Particle deposition in urban areas. Publications of the Water Research Institute 42, National Board of Waters, Helsinki, Finland. pp. 40-122.

Melanen, M. 1982. Valtakunnallisen hulevesitutkimuksen tulokset. Vesitalous, 3/1982, 1-20.

Publications, the years 2000-2009:

Aaltonen, J., Hohti, H., Jylhä, K., Karvonen, T., Kilpeläinen, T., Koistinen, J., Kotro, J., Kuitunen, T., Ollila, M., Parvio, A., Pulkkinen S., Silander, J., Tiihonen, T., Tuomenvirta, H. & Vajda, A. 2008. Rankkasateet ja taajamatulvat (RATU). The Finnish Environment 31. Helsinki: Finnish Environment Institute (SYKE).

Kotola, J. & Nurminen, J. 2003. Kaupunkialueiden hydrologia – valunnan ja ainehuuhtouman muodostuminen rakennetuilla alueilla, osa 2: koealuetutkimus. Helsinki University of Technology Water Resources Publications 8. Espoo: Helsinki University of Technology.

Metsäranta, N. 2004. Valunnan muodostuminen rakennetuilla alueilla. Vesitalous 1/2004: 26-29.

Metsäranta, N., Kotola, J. & Nurminen, J. 2005. Effects of urbanization on runoff water quantity and quality: experiences from test catchments in southern Finland. Journal of River Basin Management, 3(3), 229-234.

Sillanpää, N. 2007. Pollution loading from a developing urban catchment in southern Finland. In: Proceedings of the 11th International Conference on Diffuse Pollution, 26-31 August 2007, Belo Horizonte, Brazil.

Vakkilainen, P., Kotola, J. & Nurminen, J. (eds.) 2005. Rakennetun ympäristön valumavedet ja niiden hallinta. The Finnish Environment 776. Helsinki: Ministry of the Environment.

Master's theses

Aaltonen, J. 2008. Sadanta-valuntaprosessi taajama-alueella: MOUSE ja MIKE SHE-ohjelmien testaaminen. Helsinki University of Technology, Department of Civil and Environmental Engineerin. M.Sc. thesis.

Immonen, S. 2008. Kokonaisfosforikuormitus taajamavaluma-alueella: Ilmastonmuutos näkökulmana. Helsinki University of Technology, Department of Civil and Environmental Engineerin. M.Sc. thesis.

Metsäranta, N. 2003. Valunnan muodostuminen taajama-alueilla: Laskentamallin kehittäminen ja soveltaminen. Helsinki University of Technology, Department of Civil and Environmental Engineerin. M.Sc. thesis.

Samposalo, S. 2007. Lumen ominaisuudet taajama-alueilla. Helsinki University of Technology, Department of Civil and Environmental Engineerin. M.Sc. thesis.

Tiihonen, T. 2007. Hydrologiset prosessit taajama-valuma-alueilla: Alueellisesti hajautetun taajamahydrologiamallin kehitys ja soveltaminen. Helsinki University of Technology, Department of Civil and Environmental Engineerin. M.Sc. thesis.

Publications, the years 2010-2014:

Hujanen, J. & Sänkiaho, L. 2011. Hulevesien hallintaa tiiviisti rakennetussa kaupunkiympäristössä. Vesitalous 6/2011, 6-10.

Krebs, G., Kokkonen, T., Valtanen, M., Koivusalo, H. & Setälä, H. 2013. A high resolution application of a stormwater management model (SWMM) using genetic parameter optimization. Urban Water Journal, 10(6), 394-410.

Krebs, G., Kokkonen, T., Valtanen, M., Setälä, H. & Koivusalo, H. 2014. Spatial resolution considerations for urban hydrological modelling. Journal of Hydrology, 512, 482-497.

Pouta, A., Tiainen, N., Sillanpää, N. & Setälä, H. 2011. Yhteistyöllä teollisuuskiinteistöjen hulevedet hallintaan. Vesitalous 6/2011, 16-19.

Sillanpää, N. 2013. Effects of suburban development on runoff generation and water quality. Aalto University publication series DOCTORAL DISSERTATIONS 160/2013. Helsinki: Aalto University School of Engineering. D.Sc. thesis.

Sillanpää, N. & Koivusalo, H. 2013. Catchment-scale evaluation of pollution potential of urban snow at two residential catchments in Southern Finland. Water Science and Technology, 68(10), 2164-2170.

Sänkiaho, L. & Sillanpää, N. (eds.) 2012. STORMWATER-hankkeen loppuraportti. Taajamien hulevesihaasteiden ratkaisut ja liiketoimintamahdollisuudet. Aalto yliopiston julkaisusarja TIEDE+TEKNOLOGIA 4/2012. Espoo: Aalto University School of Engineering.

Valtanen, M., Sillanpää, N. & Setälä, H. 2011. Tutkimustietoa keskustojen hulevesistä ja biosuodatuksesta. Vesitalous 6/2011, 6-10.

Valtanen, M., Sillanpää, N. & Setälä, H. 2014a. Effects of land use intensity on stormwater runoff and its temporal occurrence in cold climates. Hydrological Processes, 28, 2639-2650.

Valtanen, M., Sillanpää, N. & Setälä, H. 2014b. The effects of urbanization on runoff pollutant concentrations, loadings and their seasonal patterns under cold climate. Water, Air & Soil Pollution, 225, 1977.doi:10.1007/s11270-014-1977-y.

Master's theses

Hätinen, N. 2010. Hulevesien haitta-aineet ja käsittelytarve pohjavesialueilla sijaitsevilla teollisuuskiinteistöillä. Ympäristöekologian tutkimuksia ja raportteja 77. University of Helsinki, Department of Environmental Sciences. M.Sc. thesis.

Järveläinen, J. 2014. Land-use based stormwater pollutant load estimation and monitoring system design: Case of Lahti city, Finland. Department of Civil and Environmental Engineering, Aalto University School of Engineering. M.Sc. thesis.

Pajari, J. 2014. Quality Assurance of Hydrometeorological Data in Urban Areas. Department of Civil and Environmental Engineering, Aalto University School of Engineering. M. Sc. thesis.

Tikkanen, H. 2013. Hydrological modeling of a large urban catcment using a stormwater management model (SWMM). Department of Civil and Environmental Engineering, Aalto University School of Engineering. M. Sc. thesis.

Urban areas are facing new challenges caused by climate change. New research information is needed about rainfall quantities and quality to manage the impacts of stormwater in urban environments. A combination of environmental measurements and GIS based maps can provide new opportunities to illustrate urban environments to serve planning and decision making processes. In the city of Lahti there is already a tradition for environmental research, but this recent project has strengthened the existing cooperation between the partners. The main goal of the project has been to establish a common long term research platform in Lahti region, by which multidisciplinary research and RDI can be realised. Also positive experiences from cooperation in Master level urban and environmental studies have been achieved.

The Urban Laboratory for Sustainable Environment project started in 2012, with the main partners being Aalto University, as coordinator, and the partners Helsinki University and Lahti University of Applied Sciences. This publication presents part of the results of the project. A seminar was held in Lahti Science Park in April 2014 where the participants were presented the main research and adaptation results and were able to discuss them with different experts.

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Vipuvoimaa EU:lta 2007–2013
Euroopan unioni
Euroopan aluekehitysrahasto
Lahti University Campus
LAHDEN YLIOPISTOKAMPUS
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