Editorial: Modeling the urban water cycle as part of the city

Integrated urban water management was introduced as a concept over two decades ago. At that time the primary focus was to establish the basic understanding that urban drainage is not a singular process in a sewer pipe but one that actually influences the complete water management in a city. Much of the original thinking and basic methodologies evolved from a one-off conference in Denmark, 'Interurba – Interactions between sewers, treatment plants and receiving waters in urban areas', held in April 1992. This was followed by a decade of research effort, focused around the development of governing modeling principles and software tools to support the integrated analysis of urban water systems. This latter activity involved linking existing tools and the development of novel complex models that simulated whole integrated systems. The efforts of that early research period were summarized in the conference 'Interurba II – Interactions between sewers, treatment plants and receiving waters in urban areas', held in Lisbon in February 2001. Since then further research, again predominantly focused around modeling, has moved the field further forward and, crucially, has also led to a slow introduction of these new models into practice.

More recently, the aforementioned drainage-centric concept of integrated water management has evolved into the notion of total water cycle management. This requires consideration of the development of urban systems as catchments as well as socioeconomic effects and their interaction with water management. A significant driver in the development of such novel concepts was the focus on decentralized infrastructure for water supply and drainage. New tools and models emerged that have their origin in securing water services. These models outlined the complex interactions and feedbacks between decentralized solutions such as infiltration and rainwater harvesting and traditional pipe networks. The topic received even more attention due to climate and land use changes, which further increase pressure on the system. This development has been accompanied by advances and integration with other fields such as social, economic and urban planning. These issues were originally driven by experts outside the traditional engineering field. However, the research community has taken up the problem as a mutual task and as an example of interdisciplinary research.

Experts in these areas joined water engineers to take up this interdisciplinary challenge of understanding the urban water cycle within the context of the city at a recent workshop in Obergurgl, Austria – denoted as 'Interurba III – Modeling the water cycle as part of the city', held in June 2013. A key conclusion of their discussion was that the focus of integrated urban water management must expand to the complete urban system, and modeling has to see the water system as part of a city and its engineered, environmental, social and economic systems.

This special issue, which features fully peer reviewed contributions from the Obergurgl workshop attendees and other leaders in this area, reports on modeling urban water management in interaction with urban development and under consideration of socioeconomic effects. The special issue presents a state of the art in this maturing field by presenting the most recent findings of high quality research. The contributions from an open call to the research community are structured as following: based on a review article, methods and tools are presented in a series of seven papers. Next, six case studies of different size and scope are presented, followed by a compilation of five examples where research attempts have been brought into practice.

REVIEW AND CURRENT STATE

Urich & Rauch (2014) present the current status of integrated modeling of the urban water cycle. Starting from a critical review of historical developments in integrated modeling, they distinguish between two major dimensions that need to be considered, i.e. the biophysical system (comprising both the urban environment and the water infrastructure) and the societal system. Based on this distinction, they position different software tools and models and propose a promising way ahead by coupling agent based models with procedural modeling to create virtual environments.

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DEVELOPMENT OF METHODS AND TOOLS

The next seven papers of this special issue focus on new assessment methods and modeling tool developments. Ding *et al.* (2014) show the development of an Urban Water Harmony model, introducing a more integrated approach for urban water management to aid decision makers and enable more effective water management. For a holistic assessment, various urban and water indices were combined in an integrated evaluation index, and an evaluation over 11 years is shown for Beijing. Holguin-Gonzalez *et al.* (2014) develop an integrated ecological modeling framework, comprising different sub-models (wastewater treatment, river water quality, hydraulics and ecological assessment), to quantify the impact of investments in wastewater treatment on water quality. Their case study application identified a limited effect of an upgrade of a wastewater treatment plant on water quality. Arden *et al.* (2014) introduce a model combining surface runoff and ecohydrology, which provides a quantitative understanding of complex long-term variability of urban hydrologic processes and impacts of urbanization. Porse (2014) presents an approach to evaluate cost effectiveness of urban floodplain developments as a tool for informing assessment of land-use allocation and zoning decisions. In that work it is shown that defining different zones for development can enable efficient flood control. Mair *et al.* (2014) present a web-based urban water management modeling platform for simplifying the setup and use of complex integrated models. The paper demonstrates how flooding behavior of new urban developments can easily be assessed with the web platform, i.e. to inform discussions in interdisciplinary and interactive stakeholder workshops. Sitzenfrei & Rauch (2014) develop an approach to couple models for centralized water infrastructure (pipe networks for water supply and drainage) for city scale analysis. That coupled model is used for quantifying the impact of implementing decentralized measures on centralized water infrastructure, which helps to improve planning of where to implement such measure in existing networks. Presenting the results in easily communicable geographic information system (GIS) maps also supports non-expert stakeholder decision processes. Diao *et al.* (2014) argue that water distribution system complexity is largely due to urban development and introduce a clustering strategy of water distribution system analysis to identify critical components and quantify community impacts.

CASE STUDIES

The next six papers in this special issue present case study applications of integrated modeling. Vleeschauwer *et al.* (2014) integrate conceptual and hydrodynamic sewer-river models to evaluate the efficiency of three different climate change adaptation strategies, namely source control, retention basin and end-of-pipe measures. Joshi & Obaidy (2014) show the impact of urban growth on the soil, surface runoff and stormwater quality, identifying high anthropogenic influences. Huang *et al.* (2014) show how low impact developments can be implemented as urban growth adaptation measures to improve water balance and flood control. Belmeziti *et al.* (2014) present an integrated urban drainage and drinking water saving approach for investigating how much drinking water can be substituted by rainwater harvesting. Garofalo *et al.* (2014) couple a conceptual catchment basin model and a hydrodynamic model to analyze the removal efficiency of filter media with respect to particulate matter. Finally, Passarello *et al.* (2014) investigate the uncertainties of a groundwater balance model and show how changes in scientific interpretation can influence decisions.

ESTABLISHING FINDINGS IN ENGINEERING PRACTICE AND IMPLEMENTATIONS

Integrated modeling studies are often still seen as a scientific playground rather than normal engineering practice. This is partly due to the significant further research needed for effectively linking different models for practical applications, but also because the practice of urban water infrastructure planning does not yet typically adopt integrated approaches and is instead characterized by silos across disciplines and urban sectors. To advance integrated urban water management approaches, it is important to demonstrate the benefits to engineering practitioners, as well as provide the necessary tools for this often complex planning task. In this special issue five papers target practitioners in order to provide such best practice examples. Aziz *et al.* (2014) show how a computational fluid dynamic model can be used to assess the effectiveness of a self-cleansing sewer overflow screening device. This helps to reduce maintenance effort and environmental impact. Kertesz *et al.* (2014) evaluate the hydraulic and economic effectiveness of four stormwater utility credit programs for single family residences in the United States. Lot-scale bioretention facilities contribute to the reduction of stormwater impacts on receiving water bodies. The availability of a simple stormwater calculator together with suitable financial instruments has the potential to encourage stormwater management by homeowners. Leskens *et al.* (2014) address the problem that complex models can often only be used by experts by presenting the application of an interactive urban water simulation model which is intended to be used by decision makers to test different scenarios during workshops. Kleidorfer *et al.* (2014) also present a possibility to simplify model applications for practical engineering. Here the impact of urban development (change of impervious area) is translated into a change of the return period of design rainfall events, which makes it easier to consider in urban drainage applications or guidelines. Urban development is not the only important factor when investigating long-term planning of urban water infrastructure, as demonstrated by Tscheikner-Gratl *et al.* (2014). They present an integrated approach for rehabilitation of aging infrastructure and adaptation to urban development and climate change in order to investigate potential reduction of costs for building measures.

SUMMARY AND CONCLUSIONS

This special issue brings together current knowledge on modeling urban water management in interaction with urban development and under consideration of socioeconomic effects. It further presents a state of the art in this maturing field by presenting the most recent findings in 19 papers of high quality research. A key conclusion of this special issue is that the focus of integrated urban water management must expand to the complete urban system, and modeling has to see the water system as part of a city and its engineered, environmental, social and economic systems.

The guest editors hope that the findings create awareness and recognition of this multi-disciplinary field within the wider academic community.

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