5 sustainable development applications

water in the city

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Water in the City
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ŁÓDŹ CREATES

Ladies and Gentlemen,

Great civilizations emerged near water and thanks to water. After the industrial revolution it became clear that seeing water only as an inexhaustible resource and means of transport eventually impedes development due to water exploitation, pollution, evening out of the beds of water bodies and coastline, and the disappearance of aquatic organisms that participate in water self-purification processes.

This experience brought about a return to water-related ecosystems. Previously orientated away from water, urban architecture is now once again turning to rivers, lakes and oceans. Growing populations and demand for good water present governments and local authorities with the challenge of establishing a new water management approach. Climate change has pushed this challenge even further due to the growing threats associated with a lack or excess of water.

As a result, optimized water management in urban spatial planning processes is essential for the quality of life and safety of residents. Moreover, it allows to prevent phenomena that result e.g. from climate change. Water bodies are becoming an increasingly important component of the urban structure. Consideration for water is an important duty for all entities involved in shaping the urban space, both public and private. Therefore, urban water management is a key issue in the National Urban Policy that is now being established by the Ministry of Infrastructure and Development.

In light of the abovementioned challenges, the Ministry of Infrastructure and Development would like to recommend this guidebook entitled "Water in the city" to all interested parties. This publication is in accordance with funding programmes for local governments associated with water and water and sewage management that the Ministry has engaged in thus far. At the same time, this publication offers an excellent introduction to the activities that we are planning to undertake to support cities within the framework of the financial outlook for 2014–2020. I wholeheartedly invite you to read this guide.

Adam Zdziebło
Secretary of State
Ministry of Infrastructure and Development

Contents

Introduction

Our guidebook on urban ecosystem services opened a new era in the history of our series entitled *Sustainable Development Applications*. It was our first thematic publication dedicated entirely to the extremely relevant issues of nature in the city. Given the importance of this topic we decided to continue with it in the fourth and now fifth guidebook which you are now holding in your hands (or reading on your computer screen). This time our focus is on water in the city. Water and greenery are very strictly interrelated: urban greenery may not be efficiently managed independently of water just as it is impossible to effectively solve the qualitative and quantitative problems of water management without taking green infrastructure into account. This interrelationship is well illustrated by examples of ecological engineering or ecohydrology: two concepts that we often refer to in our publications as these effectively combine ecological and engineering knowledge to increase the effectiveness and efficiency of natural system management.

While the two previous publications dealt with urban greenery, the current guidebook is dedicated to water in the city. The opening chapter of this publication is entitled "Water as the backbone of quality of life in the cities of the future" and presents the challenges of urban water management in the context of the global challenges of sustainable development and the actions undertaken in this field by international organizations. Subsequent chapters show the practical issues associated with urban water management at the strategic, planning, health, financial and technical levels; all of these topics are eventually summarized in the chapter on integrated urban management. As before, the last chapter of this guidebook presents a collection of good practices, in this case related to urban stormwater management.

The figure below illustrates the interrelationships between the chapters of the last three guidebooks of the series entitled *Sustainable Development Applications* (3–5), showing how the problems discussed in this guidebook are closely related to those in our previous publications. Aiming to show the practical relationships between the discussed issues, this time we decided to additionally illustrate most of these with concise case studies at the end of each chapter. In many cases urban water-related issues are placed in the broader context of managing the urban natural system or even more broadly, the socio-ecological system of the city.

Over the last two years, the Sendzimir Foundation has given a great deal of consideration to water in the city. This included local projects carried out as part of the Foundation's Summer Academy "Challenges of sustainable development" series (in the years 2013 and 2014) and Autumn Academy "Challenges of Sustainable Water Management" in 2013. These were organized within the framework of a project entitled "Challenges of Sustainable Water Management. Ecosystem services in an era of climate change" which received funding from the National Fund for Environmental Protection and Water Management and the patronage of the Minister of the Environment. Participants tried to solve the problems of water management in the cities of Torun, Poznan and Krakow in cooperation with municipal authorities and other stakeholders. The reports prepared by the participants of these Academies provide many practical tips and are available for downloading from the Sendzimir Foundation's webpage.

The last of these reports concerning sustainable stormwater management in Krakow (where the example of a community housing estate at Magnolia St. was used) was especially revealing and convinced us of the need to carry out large demonstrative projects of this type in Poland. Projects where such solutions were implemented on a large scale in housing estates in other countries include Augustenborg (Malmö, Sweden) and Kronsberg (Hannover, Germany). These undertakings are described in the good practices section at the end of this guidebook to serve as inspiration. Similar implementations in Poland could easily be classified as priority projects of urban revitalization where European Union funds could be used. Urban investments could also benefit from other solutions such as green public procurement. Demonstrative projects of this type could become the seedlings of broader sustainable urban stormwater management programmes, such as in Augustenborg and Kronsberg.

On a smaller scale, the Sendzimir Foundation has contributed to the promotion of the practical implementation of this type of solution by building small showcase rain gardens in Lodz and offering brochures with information on rain gardens adjusted to the Polish climatic conditions and indigenous plant species. Rain gardens are particularly strongly popularized in Australian cities, e.g. Melbourne which we featured in one of the good practices of the previous guidebook (SDA4).

Last but not least, residents themselves have pointed to the interrelationships between urban water and greenery through an internet application at <www.licznazielen.pl> developed for the major Polish cities of Krakow, Lodz, Poznan and Warsaw as part of the "Licz na zieleń" project (Polish for "Count on greenery"). In the implementation of this project, the Sendzimir Foundation has benefited from the best experience in Participatory Geographic Information Systems and so-called geosurveys, solutions presented in the previous guidebook published in this series. These are now being applied by the Sendzimir Foundation in collaboration with the authorities of the abovementioned cities to support nature management in Polish cities. A review of the maps with survey results shows that when asked to indicate places where they like to spend time among greenery (or other valuable green spaces), residents of the abovementioned cities commonly point to those related with water.

Whether planning the further development of Polish cities, applying for financing for revitalization projects from European Union funds or implementing the guidelines of the Polish National Urban Policy, nature-related issues should receive more attention. This was our consideration when preparing this and previous guidebooks published in this series. Now we may only wish that the readers find the contents inspiring and useful to improve the quality of life in cities.

Tomasz Bergier, Jakub Kronenberg, Iwona Wagner

WATER AND THE URBAN NATURE SYSTEM

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Water as the backbone of quality of life in the cities of the future[1]

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University of Lodz
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According to the UN-Habitat report, in 2008 for the first time in history more than half of the global population lived in cities, with this number expected to reach 60% in the next few years. Progressing urbanization is creating new challenges in terms of the quality of life in a city, as well as residents' health and ecological safety. The efficiency of traditional engineering solutions used in water and sewage management systems is also called into question. From this perspective, it becomes clear that water and environmental management require innovative solutions based on the integration of engineering expertise with the understanding of biological and hydrological processes. This is the approach of ecohydrology.

Key words: ecohydrology, urbanization, water in the city, UNESCO International Hydrological Programme, blue–green infrastructure

[1] This chapter contains a synthesis of issues more broadly discussed in these articles: (Zalewski 2013, 2014).

Introduction

In the 21st century, with the rate of exploitation of environmental resources exceeding the biosphere's regenerative capacity, the most fundamental question for humans is: what is the future of life and civilization? The first step towards finding the answer is determining the main threats to the natural environment. These are:

- alterations and degradation of the basic ecological processes necessary to sustain life on Earth, e.g. the water cycle and the cycle of nutrients, such as nitrogen, phosphorus and carbon;
- degradation of the biosphere through deforestation, urbanization and transport;
- emission of pollutants;
- excessive use of all types of environmental resources.

The second step and essential prerequisite for the future of life, civilization and the true improvement in human welfare is understanding the complexity of interactions between abiotic systems (the physical environment), biotic systems and socio-economic systems. It is vital to prepare a new paradigm and new solutions based on interdisciplinary science. This process was initiated by the Bruntland report (WCED 1987). The next step was the establishment of the theoretic fundamentals of hydrology integrated with ecology, i.e. ecohydrology (Zalewski et al. 1997, Zalewski 2011) as part of UNESCO's International Hydrological Programme. The process was completed with the adoption of the Columbus Declaration (EcoSummit… 2013) where the harmonization of human needs with the environment's capacity to absorb stress and regenerate were identified as the primary objective.

> It is of crucial importance to understand the complexity of interactions between the abiotic, biotic and socio-economic systems.

Water and the quality of life

Water determines not only environmental quality but also the potential for economic and social development. This was reflected in international commitments such as the UN Millennium Development Goals and "The Future We Want" declaration adopted at the Rio+20 conference in 2012. These issues have also been addressed in the six priority themes of the eighth phase of UNESCO's International Hydrological Programme (UNESCO IHP), the world's largest intergovernmental hydrological project for the years 2014–2021. One of these themes (Theme 4: Water and Human Settlements of the Future) is dedicated directly and exclusively to cities (UNESCO 2012). Another theme is dedicated to ecohydrology (Theme 5: Ecohydrology, Engineering Harmony for a Sustainable World) with urban ecohydrology as one of its priority areas. It deals with broadly defined aspects and interactions between green and blue infrastructure and aims to improve the functioning of the urban environment and provide residents with ecosystem services. In its latest publication, UNESCO IHP discusses the world's water-related goals in the post-2015 Sustainable Development Goals proposed by the UN. The following goals were proposed with regard to water: to reduce water pollution from main sources by 30% at the national level by increasing urban waste water collection and purification to at least 80%; to increase industrial waste water purification to at least 95%; to reduce diffuse pollution by 30% and undertake actions aimed at limiting pollution at its source by 2030 (UNESCO 2014). Urban water-related issues are given such high priority due to the fact that over half of the world's population lives in urbanized areas and the rate of urbanization has never been so fast. Cities are the main water polluters. On the other hand, the quality of life in the city is determined to a large degree by water and greenery, the most important elements of ecohydrological water management that help improve the condition of the natural environment and the ecological safety of city dwellers.

Single-sector vs systemic approach

The safe and sustainable future of civilization requires access to food and water, and the production of these depends on the condition and functioning

Figure 1. UNESCO IHP VIII strategy for the years 2014–2021

of the biosphere. Therefore, it is vital to understand why water is increasingly scarce in some biosphere areas, why fresh water is often polluted and how these trends may be reversed. This is all the more important since the direct consequences of these phenomena are decreased habitat numbers and reduced biodiversity and biological productivity.

Unfavourable phenomena are, in many cases, the result of adopting a single-sector approach, with insufficient communication between different users and decision makers as well as the lack of exchange between experts in various disciplines. The lack of dialog between researchers who deal with environmental problems and engineers is particularly challenging as it leads to the excessive use of technology in the environment and is associated with high costs. The result is increasing environmental degradation, quite contrary to the intentions. Furthermore, current research and educational programmes dedicated to the environment all too often fail to emphasize the integrity of ecological processes shaped by evolution, especially the scope and results of man-made modifications and the knowledge on how to reverse these changes. Superficial monitoring of the condition of the environment does not allow for the expansion of knowledge necessary for the development of new methods and systemic solutions for sustainable environmental management (Zalewski 2011).

New, ecohydrology-based ways of using and shaping water and greenery in urban spaces may be in contrast to the mechanistic approach to water resource management. In light of global climate change, the latter approach leads to a constant increase in costs as well as threats and damage. Sustainable and resident-friendly blue-green cities require a new perspective and therefore the mechanistic/deterministic approach[2] must give way to a systemic/evolutionary approach[3] defined in the six priority themes of UNESCO IHP (figure 1).

Sustainable development is often impeded by the failure to appreciate its local dimension. The Nobel laureate, Elinor Ostrom, was among the researchers who highlighted the importance and high effectiveness of local economic systems. She showed that any community living in particular environmental conditions had to figure out its own system for the sustainable use of natural resources and sustainable

[1] The mechanistic/deterministic approach assumes the achievement of one specific goal in limiting environmental management-related threats while ignoring the interactions between the environment and infrastructure.

[2] The systemic/evolutionary approach is a comprehensive approach that assumes the achievement of more than one goal and includes interactions between the natural environment and infrastructure.

coexistence within the ecosystems. The structure of ecosystems and their potential to provide humans with services result from specific geomorphological processes, climate, historically determined cultural patterns and the intensity of usage. Maintaining the single-sector mechanistic/deterministic approach could cause the functioning of the biosphere to deteriorate within a few decades. At the same time, the environment's capacity to produce, absorb and regenerate is declining, potentially leading to local, regional and global conflicts.

Challenges associated with water in the city

The problems described above affect mainly cities as these are sites of landscape and biosphere degradation responsible for changes in the water cycle and the cycle of matter. Moreover, cities face contradictory aspirations and priorities of various stakeholder groups.

One of the most important (yet often neglected by decision makers and practitioners alike) effects of the mechanistic approach to urban water management is accelerated rainwater runoff. The result is accelerated and increased surface runoff and consequently, flooding and extreme river flow. Reduced water retention and extended periods of drought prevent the functioning of green infrastructure in cities. Minimum river flows are also reduced, threatening the maintenance of biological life. Additionally, widespread riverbed regulation leads to the degradation of rivers' structure and biological function, and reduces their self-purification capacity. Excessive use of technology in the landscape coupled with the common practice of dumping sewage and stormwater into rivers increases the cost of water resource management and decreased groundwater recharge (Wagner and Zalewski 2009). Air pollution increases and urban heat islands develop, negatively affecting human health (cf. chapter on the interrelationships between water and human health: Kupryś-Lipińska et al. in this volume). These processes lead to the loss of ecosystem function and services and reduce their resilience to climate change.

> Any community living in particular environmental conditions has to figure out its own system for the sustainable use of natural resources and sustainable coexistence within the ecosystems.

The acceleration and intensification of surface runoff in urban catchments results in the increased export of pollutants. These pollutants access rivers directly through increased surface runoff but also indirectly by means of: runoff from stormwater drainage systems that collect water from areas often significantly larger than the physical coverage of the natural drainage basin and exceeding aquifer capacity; runoff from the storm overflows of combined sewer systems that additionally pollutes sewage waste aquifers; and illegal discharges of point source pollution. Deteriorated water quality prohibits the development of biodiversity and prevents society from safely benefiting from the environment.

The negative impact of hydrological stress and pollution is exacerbated by interventions where the physical structure of river valley and riverbed ecosystem is altered. These interventions are common in cities and include river development and hydrotechnical works which consist of riverbed regulation, straightening and development with the use of concrete slabs as well as underground river channelling. At the same time, the cross section of a river is also changed, narrowed or the river is disconnected from the valley and wetlands etc. The development of river valleys for residential, industrial or road purposes is equally damaging. Habitat simplification has a negative effect on biodiversity, sediment transport and ion exchange with bottom sediments. These processes are essential for rivers' self-purification capacity: when these processes are distorted, the self-purification capacity of a river decreases.

There is much more to the ecological processes described above than just impaired landscape aesthetics. On a social level, these processes translate into a wide range of benefits that account for the creation of safe and attractive urban spaces. Reversing the process of natural system degradation may provide a number of ecosystem services, such as flood and drought prevention, air and water quality control, beneficial effects on residents' health, high

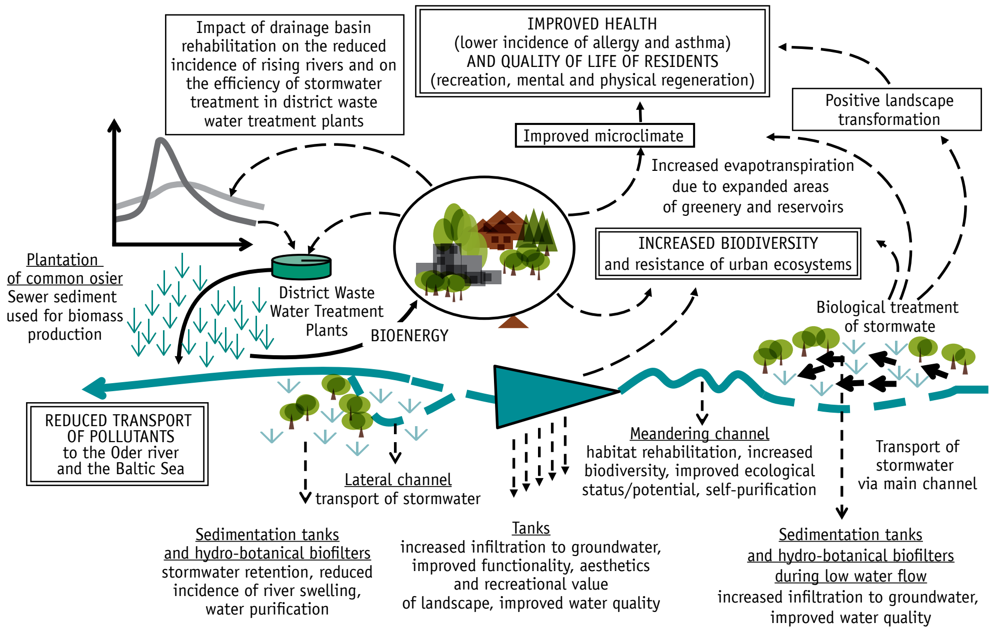

Figure 2. Concept of urban river rehabilitation where ecohydrology and systemic solutions are used to recreate ecosystem services and the cycles of water and biogenic substances, and to reduce the city's operating costs. These activities were undertaken within the framework of research and implementation projects developed as a result of collaboration between scientific institutions and the City of Lodz Office

quality public space, safe recreational space and reduction in the city's operating costs.

Solutions

Process-oriented thinking

The growing awareness of the need for environmental protection dates back to the industrial era. At the time, it was a response to advancements in biological sciences in the 18th and 19th century and ecosystem degradation caused by intensive exploitation of natural resources. This means that these processes were accompanied by a growing understanding of the determinants and dynamics of ecological succession. However, restoration ecology is not enough to halt the process of environmental degradation in the 21st century. The two principal reasons for this are demographics and economy. It is worth bearing in mind that human impact on the biosphere coupled with the world's increasing population, global climate change and economic mechanisms that force mass consumption are generating a growing demand for ecosystem services and placing increasing pressure on the environment. The commonly applied criterion of gross domestic product (GDP) has become "an erroneous indicator of national success" as it concentrates on consumption and finance but fails to include natural resources, human welfare, stability and equality (Costanza et al. 2014).

The negative changes in cities may be reversed by shifting the paradigm of water management. Well-managed waters will become a valuable resource that improves the living conditions and health of residents, especially with the current intensification of climate change. Such policy is made possible by deliberate and safe stormwater retention in the landscape in urban areas (Wagner and Zalewski 2009) and its purification. Science can offer a number of solutions, such as the design of ecosystems that benefit both nature and humans, i.e. ecological engineering (Mitsch 1996; Mitsch and Jorgensen 2004). Wetlands, for example, may be used as a tool to reduce the outflow of pollutants from urbanized

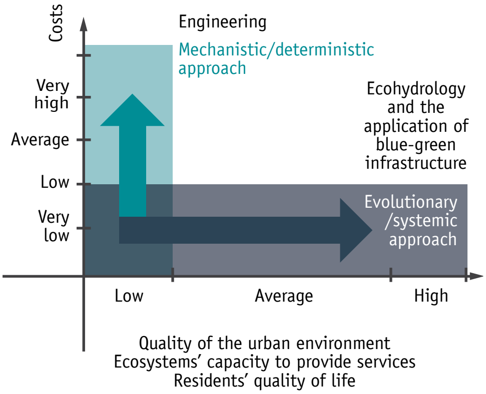

Figure 3. Increased efficiency and reduced costs due to the integration of engineering, ecohydrology and biotechnology

areas. The systemic solutions offered by ecohydrology are another option.

Ecohydrology for the improvement of quality of life in cities

Ecohydrology is an integrated, multidisciplinary field of science oriented at problem solving where the *regulation* of ecological and hydrological processes is the keyword. It encompasses not only hydrology and ecology, but also geophysics, geology, molecular biology, genetics, geoinformatics, mathematical modelling, socio-economic and legal studies. Ecohydrology studies the links between hydrological processes (such as the water cycle in the urban landscape, river flow, reservoir retention time) and biological processes (e.g. transpiration, evaporation, infiltration to groundwater, transformation from biogenic to biomass, plant growth, biofiltration). This knowledge is used for reciprocal regulation of the abovementioned processes, e.g. to improve the functioning of the environment (including blue and green urban infrastructure).

The effective management of water and of the dynamics of nutrient cycling requires the harmonization of conventional hydrotechnical solutions with shaping of the landscape in such a way that ecosystem biotechnology (involving living organisms that transform matter) is applied for process regulation. One example is the construction of denitrifying barriers with bacteria that reduce the transfer of nitrates to water ecosystems by converting them to gas. The practical implementation of ecological knowledge is also crucial, e.g. to apply microbiology and genetic analysis to harness aquatic microorganisms to mineralize organic matter and biodegrade other types of pollution, e.g. by creating ecotone buffer zones.

Such actions require the development and testing of new solutions in ecosystem biotechnology. Studies in urban ecohydrology are one example. The concept of river renaturalization, cascades of reservoirs built over the concept of ecohydrology and the sequential sedimentation/biofiltration system for the treatment of stormwater all emerged as part of research and development efforts. The proposed system acts as a systemic solution where multiple solutions are sought as a result of harmonizing green and blue infrastructure with the city's social and functional systems (figure 2).

Summary

Solutions based on the integration of the latest engineering achievements with blue-green infrastructure and applied ecohydrology allow improved effectiveness of corrective measures in urban areas while at the same time reducing their costs (figure 3). It is worth highlighting that the idea of integrating engineering with biological processes to improve the effectiveness and reduce the costs of water management was first proposed by Statzner and Sperling (1993). Solutions of this type also help accelerate the achievement of the requirements of European Union directives (such as the Water Framework Directive), thereby reducing the risk of high penalty payments being imposed on Poland. Furthermore, as the level of education and awareness among society grows, so do the expectations for quality of life. This in turn is increasingly dependent on a sound environment and the proximity of green areas and reservoirs in the city. Green areas and water bodies reduce the operating costs of infrastructure and the number of factors causing asthma and allergy, while also creating opportunities for mental and physical regeneration. Moreover, blue-green infrastructure carries aesthetic and cultural values that are increasingly valuable to residents. In many cities around the globe, river valleys and green areas are perceived by engineers, urban planners and landscape architects as an axis around which urbanized areas are functionally organized.

According to Romer (2006), progress, development and innovation depend just as much on technology as they do on ideas and systemic solutions. The sustainable development of our planet requires the development of a holistic and multidisciplinary approach to environmental management. The current mechanistic/deterministic approach must give way to an evolutionary/systemic approach oriented at the application of processes for the sustainable use of resources. Optimizing societal benefit is essential (Zalewski 2013). However, reducing the consumption of energy and natural resources used for technological improvements or other activities remains a priority. As far as methodology is concerned, reductionism and intellectual specialization must be substituted by an integrative, interactive, preventive, adaptive and ethics-based approach. This paradigm shift on various levels should minimize the recent trend of excessive exploitation and excessive use of engineering in the environment and lead to the harmonization of social needs with the environment's absorptive and regenerative capacity.

References

Costanza, R., Kubiszewski, I., Giovannini, E. et al., 2014. Time to leave GDP behind. *Nature*, 505, pp. 283–285.

EcoSummit 2012 Scientific Committee, 2013. Harmonization of societal needs with the ecosphere in the Anthropocene Era. *Ecohydrology and Hydrobiology*, 13, pp. 6–7.

Mitsch, W., 1996. Ecological engineering. A new paradigm for engineers and ecologists. In: Schulze, P.C. (ed.), *Engineering within ecological constraints*, National Academy Press, Washington, D.C.

Mitsch, W., Jorgensen, S.E., 2004. *Ecological engineering and ecosystem restoration*, New York: Wiley.

Romer, D., 2006. *Advanced macroeconomics*, California: McGraw-Hill Irwin.

Statzner, B., Sperling, F., 1993. Potential contribution of system-specific knowledge (SSK) to stream management decisions: ecological and economic aspects. *Freshwater Biology*, 29, pp. 313–342.

UNESCO, 2012. *Water security: responses to local, regional, and global challenges. Strategy plan*, Paris: UNESCO IHP.

UNESCO, 2014. *Water in the post-2015 development agenda and sustainable development goals*, Paris: UNESCO IHP.

Wagner, I., Zalewski, M., 2009. Ecohydrological approach for protection and enhancement of ecosystem services for societies at the Pilica catchment demonstration project. *Ecohydrological and Hydrobiological Journal*, 9, pp. 13–39.

WCED (World Commission on Environment and Development), 1987. *Our common future*, Oxford: Oxford University Press.

Zalewski, M., 2011. Ecohydrology for implementation of the UE water framework directive. *Proceedings of the Institution of Civil Engineering Water Management*, 164, pp. 375–385.

Zalewski, M., 2013. Ecohydrology: process-oriented thinking towards sustainable river basins. *Ecohydrology and Hydrobiology*, 13, pp. 97–103.

Zalewski, M., 2014. Ecohydrology, biotechnology and engineering for cost efficiency in reaching the sustainability of biogeosphere. *Ecohydrology and Hydrobiology*, 14, pp. 14–20.

Tools for strategic planning and management of urban water

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The concepts of sustainable development, including integrated water resource management have been incorporated into European Union directives, national laws and programmes, and are being successively transposed into regional plans and strategies. Unfortunately, this is not always reflected in cities' and communes' local activities and development strategies. In communes, spatial and environmental resource management lies within the competence of local governments (of communes/ cities) which are not eager to set the objectives of integrated water management among their development priorities. There is also a lack of effective legal and planning tools for their execution. Yet it is precisely these decisions made at the local level, in rural and urban communes, that are essential for the achievement of the strategic goals laid out in superior documents.

In this chapter we highlight the most significant strategic goals and documents associated with water management, green infrastructure and sustainable development at the European and national level, and present the challenges associated with their implementation at the local (urban) level. We use the example of the "Integrated Development Strategy for Lodz 2020+" to show how the available local strategic management tools can be used to reinforce the role of water in the city through integrated actions.

Keywords: strategic planning, integrated planning, urbanism, climate change adaptation

Introduction

Ever since Poland joined the European Union (EU), Polish legislation has been undergoing continuous transformation to adapt to EU regulations. Two directives are crucial for water management: the Water Framework Directive and the Floods Directive, both of which place emphasis on integrated water resource management. The primary objective of water management in Poland, as stipulated in the Draft National Water Policy 2030 is: "to ensure common access to clean and healthy water and significantly reduce the threats caused by flooding and drought alongside maintaining water bodies and the associated ecosystems in good condition, meeting justified water-related economic needs, improving territorial cohesion and aiming to level regional disproportions". These objectives are also in line with the broader context of Polish and EU development strategies as well as the concepts of sustainable development, green economy and environmental protection.

The increased coherence of activities at the national and regional (voivodeship) levels with the broader European policy as well as the clarity of long-term goals based on the principles of sustainability are the unquestionable advantages of interdisciplinary integration and legal transformation. On the other hand, the European, national (programme-based) and regional legal and strategic tools lay the foundation for the use of local tools for the needs of particular activities in communes and cities. Superior guidelines point straightforwardly to the goals that are to be achieved and even the detailed activities to be carried out by communes. Strategic goals may be achieved on various levels, such as the financial/legal level through the introduction of economic motivation. This would mean fees for the use of environmental resources and penalties for environmental pollution, as well as financing for local retention systems.[1] However, spatial management-related decisions as stipulated by the principal planning documents are equally important (studies of determinants and directions of spatial development, local spatial management plans; cf. next chapter on the role of urban planning and architecture in water management) since the effectiveness of urban water management depends not only on the capacity of water and sewage or anti-flood infrastructure, but above all on the degree of surface sealing and the possibilities of on-site stormwater management.

Communes and cities enjoy vast freedom in establishing their own strategic programmes to form the basis of effective actions within their boundaries. Unfortunately, the socio-economic objectives of local strategies are typically formulated in isolation from the benefits of managing the natural potential of ecosystems. Water management also tends to be incorporated only to a limited extent to meet the water-related needs of residents and the economy, and to protect from flooding. Strategies and local programmes which take into consideration the need for local retention in urban catchments or the renaturalization of rivers and valley biocenoses to improve water quality are rare. Therefore, the planning and coordination of activities designed for the effective use of ecosystem services and blue-green infrastructure in urban space is very complex, all the more so because transforming social awareness takes much longer than the amendment of legal acts.

Communes and cities enjoy vast freedom in establishing their own strategic programmes. These should include not only socio-economic objectives but also environmental ones.

European, national and regional tools

The strategic context of sustainable development

The principal document that defines the development priorities for EU member states is the Europe 2020 strategy.[2] This strategy is based on the priorities

[1] For example, the municipal authorities of Krakow allocated 1 million PLN in 2014 for the construction and installation of stormwater retention reservoirs as part of the "Small retention program for Krakow". Cf. chapter on financial mechanisms: Burszta-Adamiak in this volume.

[2] Europe 2020: A European Strategy for Smart, Sustainable, and Inclusive Growth, Communication from the Commission COM(2010) 2020, Brussels 2010.

of smart, sustainable and socially inclusive growth and provides for the long-term challenges of globalization, population ageing and the need for rational use of resources. Europe 2020 highlights sustainable development and green development among the key areas for innovation, the establishment of new enterprises and strengthening Europe's leading role in the world. The purpose of this declaration was not only to promote sparing use of natural resources but also knowledge-based, low-carbon economies with environmentally-friendly technology, where new, green work places are created and social cohesion is maintained. Blue and green infrastructures are examples of such low-carbon and resource-sparing activities. Apart from being environmentally-friendly, blue-green infrastructure also helps reverse the effects of environmental degradation to a certain degree, by helping to improve the use of the existing natural resources and the natural system's ability to provide ecosystem services. This in turn translates directly into economic and social benefits.

The National Development Strategy highlights the importance of green infrastructure in shaping user-friendly public space, and the need to establish sustainable development standards for urban areas.

The Polish government used the time frame outlined in Europe 2020 to determine the framework for national actions and establish medium and long-term visions and development guidelines for Poland by 2020[3] and 2030.[4] The priorities laid out in the National Development Strategy include rational resource management, improving environmental conditions and adapting to climate change. The action planned for the years 2012–2015 aimed at "introducing an integrated system of natural resource protection and management based on comprehensive inventory records and the integration of this system with spatial management plans" appears especially promising in the context of blue-green infrastructure implementation. This document highlights the importance of green infrastructure (particularly in urban areas) in shaping user-friendly public space, the need to establish sustainable development standards for urban areas and the need for a new approach towards environmental protection in cities.

Water resource management

The fundamental objectives of water management in Poland result from the provisions of the Water Framework Directive and the Floods Directive and have been included in subsequent amendments of Water Law,[5] the Draft National Water Management Strategy 2030[6] and Water Policy 2030. These objectives have also been reflected in major water management-related planning documents (cf. table 1 in the next chapter), such as: the National Water and Environmental Programme, water management plans for river basins, flood risk management plans and drought impact prevention plans for river basins, as well as the conditions for the use of waters in a water region and, where appropriate, conditions for the use of waters in drainage basins (figure 1).

The Water Framework Directive sets the framework, objectives and actions for EU water policy.[7] The main goal with regard to water management in Poland is to achieve a good condition of surface and underground waters by 2015. This goal is being attained through water management plans in drainage basins and supplementary Master plans for the Vistula and Oder river basins, as well as the National Water and Environmental Programme.[8]

The condition of waters may be improved e.g. by protecting aquatic ecosystems and preventing their further deterioration as well as limiting the amount

[3] National Development Strategy 2020: Active Society, Competitive Economy, Efficient State, Ministry of Regional Development, Warsaw 2012.

[4] Long-term National Development Strategy Poland 2030: Third Wave of Modernity, Ministry of Administration and Digitization, Warsaw 2013.

[5] Act of 18 July 2001 Prawo wodne [Water Act] (Journal of Laws of 2001 no. 115, item 1229, as amended).

[6] Water Management Strategy. Draft amendment. KZGW (National Water Management Authority), Warsaw 2006.

[7] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for the Community action in the field of water policy (the so-called Water Framework Directive, WFD).

[8] The National Water and Environmental Programme also includes the requirements of other directives, such as the Nitrates Directive, the Urban Waste Water Treatment Directive and the National Programme for Municipal Waste Water Treatment).

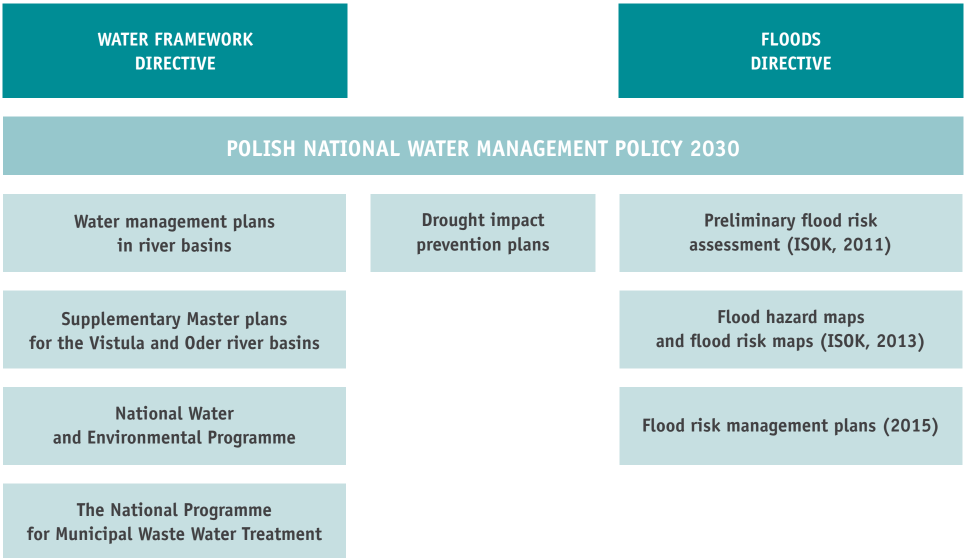

Figure 1. Major strategic documents for the execution of water management goals in Poland

of pollution introduced into waters. However, the achievement of this goal remains a great challenge, partly due to the need to integrate activities in many other fields. The Urban Waste Water Treatment Directive[9] places the duty on member countries to equip all urban agglomerations with systems and installations to collect and convey urban waste water to treatment plants, and to meet specific requirements as to the quality of the treated waste water. The undertakings to be carried out with regard to the construction, expansion or modernization of urban waste water treatment plants and combined sewer systems by the end of 2015 have been laid out in the National Programme for Municipal Waste Water Treatment, a tool designed to help meet treaty requirements. In doing so, communes may benefit from EU funding (Infrastructure and Environment Operational Programme, regional operational programmes and Rural Development Operational Programme), national funds (National Fund for Environmental Protection and Water Management as well as voivodeship, or regional, funds for environmental protection and water management) and other sources of funding. Unfortunately, there is a flip side to equipping urban areas with combined sewer systems: not only are investors not being motivated to introduce green solutions, but on the contrary, they are forced to direct stormwater into the sewer system,[10] further overloading the existing networks.

Effective activities aimed at improving the ecological condition of waters (including those in urbanized areas) go far beyond waste water treatment. According to the Water Framework Directive, not only physicochemical elements but also morphological and biological elements are responsible for the good ecological condition of waters. These latter elements can benefit significantly from reducing extreme water flow in rivers fed by stormwater from cities, and limiting incoming pollution. This may be achieved in urban catchments e.g. through the use of the best practices in on-site stormwater management presented in this guidebook. There are many opportunities at the local level to imple-

[9] Council Directive 91/271/EEC of 21 May 1991 concerning urban waste water treatment.

[10] In accordance with article 28, section 5 of the Ordinance from the Minister of Infrastructure on the appropriate technical conditions for buildings and their location (Journal of Laws of 2002 no. 75, item 690, as amended)

ment these types of solutions. However, a shift in the approach towards urban water management is essential. Stormwater must begin to be viewed as a resource, and technical solutions integrated with blue-green infrastructure and innovative solutions as those described in this guidebook must be applied (cf. next chapter and chapter on technical tools: Wagner and Krauze in this volume).

Polish legislation lacks unequivocal provisions in support of local stormwater management practices (Łomotowski 2008; Kundzewicz 2014). These practices are currently regulated by two legal acts;[11] however, the ecological fundamentals of blue-green infrastructure or ensuring their connection in the city are not the subject of legislation at all. The Water Act and the Environmental Protection Act[12] cover retention programmes in drainage basins but fail to include activities at the local level, especially in cities whose connection with the drainage basin is being marginalized. These legal acts also make reference to the protection of species and habitat diversity yet do not apply to highly modified landscapes with few protected species but enormous demand for ecosystem services (i.e. cities). These objectives may be supported through the use of mechanisms such as recommendations in local spatial management plans and decisions on the conditions for land use[13] as well as through public education and raising awareness, with the ultimate goal being the reassessment of the priorities in urban spatial planning.

Flood risk management

The Floods Directive[14] brought about a radical shift in the perception of flood safety and the associated tasks. The strategic goal is no longer to protect from flooding and ensure full safety but to reduce and manage flood risk. This is achieved through better integration with spatial planning (Januchta-Szostak 2012), e.g.: increasing the space available for rivers (controlled flooding), more effective water retention, and activities aimed at sustainable management of drainage basins (including urban catchments). These goals are also highlighted in Poland's strategic document, the National Environmental Policy[15] which stresses the need to increase water retention and restore the adequate role of spatial planning.

The principal tool for the execution of the goals identified by the Floods Directive, are flood risk management plans that ought to be established by 22 December 2015 in accordance with the provisions of the Directive. However, it is flood hazard maps and flood risk maps, available since the end of December 2013, that are key for spatial planning and water management in cities. The information conveyed by these maps allows the management of river valleys and riverside urban areas to be adjusted to the threat level and to minimize potential flood damage (the proposed planning guidelines in this regard are presented in the next chapter). These documents are taken into consideration when establishing spatial management plans for voivodeships, studies of determinants and directions of spatial development for communes, local spatial management plans and in decision-making on the location of public investments or on the conditions for land use.

Urban floods and short-term inundations (not included in flood risk management plans) as well as the phenomena of urban drought and urban heat islands are a particular type of water-related threat, typical for the urban environment and increasingly common as climate change progresses. If these threats are to be minimized, the environment of urban catchments must be shaped in a responsible way and green infrastructure used.

[11] Ordinance of the Minister of the Environment of 24 July 2006 on the conditions for discharging waste water into water or soil and on substances particularly hazardous to the aquatic environment (Journal of Laws of 2006 no. 137, item 984, as amended) and Ordinance of the Minister of Infrastructure of 12 April 2002 on the appropriate technical conditions for buildings and their location (Journal of Laws of 2002 no. 75, item 690).

[12] Prawo ochrony środowiska [Environmental Protection Act] (Journal of Laws of 2001 no. 62, item 627, as amended).

[13] Planning tools and guidance are discussed in more detail in the next chapter.

[14] Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks.

[15] The National Environmental Policy for 2009-2012 and Its 2016 Outlook. Ministry of the Environment, 2008.

The environment and green infrastructure

In 2013, the European Commission introduced a document entitled "Green Infrastructure: Enhancing Europe's Natural Capital"[16] in response to the European Union's Biodiversity Strategy to 2020,[17] where the Commission's duty to develop a strategy to protect green infrastructure was established. In this document, the European Commission emphasizes the issues of insufficient protection of natural capital and underestimation of the value of ecosystem services. It also highlights the key role of natural capital in emerging from crisis, improving competitiveness and shaping new development areas for the EU. It also puts forward a proposal to recognize natural capital as the backbone of regional development strategies and job creation.

There are two directives that are inseparably linked with the implementation of the green infrastructure concept (especially in the context of water resources): the Habitats Directive[18] and Birds Directive[19] which set forth the objectives for the protection of aquatic and water-dependent ecosystems. Changes in urban drainage basin management (increased volume and speed of surface runoff) lead to changes in the tidal regime, which in turn alters the course of ecological processes and causes the physical structure and species composition to fade, eventually leading to the degradation of aquatic ecosystems. The provisions of the Ramsar Convention[20] and the European Landscape Convention[21] grant protection as well. In Poland, the Environmental Protection Act and Nature Conservation Act[22] are the primary pieces of legislation in this regard.

Adapting to climate change

The management of underground and biological resources, the protection of these, and activities aimed at maintaining and restoring healthy, efficient ecosystems allow socio-economic systems to adapt to climate change and help prevent disasters. The need to establish and implement political strategies in this field was expressed in EU's "White Paper — Adapting to climate change: towards a European framework for action".[23] This paper highlights the fact that the use of nature for climate change mitigation and control in both urban and rural areas may provide a more effective method of adaptation than depending only on man-made infrastructure. In Poland, the "Strategic Adaptation Plan for Sectors and Areas Sensitive to Climate Change up to 2020 with a Perspective to 2030"[24] fits into the adaptive activities resulting from EU's strategy. This document deals with the aspects of protecting biodiversity and adjusting the sectors of water management, spatial management and construction to climate change. Urban areas are among the main focal points of activities.

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Planning urban development

The intensification of urbanization processes in Europe on the one hand and the challenges of sustainable development on the other, urged changes in the approach towards spatial planning and urban management. The New Charter of Athens[25] adopted

[16] Green Infrastructure: Enhancing Europe's Natural Capital, Communication from the Commission COM(2013) 249 final, Brussels 2013.

[17] An EU Biodiversity Strategy to 2020, COM(2011) 244 final, Brussels 2011.

[18] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

[19] Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds.

[20] Convention on Wetlands of International Importance, especially as Waterfowl Habitat signed on February 2, 1971 in Ramsar, ratified in 1978.

[21] European Landscape Convention adopted in Florence on October 20, 2000 (Official Journal of 2006 no. 14, item 98).

[22] Nature Conservation Act (Journal of Laws 2004 no. 92, item 880, as amended).

[23] White Paper – Adapting to climate change: towards a European framework for action, COM(2009) 147, Brussels 2009.

[24] The Strategic Adaptation Plan for Sectors and Areas Sensitive to Climate Change up to 2020. Covering a Perspective to 2030 (SAP 2020), Ministry of the Environment, Warsaw 2013.

in 1998 by the European Council of Town Planners during a congress in Athens, later amended in 2003, laid out the current challenges associated with urban planning as well as the main priorities for urban planning in the 21st century.[26] One of the principal recommendations of the Charter with regard to shaping the urban environment was to perceive the city as an ecological system where the consumption of non-renewable resources and waste production ought to be reduced. "Perhaps the major issue in the 21st century will be the wise use of resources, especially natural, non-renewable ones, and primarily space, air and water. […] Rivers, torrents, and floodplains will be used, via catchment zone management, to mitigate the effects of floods and other extreme weather phenomena caused by climate change and poor engineering. Forests and green areas in and around the city will be increased, so that they are able to play a major role in improving air quality and stabilising temperatures." The authors and signatories of the New Charter of Athens highlight the importance of ecosystems and the need to ensure biodiversity in urban areas. On the other hand, strong emphasis is also placed on shaping public space and on the identity, coherence and attractiveness of the urban landscape. Another document where these priorities are emphasized is the Leipzig Charter;[27] here the recommendations include ensuring high-quality public space, improving the quality of life in the city and of public municipal services e.g. through energy efficiency and the sparing and efficient use of natural resources.

By comparison, the Baltimore Charter holds key importance for the integration of water management with spatial planning in the USA. This was a commitment to develop new, decentralized water systems that mimic natural cycles. The goal is to protect public health and safety and to regenerate the natural and anthropogenic landscapes based on the following principles: on-site and neighbourhood water management, the use of green infrastructure, restoration of urban drainage basin functions, creation of green cities and smart growth. Some American cities, e.g. San Francisco, Chicago and Portland boast exceptional accomplishments in the field of integrated water management in association with spatial planning, landscape architecture, and the design of transport and sewage infrastructure.

Europe's "Thematic Strategy on the Urban Environment" directly addresses urban areas and aims to improve the quality of the urban environment and make cities attractive and healthy places to live, work and invest, as well as to reduce cities' negative impact on the natural environment through interdisciplinary cooperation. One of the proposed means of achieving this goal is the establishment of guidelines for integrating environmental issues with urban policy. These should be based on good practices and expert opinions, and lead to better planning and preventing discrepancies between the applied solutions.

> Revitalization and regeneration of brownfields is preferred over the use of greenfields. New urban planning standards are necessary to limit the loss of biologically active areas.

Poland's National Strategy of Regional Development 2010–2020[28] is dedicated to the above issues. The strategy is based on the assumption that urbanization should not distort the rational proportions between biologically active and built areas. The protection and rational use of natural resources, and adaptation to climate change were included among the 11 strategic areas. The importance of urban natural enclaves is also highlighted in the National Spatial Development Concept 2030. Here, preference is given to regeneration over the development of new areas as well as to new architecture/construction standards that reduce the

25 New Charter of Athens 2003: The European Council of Town Planners' Vision for Cities in the 21st century, European Council of Town Planners, Lisbon 2003.

26 In principle, the New Charter of Athens modified the assumptions of the Athens Charter of the CIAM of 1933 by shifting from the idea of „functional city" to „sustainable city".

27 Leipzig Charter on Sustainable European Cities of 27 April 2007, adopted during a meeting of Member States' Ministers responsible for Urban Development in Leipzig, 24–25 May 2007.

28 National Strategy of Regional Development 2010–2020: Regions, Cities, Rural Areas, Ministry of Regional Development, Warsaw 2010.

loss of biologically active areas. A National Urban Policy is being established by the Ministry of Infrastructure and Development based on these two documents. The policy will include: the need for integrated planning of functional urban areas to improve water and air quality; adaptation to climate change; improving the quality of the urban environment; and sustainable management of stormwater and of the natural system of a city.

Local tools

The integration of superior guidelines in local activities

European, national and regional sustainable development goals are implemented at the local level in individual communes which are responsible for the management of natural resources. The fundamental legal document that determines the tasks and duties of communes, such as those related to water and environmental management, is the Act on Local Self-Government.[29] While following superior guidelines, town authorities enjoy a relatively high degree of autonomy in the design of programmes and strategies for urban development and the creation of cities' quality and individuality. At the same time, however, local governments are under pressure from voters which means that the goals and directions for action are oriented primarily at meeting the most urgent socio-economic needs and ensuring quickly visible effects for improved quality of life. When designing a strategy it is difficult to predict the consequences that the decisions made in accordance with its priorities will have for water management and the environment, as the effects will only be observed in the long run. Environmental impact assessment tools are still being used all too rarely to aid in strategic planning and urban space management.

From the point of view of long-term and integrated urban water management, the ample freedom to act makes room for the conscious inclusion of water-related aspects in the development of all urban sectors (such as transportation, construction, spatial planning, municipal services, education, sports or health). This ensures coherent actions and multidimensional benefits. Due to the fact that cities formulate and execute strategic tasks on their own, local governments are able to include the specificity of a city and region, including physiographical determinants such as climate, landform, water relations, valuable ecosystems and fauna and flora species, as well as the most essential natural areas that are indispensable if urban residents are to be provided with high-quality ecosystem services (cf. next chapter). This is crucial since the same superior guidelines e.g. concerning blue-green infrastructure will be implemented differently in cities in sub-mountainous areas, where surface runoff is significant due to strongly inclined slopes than in lowland cities or those located near large rivers. This individual approach to the implementation of superior strategies allows for cities to be incorporated in the natural system of a region which is of utmost importance for the proper functioning of urban natural systems. An integrated and individualized approach may bring about local decisions to protect these areas; build the city inwards (compact cities) and further condense invested areas (e.g. by way of revitalization or concentration of urbanized zones within the city centre), and to prevent urban sprawl. However, development must be compensated by increasing the biologically active surface area in the condensed urban areas to ensure high quality of life. Biologically active areas create friendly, healthy and more attractive space – a goal that may be achieved by including green infrastructure at an early planning stage. Integrated actions to support water retention (cf. chapter on technical solutions: Wagner and Krauze in this volume) aid in the proper functioning of green infrastructure. Investing in city centres rather than the costly development of distant locations benefits all residents in the long

From the point of view of long-term and integrated urban water management, there is a need for the conscious inclusion of water-related aspects in the development of all urbansectors.

[29] Act of 8 March 1990 on Local Self-Government (Journal of Laws 1990 no. 16, item 95).

run by preventing urban sprawl, reducing the cities' operating costs, improving the quality of life and preserving suburban public recreation areas.

Strategic planning and water management tools established at the local level

Municipal authorities have at their disposal a wide range of local tools to support the above goals, including: environmental protection programmes, studies of determinants and directions of spatial development, local spatial management plans, river management plans, small retention programmes and projects, sectoral policies regarding water and natural resources as well as other visions and development strategies for cities. Some of these are not required by law (cf. table 1 in the next chapter) but may be very helpful tools in the implementation of specific activities. For example, small retention programmes may be a useful tool for the analysis of the hydraulic effects of spatial management, evening out the flow in urban aquifers or improving the retention capacity of urban catchments.

The environmental protection programme is a document that consolidates all actions at the commune level and its establishment may be viewed as an opportunity to introduce a coherent and efficient management system. Bearing in mind the strong ecohydrological links between the water cycle of a city and the functioning of its natural system, both the diagnosis and analysis of needs as well as the environmental protection programme itself create the perfect basis for the inclusion of urban water management goals as an important element of urban development.

Development must be compensated by increasing the biologically active surface area in the condensed urban areas to ensure high quality of life.

The study of determinants and directions of spatial development may be a particularly potent tool to support sustainable stormwater management and green infrastructure in cities (Januchta-Szostak 2012; cf. also next chapter in this volume). It allows for example to exclude from construction green areas that are valuable for stormwater retention and infiltration; to protect water ecosystems together with their buffer zones from being built up; to ensure spatial links between blue and green infrastructure; to indicate areas to be built up and/or determine the principles of development (e.g. the proportion of biologically active areas, the need for water retention or limits for the use of impervious surfaces) (cf. chapter on technical solutions: Wagner and Krauze in this volume). The principles established in the study regarding the protection of the environment and its resources as well as nature and the cultural landscape, particularly the guidelines concerning their determination in local management plans,[30] make it possible to harness the potential of blue-green infrastructure and ecosystem services.

The development strategy of a commune may be one of the fundamental documents determining the directions for development, including water resources. A properly and meticulously prepared strategy allows for a coherent vision of a modern, functional and friendly city to be implemented, while at the same time being a convenient planning tool for financing and monitoring progress in the implementation of integrated solutions. Water ecosystems, especially large rivers, are often crucial elements of such strategies. Some cities in Poland (e.g. Bydgoszcz, Tczew, Warsaw, Poznan) have adopted strategies and programmes aimed at "returning to rivers". However, these programmes are aimed primarily at: improving the quality of waterfronts; tourism and economic activation of coastal areas; improving flood protection, and rarely include e.g. the restitution of valley biocenoses or activities covering entire drainage basins that could help slow down and improve the quality of surface runoff from urban areas, thereby improving the quality of water and reducing flood risk. The wording in local strategies is another challenge since different communes have different priorities. Many cities grapple with urban floods and short-term inundations caused by excessive surface sealing in the city itself or too quick runoff from neighbouring communes. Effective water management requires the inclusion of hydraulic data

[30] Prawo ochrony środowiska [Environmental Protection Act] (Journal of Laws of 2001 no. 62, item 627, as amended), article 72.

from catchment areas which do not coincide with the administrative borders of communes (cf. next chapter in this volume). This requires cooperation between communes as well as the coordination of the objectives of strategies for various sectors.

Summary

The objectives of water management-related activities are strictly defined in European and Polish policies. However, when it comes to the implementation of these, local authorities are free to establish their own mechanisms for integration with the development strategy of cities, using the local strategic tools described in this article. The fact that objectives and priorities that incorporate sustainable water management are stipulated in strategic documents is only half of the success equation. The achievement of these goals requires the integration of actions in the social, economic and spatial domains as well as the adoption of a catchment-based approach to urban water management and planning (cf. chapter on integrated management: Krauze and Wagner in this volume). This means including the ecohydrological effects of decisions concerning economic and spatial issues not only at the city level but also in surrounding communes located in the same drainage basin. Water management-related goals may be achieved faster and at lower cost when ecosystem-based water management methods and ecosystem services are put to use. In practice, this means incorporating integrated solutions in all activities in the urban space so that blue-green infrastructure, best practices in stormwater management and ecohydrological solutions are employed. On the other hand, making use of the social and landscape values of water and greenery (the subject of the next chapter) may help achieve other strategic goals associated e.g. with improving a city's image, the attractiveness of public space or resident integration. A holistic approach is necessary not only when strategies are developed but also to allow their content to be consistently transposed into the design and implementation stages.

> Effective water management requires cooperation between communes as well as the coordination of the objectives of strategies for various sectors.

Case study:
water in the urban space of Lodz: example of a strategic approach

The city of Lodz is characterized by very limited natural water resources, land with significant slopes (for a city in central Poland) and poor retention capacity. The fundamental reason for this is the city's location in the primary watershed between the Vistula and Oder rivers, coupled with a large proportion of impervious surfaces and limited groundwater retention capacity. Eighteen small, radially arranged streams with limited retention capacity collect stormwater from an area of over 290 km^2. The result is the nearly complete loss of water from the city while excess water causes temporary inundations in Lodz and the downstream areas of its catchments.

One of the ways to improve urban water management is to increase the number of aquifer-based retention reservoirs. Some of these are being restored in their previous locations where they were damaged, filled or covered with vegetation. Some are being designed and created from scratch. The integration of all related actions became the basis for the "Annex to the assumptions of the general river project: reservoirs" prepared in 1999 and used by the City of Lodz's Department of Municipal Services to establish a small retention programme for Lodz in 2001. This programme is being implemented via projects that include not only rivers but also their valleys, drainage basins and local communities.

The Sokolowka river drainage basin (figure 2) is a good example of integrated efforts. The investment was based on a General Project established in 2003 that adopted an overall view of the drainage basin. The General Project served two main purposes: to assess the drainage basin's potential (e.g. the possible sites for reservoirs and areas of natural value) and indicate the tasks necessary for the achievement of the assumed goals (i.e. improved water quality, increased retention capacity of the river, increased biodiversity, improved living conditions for residents). The planned undertakings included environmental, landscape, engineering and social features. As part of the implementation process, reservoir retention was restored, a water pre-treatment system was constructed (cf. chapter on technical solutions: Wagner and Krauze in this volume) and a technical project of river rehabilitation was developed which is currently awaiting implementation. A number of activities that improve (albeit indirectly) the quality of water and residents' quality of life were also carried out, such as a new, covered riverbed that effectively eliminated illegal dumps of sanitary waste. Furthermore, properties were connected to the newly completed sanitary sewage network (which eliminated cesspits) and local roads were equipped with drainage systems. The total cost of activities carried out in the years 2004–2012 in the upper Sokolowka drainage basin exceeded 26 million PLN: over 18 million PLN in rearranging the water and sewage management system and about 8 million PLN in the execution of investments in rivers. The innovative investments carried out in the Sokolowka drainage basin employ a number of ecohydrological solutions designed to improve the quality of water that feeds rivers and reservoirs. Similar solutions are currently being applied in other rivers of Lodz (cf. case study on reservoirs in Arturowek in the chapter on technical tools: Wagner and Krauze in this volume).

Still, extreme flows continue to hamper the functioning of overfilled rivers in Lodz and more advanced solutions that will enhance the stormwater retention potential of the city's natural system are needed. One of the goals of the Blue-Green Network concept described in the previous guidebook in this series (Zalewski et al. 2012; Wagner et al. 2013) was to enhance water retention in the landscape, bringing about a host of associated benefits for the city. This concept was included in the study of determinants and directions for spatial development for the City of Lodz in 2010 and in the Integrated Development Strategy for Lodz 2020+ established by the City of Lodz Office in 2012 (UMŁ 2012). The Strategy has 3 main pillars:

- pillar 1: economy and infrastructure;
- pillar 2: society and culture;
- pillar 3: space and the environment.

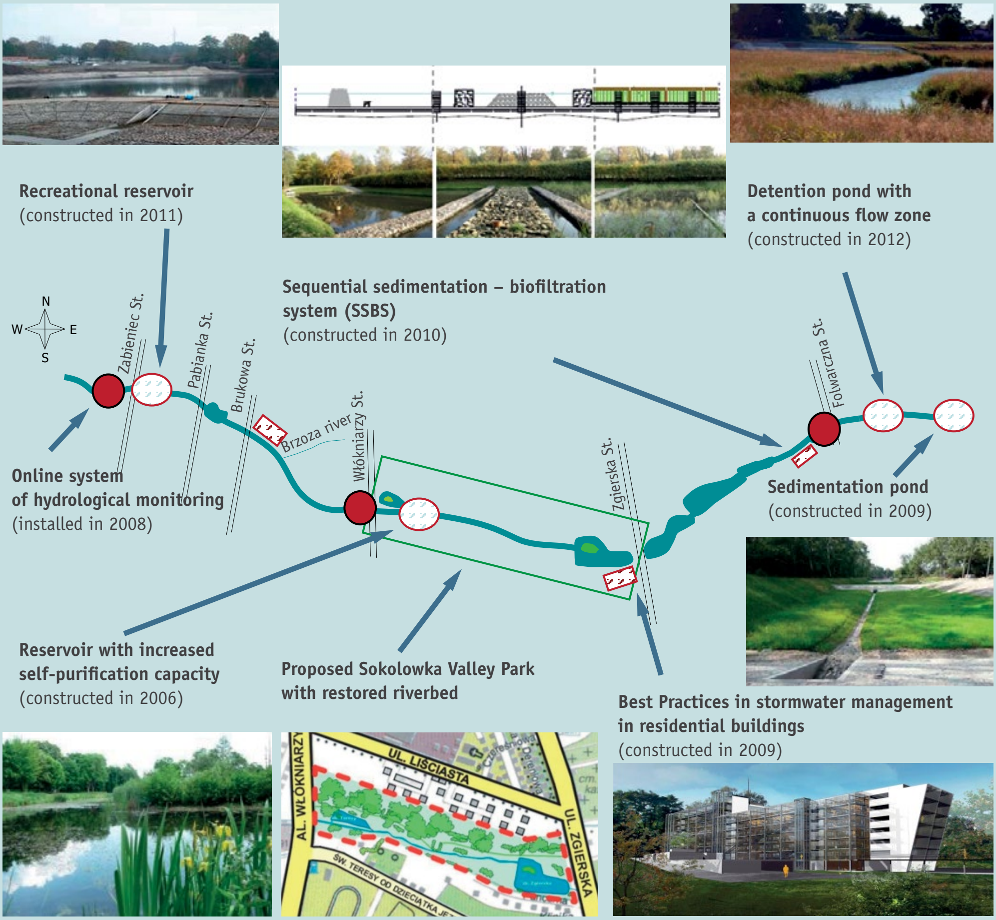

Figure 2. Construction of retention reservoirs on the Sokolowka river carried out during the last 10 years by the City of Lodz in the Sokolowka drainage basin as part of a small retention programme for Lodz. Some works were performed as a result of cooperation between city authorities and researchers within the framework of EU projects (SWITCH and POIG)[31] (Wagner and Zalewski 2009)

The Blue-Green Network concept became one of the constituents of the third pillar. The goal of this pillar is to "improve Lodz residents' quality of life and increase the attractiveness of the City by using the potential of the natural environment, maintaining and arranging biologically active and recreational areas, and building a healthy lifestyle". According to the provisions of the Strategy, this goal is achieved through integrated actions such as:

- the skilful use of ecosystem services and nature's potential to provide a stable base for further sustainable development of Lodz as a compact city;
- improving the quality of the natural environment, sustainable development, the creation of a centre with urban and spatial order to reduce the spread of the urban fabric;

[31] SWITCH (FP6 EU, GOCE 018530); POIG.01.01.02-10-106/09-04 "Innovative resources and effective methods of safety improvement and durability of buildings and transport infrastructure in the sustainable development" (financed from the European Regional Development Fund as part of the Innovative Economy Operational Programme).

- minimizing negative environmental impacts through spatial, health, residential, educational and transport policy, economic and promotional activity, and the public procurement system;
- using the opportunities to create a Blue-Green Network integrated in a single, functional, readily accessible, well-connected and coherent network of urban and metropolitan green areas.

Since 2013, the City of Lodz Office has been implementing a comprehensive strategic management system comprising of sectoral policies. These policies set development guidelines for particular areas of urban activity and translate the main Strategy into specific activities. Sectoral policies are time-correlated with the Strategy and allow for the costs of executing specific goals to be estimated as well as to identify, monitor and evaluate the results. The management of water and the natural environment have been included in the Municipal Management and Environmental Protection Policy adopted in 2013. It assumes the protection and integrated management of the city's natural capital which is deemed indispensable to ensure high quality of life, and highlights the fact that ecosystems require proper maintenance and often revitalization in order to provide services. The document lists the promotion, initiation and implementation of all activities aimed at drainage basin de-sealing and increasing on-site stormwater retention as the priorities of rainwater management. The construction of retention reservoirs is also crucial as these help eliminate the effects of excess rainwater.

References

Januchta-Szostak, A., 2012. Urban water ecosystem services. *Sustainable Development Applications*, 3, pp. 91–110.

Kundzewicz, Z., ed., 2014. Raport o zagrożeniach związanych z wodą. *Nauka*, 1, pp. 59–195.

Łomotowski, J., ed., 2008. *Problemy zagospodarowania wód opadowych*, Wroclaw: Seidel-Przywecki.

UMŁ (City of Lodz Office), 2012. Strategia zintegrowanego rozwoju Łodzi 2020+, Lodz: City of Lodz Office.

Wagner, I., Krauze, K., Zalewski, M., 2013. Blue aspects of green infrastructure. *Sustainable Development Applications*, 4, pp. 145–155.

Wagner, I., Zalewski, M. 2009. Ecohydrology as a basis for the sustainable city strategic planning – focus on Lodz, Poland. *Reviews in Environmental Science and Bio/Technology*, 8, pp. 209–217.

Zalewski, M., Wagner, I., Fratczak, W., Mankiewicz-Boczek, J., Parniewki, P., 2012. Blue–green city for compensating global climate change. *The Parliament Magazine*, 350, pp. 2–3.

The role of urban planning and architecture in water management[1]

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Many architects and urban planners are increasingly aware of the negative effects of urbanization and the need to incorporate water management in spatial planning. However, neither a legal framework nor the economic tools exist to support an integrated and environmentally-friendly approach to spatial and water management in cities. Spatial planning in Poland may be characterized as bottom-up; it is based on the right of local self-governments to decide on the forms of spatial management in a commune and fails to include the drainage basin approach. Therefore, it makes sense to look into good practices and broaden the entries of principal planning documents (i.e. studies of determinants and directions of spatial development for communes, local spatial management plans) so that water resources are consciously managed and non-technical flood protection measures more widely used. Flood hazard maps and flood risk maps as well as small retention programmes developed in some cities can be used to establish detailed guidelines concerning land use in river valleys, areas at risk of flooding, and entire urban catchments. This chapter proposes guidelines for planning and design that could help improve not only the ecohydrological condition of cities, but spatial order and residents' quality of life as well.

Keywords: strategic planning, spatial planning, climate change adaptation, water management

[1] This article presents the conclusions of studies carried out by the author at the Faculty of Architecture of the Poznan University of Technology in 2014 as part of a DS.PB project entitled *Improving the quality of neighborhood and public space in Poznan with the use of sustainable stormwater management systems.*

Introduction

The current trends in urban planning expressed in the New Charter of Athens (2003)[1] or the Leipzig Charter (2007)[2] highlight the need to shape compact and user-friendly cities while at the same time emphasizing the wise use of natural resources. These two goals are sometimes difficult to reconcile, especially when economic priorities strongly dominate over environmental considerations.

Significant anthropogenic transformation of the urban environment alters the natural water cycle. Urbanization processes in the 19th and 20th centuries left the water networks of many cities greatly impoverished. Once numerous ponds, wetlands, oxbow lakes, moats, channels and streams were filled up or channelized, and large rivers regulated. Surface sealing changes the flow dynamics of aquifers that receive rainwater; urban floods and local inundations are becoming increasingly common. Interventions typically concentrate on river valley areas and consist of improvements in flood protection despite the fact that water must be managed at the source of the problem, i.e. in the entire drainage basin, and not just its mouth.

Just as high waters and flooding are the result of channelized runoff made up of billions of raindrops, the effectiveness of sustainable urban water management depends on the large-scale implementation of minor, environmentally-friendly solutions. This requires educational activities, effective planning, technical and economic tools, appropriate legislation, and above all, integrated urban planning and management based on the availability and exchange of information as well as the coordination of activities to reduce costs and achieve synergy in the execution of different, often disparate goals of sectoral strategies.

Trends such as ecological urbanism, green urbanism and green architecture are increasingly present in the design of buildings and entire urban structures in Europe, USA or Australia. Poland, too, is seeing a steady rise in the number of investments that may boast LEED[3] or BREEAM[4] certification. Unfortunately, Polish spatial management still lacks a comprehensive approach and effective tools for the implementation of water management goals; the isolated examples of good practices are just a drop in the ocean.

The possibilities of water management in a drainage basin are largely determined by the way land is used in that area. Therefore, water management cannot be treated merely as the subject of sectoral policy; instead it requires full integration with spatial management, urban planning and architecture.

Spatial planning tools in Poland vs. urban water management

The role of water in shaping urbanized space should not be limited only to reducing the threats associated with its shortages (drought), excess (torrential rains, floods, short-term inundations) or low quality (waste water management, surface and groundwater pollution). The full use of water's potential in terms of provisioning, regulating and cultural services (Kronenberg 2012) at all levels of planning and design is equally important: from the National Spatial Development Concept and regional spatial development plans, through studies of determinants and directions of spatial development for communes, to local plans and the design of individual buildings and public and private space.

1 New Charter of Athens 2003: The European Council of Town Planners' Vision for Cities in the 21st century, European Council of Town Planners, Lisbon 2003.

2 Leipzig Charter on Sustainable European Cities of 27 April 2007, adopted during a meeting of Member States' Ministers responsible for Urban Development in Leipzig, 24–25 May 2007.

3 Leadership in Energy and Environmental Design: a certification system developed in the United States that has become one of the most popular multi-criteria rating systems and aims to promote and help create green buildings.

4 Building Research Establishment Environmental Assessment Method: buildings assessed under BREEAM receive a certificate of the British Research Establishment who assess the functioning of a building in its surroundings within the categories of: energy savings, water savings, management of materials, user comfort, impact on the natural environment, minimizing pollution, building management, minimizing waste.

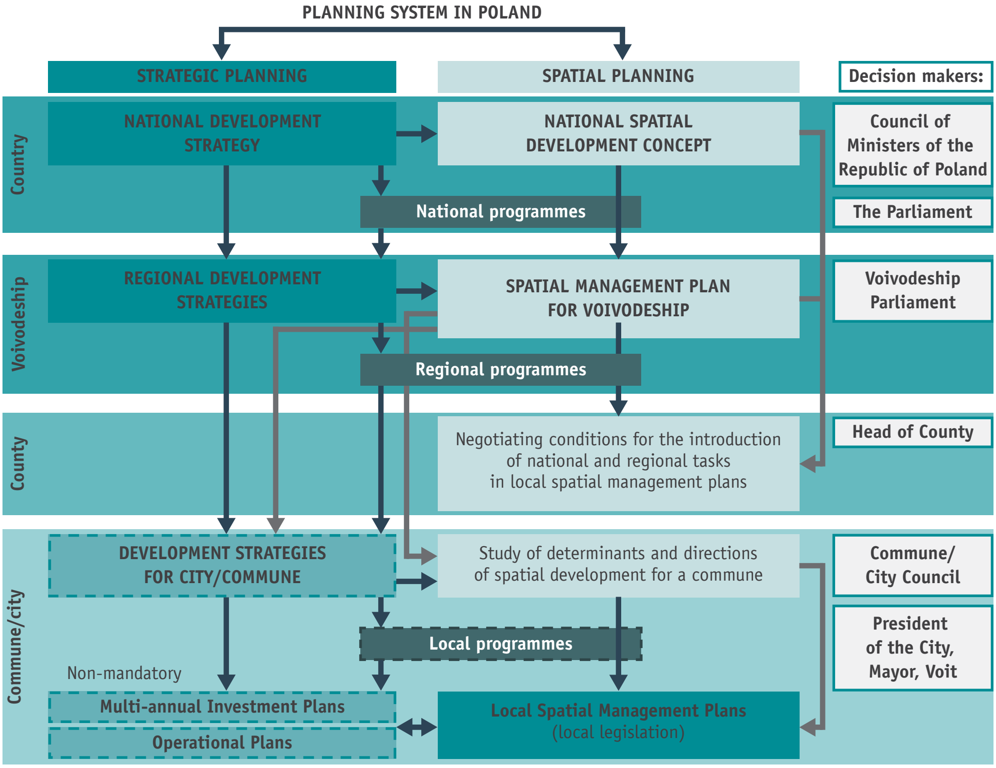

Figure 1. Schematic representation of the spatial planning system in Poland (based on Maier et al. 2012)

Spatial planning in Poland is carried out on three levels (figure 1): national, regional and local (cities/ communes). The planning system is based on the coherence of plans with development strategies on all levels of government and self-government administration.

The formal and legal basis for the execution of undertakings is developed at the local level as the spatial planning system in Poland is bottom-up. Local governments have the right to decide on spatial development in the commune while incorporating the guidelines of superior plans and supra-local public investments. The primary tools for spatial planning are studies of determinants and directions of spatial development and local spatial management plans which must be compatible with the development strategies of cities and regional spatial management plans, and include the arrangements of other superior sectoral programmes and plans, e.g. water management plans.[5]

Administrative divisions apply for the purposes of spatial planning while drainage basin areas and water regions are used for water management (table 1). Difficulties in the coordination of spatial and water management result from the disparity in areas covered by the plans and the different priorities of the responsible institutions.

Interestingly, there are no formal planning documents concerning water management at the local level of cities and communes (table 1), i.e. where the fundamental decisions on spatial management are made. Therefore, there can be no talk of a catchment-based approach to spatial planning when a hydrographic drainage basin not only does not constitute

[5] Prawo wodne [Water Act] (Journal of Laws 2005 no. 239, item 2019, as amended), articles 113 and 118.

Table 1. Tools for spatial planning and water management

Planning level	Strategic documents	Spatial management plans	Water management-related plans and programmes
National	National Development Strategy, The National Environmental Policy for 2009-2012 and Its 2016 Outlook	National Spatial Development Concept Programmes that include government tasks related to public investments of national significance	National Water and Environmental Programme including catchment zone-based divisions Water management plans for river basins Flood risk management plans Drought impact prevention plans for river basins National Programme for Municipal Waste Water Treatment
Regional	Development strategy for voivodeship	Spatial management plan for voivodeship Programmes that include tasks related to public investments of regional significance	Water management plans for river basins in water regions Drought impact prevention plans for water regions Conditions for the use of waters in a water region and, where appropriate, conditions for the use of waters in drainage basins Regional environmental protection programmes Regional small retention programmes
Local	Development strategy for city/commune Long-term investment plan for city/commune	Study of determinants and directions of spatial development for commune Local spatial management plans	At the local level, a water management programme and study are established for the commune or city to allow the execution of the commune's water management-related goals (article 7, section 1, item 1 of the Act on Local Self-Government). However, the development of the study is not mandatory

the basic area of planning and decision-making, but even determining its boundaries within the city and the degree of surface sealing in these areas proves challenging. Consequently, the acquisition, analysis and exchange of information regarding the determinants and priorities for the management of local drainage basins is hampered.[6] Some cities, especially those troubled by short-term local inundations (e.g. Krakow, Lodz, Poznan, Leszno), floods or drought are working out analyses for the retention capacity of urban catchments, water management-related studies and programmes for the city or commune, or small retention programmes. However, these documents are not obligatory and rarely translate into the entries of spatial planning documents.

There is only one planning tool that may be used at the local level to influence how the landscape and functional/spatial structure of the entire commune or city is shaped in Poland: the study of determinants and directions of spatial development for a commune. Although this document is not a legally binding piece of legislation, it is mandatory and applies to the entire area of a commune or city with county rights. This provides the opportunity to link the forms of land use with water management priorities, e.g. by including the

[6] The difficulties stem from the limited accessibility and coherence of data on land development, difference in scope (administrative boundaries do not overlap with drainage basin boundaries), the level of detail, quality and form of entry.

determinants associated with the size and quality of water resources or water-related threats (areas at significant risk of flooding according to flood hazard and flood risk maps). The preparation of studies of determinants and directions of spatial development is aided by studies in physiographic ecology which include a wide range of information of crucial importance for water management, e.g. concerning the geological structure, terrain, land cover; climate; surface and groundwater; soils; and plant cover. If these latter studies were analysed within the boundaries of hydrographic catchments instead of administrative boundaries, they could be used e.g. to identify areas of high retention capacity and ecological potential, as well as areas of reduced retention capacity that require compensation. The assessment of environmental impact could also be applied to protect valuable habitats and tall greenery, as well as to restore the retention capacity of drainage basins. In German cities, aquatic ecosystem protection and revitalization programmes may be financed from funds acquired as a result of so-called compensatory regulation.[7]

Water management requires educational activities, effective planning, technical and economic tools, appropriate legislation, and above all, integrated urban planning and management.

Local spatial management plans are the only pieces of local legislation dedicated to spatial management; their entries must be consistent with those of the study of determinants and directions of spatial development. These plans determine the indicators, forms and functions of development, primarily the details of land use (including in areas excluded from construction) and the required percentage share of biologically active surfaces, providing ample opportunities to influence water management and mitigate the effects of flooding. If the entries of these local plans were formulated on the basis of analyses of drainage basin retention capacity and strictly followed, they could be more widely used to regulate the degree of surface sealing. Unfortunately, investors all too often exceed the admissible size of impervious surfaces with impunity, and investments are not required to be hydrologically neutral. From the point of view of environmental quality and water retention, it would be very helpful if not only quantitative but also qualitative requirements were used to shape biologically active surfaces, similarly to the German FLL guidelines of The Research Society for Landscape Development and Landscape Design (*Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau* e.V.).

Regrettably, Polish legislation lacks entries that would allow for decentralized stormwater management and any obligation to retain it – both in public spaces and individual lots. On the contrary, investors are obligated to channel stormwater to the sewer network. The discharge of stormwater on own, non-hardened surface, into sumps or retention reservoirs is admissible only when there is no possibility of connecting to a stormwater collection or combined sewer system.[8] By contrast, the British Flood and Water Management Act[9] abolishes the right to automatically connect new investments to collective sewer systems. Instead, it provides for the use of sustainable urban drainage systems (SUDS) designed to reduce flood damage and improve water quality. In cases where these systems support more than one property, the responsibility for their implementation and maintenance lies with local authorities.

Guidelines for planning and design

When cities are planned and designed in Poland, greater emphasis is still being placed on effective drainage than on rainwater retention, purification and on-site use (figure 2). Meanwhile, the guidelines of European water-related directives (Water Framework Directive[10] and Floods Directive[11]) and experience with their implementation

[7] The duty is established by the Federal Nature Conservation Act and Federal Building Code which impose compensatory fees on those responsible for significant interventions in nature and landscape (Maier et al. 2012).

[8] Ordinance of the Minister of Infrastructure on the appropriate technical conditions for buildings and their location (Journal of Laws 2002 no. 75, item 690, as amended), article 28, section 5.

[9] The Flood and Water Management Act of the United Kingdom of 8 April 2010.

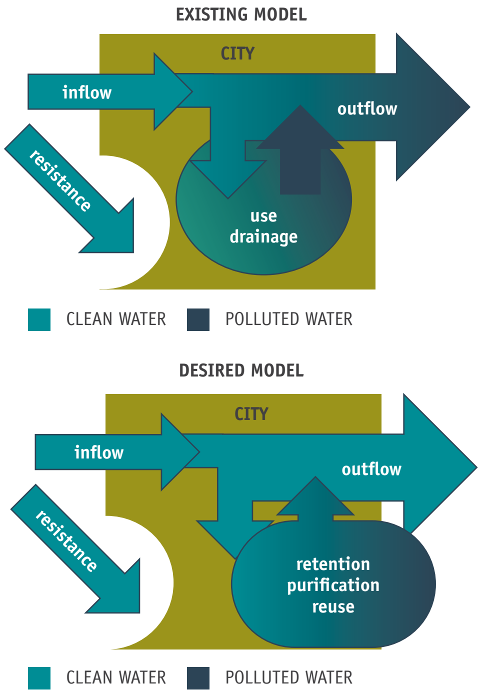

Figure 2. Flow models illustrating water management in cities. Left: the existing model in Polish cities characterized by poorly effective flood protection, drainage of polluted stormwater to aquifers, lack of retention. Right: the desired model with the flow characterized by unchanged qualitative and quantitative parameters; retention, purification and reuse of rainwater (based on Januchta-Szostak 2011).

in developed countries (such as the Netherlands, United Kingdom or Germany), as well as assessments of the situation in Poland (Kundzewicz et al. 2014) all point to the need for better integration of water management and spatial planning, both in terms of shaping river basins and drainage basin management.

The British LIFE project (Long-term Initiatives for Flood-risk Environments) is a good example of integrated planning. The authors showed how the needs of urbanization could be reconciled with different types of flood protection and the use of ecosystem services. In 2005, the British government approved a strategy called Making Space for Water which established the principles of land development in areas at risk of flooding. These principles include e.g. adjusting development to the scale and type of flood-related hazards and the introduction of SUDS in urban catchments.

River basin management

Information provided by flood hazard and flood risk maps can be used for the purposes of spatial planning, to limit or prohibit construction in floodplains and to regulate land use in these areas, as well as to protect particularly valuable aquatic and water-dependent ecosystems (figure 3).

Areas located in 100-year floodplains (1% annual risk of flooding) should be excluded from construction. However, in European cities where development pressure on land is high, some forms of development and construction are allowed that do not increase flood hazard and do not impede water flows, but improve the accessibility and efficiency of waterside land use. Guidelines on the development of specific flood risk zones, similar to those of the British Planning Policy Statement 25 (DCLG 2009) would be very helpful in establishing local spatial management plans (figures 4 and 5).

A set of detailed guidelines may be established on the basis of hazard zone maps, vulnerability to flood damage and flood risk assessment, for instance: the appropriate land uses; surface and rainwater management; land accessibility, communication and transportation; the use of local natural resources (water and energy); or even the preferred types of construction for buildings.

On the other hand, the preservation and restoration of aquatic and water-related ecosystems, especially the biodiversity of the littoral zone given its essential role in water self-purification, is also of utmost importance. Planning documents should include entries concerning:

[10] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for the Community action in the field of water policy.

[11] Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks.

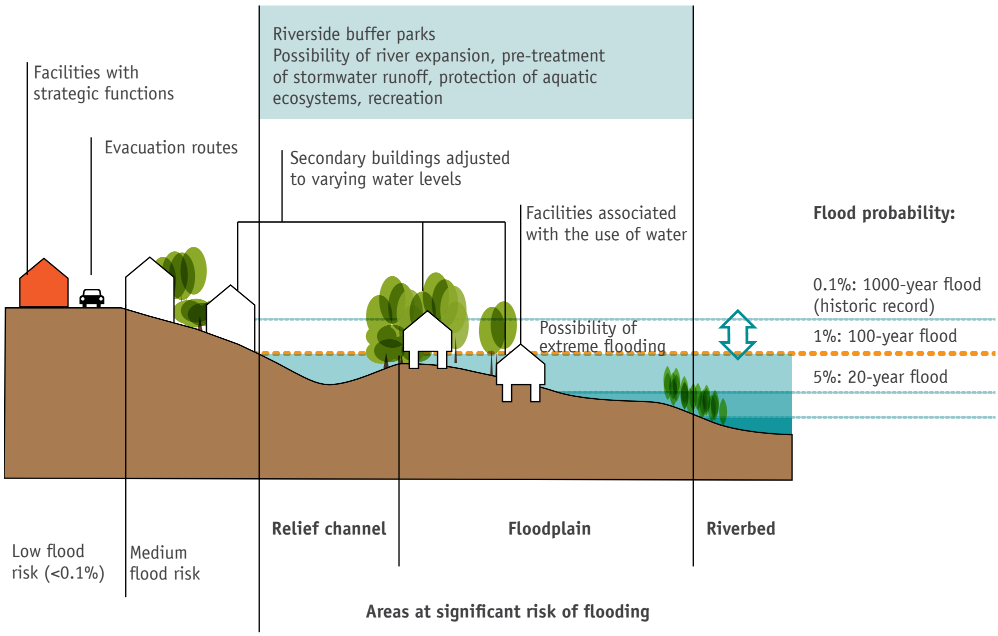

Figure 3. River valley development in accordance with the EU Floods Directive: increased space for river expansion, with the functions and form of development adjusted to the level of flood risk

- the creation of continuous systems of riverside parks based on the hydrographic network (blue-green networks);
- increasing retention capacity by restoring wetlands and broads, uncovering and extending previously channelized, small aquifers that collect rainwater (creating meanders);
- protecting and shaping buffer zones along aquifers (a minimum of 30 m wide for cities and at least 100 m for open land) to allow: the pre-treatment of stormwater runoff from urbanized and agricultural areas; river expansion during high waters; and the creation of migration corridors and recreational areas for residents (Januchta-Szostak 2013; Maier et al. 2012).

Urban stormwater management

Sustainable urban drainage systems (SUDS) (Januchta-Szostak 2011) are designed to slow down and reduce surface runoff in cities. However, these systems use up large areas of land and thus are rarely implemented: first, because this would imply shrinking investment areas and second, because local authorities have no experience in assessing their efficiency and maintenance costs. It is essential to use SUDS comprehensively, not only as infrastructure but also as elements of architecture and landscape of high aesthetic and functional value. This approach helps increase social acceptance and dissemination.

The possibilities for SUDS implementation in different types of urban space depend on a number of factors, such as: the nature of land use; the ownership structure and retention capacity of various types of urban space; and the needs in terms of public space management (table 2).

The adoption of a holistic approach allows SUDS to improve not only the ecohydrological conditions but also spatial order and quality of life in the city, allowing these systems to contribute to the execution of the strategic goals of water management and urban planning. Plans, projects

Environment Agency flood zone classification	Appropriate uses	Vulnerability table
Zone 1 (low probability) Areas with a less than 1 in 1000 annual probability of flooding in any year (<0.1%)	**Highly vulnerable uses** Emergency services should be located in zone 1 exclusively and in zone 2 only in exceptional cases.	Zone 1: Highly vulnerable
Zone 2 (medium probability) Areas with an annual probability of flooding between 1 in 100 (1%) and 1 in 1000 (0.1%)	**More vulnerable uses** Residential development should be located in zone 1 or 2, and in zone 3 only in exceptional cases.	Zone 2: More vulnerable; exceptionally
Zone 3a (high probability) Areas with an annual probability of flooding greater than 1 in 100 (>1%)	**Less vulnerable uses** Buildings used for offices, administrative or commercial functions etc. may be located in zones 1, 2 and 3a.	Zone 3a: Less vulnerable; exceptionally
Zone 3b (functional floodplains)** Typically areas with an annual probability of flooding greater than 1 in 20 (5%))	**Water compatible uses** The development of harbours and marinas as well as open recreational areas may be considered in zone 3b.	Zone 3b: Water compatible

** This is not shown on the Environment Agency website.

Figure 4. The functions of development and land use based on vulnerability to flood damage (based on DCLG 2009)

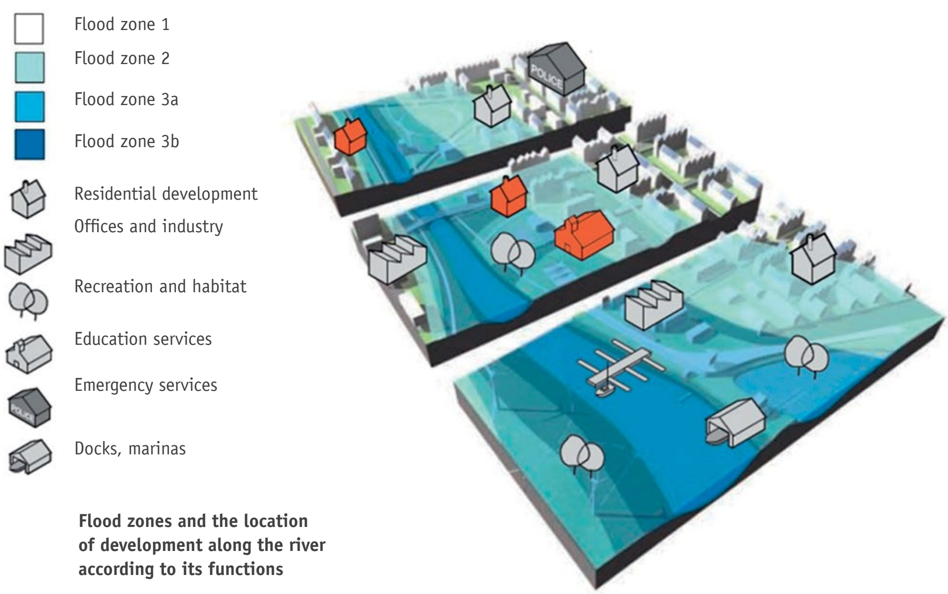

Figure 5. Flood zones and the appropriate location of development with different uses along the river (Baca Architects and BRE 2009)

and programmes such as Singapore's ABC Waters (Active, Beautiful, Clean Waters, cf. case study at the end of this chapter) prove that synergy may be achieved even in highly urbanized environments. The Uptown Normal Circle in the town of Normal, Illinois, USA (project by Hoerr Schaudt) is another example of this effect; here, the spatial arrangement is associated with a stormwater management and purification system for water running down the streets (figure 6).

The application of SUDS in the arrangement of buildings and public spaces allows social expectations concerning the quality of urban space to be coupled with enhancing the efficiency of technical infrastructure and the city's ecological assets. The cultural potential of water expressed in the abundance of multisensory cues and its symbolic message make it the perfect material for attractive compositions in public spaces. Water compositions help shape the desired features of good public space (table 3).

Photo: <www.hoerrschaudt.com>

Figure 6. Uptown Normal Circle equipped with a stormwater management system in Normal, Illinois, USA

Summary

In the face of climate change and constant urbanization pressures, a radical shift in the approach to stormwater and surface management is required in Polish cities to protect the natural environment and respect the rights of water in particular. Improving the integration of spatial planning with water management on different fronts is essential.

The following steps need to be taken with regard to legislation and planning:

- adjust the Construction Act and the Act on spatial management and planning to the requirements and strategic goals of water and environmental management, such as abolishing the obligation to connect new investments to the combined sewer network and introducing the legal tools to support the decentralization of stormwater management systems;
- include catchment-based management in local planning documents: introduce mandatory development of small retention programmes in cities or extend the scope and significance of studies in physiographic ecology; include water and environmental goals in studies of determinants and directions of spatial development of a city/commune and transpose the requirements of these to the entries in local spatial management plans and decisions on the conditions for development;
- detail the principles of spatial planning in areas of significant flood risk. Use flood hazard and flood risk maps to establish guidelines for the conditions of land use (and development where appropriate) for particular risk zones. Include urbanization pressures on the one hand and the need to protect ecosystems and to guarantee certain retention capacity on the other. Limit the possibilities of issuing building permits by way of administrative decisions, especially in flood risk zones;

Table 2. The possibilities for applying different elements of SUDS depending on the type of urban space (based on Januchta-Szostak 2011)

Type of urban space/ type of development	Surface run-off index	Benefits of implementing SUDS for public use	Proposed SUDS implementation	
			In public areas	In private areas
Historic city centres quarter development (very dense)	0.7 ÷ 0.9	Improved aesthetics of representative public spaces; resident integration, recreation, elimination of stormwater runoff to the combined sewer network; improved conditions for vegetation (replenishing groundwater), increased area of greenery, improved microclimate	Decorative compositions with recirculating water on squares, retention in underground reservoirs (recommended) and open reservoirs (limited), infiltration with the use of underground elements (leaching systems, drains, plain edge channels), municipal use of water for firefighting, plant irrigation and street cleaning	Limited possibilities of using green roofs (guidelines of building maintenance operatives); retention in underground cisterns, recirculation systems, vertical gardens; municipal use of water for toilet flushing and irrigation within buildings or quarters
Downtown areas quarter development, compact along streets	0.5 ÷ 0.7	Improved aesthetics of public space and opportunities for resident integration and recreation, increased area of greenery, reduced surface runoff, improved microclimate	As above; the use of all public areas of greenery (squares) for retention and infiltration, and the introduction of street furniture involving water and water playgrounds	Green roofs and facades; retention, infiltration and purification, the use of rainwater for toilet flushing and irrigation
Single family dwellings in housing estate areas sparse development along streets, detached and terraced housing	0.2 ÷ 0.5	Possibility of creating spaces for integration, playgrounds and rain gardens; reduced surface runoff, increased area of public greenery, calming road traffic	The use of water playgrounds, rain gardens, streetside retention/infiltration zones to slow down traffic, integrate and educate residents; small public spaces — no possibilities for park creation	Water management primarily on individual lots; retention and infiltration in private gardens, green roofs, rainwater used for toilet flushing, irrigation of gardens and housekeeping tasks — saving drinking water
Multi-family residential areas block housing, sparse development	0.2 ÷ 0.5	Individualized space, the use of water for resident integration, playgrounds and rain gardens, reduced runoff, calming road traffic	Ample possibilities for retention, infiltration and biological purification in public space with the use of landscape systems, street furniture involving water, educational pathways and playgrounds	Green roofs and facades; retention and infiltration through perforated surfaces of parking lots; municipal use of rainwater to irrigate greenery within the housing estate
Areas of large-scale development industrial, commercial development	0.2 ÷ 0.7	Elimination of polluted stormwater runoff, improved visual and functional attractiveness, creating an eco-friendly image	Small public spaces, mainly associated with public transport —use of filtration and sedimentation for runoff purification and neutralization of pollution; decorative compositions of plants and water	Green roofs and facades; retention and infiltration through pervious surfaces of parking lots, filtration and sedimentation; municipal use of water as above and in decorative/recreational systems
Park areas recreational and auxiliary development	0.0 ÷ 0.1	Improved attractiveness and educational qualities of parks; increased biodiversity; pre-treatment and infiltration of stormwater runoff, groundwater recharge	The primary areas for the application of retention/infiltration systems; possibility of creating sustainable biotopes of significant landscape, social and natural value; sites for large reservoirs and landscape arrangements, such as wetlands and infiltration fields	

Table 3. Possibilities of using water to create attractive public spaces (based on Januchta-Szostak 2011)

Key features of good public space	The objectives and desired ways to arrange public space with the use of water
1. Integrative	• inspiration to actively participate in space; • spatial arrangement and equipment of space that allows users to interact with each other and facilitates intergenerational integration; • stimulation of people-to-people contacts, encouragement to play, "taming" water; • co-responsibility for the functioning of the system, neighbourhood connection, efficient management, pride; • building social consensus for environmentally-friendly solutions; • participation in the creation and maintenance of public spaces; • creating habitats that are attractive to various animal species (possibility to observe and get to know the biodiversity of urban ecosystems).
2. Accessibility and continuity	• physical availability of public space for all users, including children, the elderly and disabled; • visual and physical contact with water; • continuity of waterside walking and cycling paths; • exposing water at intersections of recreational pathways and public transport routes, and at the points of destination; • creating clear entrances to stormwater management areas (e.g. in parks) that are inviting, intriguing and readily accessible; • compositional continuity of water bodies (from source to outlet); • associating flow directions with the compositional axes of public spaces (visual guidance for users).
3. Educative	• using water's symbolic and compositional qualities to convey the essence or cultural importance of a place (*genius loci*); • mysteriousness: intriguing, encouraging to explore space while giving a sense of both adventure and safety; • edutainment: the use of simple hydrotechnical equipment (such as mini-weirs, sluice valves, drain wells, pumps, Archimedean screws, water tables), learning the laws of physics and hydraulics through play; creating compositions that can be modified by users; • using ecosystems to arrange educational pathways and games or cultural events; • visual clarity of the processes of water transportation, retention, infiltration and purification (stormwater management systems), reflecting the stages of the hydrological cycle; • the use and exposure of water purification processes (elimination of garbage and neutralization of pollutants); • shaping ecological awareness: providing information on aquatic ecosystems (the related processes, principles of functioning and significance) and their impact on the natural environment and humans.
4. Comfort and safety of use	• safety of use, especially for children: safely shaped structure of the coastline and bottom of water bodies (gradual progression), depth adjusted to the type of use; constraining water depth by creating wetlands; in the case of deep reservoirs with steep banks: restricting access to water with balustrades, short walls, railings or strips of greenery; • building bridges, piers and platforms for safe water-viewing, the use of stones, pieces of concrete etc. as alternative pathways across shallow waters;

Key features of good public space	The objectives and desired ways to arrange public space with the use of water
4. Comfort and safety of use **(cd.)**	• spatial arrangement and amenities for various groups of users (children, the elderly, the disabled); creating comfortable lookouts or places to sit (short walls, benches, tree trunks, large stones etc.) to encourage residents to observe surroundings and become acquainted with them; • ensuring appropriate lighting of public spaces (possible use of reflections in the water); • using the positive psychological and microclimate impacts of water; • simplicity of water installations (avoiding the use of technologically advanced solutions); fail-safe, easy to maintain; • constructions such as shelters close to attractive elements of the system allow observations during rain and heat waves (shade); • the use of water (water curtains, phytoremediation) to reduce the negative impact of the urban environment (e.g. traffic).
5. Image of a place	• clean water and coastline; • clear structure and compositional coherence with public space and architecture; • architectural aesthetics (colours, quality of materials and performance): adjusting to the place's ranking, the use of local materials and techniques; • diversified water forms and the use of compositional assets (reflection, movement, variability, coastline shape etc.), multisensory aesthetic effects: visual, acoustic, aromatic, tactile; • creating elegant, simple compositions, moderation in the choice of forms, textures and colours; • the use of varied water levels and water dynamics in the composition; • symbolic message of water compositions; • using the aesthetics of plant compositions accompanying water bodies; • charm, appeal, secrecy, the magic of water (magical places); • identity: highlighting specific features of a place, reference to historic forms, building on traces, recreating aquifers of the past; • prestige: the water foreground increases the prominence of representative sites by exposing architecture and art in public spaces; • possibility of organizing cultural events.
6. Functional attractiveness	• multifunctional water and water-related arrangements (biocenotic, educational, decorative, recreational, isolating, sanitary etc. functions), e.g. using the sound of water to neutralize traffic noise or strips of greenery to create visual barriers and for access control; • forms and functions adjusted to the prominence and character of a public space; • possibilities for water and waterside recreational activity (urban beaches, swimming, boats/kayaks, water playgrounds, angling etc.); offering a wide spectrum of activities in public space; • adjusting to different forms of human activity; zoning of activity areas (stimulation/relaxation, integration/isolation); • improved attractiveness of public space in different seasons and during unfavourable meteorological conditions (rain and heat waves).

- make better use of environmental impact assessments: include compensation for lost retention capacity of urban catchments;
- increase the presence of non-technical flood prevention measures[12] through coordinated planning, legal and economic activities;
- implement integrated planning and design methods, improve inter-sectoral integration, data coherence and availability.

In the economic domain, it is vital to:

- use economic tools to motivate investors to increase the percentage share of biologically active areas. Encourage stormwater retention and management on individual properties by introducing subsidies for the installation of stormwater collection systems or differentiating stormwater collection fees depending on: the volume and degree of pollution, point valuation on the ecological value of land, and the type of solutions used for retention/infiltration;
- impose penalties for exceeding the percentage of impervious surface area stipulated in the construction project and building permit;
- redistribute the environmental fee for the collection of polluted stormwater to property owners.

In the social domain, it is necessary to:

- extend educational and promotional activities by promoting good stormwater management practices and supporting environmental education programmes and local grassroots initiatives;
- develop space and public facilities (especially schools and kindergartens) in a way that allows environmental education through play (e.g. recreational/educational pathways, water playgrounds, rain gardens);
- include local communities in the processes of planning, implementation, maintenance and monitoring of small retention systems and water ecosystem revitalization;
- use the cultural potential of water ecosystems and elements of infrastructure (SUDS) to create sustainable, multifunctional and socially attractive public spaces (parks, squares, streets, coastlines and public facilities) that are accessible to all users.

The primary role of urban planning in water management is to coordinate planning processes by including e.g. the main water management goals and translating these into the supervision of the degree of surface sealing and type of land use. Water sensitive planning and design is also crucial, both at the urban level and at the level of particular districts, housing estates and public spaces (such as parks, squares or river valleys). Individual buildings and lots should use architectural solutions that allow them to reduce and slow down surface runoff as well as to retain, purify and use rainwater on-site. The benefits of sustainable stormwater management and environmentally-friendly development of waterside areas are appreciable not only in the domains of ecohydrology and landscape but also on the social and economic levels (cf. Januchta-Szostak 2012).

[12] Such as: improving the retention capacity of urbanized catchments by reducing the degree of admissible surface sealing and volume of surface runoff from particular urban areas, as well as increasing the retention capacity of river valleys (creating riverside buffer parks, restoring oxbow lakes and wetlands).

Case study:
Singapore: integration of spatial planning and water management

Singapore is the second most densely populated country after Monaco (7,540 people/km^2). The island's 572 km^2 area has been 90% urbanized. The country has very little natural open space (4.5%) and scarce water resources (figure 7). The current household use of potable water is 155 litres per person per day. Drinking water is imported from Malaysia and obtained from precipitation, desalinated ocean water or purified waste water. For many years, rainwater resources were being squandered as they were quickly directed to the ocean via channelized rivers. Heavy pollution and the associated environmental degradation were also an issue. Due to significant urbanization and the intensification of extreme weather events (monsoon rains, typhoons), Singapore is at risk of urban and ocean flooding. Periods of drought are also acutely experienced on the island.

Singapore authorities have focused on new technology, the integration of spatial planning with water management, and the participation of society and businesses in the protection of water resources (3P Approach – Water for All: Conserve, Value, Enjoy programme). Singapore's Ministry of the Environment and Water Resources in agreement with the Urban Redevelopment Authority (responsible for the country's spatial planning) introduced a host of programmes aimed at using stormwater in urban drainage basins (which now cover 2/3 of the country's surface area) through the implementation of SUDS, river revitalization, the construction of retention reservoirs and the use of green infrastructure. Among the most crucial of these programmes is ABC Waters (Active, Beautiful, Clean Waters, 2007–2030) that aims to: invigorate waterside public spaces, bring people closer to water, encourage a sense of co-responsibility for the environment and water resources (Active); beautify water bodies and areas of greenery integrated with the urban landscape, promote development that goes beyond anti-flood and retention measures, create tourism and urban water attractions (Beautiful); improve water quality, provide ecological education and build a relationship between residents and water (Clean) (figures 8 and 9). The programme included the establishment of integrated water management and spatial management plans. Over 100 potential locations for project implementation were indicated, and a legal framework and recommendations were developed that included guidelines for the creation of rain gardens, bioretention swales, purification biotopes, river and canal renaturalization, and the enhancement of biodiversity. The programme is partly financed from taxes: the water conservation

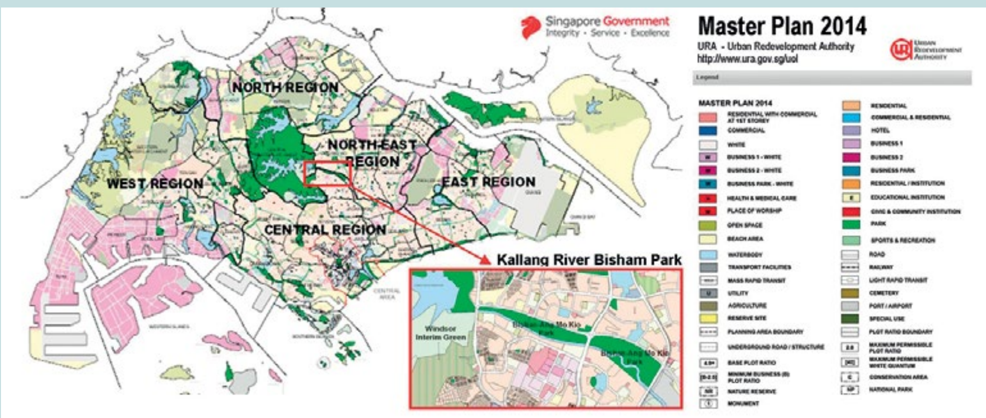

Photo: Urban Redevelopment Authority <www.ura.gov.sg/uol>

Figure 7. Singapore: local plan 2014 Urban Redevelopment Authority, Singapore

Photo: Atelier Dreiseitl <www.dreiseitl.com>

Rysunek 8. Bisham Park (Kallang River) was created as part of the ABC Waters programme

Figure 9. Left: bird's eye view of Bisham Park. Right: transformations of the river Kallang: A) concrete riverbed prior to the revitalization, B) view of the valley after renaturalization

tax for water resource restoration, the waterborne fee based on the volume of water supplied, and sanitary appliance fee for waste water collection based on the number of sanitary fittings in a premise. Singapore's National Water Agency is responsible for the execution of projects.

One of the most spectacular investments is Bisham Park (project by Atelier Dreiseitl, 2012, area of 62 ha) which allows to retain monsoon rainfall and prevent flooding while at the same time providing attractive space for recreation and habitat for many plant and animal species. The channelized section of the river Kallang (a 2.7 km long concrete canal) was renaturalized and extended to 3.2 km (figures 10 and 11). Retention capacity was greatly increased in that part of the valley and the revitalization of the littoral zone enhanced the river's self-purification capacity. The beautiful landscape arrangement, the park's availability and educational qualities coupled with the adjacent service facilities and playgrounds have become an attraction for both residents and tourists.

References

Baca Architects, BRE, 2009. *Long-term initiatives for flood-risk environments*, London: Crown.

DCLG (Department for Communities and Local Government), 2009. *Planning Policy Statement 25: Development and flood risk. Practice guide*, London: Crown.

Januchta-Szostak, A., 2011. *Woda w miejskiej przestrzeni publicznej. Modelowe formy zagospodarowania wód opadowych i powierzchniowych*, Poznan: Wydawnictwo Politechniki Poznańskiej.

Januchta-Szostak, A., 2012. Urban water ecosystem services. *Sustainable Development Applications*, 3, pp. 91–110.

Januchta-Szostak, A., 2013. Multifunctional riverside buffer parks — the research on nature-urban revitalisation of river valleys. *Journal of Sustainable Architecture and Civil Engineering*, 4(5), pp. 42–50.

Kronenberg, J., 2012. Urban ecosystem services. *Sustainable Development Applications*, 3, pp. 13–30.

Kundzewicz, Z.W., Gromiec, M., Iwanicki, J., Kindler, J., Matczak, P., 2014. Raport o zagrożeniach związanych z wodą — wprowadzenie. *Nauka*, 1, pp. 59–62.

Maier, W., Bender, E., Bigga, L., eds., 2012. *Urban rivers — vital spaces*, Stuttgart: REURIS.

Water in the urban space and the health of residents

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The processes of urbanization deprive cities of water and greenery and residents of a healthy living environment. Concrete-dominated space makes people more prone to cardiovascular diseases, obesity, depression, osteoarthritis, asthma and allergy. The lack of water and greenery in urban space is one of the significant causes of allergies which are currently the top health concern for Polish children and adults below the age of 30. The inclusion of blue-green infrastructure in urban planning is one of the crucial preventive measures in the fight against the epidemic of lifestyle diseases. Blue-green infrastructure improves air temperature and humidity, reduces pollution, stimulates the human immune system, provides favourable conditions for outdoor activities, and consequently, helps maintain proper body weight, good physical endurance and optimum mental health. In this chapter we show how the inclusion of blue-green infrastructure in the urban system helps to retain water and support the ecosystems' ability to provide services by creating healthy urban space, thus improving the living conditions of residents and helping the city move closer to sustainable development.

Keywords: asthma, allergies, diseases of affluence, blue-green infrastructure, water in the city, soil sealing

Introduction

According to data from the Central Statistical Office of Poland, in the 21st century asthma and allergy have become the number one health problem for children and adults below the age of 30. The prevalence of these diseases has risen dramatically in recent years (figure 1). In the mid-1990s, asthma sufferers aged 13–14 years old, in Poznan constituted 2% of the city's population, while in 2001–2002 this number had risen to over 5%. Prevalence rose from 2.3% to 6.8% in the same period in Krakow (Lis et al. 2003). In other words, disease morbidity in large cities more than doubled in less than a decade.

A detailed data analysis for Lodz province (Lodzkie Voivodeship) where the prevalence of asthma and allergic rhinitis is around the national average (Kupryś-Lipińska et al. 2010) has revealed an approximately 3-fold difference in morbidity between the densely built city centre and green rural areas located 18 km away (figure 2). This phenomenon was confirmed by another study on the prevalence of asthma carried out in Lodz province in a group of adolescents aged 12–16 years old (Majkowska-Wojciechowska et al. 2007).

Urbanization and health

People live in a close relationship with nature. The rapid changes in the natural environment caused by the development of civilization exceed the body's natural ability to adapt and are one of the main contributors to non-infectious chronic diseases, known as lifestyle diseases or the diseases of civilization. As residents have less and less everyday contact with nature, and neither the need, space or motivation to engage in physical activity, the risk of developing one of these diseases increases dramatically. Lifestyle diseases include cardiovascular diseases, diabetes, osteoarthritis, cancer, depression and other psychological disorders, as well as chronic respiratory diseases and allergies. The latter are largely attributed to the lack of water and diversified assemblages of indigenous plants in the urban space.

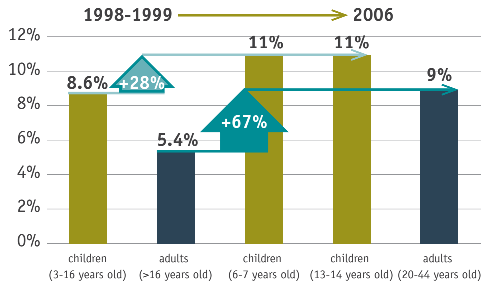

Figure 1. Increased prevalence of bronchial asthma in Poland (based on Liebhart et al. 2007; Samoliński et al. 2009)

Urban desiccation results from the uncontrolled spreading, high density of development and disproportionate expansion of grey infrastructure (traditionally designed buildings, streets, parking lots, sidewalks, concrete or asphalt yards) in comparison with green and blue infrastructure. Each and every decision to regulate the remaining semi-natural rivers or reservoirs in the city, to fill up or channelize a drainage ditch or wetland, carry out an investment at the expense of a green space, square, park, meadow or old orchard, to extend a street lane or sidewalk at the expense of streetside greenery or similar actions degrade the city's natural system which acts as a natural air humidifier (we discussed this topic in the previous guidebook in this series called "Nature in the city. Solutions"). These might seem local actions of no significance to the functioning of the city as a whole, however, their widespread application alters the conditions for water cycling and urban greenery, and has serious health implications for city dwellers. The effect of excessive urban desiccation is further intensified by traditional water management methods oriented at draining off stormwater as quickly as possible.

Increased prevalence of allergic diseases and bronchial asthma

Allergic diseases including most cases of asthma result from the immune system's abnormal response to allergens: substances (usually proteins) commonly present in the environment that are harmless to healthy people. In the early 20th

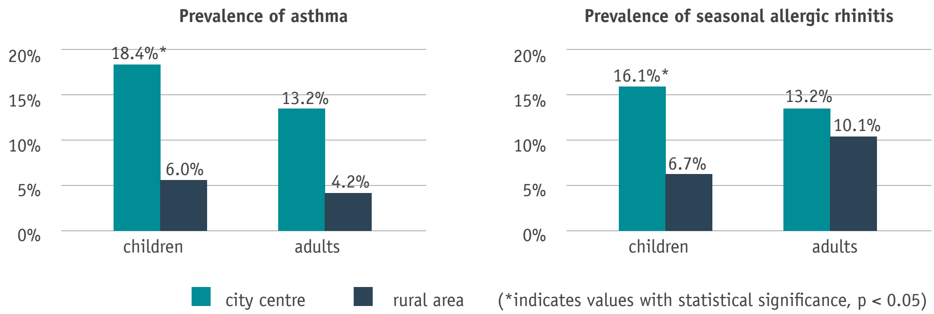

Figure 2. Comparison of the prevalence of asthma and allergic rhinitis in the urban and rural population in Lodz province (based on Kupryś-Lipinska et al. 2009)

century allergies were rare (affected less than 1% of the population) and poorly known (Kupryś and Kuna 2003). However, in the second half of the 20th century this proportion rose even up to 40% is some communities. According to the World Health Organization (WHO), there are currently over 400 million sufferers of allergic rhinitis and over 300 million sufferers of bronchial asthma around the globe (Bousquet et al. 2007). Which leads to the question: Why the change?

Genetic factors are one of the most important contributors to the increased morbidity. However, genes are not the only factor to blame for this sudden and universal increase in the prevalence of asthma and allergy around the globe. Genomic changes occur slowly and their influence in large populations can be observed only after generations. Meanwhile, epidemiological studies have shown environmental factors play a key role in the development of allergic diseases and asthma. These factors can act in a number of ways, e.g. by activating genes that are responsible for allergy or by facilitating the contact of allergens with immune cells, consequently damaging the natural protective barrier of the skin and mucosa. The increased risk of developing these diseases may also result from increased allergen concentrations, their prolonged action, or the introduction of new allergens in the environment or changes in their allergenicity (i.e. ability to trigger an allergic reaction).

Epidemiological studies have shown environmental factors play a key role in the development of allergic diseases and asthma.

One of the unquestionable manifestations of environmental changes is fast urban development that has the most pronounced effect on the living conditions of societies. Moreover, it is a process that affects vast numbers of people: while in the 1960s only 25% of the global population lived in cities, currently this number is approaching 55%. Therefore, the causes of increased morbidity are being sought among the factors associated with the advancement of civilization. Studies show that allergies and asthma are most prevalent (affect even up to 40% of the population) in highly developed countries with a western lifestyle, especially in residents of large cities. Disease incidence is 15 times higher than in developing countries (ISAAC 1998; ECRHS 1996).

Causes of high allergy and bronchial asthma morbidity in cities

The causes of the high prevalence of lifestyle diseases including bronchial asthma and allergy among urban residents are complex, but urbanization is undoubtedly an aggravating factor (figure 3).

Higher temperatures and reduced biodiversity

Cities that are built up with grey infrastructure and deprived of water and greenery are grappling with the urban heat island effect. The increased coverage of impervious surfaces associated with dense development and road networks coupled with the use of easily heating materials contribute to the occurrence of extremely high temperatures in the summer and significantly increased temperatures (compared with suburban areas) in the winter. Differences in temperature between the city and areas located beyond its boundaries can be staggering and are affected by climate zone, city size, development density, 3-dimensional structure, and level of economic development. Studies in over 400 large cities worldwide have shown that the urban heat island effect is responsible for an annual increase in air temperatures of about 1.5 (± 1.2)°C during the day and about 1.1 (± 0.5)°C at night (Peng et al. 2012). However, at the level of individual cities this process is much more diversified. For instance, the temperature difference between the city centre of Lodz and its suburbs hovers around 2–4°C most of the time, occasionally reaching 8°C, while the maximum observed difference was even 12°C (Kłysik and Fortuniak 1999).

Persistent high temperatures can have a negative effect on human health, exacerbating health problems, causing malaise and even premature death, especially in individuals suffering from chronic cardiovascular or respiratory diseases, as well as in infants, young children, the elderly, and in the socially excluded and living alone. The most dangerous situation occurs during hot summers in parts of the city without greenery (large squares, parking lots, extensive road and residential infrastructure with no green space). Daytime temperatures in such spaces can reach 40–50°C, making it impossible to stay outside or go about daily activities. It is estimated that heat waves in Europe in 2003 were responsible for at least 52,000 premature deaths (EPI 2006), predominantly in overheated cities. The small presence of blue-green infrastructure contributes to this effect significantly by further impairing the city's ability to adapt to global climate change (EEA 2012).

Due to the increased temperatures, plant pollination periods are longer and intensified, especially in undiversified natural systems. The risk of disease can be exacerbated in urban space that is depleted of indigenous species and characterized by poor biodiversity, e.g. where only one or two species are present in large numbers in an area. Allergy-causing species, especially when growing densely and without other plants, have a stronger effect on the human body. It is also worth remembering that higher temperatures increase the expansion of new plant species and the chances of survival for exotic species. The latter should not be used in cities as they may bring about new, previously unknown allergies (Carinanos and Casares-Porcel 2011).

Decreased air humidity and atmospheric air pollution

Another phenomenon associated with the urban heat island effect is decreased air humidity. In Lodz, the differences in relative humidity between the city centre and its surroundings tend to reach 20–30%, with the highest recorded differences around 40% (Fortuniak et al. 2006).

Desiccated air affects human health in two ways; firstly by causing dryness and damage to the skin and mucosa, making it easier for bacteria, viruses and allergens to have a detrimental effect on the body. Secondly, particulates and pollutants are more easily suspended in dry air and hence the increased risk of disease.

Atmospheric pollution increases the prevalence of allergies. Elevated concentrations of SO_2, O_3 and small particulate matter (PM10) exacerbate the symptoms of asthma. Pollution with organic compounds, oxides and ozone, which is related to car exhaust fumes, especially from diesel engines, is typical for large cities in highly developed countries and also contributes to the development of allergies. The incidence of pollinosis in Japan was found to be higher in individuals living close to highways (with comparable concentrations of cedar pollen in the atmospheric air) (Ishizaki et al. 1987). In Germany, the prevalence of pollinosis, symptoms of allergic disease and allergy to pollen, dust mites, cat allergens and milk were found to increase with atmospheric air levels of nitrogen (NO_2) (Kramer et al. 2000) which reflect the degree of air pollution from car exhaust fumes.

The negative effect of pollutants consists of damaging the airway epithelium. This facilitates

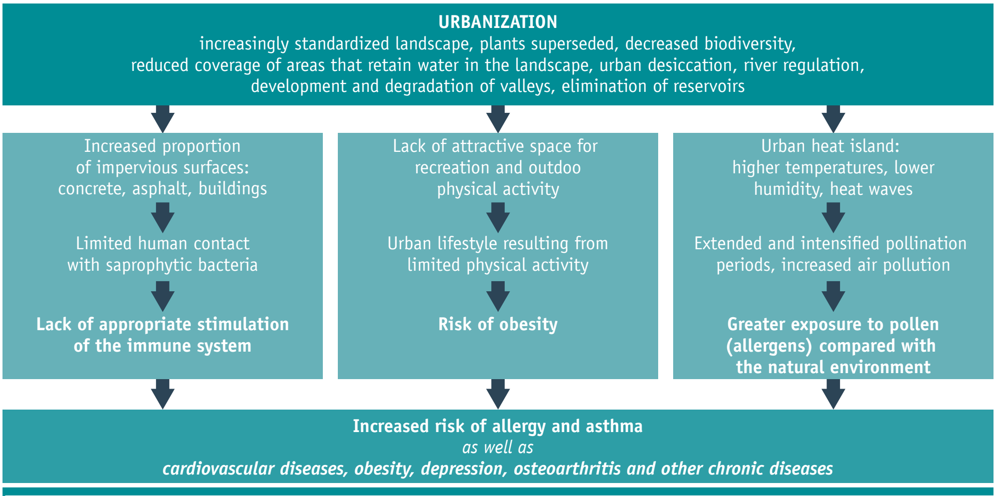

Figure 3. Impact of urbanization on the incidence of bronchial asthma, allergy and other lifestyle diseases

the penetration of allergens and their contact with the immune system, and leads to inflammation of the respiratory tract. Chemically active compounds can also act on allergens directly by changing the structure of proteins, thereby contributing to their increased ability to trigger an allergic reaction. Additionally, pollutants may cause plants to produce proteins that have protective functions for the plant but are strong allergens for humans.

Lack of contact with microorganisms

The results of epidemiological studies point to a strict correlation between the incidence of asthma and the development of grey infrastructure (Rodriguez et al. 2011; von Hertzen and Haahtela 2006). Surface sealing, river regulation, the elimination of green spaces and aquatic ecosystems are all activities that reduce the humidity of the urban environment. Consequently, the numbers of microorganisms living in the air, water and soil declines as these are unable to survive the conditions of urban drought. This in turn causes qualitative and quantitative changes in bioaerosols: a suspension of airborne microorganisms and the products of their decomposition, as well as other components of living organisms from the soil and air.

This type of environment does not create healthy living conditions for urban residents. According to the hygiene hypothesis, allergy (which is also the primary cause of asthma) results from dysfunctions of the immune system. The system's normal development occurs during a child's contact with pathogenic microbes. Limited exposure or the lack of it, e.g. due to excessive cleanliness, food sterilization and the widespread use of antibiotics contributes to the development of allergy and asthma (Kuna and Kupryś-Lipińska 2010). Saprophytic microorganisms (bacteria and fungi) in the external environment are equally important to human health: due to their diversity and large numbers they may be playing a key role in the development of allergy.

The crucial role of external bacteria in the development of the immune system was confirmed by studies on the impact of the rural environment on the prevalence of allergy and asthma. Children born in rural households were shown to develop these diseases less often (Filipiak et al. 2001), especially when the households included animal farms which increase the number of microbes in the environment. The risk of developing allergy and bronchial asthma in people who migrate from rural to urban areas (more deprived from the point of view of microbiology) increases to levels found in individuals born in cities, suggesting a strong influence of urbanization-related factors on human health, irrespective of exposure time.

Urban lifestyle

In addition to the dense development in cities depleted of attractive green spaces and water, the increasing popularity of a sedentary lifestyle and spending time mostly indoors are also detrimental to health and lead to restricted contact with microbes in the natural environment. People living in multi-family housing have significantly less contact with microbes than those living in single-family houses or outside of the city that have more opportunities and possibilities of spending time outdoors. Limited physical activity is also responsible for an increased risk of cardiovascular diseases (Drygas et al. 2000) and obesity, another plague of civilization with serious health implications. Obese individuals are at greater risk of developing diabetes, cardiovascular diseases, osteoarthritis, depression and bronchial asthma. In the case of asthma, this effect is directly correlated with body mass index (BMI): in individuals whose BMI exceeds 25 (overweight and obese), annual asthma incidence increases by over 50% compared with people with a normal BMI score (Beuther et al. 2007).

Blue-green infrastructure in shaping a healthy city

Urban development is an inevitable consequence and the driving force of the advance of civilization. It is economically, socially and culturally beneficial and desirable. The challenge, however, is to guide this development so that it has a positive effect on all areas of life, including the quality of the natural environment and the associated human health impacts. This is where integrated urban management comes into play (cf. chapter on integrated management: Krauze and Wagner in this volume) where both the infrastructural needs of the growing population, and quality of life and health-related needs are met.

Shaping the natural environment in cities is a particular challenge: the space available for ecosystems is severely limited due to the significant land transformations caused by the increasing density of grey infrastructure and intensive human activity. At the same time, high prices of land create strong pressure for dense development. As a direct consequence, water cycling in the landscape is disturbed, (bio)diversity of the urban natural system decreased and ecosystem continuity lost. These effects lead to the dysfunction of the natural system, limiting ecosystems' ability to provide services that are essential for urban residents' health. Corrective measures should focus on restoring this ability.

Water retention in the city: improved air humidity and quality

Water retention in the city is the key to a healthy living environment. It may be increased via planning tools (greater proportion of biologically active areas, surface de-sealing, creating more diverse and interlinked blue-green infrastructure) combined with the best practices in stormwater management, ecohydrological solutions and ecosystem biotechnology (cf. chapter on technical solutions: Wagner and Krauze in this volume). This helps decrease air temperatures, increase its humidity and improve its quality. The results of numerous international studies show that lower air temperatures and higher humidity lead to reduced concentrations of harmful particulates, especially PM10: a mixture of very small particles (less than 10μm in diameter) that may contain toxic substances such as polycyclic aromatic hydrocarbons, e.g. benzo(a)pyrene, heavy metals, dioxins and furans. A study in the Romanian city of Drobeta-Turnu Severin revealed that the irritant effect of these pollutants on the respiratory tract is so dramatically reduced during humid weather that it translates into significantly less hospital admissions for exacerbation of chronic respiratory diseases (Leitte et al. 2009).

In cases where the use of a blue-green infrastructure system is impossible, the presence of at least some greenery in densely built areas can have a positive local effect whose importance for neighbouring residents cannot be overestimated. A single tree can transpire up to 500 litres of water a day, acting as a local air humidifier. However, the mere presence of trees does not improve microclimate unless they are provided with sufficient amounts of water. In the face of drought, plants stop transpiring water into the atmosphere (Wagner et al. 2013). Therefore, it is essential to provide the root system of trees with access to water and this is a potential application for the valuable stormwater retained in the urban space.

The presence of plants also improves air quality. Filtration capacity depends primarily on the leaf surface area, which explains why trees are much more efficient at capturing pollutants than low shrubs or lawns. Notably, sparse tree groupings which allow the free flow of air and tree alleys are more efficient than single trees. The best outcomes can be achieved through the incorporation of diversified, incremental plant assemblages (e.g. lawn + shrubs + trees). A park can filter even up to 85% of pollutants, and a tree-lined roadway – up to 70% (Bernatzky 1983).

Preserving natural system (bio)diversity: reducing the amount of allergens and stimulating the immune system

Diversity is a crucial element of blue-green infrastructure design in urban strategies aimed at disease prevention, and covers the species, ecosystems and landscape forms of a city. Diversified natural forms that retain their natural character (to the extent possible) support the resistance of the urban natural system in conditions of stress and changing external factors such as climatic changes and anomalies. In turn, a functional natural system reinforces human resilience: contact with nature promotes mental and physical regeneration and the presence of microbes in the environment stimulates the immune system.

In parts of the city where plantings are made it is vital to enhance biodiversity and plant indigenous species. Ensuring diversity in terms of taxonomy (different species and genera), morphology (diversified sizes and shapes) and biology (different pollination strategies and periods) can be a good strategy. High quality natural systems are based on indigenous (i.e. typical for the region) species and phytocenoses. It is also advisable to plant trees which do not tend to cause allergy, so the recommended species for Polish cities would include: hornbeam, maple, elder, spruce, pine, as well as jasmine, horse-chestnut, rowan, fir, larch, female (pollen-free) poplar, willow and ash trees; shrubs such as cotoneaster, boxwood, dogwood, forsythia, quince, barberry and hawthorn; and climbing plants such as the common ivy, five-leaved ivy and silver lace vine. Apart from their beneficial effect on human health, these species are also better adapted to local conditions and therefore more likely to function properly in conditions of urban stress due to their ability to regenerate from the natural gene pools of phytocenoses near the city.

Preserving the continuity of the natural system: better mental and physical regeneration

To preserve the continuity of the natural system, efforts should be made to ensure that its elements are distributed as evenly as possible throughout the city and interconnected with physical, spatial links. This applies to both semi-natural and natural aquatic and land ecosystems, as well as artificial elements with environmental/social functions, such as: ecohydrological solutions, stormwater management-related structural solutions, streetside greenery, community gardens, cemeteries, parks etc. One example of this approach has been described in the first guidebook in this series: the Blue-Green Network concept for the city of Lodz (Zalewski et al. 2012; Wagner et al. 2013).

The functioning of ecosystems that are interconnected and form a network (natural system) is much better than in isolation. This is because the natural system's capacity for long-term water retention and its slow release is improved, as well as its performance in extreme conditions, e.g. during extended periods of drought and in high temperatures, which is precisely when ecosystems' impact on urban microclimate is of greatest value to city residents.

Preserving natural continuity improves the attractiveness of urban space and the availability of green areas to residents. It also creates opportunities for outdoor physical activity and helps develop the need for this and change health behaviour habits. The habit of resting through recreation and sports enhances mental and physical regeneration and helps maintain normal body weight, good physical endurance and mental health. It is also a way of preventing the most common chronic diseases associated with urbanization-induced lifestyle changes and the effects of the urban social environment, i.e. obesity, diabetes, cardiovascular diseases, osteoarthritis, depression, neurotic conditions, asthma and allergy. The connections between green spaces allow the development of alternative forms of transportation, encouraging increased physical activity and contributing to the reduction of harmful car emissions. Data from Atlanta shows that the temporary reduction in traffic intensity by 22.5% at the time of the Olympic Games resulted in a reduction in the number of asthma-related hospital admissions by 41.6%, while not affecting the number of admissions for other reasons (Jackson and Kochtitzky 2001).

Natural capital in sustainable urban development

The current recommendations for the treatment of many chronic diseases (including allergy and bronchial asthma) include custom-tailored therapy that is adjusted to the patients' needs, possibilities and expectations. This approach yields good treatment results at the individual level. However, systemic solutions are required to reverse the unfavourable urban trends. The creation of an urban environment that is truly friendly to human health seems to be one of the most important preventive measures in the fight against the epidemics of non-infectious chronic respiratory diseases and many other diseases of civilization.

A healthy urban environment is also the backbone of sustained and sustainable urban development that is based on the uniform development of economic, social and natural capital. Apart from its intrinsic value, natural capital contributes to the shaping of a healthy society (enhances social capital). This in turn increases competitiveness and satisfaction and helps equalize development opportunities; in combination with attractive green space these are the features of an investor and employer-friendly city (enhanced economic capital).

The practicalities of the concept of natural capital are associated with blue-green infrastructure. With integrated planning, it can unite a city's structure and functions. This is only possible, however, if blue-green infrastructure is genuinely incorporated in the planning and design as well as investment and revitalization processes, on a par with grey infrastructure, from the very early stages. The health of future generations growing up in the cities designed by us today argues for this kind of approach.

References

Bernatzky, A., 1983. The effects of trees on the urban climate. In: *Trees in the 21st century*, Berkhamster: Academic Publishers, pp. 59–76.

Beuther, D.A., Sutherland, E.R., 2007. Overweight, obesity, and incident asthma: a meta-analysis of prospective epidemiologic studies. *American Journal of Respiratory and Critical Care Medicine*, 175(7), pp. 661–666.

Bousquet, J., Dahl, R., Khaltaev, N., 2007. Global alliance against chronic respiratory diseases. *Allergy*, 62(3), pp. 216–223.

Carinanos, P., Casares-Porcel, M., 2011. Urban green zones and related pollen allergy: a review. Some guidelines for designing spaces with low allergy impact. *Landscape and Urban Planning*, 101, pp. 205–214.

Drygas, W., Kostka, T., Jegier, A., Kuński, H., 2000. Long-term effects of different physical activity levels on coronary heart disease risk factors in middle-aged men. *International Journal of Sports Medicine*, 21(4), pp. 235–241.

ECRHS, 1996. Variations in the prevalence of respiratory symptoms, self-reported asthma attacks, and use of asthma medication in the European Community Respiratory Health Survey. *European Respiratory Journal*, 9(4), pp. 687–695.

EEA, 2012. *Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies*, Luxembourg: Office for Official Publications of the European Union.

EPI, 2006. Setting the record straight — more than 52,000 Europeans died from heat in summer 2003. Earth Policy Institute webpage <www.earth-policy.org>.

Filipiak, B., Heinrich, J., Schafer, T., Ring, J., Wichmann, H.-E., 2001. Farming, rural lifestyle and atopy in adults from southern Germany – results from the MONICA/KORA Augsburg study. *Clinical & Experimental Allergy*, 31(12), pp. 1829–1838.

ľFortuniak, K., Kłysik, K., Wibig, J., 2006. Urban–rural contrasts of meteorological parameters in Lodz. *Theoretical and Applied Climatology*, 84(1–3), pp. 91–101.

ISAAC, 1998. Worldwide variation in prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and atopic eczema. *Lancet*, 351(9111), pp. 1225–1232.

Ishizaki, T., Koizumi, K., Ikemori, R., Ishiyama, Y., Kushibiki, E., 1987. Studies of prevalence of Japanese cedar pollinosis among the residents in a densely cultivated area. *Annals of Allergy, Asthma & Immunology*, 58(4), pp. 265–270.

Jackson, R.J., Kochtitzky, C., 2001. *Creating a healthy environment: the impact of the built environment on public health*, Washington, D.C.: Sprawl Watch Clearinghouse.

Kłysik, K., Fortuniak, K., 1999. Temporal and spatial characteristics of the urban heat island of Łódź, Poland. *Atmospheric Environment*, 33, pp. 3885–3895.

Kramer, U., Koch, T., Ranft, U., Ring, J., Behrendt, H. 2000. Traffic-related air pollution is associated with atopy in children living in urban areas. *Epidemiology*, 11(1), pp. 64–70.

Kuna, P., Kupryś-Lipińska, I. 2010. Astma oskrzelowa. In: Antczak, A., ed., *Wielka interna – Pulmonologia (part II)*, Warszawa: Medical Tribune Polska, pp. 133–134.

Kupryś, I., Kuna, P., 2003. Epidemics of allergic diseases: a new health problem in the modern world. *Polski Merkuriusz Lekarski*, 14(83), pp. 453–455.

Kupryś-Lipińska, I., Elgalal, A., Kuna, P., 2009. Urban-rural differences in the prevalence of atopic diseases in the general population in Lodz Province (Poland). *Postępy Dermatologii i Alergologii*, XXVI(5), pp. 249–256.

Kupryś-Lipińska, I., Elgalal, A., Kuna, P., 2010. The underdiagnosis and undertreatment of asthma in general population of the Lodz Province (Poland). *Pneumonologia i Alergologia Polska*, 78(1), pp. 21–27.

Leitte, A., M., Petrescu, C., Franck, U. et al., 2009. Respiratory health, effects of ambient air pollution and its modification by air humidity in Drobeta-Turnu Severin, Romania. *Science of the Total Environment*, 407, pp. 4004–4011.

Liebhart, J., Malolepszy, J., Wojtyniak, B. et al., 2007. Polish Multicentre Study of Epidemiology of Allergic Diseases. Prevalence and risk factors for asthma in Poland: results from the PMSEAD study. *Journal of Investigational Allergology and Clinical Immunology*, 17(6), pp. 367–374.

Lis, G., Breborowicz, A., Cichocka-Jarosz, E. et al., 2003. International Study of Asthma and Allergies in Childhood. Increasing prevalence of asthma in school children – ISAAC study (International Study of Asthma and Allergies in Children). *Pneumonologia i Alergologia Polska*, 71(7–8), pp. 336–343.

Majkowska-Wojciechowska, B., Pełka, J., Korzon, L. et al., 2007. Prevalence of allergy, patterns of allergic sensitization and allergy risk factors in rural and urban children. *Allergy*, 62(9), pp. 1044–1050.

Peng, S., Piao, S., Ciais, P. et al., 2012. Surface urban heat island across 419 global big cities. *Environmental Science & Technology*, 46(2), pp. 696–703.

Rodriguez, A., Vaca, M., Oviedo, G. et al., 2011. Urbanisation is associated with prevalence of childhood asthma in diverse, small rural communities in Ecuador. *Thorax*, 66(12), pp. 1043–1050.

Samoliński, B., Sybilski, A.J., Raciborski, F. et al., 2009. Występowanie astmy oskrzelowej u dzieci, młodzieży i młodych dorosłych w Polsce w świetle badania ECAP. *Astma Alergia Immunologia*, 14(1), pp. 27–34.

Wagner, I., Krauze, K., Zalewski, M., 2013. Blue aspects of green infrastructure. *Sustainable Development Applications*, 4, pp. 145–155.

von Hertzen, L., Haahtela, T., 2006. Disconnection of man and the soil: reason for the asthma and atopy epidemic? *Journal of Allergy and Clinical Immunology*, 117(2), pp. 334–344.

Zalewski M., Wagner, I., Fratczak, W., Mankiewicz-Boczek, J., Parniewki, P., 2012. Blue-green city for compensating global climate change. *The Parliament Magazine*, 350, pp. 2–3.

The financial mechanisms of urban stormwater management

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The management of stormwater runoff is associated not only with decision-making on the technological and organizational solutions but also with obtaining the necessary funds. A relatively new source of financing investments designed to ensure efficient stormwater management is the fee for discharging rainwater and snowmelt into the sewer system. In Poland, the introduction of this fee sparked many debates and protests among society. Part of the misunderstanding stemmed from inconsistent legislation and the fact that the information campaign for residents was neglected. As shown by other countries' experience, explaining to residents why the fees are introduced and the consequences of failing to collect them, as well as providing technical and financial support in the execution of water management-related undertakings is the key to the successful implementation of fees and their acceptance, as well as to the improved functioning of drainage systems in cities.

Keywords: environmental fees, fees for stormwater and snowmelt collection, impermeable surfaces, green roofs

Introduction

Environmental fees and administrative penalties are the basic source of financing for environmentally-friendly investments, including those related to stormwater management. However, current practice shows that with the increasing needs associated with stormwater runoff regulation, improving the performance of sewer systems and improving the quality of water in household taps, the financial means allocated for these purposes are insufficient. Despite this, financing stormwater discharge and purification based on income e.g. from fees for the discharge and purification of municipal sewage or the water sales revenues of water and sewerage companies is not possible because of the ban on cross-subsidization. This leaves no other choice than to implement an autonomic system of financing stormwater management. Therefore, more and more water and sewerage companies are introducing fees for stormwater and snowmelt collection. Although the requirement to introduce them and methods of their calculation are determined by Polish law, these fees have generated a great deal of controversy, both in legal and social terms. The misunderstandings stem not only from the legal inconsistency, but also from the failure to conduct a public information campaign that would allow residents to understand the objective and designation of the charged fees. The need to educate society is confirmed by the experience of other countries, such as the USA, Germany and Denmark where stormwater and snowmelt collection fees were introduced much earlier than in Poland. It is a good idea to introduce sustainable stormwater management promotion and implementation programmes simultaneously as done by the Portland authorities in the USA. These programmes provide investors with the necessary knowledge as well as technical and financial support. Similar programmes albeit at a smaller scale are offered by some Polish cities, such as Krakow, Gdansk and Warsaw.

The introduction of stormwater and snowmelt collection fees should be linked with activities promoting and implementing sustainable stormwater management systems.

Environmental fees

An environmental fee applies for the collection of rainwater and snowmelt from contaminated surfaces into sewer networks and its subsequent discharge into the ground or water. As stipulated in the Environmental Protection Act[1], the fee for rainwater and snowmelt depends on the size, type and use of land from which the rainwater and snowmelt are collected. The fee is calculated in PLN per year and per m^2 of contaminated surface.

In case of non-compliance with the conditions for environmental use specified by the administrative decision, the environmental user is charged with an administrative penalty. Such penalties together with environmental fees are important economic tools for the protection of waters. The legal basis for their collection is in accordance with the entries of the Environmental Protection Act.[2]

The funds from environmental fees and penalties are earmarked funds used to finance environmental protection and water management-related undertakings. These funds comprise the National Fund for Environmental Protection and Water Management as well as regional (voivodeship), county and commune environmental protection and water management funds. Fees are paid to the Office of the Marshal of the Voivodeship on the territory of which the environment is used, while penalties are payable to the regional (voivodeship) inspectorates of environmental protection, responsible for penalization.

[1] Prawo ochrony środowiska [Environmental Protection Act] (Journal of Laws of 2001 no. 62, item 627, as amended), article 274 section 4 item 1.

[2] Prawo ochrony środowiska [Environmental Protection Act] (Journal of Laws of 2001 no. 62, item 627, as amended), article 298, section 1.

Key issues associated with rainwater and snowmelt fee calculation:

- the fee for rainwater and snowmelt collection is not a tax but a price for the service provided by the water and sewerage company, similarly to the water supply and sewage collection;
- the implementation of fees for rainwater and snowmelt is a long-term process that requires e.g. the determination of land use and the size of the contaminated impervious surface from which stormwater is collected to the stormwater sewer system, the valuation of the sewer network, its contribution in kind to the assets of water and sewerage companies, and determination of fees by the municipal council;
- some communes have introduced fees for rooftop rainwater and stormwater which are legally disputable (a roof is not paving permanently fixed to land), but justifiable in view of the exploitation costs of sewer networks which constitute the basis for fee determination;
- the failure to collect fees deprives water and sewerage companies of a source of funding that is required for investments in technical infrastructure. With the increasing presence of extreme weather events (such as torrential downpours) that make the modernization of the existing sewer network indispensable, this problem is becoming increasingly acute;
- surfaces from which rainwater and stormwater is managed on the property, e.g. introduced to the ground and not to the municipal sewer network, are not charged.

Service fees

Rainwater and snowmelt discharged to the combined or stormwater sewer system is covered by legislation on collective sewage collection, regulated by the Act of 7 July 2001 on the collective water supply and sewage collection.[3] On 16 August 2006, the Ordinance of the Minister of Construction or the so-called tariff ordinance[4] came into force which determines the methods of calculating fees and rates for rainwater and snowmelt discharge. The introduction of fees for rainwater and snowmelt collection in Polish cities was designed to motivate service recipients to manage these waters rationally and limit the pollution load, thereby helping to mitigate environmental changes. There is also an engineering side to these fees: they help to cover part of the exploitation costs associated with land drainage, to expand the existing stormwater sewer system and increase its capacity. Another advantage is allowing the construction of facilities for the pre-treatment of rainwater and snowmelt before it reaches the receiving water body (Burszta-Adamiak 2010). In accordance with paragraph 2, item 10 of the tariff ordinance, the fee for the collected rainwater and snowmelt is expressed in the monetary units that the service recipient is obligated to pay to the water and sewerage company for 1 m^3 of discharged waste water or for a measurement unit of contaminated impervious surface from which the rainwater and snowmelt is collected via the stormwater sewer system.

According to the entries of the ordinance of the Minister of Construction, in areas covered by a combined sewer network the costs of rainwater and snowmelt discharge to the combined sewer system constitute sewage collection costs that are common for all recipients of sewer services (ratepayers) (Ziemski and Bujny 2013). The fee for rainwater and snowmelt discharge into the sewer system is charged on an annual or monthly basis. It is determined for each ratepayer group based on the necessary revenues of the water and sewerage company, as is the case with the collective supply of water.

Rainwater fee implementation in Polish cities

Fees for rainwater and snowmelt collection were first introduced in Poland by the Municipal Water and Sewerage company in Pila in 2003, although preparations were underway since 1993. Other cities

[3] Act on the collective water supply and sewage collection (Journal of Laws of 2001 no. 72, item 747, as amended), articles 1 and 2 item 8c.

[4] Ordinance on the determination of tariffs, application template for tariff approval, and conditions for the settlement of payments for collective water supply and sewage collection (Journal of Laws of 2006 no. 127, item 886).

have been progressively implementing these fees ever since. At present, water and sewerage companies are charging fees e.g. in: Ostrow Wielkopolski, Nysa, Bielsko-Biala, Poznan, Biala Podlaska and Boleslawiec. Water and sewerage companies in other cities are preparing to implement stormwater fees due to the existing legal duty. Tables 1–2 present the fees for rainwater and snowmelt collection in selected cities while tables 3–4 list various ratepayer groups depending on the fee calculation method. This summary clearly shows that both the fees and the number and type of ratepayer groups are highly varied.

Examples of rainwater and snowmelt fee calculation in other countries

There are countries with much broader experience in calculating fees for rainwater and snowmelt collection as many water and sewerage companies began their implementation in the 1990s. Rainwater and snowmelt fees are charged in a number of cities in the USA, Germany, Denmark and Sweden (Burszta-Adamiak 2010; Burszta-Adamiak and Suligowski 2012).

Table 1. Fees for the collective discharge of rainwater and snowmelt calculated based on the number of m^3 of waste water collected from a contaminated impervious surface in selected cities and communes

City/Commune	Net price (min–max)*, PLN/m^3	Number of ratepayer groups	Fare validity period
City of Ostrow Wielkopolski	2.76–3.27	4	1 January 2014 to 31 December 2014
City of Biala Podlaska	5.89	1	1 April 2013 to 31 March 2014
City of Poznan	5.00	3	1 April 2014 to 31 March 2015
Commune of Glogow	2.85–5.08	4	1 January 2014 to 31 December 2014
Commune of Prudnik	1.61–2.20	2	1 July 2013 to 30 June 2014
Commune of Zory	1.82–4.39	5	1 May 2013 to 30 April 2014
Commune of Boleslawiec	2.91	1	1 January 2014 to 31 December 2014
Commune of Siedlce	3.00	1	1 March 2014 to 28 February 2015
City of Suwalki	2.60	1	1 January 2014 to 31 December 2014

* An 8% goods and services tax (VAT) is added to the net prices

Table 2. Fees for the collective discharge of rainwater and snowmelt calculated based on the number of m^2 of contaminated impervious surface in selected cities and communes

City/Commune	Net price (min–max)*, PLN/m^3	Number of ratepayer groups	Fare validity period
City of Wagrowiec	1.65–2.26	2	1 April 2013 to 31 March 2014
City of Radom	0.92–1.12	3	1 January 2014 to 31 December 2014
City of Tarnobrzeg	3.24	1	1 March 2014 to 28 February 2015
City of Elblag	1.10	1	1 January 2013 to 31 December 2014
Commune of Zawiercie	0.31–0.52	2	1 April 2014 to 31 March 2015
Commune of Czarnkow	0.72–0.96	3	1 April 2014 to 31 March 2015
Communes of Bielsko-Biala, Jawor, Wilkowice	4.14–7.06	2	1 January 2014 to 31 December 2014
Commune of Kluczbork	1.08–1.32	4	1 January 2014 to 31 December 2014
Gmina Nysa	0.35–0.65	1 group comprising 4 categories	1 July 2013 to 30 June 2014
Commune of Zory	1.44–3.48	5	1 May 2013 to 30 April 2014
Commune of Koszalin	2.11	1	1 January 2014 to 31 December 2014
Commune of Kedzierzyn Kozle	1.80	1	1 May 2013 to 30 April 2014

* An 8% goods and services tax (VAT) is added to the net prices

Table 3. Ratepayer groups in selected cities and communes where fees are charged on a PLN/m³ basis

City/Commune	Ratepayer groups (ratepayers who:)
City of Ostrow Wielkopolski	• discharge rainwater and snowmelt from industrial and warehouse areas and transportation depots; • discharge rainwater and snowmelt from roads and parking lots with an impervious surface; • discharge rainwater and snowmelt from parking lots with pervious paving with a capacity of over 500 cars; • discharge rainwater and snowmelt from other contaminated impervious surfaces.
City of Poznan	• discharge rainwater and snowmelt directly or indirectly to the facilities of the combined sewer system from contaminated impervious surfaces, including roads and parking lots, pertaining to property for residential use; • discharge rainwater and snowmelt directly or indirectly to the facilities of the combined sewer system from a contaminated impervious surface (including roads and parking lots), pertaining to property for sacral use, municipal organizational units, budgetary units, non-governmental organizations and other entities not mentioned in the remaining groups; • discharge rainwater and snowmelt directly or indirectly to the facilities of the combined sewer system from a contaminated impervious surface (including roads and parking lots), pertaining to property for industrial, commercial, service providing or warehousing purposes, transportation depots, and ports and airports.
Commune of Glogow	• discharge waste water from a contaminated impervious surface, i.e. national and regional roads and streets, as well as the adjacent road lanes and parking spaces, parking lots and communication routes near large surface stores, bus bays; • discharge waste water from a contaminated impervious surface, i.e. county and commune roads as well as the adjacent road lanes and parking lots, petrol stations and transportation depots; • discharge waste water from a contaminated impervious surface, i.e. housing estate and internal roads and streets, neighbourhood pavements along neighbourhood roads, neighbourhood parking lots; squares, parking lots, roads and other contaminated impervious surfaces associated with service providing, commercial and industrial facilities; • discharge waste water from other contaminated surfaces not included in the abovementioned groups.
Commune of Prudnik	• discharge rainwater and snowmelt to the combined sewer system; • discharge rainwater and snowmelt to the stormwater sewer system.

In the USA, several alternative methods are used to calculate stormwater fees. In most cities, an Equivalent Residential Unit (also referred to as Equivalent Runoff Unit, ERU) is applied for residential parcels. ERUs are mean or median values calculated based on the estimated impervious cover for all or selected single-family residential parcels within the territory of a given city. Billing systems can also use Equivalent Hydraulic Acre (EHA) and Basic Assessment Unit (BAU) values. A parcel's EHA is the estimated average amount of pervious and impervious surfaces within the parcel multiplied by the runoff factors applicable to each, and then multiplied by a water quality factor (determined by the sewage utility); EHAs are determined for given land use types and applicable to selected private parcels. BAU values are used for selected city-owned properties and assessed based on the average impervious area multiplied by the mean runoff coefficient.

Other solutions are also applied in the USA where the fee depends on predetermined size classes of impervious surface on land designated for residential use. An administrative fee and public road

Table 4. Ratepayer groups in selected cities and communes where fees are charged on a PLN/m² basis

City/Commune	Ratepayer groups (ratepayers on land with:)
City of Wagrowiec	• impervious surfaces of roads and parking lots; • surfaces used for industrial and warehousing purposes, and transportation depots.
Cities of Bielsko-Biala, Jawor, Wilkowice	• households; • remaining ratepayers.
Commune of Zawiercie	• surfaces used for industrial and warehousing purposes, transportation depots (excluding roads and parking lots); • roads and parking lots with an impervious surface.
City of Radom	• surfaces used for industrial and warehousing purposes or as transportation depots; • roads and parking lots with an impervious surface, including those located on land used for industrial and warehousing purposes or as transportation depots; • roads and parking lots with an impervious surface in densely populated cities.
Commune of Czarnkow	• rooftop surfaces; • surfaces of roads and parking lots; • industrial surfaces.
Commune of Kluczbork	• surfaces used for industrial and warehousing purposes or as transportation depots; • impervious surfaces of roads and parking lots located in cities with a population density exceeding 1,300 residents/km²; • impervious surfaces of roads and parking lots; • pervious surfaces (soil and gravel).
Commune of Nysa	• bituminous roads and pavements; • stone, clinker and concrete paving; • paving as above, unfilled joints between pavers; • other paving as above, unfilled joints between pavers.
Commune of Zory	• impervious surfaces of roads and parking lots, including those located on land used for industrial and warehousing purposes or as transportation depots; • impervious surfaces of roads and parking lots, including those located on land used for industrial and warehousing purposes or as transportation depots in the possession of the city of Zory; • impervious surfaces of roads and parking lots, including those located on land used for industrial and warehousing purposes or as transportation depots in the possession of entities or persons other than the city of Zory; • contaminated impervious surfaces, not mentioned in groups 1, 2 and 3, including buildings and construction excluding buildings and construction mentioned in group 5; • rooftop surfaces of residential buildings, sacral buildings and charitable organizations.

fee (road factor) are added to the stormwater fee as flat rates paid by each property on a monthly basis.

Yet another stormwater billing system uses a flat rate for each m² of pervious and impervious surface within a property, with the fee for impervious surfaces up to 40 times higher than for pervious surfaces. The monthly stormwater fees per single property charged by different US cities are shown in figure 1.

In Denmark, the stormwater fee makes up 40% of the entire drainage fee paid by residents. Residents in Sweden are charged for stormwater collection based on the area of impervious surface from which water is discharged to the sewer system.

Fees for the collection of stormwater via stormwater sewer systems in most German states are calculated based on the size of the built up area from which the water drains into the stormwater sewer system. Each year, the rate is determined per m^2 of "reduced catchment area" (verified impervious surface area multiplied by the runoff coefficient determined by the local sewage utility). Other popular methods of stormwater fee calculation in Germany are basic and stepwise tabular fees. The basic tabular fee is a fixed price for each X m^2 of a property's impervious surface or part thereof (for instance, in 2008 in the town of Detmold in West Germany this fee was 11.25 EUR annually for each 15 m^2 or part thereof). The stepwise tabular fee is charged based on rates for predefined impervious surface areas. Once the first, basic threshold is surpassed, an additional flat fee for each subsequent threshold (impervious surface area) is charged. This type of billing is used e.g. in the city of Kiel in northern Germany. In 2008, the annual fee for rainwater and snowmelt collection was 33 EUR for the first 60 m^2 and 11 EUR for each subsequent 20 m^2 or part thereof (Edel 2008).

> Countries such as the USA, Germany, Denmark and Sweden have already successfully introduced stormwater and snowmelt collection fees.

Public participation

The introduction of a new fee for the collective discharge of rainwater and snowmelt to the stormwater or combined sewer system sparked many disputes and protests among Poles. Meanwhile, staff members of water and sewerage companies are usually convinced that fee collection principles are acceptable, apprehensible and easily controllable by service recipients. This type of opinion can be found e.g. on the webpage of the utility in Zory. Part of the misunderstanding is due to negligence with regard to the information campaign for residents which ought to be carried out sufficiently early (before stormwater fees are introduced) and well thought through (explaining the reasons behind the introduction of fees, the possibilities for their reduction, the consequences of uncontrolled stormwater drainage and the associated environmental and material damage).

The incompatibility of entries in related legislation, such as the inconsistency of the act on the collective water supply and sewage collection with the tariff ordinance in the case of stormwater fees, has been pointed out in a number of court decisions and in literature and has caused a great deal of controversy (Ziemski and Bujny 2013).

Unlike Poland, the introduction of stormwater fees in many other countries was preceded by training schemes designed to facilitate their smooth implementation (Burszta-Adamiak 2011; Taylor et al. 2007). In the initial phase of stormwater fee introduction, meetings were held with residents and presentations were made on the available solutions, examples of implemented undertakings and possibilities of improving the drainage system of a given area. All ratepayers received emails and information leaflets attached to their water and sewage bills. The handouts explained the reasons behind stormwater fee introduction as well as the rates and methods of calculation. Additionally, educational materials were made available to interested residents from water and sewerage companies and municipal webpages.

Most countries offer large-scale financial support for environmentally-friendly investments (Burszta-Adamiak 2009; Doll et al. 1999). One example is Portland (USA) where multiple projects are carried out to promote systems that are in line with the concept of sustainable development, and residents and local authorities are encouraged to implement these on a larger scale. One example of such an undertaking is Portland's Ecoroof Program which helps not only to protect the environment but also to save money (a detailed description is provided in the case study at the end of this chapter).

Financial incentives used in Poland

Subsidies are a form of financial assistance for investments that meet legal requirements as well as educational and organizational activities aimed at environmental protection, including the protection of water. The principles of granting subsidies are not directly based on market mechanisms but on environmental policy guidelines or government

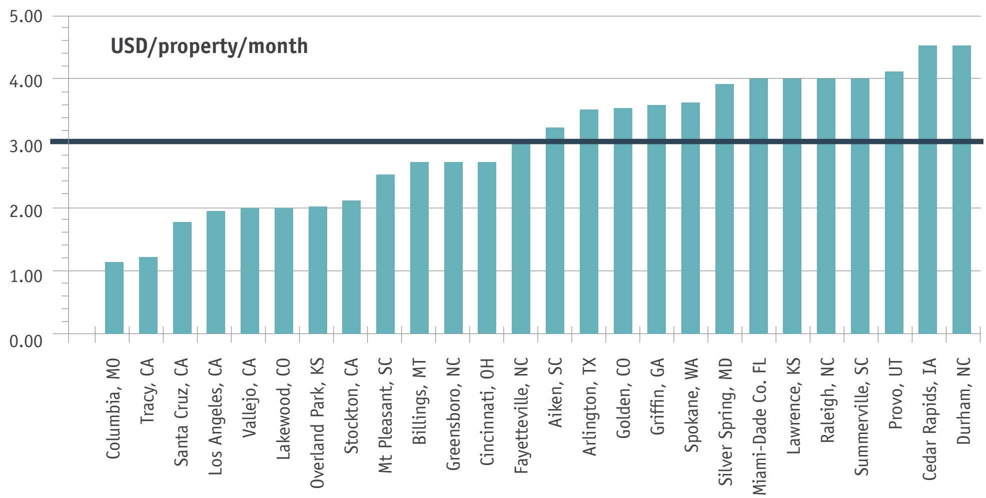

Figure 1. Monthly fees for rainwater and snowmelt collection assigned to residents of selected US cities. The dark blue line marks the average monthly fee (based on UD/WRA 2009)

programmes. In Poland, undertakings are subsidized primarily from environmental protection and water management funds (Rauba 2008). The revenues come from environmental fees and penalties. In practice, the following types of subsidies are applied:

- subsidies and loans from environmental protection and water management funds;
- loans with a preferential rate for investments related to environmental protection, e.g. offered by Bank Ochrony Srodowiska;
- budget subsidies.

Tables 5–7 present examples of subsidies within the framework of programmes carried out in 2014 that were designed to motivate residents, entrepreneurs and local governments to apply solutions aimed at increasing urban water retention and enhancing flood protection. Urban stormwater retention programmes are still new to Polish cities – and rare. The first programmes of this type were adopted through City Council resolutions in 2011 and are now offered by the cities of Sopot, Krakow, Gdansk and Warsaw.

Despite the financial possibilities offered by programmes aimed at improving stormwater management in urbanized areas, interest in the use of these funds remains minimal. This is mostly due to insufficient promotion of information on these projects among residents, investors and decision makers. Another reason is the limitations on some forms of financing. For instance, the subsidy in Gdansk will be granted only to those investors who experience "runoff-related problems" on their property such as flooding by runoff from a neighbouring property or road, and will not be granted to residents who wish to manage stormwater on their parcel. They will not receive funding for a stormwater retention or infiltration system that would allow them to manage rainwater on-site instead of discharging it to the sewer system.

The marginally low numbers of applications for financing within the framework of the abovementioned programmes suggest that a public campaign is vital for residents to understand the need to use on-site stormwater management systems and to know what types of investment can be financed. The importance of dialog between residents and decision makers, scientific institutions and public administration was clearly shown by the example of the Blue-Green Network in Lodz. The idea emerged in 2008 in the European Regional Centre for Ecohydrology under the auspices of UNESCO (Wagner et al. 2013). The FP6 SWITCH project called "Sustainable Water Management in the City of the Future" was carried out within its framework in 2010 and e.g. a sequential sedimentation – biofiltration system on the Sokolowka river for the treatment of stormwater was created. Water quality is improved through sedimentation processes and the intercep-

Table 5. Incentive programme used in Krakow

Area of investment	City of Krakow
Program title	Krakowski program małej retencji wód opadowych (2014) ("Small retention programme for Krakow")
Basis of financing	Resolution no. LXXX/1223/13 of the City Council of Krakow of 28 August 2013
Objective	To reduce discharge to stormwater sewers and receiving waters; to reduce the amount of water used for irrigation and municipal purposes
Beneficiaries	City residents: natural persons, homeowners associations, legal persons, entrepreneurs, legal persons at the commune/county level pertaining to the public finance sector
Subject of financing	Subsidies of 50% (no more than 5,000 PLN) for residents to cover the costs of purchase and installation of rainwater harvesting equipment as well as modernization costs of the existing installation to allow the connection of the rainwater harvesting system
Source of financing	City budget, regional and communal Funds for Environmental Protection. The total sum allocated to the program is 1,000,000 PLN
Notes	The subsidy may not be used for: • preparatory documentation (civil engineering design of the installation), • activities that do not guarantee a sustained environmental effect.[1]
Source of information	<www.bip.krakow.pl>

* The environmental effect is the volume of retained rainwater expressed in m^3.

Table 6. Incentive programme used in Gdansk

Area of investment	City of Gdansk
Program title	Dotacja celowa na zadania związane z ochroną środowiska i gospodarką wodną ("Designated subsidy for activities related to environmental protection and water management")
Basis of financing	Resolution no. XLVII/1051/13 of the City Council of Gdansk of 16 December 2013
Objective	Stormwater management through retention and/or discharge to the ground, waters or stormwater sewer system
Beneficiaries	Natural persons, homeowners associations, legal persons, entrepreneurs
Subject of financing	The subsidy amount is determined according to the following principles: • single subsidy of 100% of total expenditures (no more than 5,000 PLN for natural persons); • single subsidy of 100% of total expenditures (no more than 10,000 PLN for homeowners associations, entrepreneurs, legal persons, housing cooperatives and other entities).
Source of financing	City of Gdansk budget, as well as environmental fees and penalties, and penalties for tree and shrub removal
Notes	The subsidy is given in the form of reimbursement of documented costs associated with the activity after it is completed. The subsidy does not apply to technical stormwater management infrastructure performed as part of road, residential, commercial or industrial investments.
Source of information	<www.gdansk.pl>

Table 7. Incentive programme used in Warsaw

Area of investment	Mazowieckie Voivodeship
Program title	Budowa, przebudowa i remont urządzeń służących zwiększaniu retencji wodnejjako sposobu zmniejszenia zagrożeń obszarów zurbanizowanych przed powodzią ("Construction, redevelopment and renovation of water retention facilities as a way to reduce flood risk in urbanized areas")
Basis of financing	Programme for 2014 adopted by the Regional Fund for Environmental Protection and Water Management
Objective	• protection from flood and drought; • water retention aimed at mitigating the effects of hydrological drought; • retention of surface waters to reduce flooding; • protection of groundwater levels from declining too far; • increase in water resources in agricultural and forest areas.
Beneficiaries	• local authorities and their subordinate bodies; • Lasy Państwowe (National Forest Holding "State Forests"); • Kampinos National Park; • landscape parks; • organizational units created by the above entities.
Form of financing	• loan and subsidy; • up to 100% eligible costs associated with the activity; • the financing limit for subsidies is at 50% of eligible costs associated with the activity provided that a loan is taken in the amount of at least 50% of eligible costs.
Source of financing	Regional Fund for Environmental Protection and Water Management
Notes	- the subsidy is granted on the condition of taking a loan - the activity must be carried out within the boundaries of the Mazowieckie Voivodeship - financing covers the construction, reconstruction and modernization of reservoirs including the associated hydrotechnical facilities
Source of information	<www.wfosigw.pl/strefa-beneficjenta/programy-2014>

tion of diffuse pollution. A number of innovative technologies have also been used, e.g. related to shaping the structure of vegetation or the use of biodegradable geotextiles (Wagner and Zalewski 2013). The City of Lodz Office has officially adopted the Blue-Green Network concept as part of the Integrated Development Strategy for Lodz 2020+.

Summary

Poland's current system of financing stormwater management-related activities provides possibilities for funding environmentally-friendly investments. Some of these funds come from water and sewerage companies (environmental fees and administrative penalties) and some from preferential loans and subsidies from the state budget or environmental protection funds. Fees for the collection of rainwater and snowmelt are a relatively new financing tool.

To date, only a small number of water and sewerage companies in Poland have introduced such fees. This may be explained by uncertainty as to the legal basis; difficulties with the registration of runoff networks and areas; the need to adopt a fair way of determining ratepayer groups; and the public attitude, as Poles are still unwilling to accept any additional expenditures. The latter reason highlights the importance of education campaigns similar to those that have been successfully carried out in other countries. These should be included at the implementation phase of fees for stormwater and snowmelt collection via the sewer system. Education campaigns should make residents aware of the need to charge this type of fee and explain the possibilities of their reduction or elimination through sustainable and well-thought-out stormwater management.

Case study:
Portland's Ecoroof Program

The city of Portland in the USA is a renowned leader in sustainable stormwater management. Since the early 1990s, the City of Portland's Bureau of Environmental Services has been carrying out multiple projects aimed at educating society, promoting and implementing stormwater management solutions to enhance on-site infiltration and retention, as well as providing technical and financial support for investments. The achievement of these goals is associated with benefits for the city and its residents. These include: reduced load on sewer systems, improved tap water quality, improved microclimate and improved aesthetics of the immediate neighbourhood. One of the programmes within the framework of sustainable stormwater management is Portland's Ecoroof Program.

Each year, Portland receives over 800 mm of rain which amounts to about 38 million m^3 of rainwater that needs to be managed. The high degree of surface sealing caused by progressive urbanization (roofs alone account for 40% of the city's impervious surface) does not favour natural stormwater retention and infiltration. As a result, stormwater is quickly drained to sewer systems (Liptan and Strecker 2003). Moreover, stormwater runoff from impervious surfaces carries pollutants to rivers thereby contributing to the deterioration of tap water quality. This is why measures were taken to limit the amount of stormwater entering sewer systems, prevent sewer overflows and maintain the good condition of receiving waters. One of the solutions that allow for a reduction in surface runoff is green roofs or ecoroofs.[5] The programme aims to promote these and encourage residents to create this type of sustainable stormwater management systems on the roofs of private and public buildings.

Green roofs are being promoted through both financial support and public education campaigns. Financial incentives include discounts in stormwater fees (residents who create green roofs on their property have their stormwater bills reduced up to 35%), subsidies for each m^2 of greened surface in the city centre and non-repayable grants for each m^2 of ecoroof on private or public buildings.

Additionally, the city has offered developers the right to a larger development or additional floor area than otherwise allowed if their building includes an ecoroof that meets specific requirements. This option was called the Ecoroof Floor Area Ratio Bonus (Chomowicz 2012) whereby 10–30% ecoroof coverage earns the developer one square foot of additional floor area per one square foot of ecoroof (1:1 ratio). This ratio is 2:1 for 30–60% ecoroof coverage and 3:1 for ecoroof overage over 60%. The ecoroof FAR Bonus has typically been used in large-scale development projects, such as industrial, commercial and multi-family residential housing.

Educational support consists of disseminating information on green roofs and the benefits of using on-site stormwater management systems. This information is available on the official webpage and is disseminated during workshops, public demonstrations and conferences. Since 2004 the city has been the official sponsor and host of the annual Greening Rooftops for Sustainable Communities Conference. Residents can also count on expert advice and technical assistance in ecoroof installation.

Portland's Ecoroof Program was greatly expanded by the G2G Initiative: a 5-year initiative (2008–2013) for which 6 million USD were set aside. The Programme's overall achievements include:

- the creation of over 400 ecoroofs with a total area of 174,000 m^2 between 2008 and 2013 (figure 2);
- increased awareness among society on rational urban stormwater management which has translated into increased interest in ecoroofs among both private investors and institutions in Portland;

[5] In Portland, green roofs are called ecoroofs to highlight the fact that these roofs are not always green due to the wide choice of plants and possible declines e.g. due to drought. Here, the eco- prefix is also meant to emphasize the economic value of green roofs.

Historical background of the Programme

1996 — the first green roof was created in Portland on a private garage;
1999 — green roofs were officially recognized as sustainable urban drainage systems;
2001 — financial support was introduced for green roofs in the city centre;
2005 — a policy was adopted that requires all new city-owned facilities and all roof replacements to have an ecoroof covering at least 70% of the roof;
2006 — a discount was introduced on stormwater utility fees to ratepayers who created green roofs;
2008 — the Grey to Green Initiative (G2G) was launched that provided funding for ecoroofs.

- reduced load on sewer systems due to the retention of large amounts of rainwater on ecoroofs.

According to City of Portland monitoring data, ecoroofs typically capture and evaporate an average of 60% of the rain that falls on them during a year. Peak runoff is reduced by an average of 90%. This helped reduce the frequency of local inundations during intense rainfall in the city. Ecoroofs also lower stormwater runoff temperature on hot days compared to runoff from traditional roofing. All of this has had a positive effect on the receiving waters and their fish and other aquatic species.

Building on Portland's experience, other US cities such as New York, Chicago or Los Angeles have been implementing similar environmental programmes. Other countries, including Poland, are also following and giving more and more consideration to sustainable urban stormwater management systems. The secrets behind Portland's success were:

- the nearly simultaneous integration of several programmes to promote sustainable stormwater management allowed the assumed goals to be achieved relatively quickly;
- the strong involvement of local authorities in the implementation of programme objectives and comprehensive public consultations aimed at determining residents' preferences;
- project coordination by experts in many disciplines, including engineers, designers, urban planners, experts in environmental protection and landscape architects who exchanged opinions to choose the best solutions for a given location;
- a comprehensive information campaign and constantly updated official webpage of the programme <www.portlandonline.com/bes/ecoroof> with information concerning legislation, symposiums, technical data, lists of experts as well as handbooks on green roof construction, costs, choice of materials etc.;
- the implemented systems were monitored and examined to check for correctness and assess their efficacy;
- the implementation phase was preceded by pilot projects which allowed to spot and correct any irregularities before sustainable systems were implemented on a larger scale.

Photo: <www.portlandonline.com/bes/ecoroof>

Figure 2. Examples of ecoroofs in Portland

References

Burszta-Adamiak, E., 2009. Opłaty za wody opadowe – doświadczenia polskie i zagraniczne. *Gaz, Woda i Technika Sanitarna*, 3, pp. 15–18.

Burszta-Adamiak, E., 2010. Narzędzia motywacyjne dla poprawy gospodarki wodami opadowymi. *Przegląd Komunalny*, 4(223), pp. 79–81.

Burszta-Adamiak, E., 2011. Wody opadowe – edukacja i motywacja społeczeństwa. *Wodociągi i Kanalizacja,* 5(87), pp. 84–88.

Burszta-Adamiak, E., Suligowski, Z., 2012. Funkcjonowanie przedsiębiorstw kanalizacyjnych w Polsce. In: Bolt, A., Burszta-Adamiak, E., Gudelis-Taraszkiwicz, K., Suligowski, Z., Tuszyńska, A., eds. *Kanalizacja. Projektowanie, wykonanie, eksploatacja*, Warsaw: Wydawnictwo Seidel-Przywecki, pp. 27–138.

Chomowicz, A., 2012. Ecoroofs in Portland. In: *Proceedings of 49th International Making Cities Livable Conference. True Urbanism: Planning Healthy Communities for All & Exhibit on Successful Designs for Healthy Inclusive Communities*. Portland.

Doll, A., Scodari, P.F., Lindsey, G., 1999. Credit as economic incentives for on-site stormwater management issues and examples. In: *Proceedings of the U.S. Environmental Protection Agency National Conference on Retrofit Opportunities for Water Resource Protection in Urban Environments*, Chicago, pp. 13–117.

Edel, R., 2008. Opłaty za wody opadowe w Niemczech. In: Łomotowski, J., ed., *Problemy zagospodarowania wód opadowych*, Wroclaw: Wydawnictwo Seidel-Przywecki, pp.103–113.

Liptan, T., Strecker, E., 2003. Ecoroofs (greenroofs) – a more sustainable infrastructure, In: *Proceedings of National Conference on Urban Storm Water: Enhancing programs at the local level*, Chicago, Cincinnati: U.S. EPA, pp. 198–214.

Rauba, E., 2008. Instrumenty ekonomiczne ochrony wód. In: Cygler, M., Miłaszewski, R., eds., *Materiały do studiowania ekonomiki zaopatrzenia w wodę i ochrony wód*, Bialystok: Wydawnictwo Ekonomia i Środowisko, pp. 168–181.

UD/WRA (University of Delaware, Water Resources Agency), 2009. *Stormwater Utility Feasibility Report. Stormwater is drinking water in Newark*, Newark, Delaware: City of Newark.

Taylor, A., Curnow, R., Fletcher, T., Lewis, J., 2007. Education campaigns to reduce stormwater pollution in commercial areas: Do they work? *Journal of Environmental Management*, 84, pp. 323–335.

Wagner, I., Krauze, K., Zalewski, M., 2013. Blue aspects of green infrastructure. *Sustainable Development Applications*, 4, pp. 144–155.

Wagner, I., Zalewski, M., 2013. Błękitno-Zielona Sieć – poprawa jakości życia w miastach w obliczu zmian klimatu. *Panorama,* 4, pp. 9–12.

Ziemski, K.M., Bujny, J., 2013. Kontrowersyjne opłaty za deszcz i śnieg. *Przegląd Komunalny*, 12, pp. 68–70.

How to safely retain stormwater in the city: technical tools

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Before 1990, the industrial area of Dahlwitz-Hoppegarten located east of Berlin covered an area of 40 ha. During the most intense rainfall, runoff speed to the Werner-Graben stream reached 360 litres per second. The area was due to be expanded by another 120 ha after 1990. According to the permit, total runoff from the extended area could not exceed 400 l/s. In other words, although the combined area was going to increase 4-fold, runoff could increase only by 10%. This goal was achieved with the use of best stormwater management practices. What is more, water quality in the river improved as did the aesthetics of the industrial area with the costs of stormwater management 25% lower compared to traditional systems. During the last 15–20 years, on-site stormwater management has become the standard procedure in urban catchments in Germany.

Keywords: blue-green infrastructure, stormwater and snowmelt management, infiltration, retention

Introduction: on-site stormwater management

New way of thinking

Precipitation is the primary source of water in the city that initiates a number of positive processes in the urban space, such as cleaning the air, attenuating microclimate and improving residents' living conditions. Precipitation allows greenery and small aquatic ecosystems to survive in the heavily transformed urban environment, shaping a healthy living environment for residents. Well-planned areas of greenery prevent flooding and urban drought and create safe space for stormwater collection (Wagner et al. 2013).

At the same time, stormwater management is one of the fundamental challenges for most modern cities where development density is constantly increasing. This process leads to residents being deprived of biologically active areas: green space and water. Surfaces sealed by grey infrastructure (streets, sidewalks, parking lots, buildings, squares, hardened and degraded soil) do not allow excess water to infiltrate the ground. Rain or thawing snow/ice flows over the surface causing flooding and local inundations that paralyze the city. In traditional water management, these were to be avoided through the use of combined and stormwater sewer systems. However, practice has shown that these systems often only exacerbate the problem. During intense rainfall, the overloaded stormwater system cannot drain rainwater quickly enough and streets are flooded. Occasionally, backflows occur causing water to flow up in other parts of the city. However, the effective removal of water from the city also has its downside: urban drought. Surface and groundwater levels decline, the urban heat island effect gets worse, green areas and human living conditions deteriorate (cf. chapter on the links between water in the city and residents' health: Kupryś-Lipińska et al. in this volume).

> We need a shift in the perception of the city: from seeing the need to desiccate it and perceiving water as a threat to understanding the benefits of increasing the presence of water in a controlled way and seeing water as a resource.

Integrated stormwater (rainwater and snowmelt) management based on on-site management offers an alternative to traditional management systems. Here, the goal is not draining water from the city as quickly as possible, but retaining it where it fell or in the nearby surroundings. Water is then gradually released during dry weather (or once the flood risk is gone), mostly through evaporation and infiltration, and to a lesser degree through surface runoff and into sewer systems. This requires a shift in the perception of the city: from seeing the need to desiccate it and perceiving water as a threat to understanding the benefits of increasing the presence of water in a controlled way and seeing water as a resource and an essential element of high quality of life.

Concepts and solutions applied around the globe

Countries that are world leaders in terms of the technical knowledge, implementation, establishment of guidelines as well as legal, organizational and economic tools for on-site stormwater management include the USA, Canada, Australia and New Zealand. These countries were faced with the problems associated with intensive urbanization, flooding and drought much earlier than Europe and have been applying best practices for 50 years. In Europe, Germany, Scandinavian countries, the UK and France have the most experience.

New ways of rainwater and snowmelt management have been described in multiple concepts (see box) and solutions which have a lot in common:

- acknowledge the importance of water as the basis of a fully functioning natural system that provides urban residents with a wide range of benefits (ecosystem services);
- accept the presence of water in the city and design space for it;
- use technical (construction) solutions that enhance dispersed stormwater infiltration and retention in the urban drainage basin, and its treatment;
- allow the use of best practices in stormwater management alone or in combination with traditional methods (combined or stormwater sewer systems);

- allow stormwater management to be combined with urban and landscape architecture and with the city's natural system.

The use of best practices provides a multitude of benefits, such as:

- avoiding or minimizing flooding or urban drought and the associated effects;
- creating an integrated infrastructure system (grey, green and blue infrastructure) that can adapt to changing conditions (climate change, urban spatial development, demographic and economic changes);
- stormwater purification and limiting the spread of pollutants;
- reducing the pressure on receiving water bodies by reducing the number of pollutants and hydraulic stress caused by sewer systems (best practices allow to reduce peak flow, attenuate and lengthen the duration of high flows, increase baseflow and groundwater levels);
- reducing the load on stormwater and combined sewer systems and improving their performance in extreme conditions;
- reducing the costs of stormwater management and other operating costs in cities (less need for irrigation, lower environmental fees, less flood damage etc.);
- societal benefits derived from ecosystem services and multifunctional space (the application of sustainable solutions allows to use land for a park, space for recreation or education, and even a playing field or urban square. Renaturalized rivers not only have enhanced retention capacity, but can become attractive places for residents to spend their free time).

Concepts associated with rainwater and snowmelt management

Low Impact Development (LID): an approach that emerged in the USA and consists of the spatial design of new and revitalized urban areas whereby landscape features (such as terrain, geological structure, aquatic and land ecosystems) determine the framework for urban development. This approach reduces the negative impact of development on newly built and neighbouring space and on the natural system. Rainwater is used onsite based on retention in the landscape supported by technical solutions.

Water Sensitive Urban Design (WSUD): an interdisciplinary approach developed in Australia that is based on the cooperation of experts in water management, architecture, spatial planning and environmental protection. It deals with all elements of the urban water cycle (precipitation, water supply, waste water collection, aquatic ecosystems) and incorporates their functionality into urban design. The goal is for the urban water cycle (especially rainwater) to mimic the natural cycle as closely as possible. Cf. the example of Mordialloc Industrial Precinct in the section of good practices at the end of this guidebook.

Sustainable Urban Drainage Systems (SUDS): these comprise technical solutions for urban stormwater collection that are more environmentally-friendly than traditional engineering solutions. Combining different modes of action allows pollution and hydraulic stress in rivers and lakes to be minimized. This UK-based approach is illustrated by the SUDS for Schools project described in the section of good practices at the end of this guidebook.

Best Management Practices (BMPs): stormwater BMPs comprise structural activities aimed at retaining water and eliminating pollutants, as well as non-structural activities to limit surface runoff and prevent pollution. The technical solutions of BMPs form part of all of the concepts mentioned above and therefore sustainable stormwater management is often referred to as best practices or BMPs.

Green and blue infrastructure, ecohydrology

The European Commission (EC 2013) defines green infrastructure as a strategically planned network of natural areas that is designed and managed so as to provide a wide range of ecosystem services. The Commission also makes reference to blue infrastructure i.e. aquatic ecosystems (rivers and their valleys, lakes, artificial reservoirs or wetlands). Both systems combined, blue and green, are a crucial tool for the natural processes of stormwater retention and purification. Green infrastructure is particularly important for the urban landscape (land ecosystems): it helps improve water cycling, supports the functioning of grey infrastructure and reduces the load on stormwater and combined sewer systems.

Both types of infrastructure remain in close cooperation: plants are biological water reservoirs whereas water is indispensable for plant growth. The acknowledgment of this functional cohesion fits in with the concept of ecohydrology (Zalewski 2011). This concept is based on the understanding of the interrelationships between hydrological processes (such as precipitation, infiltration, runoff, interception, evaporation, river flow, water retention) and ecological processes (the biological, physical and chemical processes associated with the cycle of matter, transpiration, biodegradation, primary production, denitrification etc.). These interrelationships are applied in practice in environmental management, including that of the urban environment (Wagner and Breil 2013). Ecohydrological regulation enhances and optimizes the performance of blue-green infrastructure which is of particular importance in densely built urban areas where a desired effect (such as high water retention, high purification efficiency) is to be achieved on a small area. For instance, the choice of tree species with a higher transpiration coefficient[1] can help attenuate the urban microclimate more efficiently. Ecohydrological activities may be coupled with urban (hydro)technical infrastructure. Such combinations help to control hydrological parameters such as water flow velocity and direction to regulate e.g. sedimentation processes and water purification rates or enhance/inhibit the growth of particular plant species in aquatic ecosystems.

Stormwater management provides ample space for architects' and urban planners' imagination and creativity, and allows for the creation of multiple links between the proposed solutions, elements of architecture and the urban fabric.

The proposed methods of regulating the cycle of water and matter (e.g. nutrients and pollutants) in the urban landscape support the traditional functions of grey infrastructure, such as water purification or flood prevention. From this perspective, ecosystems and their services may be viewed as valuable urban management tools. The reduced implementation, maintenance and operating costs of urban systems that actively use green and blue infrastructure are an additional advantage (EPA 2007; cf. also the chapter on integrated management: Krauze and Wagner in this volume).

Structural solutions

Structural solutions within best stormwater management practices include constructions that enhance dispersed infiltration and retention of stormwater in the urban catchment as well as its treatment. In practice, this includes the construction of facilities and investment-related activities such as the construction, expansion, redevelopment and adaptation of grey infrastructure (e.g. green roofs, changes in street contours, new designs of greenery or pervious surfaces).

Structural solutions are classified in a number of ways. This guidebook uses the classification proposed by the European DayWater project and the guidelines of the US Environmental Protection Agency to select the following: pervious surfaces, plant buffer strips, and facilities for stormwater retention and infiltration. Some papers make a separate distinction for pre-treatment systems located immediately before the receiving water bodies.

The choice of structural solutions and facilities is determined primarily by the amount of runoff from a given area and the possibilities for its retention. These depend on the land use and physiographic features of the catchment, and precipitation properties. Land use in a catchment comprises mainly the development density of a given area and its surroundings, the presence and location of green spaces, the route and load of the sewer system and the presence of underground infrastructure. The physiographic features of land include inclination (which determines the volume and speed of surface runoff formation), the geological structure and soil conditions (which determine natural infiltration capacity), the presence of aquifers, water

[1] The amount of water that a plant transpires to produce a weight unit of dry matter.

relations, and overall climatic conditions. In engineering practice, precipitation properties (which determine the dimensions of structural facilities) typically include intensity and volume. The correct assessment of the amount of rainwater received by retention or infiltration facilities helps to prevent flooding. Emergency overflows can be designed that will safely direct excess water to the sewer system should such a threat emerge. The dimensioning of sewer systems and structural facilities presents many challenges to the good practices in urban catchments. These and dimensioning methods have been widely discussed in Polish literature (e.g. Edel 2010; Geiger and Dreiseitl 1999; Królikowska and Królikowski 2012). These papers also include detailed descriptions, technical guidelines and conditions for the choice of the proposed structural solutions.

In city centres, solutions such as green roofs or underground retention facilities can be used. The collected water can subsequently be used e.g. for irrigation or in urban water fountains. In densely built areas, infiltration is typically hampered by technical barriers such as building foundations and underground infrastructure, and is applicable only in specific locations, such as stadiums or parks. Outside of the city centre and along its borders, infiltration facilities can be used that are commonly combined with pervious surfaces, greenery and even tall trees. Small retention can be used in parks, in combination with urban green spaces and street furniture. Areas located outside of city boundaries offer much wider possibilities: here, surface infiltration and retention may be used freely, both in combination with open public spaces and recreational areas, as well as on private property. In the case of new investments, on-site stormwater management allows to save on the costs of sewage infrastructure as well as to improve the quality and attractiveness of these areas. In practice, stormwater management provides ample space for architects' and urban planners' imagination and creativity, and allows for the creation of multiple links between the proposed solutions, elements of architecture and the urban fabric. The ultimate prerequisite is to apply these solutions in such a way that the designed space is safe for all users.

Below is a collection of examples of sustainable stormwater management solutions that most efficiently contribute to the improvement of microclimate and the urban natural system.

Pervious surfaces

Pervious pavements, asphalt and grass pavers

Large surfaces devoid of greenery, such as parking lots, roads and sidewalks cause the most trouble in terms of uncontrolled surface runoff. Green infrastructure is often impossible to apply. However, it is possible to use materials that allow water to infiltrate, i.e. pervious paving and asphalt. Concrete grids or synthetic reinforcement grids allow the

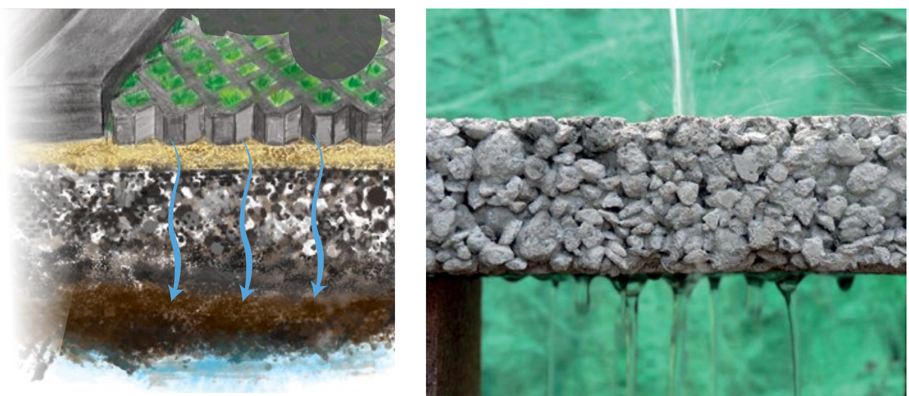

Photo: Chesapeake Stormwater Network

Figure 1. Pervious surfaces: schematic representation of a concrete grid with grass on a bedding, and water percolating through a pervious surface layer

Photo: Clemson University

Figure 2. Grass buffer strips along communication routes: schematic representation and real-world application in combination with an infiltration basin and footbridge in Aiken, USA

growth of grass within the grid system (figure 1). Pervious surfaces are placed on a sub-base that allows further infiltration, such as bedding made of natural material (crushed rock, sand, gravel, stones) or infiltration boxes.

Plant buffer strips

Green roofs and walls

Increasing the coverage of biologically active areas by preserving or expanding green areas (lawns, squares, green spaces, streetside greenery etc.) is vital to restore the urban water cycle. Green roofs and walls covered with vegetation (on specially prepared growing media) fit in well with this strategy, particularly in densely built areas (Kaźmierczak 2013). Depending on the construction and rain intensity, green roofs can retain all of the rain that falls on them. Other benefits include thermal insulation of buildings, increased evaporation, increased biodiversity and coverage of biologically active areas as well as providing additional space for residents to use. Green walls also help regulate temperatures, improve buildings' thermal insulation and aesthetics; the plants can feed on rainwater.

Vegetated buffer strips

Vegetated grass buffer strips are a good solution in areas with looser development, especially near roads. These slightly inclined vegetated surfaces allow the slow (horizontal and lateral) flow of stormwater from adjacent land (figure 2). Plant buffer strips effectively trap sediment and associated pollutants and are therefore commonly used for pre-treatment and as protective areas for other solutions (e.g. basins).

Contouring of streets and green infrastructure

Green areas (and infiltrating facilities) must be located below communication routes in order to capture stormwater from the streets and sidewalks. The simplest way of draining a street is by allowing water to flow freely through indentations in curbs (figure 3).

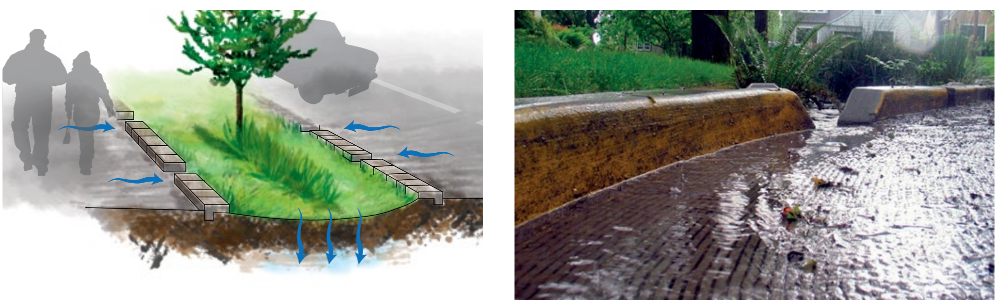

Photo: Kevin Robert Perry, City of Portland

Figure 3. Curb indentations channel water, allowing it to flow from the streets and sidewalks. The photo shows runoff water flowing down NE Siskiyou street in Portland, Oregon, USA

Stormwater infiltration facilities

Stormwater infiltration facilities are used on land with sufficient permeability, where the proportion of biologically active or pervious areas cannot be increased or larger quantities of water need to be managed despite the use of such areas. In principle, water that flows into these facilities leaves them by infiltrating to the ground. Other ways of discharging water (such as into the sewer system or directly to the river) are used as emergency overflows only in case of overloading.

Infiltration basins

Infiltration basins are depressed landforms covered by vegetation and characterized by high infiltration capacity and low water flow velocity (<0.15 m/s). Ideally, the slopes should be only slightly inclined and the underlying soil must be permeable. Infiltration can also be enhanced with additional infiltration layers. Infiltration basins are effective at removing pollutants and may therefore be used for the pre-treatment of water before it is diverted to other areas with blue-green infrastructure. Weirs can be constructed to increase retention capacity, sedimentation and infiltration, and to reduce the drainage rate by reducing inclination. Infiltration basins may be located in areas with varied development density (figure 4). Their irregular shape and diversified depth support the growth of assorted plants.

Photo: <greenworkspc.com>

Figure 4. Infiltration basin in open land (schematic representation) and densely built land (photo): in addition to retaining water this is the main element of landscape architecture in a housing estate in Portland

Detention basins

Photo: <www.sudswales.com>

Figure 5. Detention basin used for recreation during dry weather (schematic representation) and to collect water from the streets and parking lot

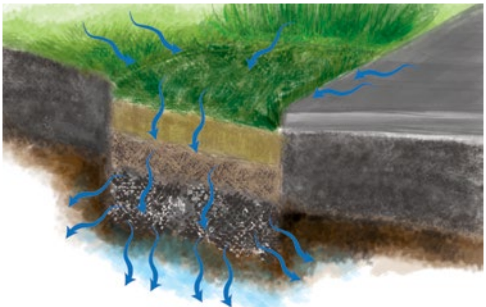

Photo: J. Coleby-Williams

Figure 6. Cross section through a drainage well (Burszta-Adamiak 2011) and drainage well in a homeside garden in Bellis, Wynnum, Queensland, Australia

Detention basins display similar features and mode of action to infiltration basins but are larger, deeper and used to drain larger areas (above 1 ha) (figure 5). Detention basins are suitable for areas with varied development density and for road drainage (especially highways). Where allowed by the quality of the conveyed waters, these basins may also serve recreational and aesthetic purposes. In catchments with significant amounts of sediment, initial sedimentation of inflowing water prevents the detention basin floor from silting up during exploitation.

Infiltration wells

In densely built areas where water cannot be retained on the surface, subsurface infiltration systems may be used. Many prefabricated products made of plastics for underground retention and infiltration are available on the market. Infiltration wells offer a more affordable alternative (figure 6): wells filled with infiltration material covered with soil, stones or other material that receive water from surrounding impervious surfaces. Infiltration wells can occupy dozens of square metres, but are typically small (<4 m²) and no more than 2 m deep. Lining the floor of the drainage well with geotextile fabric separates the adjacent soil from the filling material and prevents soil collapse. Water infiltrates through the floor or both the floor and sides of the well.

Photo: <www.csc.temple.edu>

Figure 7. Cross-section through an infiltration ditch (schematic representation) and infiltration ditch near Einstein hospital in East Norriton, Pennsylvania, USA

Infiltration ditches and grass ditches

Infiltration ditches are linear sections of land typically located along roads (figure 7), filled with infiltration material (similarly to a drainage well) and covered with stones, rock or vegetation. Rainwater percolates to the soil or a perforated pipe, and excess water may be diverted to traditional overflows. A popular alternative to the classic

Photo: <expo2010.freiburg.de>

Figure 8. Grass ditch along tramway tracks in the city centre of Freiburg, Germany

ditches made of concrete are grassed ditches, which are triangular in cross-section with gentle slopes (typically an inclination of 1:3 on the side of the road, 1:3–1:5 on the external side) that collect stormwater; part of it infiltrates and the rest is conveyed elsewhere over the surface (figure 8).

Stormwater tree trenches

Stormwater tree trenches integrate underground retention with tall greenery, e.g. streetside greenery (figure 9). In densely built areas, trees can also evaporate water collected directly from specially designed underground retention systems. In each

Photo: SvR Design Company

Figure 9. Example of streetside greenery combined with an infiltration system, and cascade of greenery fed with water from roofs, Maynard Avenue Green Street, Seattle, Washington, USA

case, a strip of tree plantings is connected with a cohesive underground retention, infiltration or combined retention/infiltration system that allows the flow of the retained water between plants. During heavy rainfall, excess stormwater can be captured by traditional sewer systems.

Above ground stormwater retention systems

Stormwater retention systems are designed to hold excess runoff from urban drainage basins and may be temporarily or permanently filled with water. Part of the water may infiltrate and evaporate, but


Photo: De Urbanisten

Figure 10. Dry detention pond of Benthemplein water square in Rotterdam, the Netherlands: photo during dry weather and visualization during wet weather

most of it flows to receiving water bodies in the form of surface runoff or via underground pipe systems.

Dry detention ponds

Dry detention ponds are filled with water only during torrential rain. Water flowing down from roads (typically highways) or densely built up land is retained until the flood risk is gone, and subsequently discharged to a receiving water body or sewer system. The size, capacity and features of these reservoirs is variable; from the point of view of ecosystem services, the most valuable are those semi-natural dry detention ponds that integrate elements of green and blue infrastructure. In addition to their retention capacity, these areas offer attractive, open, green space for residents in rain-free periods and may be used for sports and recreation, e.g. the Liourat à Vitrolles stadium in France. Dry detention ponds may also be combined


Photo: Center for Watershed Protection
Photo: I. Wagner

Figure 11. Detention ponds with continuous flow zones: reservoir in the Sokolowka river in Lodz and in Virginia, USA

with urban architecture. An interesting and bold example is Benthemplein water square in Rotterdam (figure 10). It serves as attractive public space during dry weather and can accommodate nearly 2 million litres of water during rain. Since its construction in 2013, maximum capacity has not been reached.

Detention ponds with continuous flow zone

Detention ponds with a continuous flow zone (figure 11) are a variant of dry detention ponds, often located within aquifers. These are made up of a wider, dry upper level which is submerged only in cases of intense rain and a bed with standing water or shallow marsh (0.2–0.5 m deep). These aesthetic landscape elements are also biodiversity safe havens. Their efficacy in removing solids and heavy metals is high and comparable with retention ponds and stormwater wetlands, and may be further increased with increasing retention periods.

Retention ponds

Retention ponds are solutions used in the riverbed itself or its immediate neighbourhood (figure 12). Their role is to hold water that was already conveyed to the river through direct surface runoff and via stormwater or combined sewer systems. These reservoirs attenuate extreme storm flows, thereby increasing the retention capacity of the river. Stormwater is purified primarily through intensified sedimentation. Plantings may be added to aid in the biological removal of pollutants. Retention ponds are often important elements of the urban landscape that enhance the natural value of a city and serve aesthetic, educational and recreational purposes. Maintaining short retention times (<2 weeks) helps prevent colonization by cyanobacteria which can form toxic blooms in the summer.

Photo: Barbara Gortat

Figure 12. Retention pond by the Sokolowka river in Lodz in 2006 when it was constructed and 6 years later, with established vegetation

Biological stormwater treatment systems

Biological stormwater treatment systems use macrophytes (such as the common cattail, miniature cattail, calamus, yellow iris, tule and the common reed) for stormwater purification at the edge of a receiving water body (river, reservoir, lake). Their performance can be enhanced with pre-treatment facilities: separators and sediment forebays, especially when inflowing water is heavily polluted, e.g. from the streets, parking lots or service stations. This helps maintain the proper functioning of biological systems.

Stormwater wetlands

Perhaps the most popular solution for the retention and purification of stormwater immediately before its release into aquatic ecosystems are stormwater wetlands (figure 13). These are vegetated systems with extended retention periods that are permanently filled with varying levels of water. Most urban stormwater wetlands use horizontal surface flow and are most suitable during rapid stormwater flows due to their large capacity and throughput.

[2] A system of this kind was created in the Sokolowka river in Lodz as part of EU's SWITCH project (FP6 EU, GOCE 018530) and POIG.01.01.02-10-106/09-04 "Innovative resources and effective methods of safety improvement and durability of buildings and transport infrastructure in the sustainable development" financed from the European Regional Development Fund within the framework of the Innovative Economy Operational Programme.

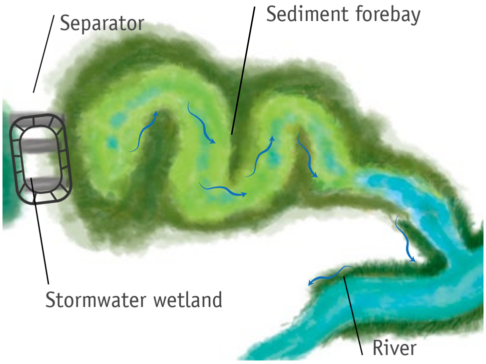

Figure 13. Schematic representation of a treatment wetland used for stormwater purification and photo showing a large stormwater wetland in Massachusetts, USA

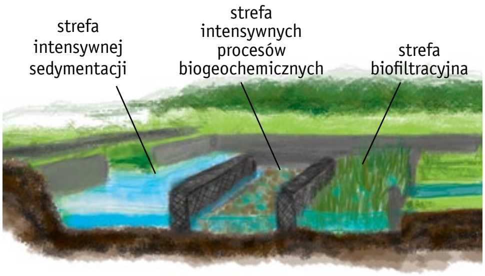

Figure 14. Sequential sedimentation – biofiltration system: schematic representation and pilot project in the Sokolowka river in Lodz

Submerged and floating vascular plants effectively remove pollutants and enhance sedimentation.

Sequential sedimentation – biofiltration systems

Sequential sedimentation/biofiltration systems (figure 14) are stormwater treatment systems that use ecohydrological regulation. These are applied at the inflow of stormwater into a receiving water body or in the aquifer itself.[2] The system is made up of 3 zones: intensive sedimentation (where a combination of fixed and mobile constructions modify the hydrodynamics of the chamber, increasing sedimentation); intensive biogeochemical processes (where the coarse limestone fraction captures phosphorus compounds); and biofiltration (where biogenic substances are eliminated by macrophytes). The zones are separated by gabions of coarse gravel which additionally filter the water.

Shoreline vegetated buffer strips with biogeochemical barrier

Sedimentation – biofiltration systems can be combined with plant buffer strips on the periphery of water bodies[3] (figure 15). Pollutants are removed through intensive sedimentation and assimilation by aquatic plants, as well as adsorption on biogeochemical barriers in the form of gabions filled with dolomite or limestone rock covered with a coconut mat. This solution may be applied for the pre-treatment of stormwater conveyed to rivers and other water bodies via stormwater outlets but only when the drained surface is small and water flow velocity during rain is not high enough to damage the plants.

[3] This solution was applied in the project entitled "Ecohydrological rehabilitation of Arturowek recreational reservoirs (Lodz) as a model approach to the rehabilitation of urban reservoirs" (EH-REK; LIFE08 ENV/PL/000517).

Photo: Tomasz Jurczak

Figure 15. Buffer zone with biogeochemical barrier for the pre-treatment of water conveyed directly to the reservoir: schematic representation and pilot project in the ponds of Arturowek in Lodz

Non-structural solutions

The implementation of sustainable stormwater management solutions is not limited to technical activities but requires the establishment of a wider background. This background is formed by a wide range of non-structural (soft) measures in the following areas (EPA 2005):

- education/awareness: educating residents and information campaigns on the alternative ways of stormwater management;
- planning and management: vehicle emissions control, conscious design of the urban space, plant design, reducing the coverage of impervious surfaces and separating these from the stormwater sewer system;
- stormwater system maintenance: street cleaning, cleaning of manholes and drains, water jetting the sewer system, road and bridge maintenance, maintenance of stormwater channels as well as ditches and aquifers;
- pollutant spill prevention and cleanup: control of oil leakage from vehicles and tankers, tightness control of sanitary sewers and cesspits;
- control of waste storage: stormwater sewer labelling, collection of hazardous waste from households, collection and recycling of used oil;
- control of illicit connections: prevention, detection and elimination of illegal connections to the stormwater sewer network;
- stormwater reuse: non-consumptive use of stormwater (e.g. for toilet flushing, irrigation of municipal greenery).

The experience of the USA's National Pollutant Discharge Elimination System (NPDES) suggests that non-structural activities that engage and include multiple stakeholders (residents, schools, entrepreneurs, decision makers, politicians, artists & the media) can actually be more effective at solving stormwater-related problems than structural activities. Non-structural activities are grounded in a common understanding of the challenges of traditional urban stormwater management, the effects of decisions and activities taking place in the urban space, the need for a new approach and the associated benefits. These constitute the starting point for the creation of a platform of cooperating institutions, the establishment of guidelines, legal frameworks and procedures, as well as the creation of a culture of responsibility for common activities in both public areas (e.g. spatial planning, architecture, environmental protection, infrastructure design) and private areas (e.g. the need to retain runoff generated on one's own property).

Non-structural planning measures: using the potential of blue-green infrastructure

Spatial planning is crucial for the creation of conditions that will encourage sustainable stormwater management. Design goals should include the functional connection of blue-green infrastructure and its coherent incorporation in the dense urban development, which is often a great challenge. However, this approach is vital to preserve the high potential of a city's natural system that translates into its ability to provide ecosystem services, including stormwater retention. This may be achieved by integrated thinking on the city and its natural system (cf. chapter on integrated management: Krauze and Wagner in this volume). The optimum use of the natural potential of blue-green infrastructure requires diversifying its forms and ensuring spatial links between these, thereby increasing urban infiltration.

Reducing the proportion of sealed surfaces

Reducing the proportion of sealed surfaces in the urban space is one of the fundamental measures for retaining water in the city. This can be achieved in several ways. The basic measure is indicating areas that naturally retain water through natural retention, infiltration and surface runoff processes and protecting these from development. These are often wetland areas and therefore exclusion from development also reduces the chances for an investment with a high risk of flooding or temporary inundation. Rivers and river valleys should be placed under special and absolute protection as receiving water bodies for stormwater, as well as corridors that link the urban natural system with its surroundings.

A subsequent step is determining the development conditions for new investments and revitalized areas in particular zones of the city. There are two possibilities here. The first is associated with determining the type of development, i.e. the minimum size of a parcel and development density, the maximum admissible proportion of impervious surfaces or minimum proportion of biologically active areas. Detailed technical requirements and guidelines can also be specified concerning the use of best practices and materials for the construction and hardening of large surfaces (e.g. pervious surfaces of streets, driveways, parking lots). A good practice that helps increase local water retention is the requirement of maintaining diversified terrain near investments (depressions, diversified slopes, land irregularities that retain water) instead of flat land covered with grass.

The second possibility consists of the introduction of a requirement to maintain a specific amount of runoff once the investment is finalized. Surface runoff can be expected to remain unchanged compared with pre-investment values or to constitute a specific amount after the construction is finished (e.g. a runoff coefficient of 0.1 would mean that 90% of rainwater is retained in the analysed area). Solutions of this kind have been successfully used in Germany and are now being implemented in Poland as well (Krakow).

Ensuring the diversity of blue-green infrastructure

The preservation of the diversity and high quality of blue-green infrastructure consists primarily of preserving the diversity of its elements in the urban landscape (rivers, river valleys, reservoirs, natural and artificial wetlands, parks, squares, orchards, gardens, community gardens, greened cemeteries, streetside greenery, areas of particular ecological value etc.). It is good practice to use indigenous species and plant assemblages that are adjusted to the physiography of the area. Not only is this a way to increase the natural value and importantly, the health value of a city, but to create original and pleasant landscape elements that shape residents' natural identity as well. Still, this solution is rarely found in Poland.

From the point of view of blue infrastructure, it is essential to take on actions aimed at preserving the existing aquatic and water-related ecosystems (that favour water retention) together with their vegetated buffer zone (that helps improve the quality of water and the condition of ecosystems) unchanged to the extent possible. The concept of zone-based development of small river valleys established and used in Lodz can serve as an example. Here, the assumption is that every urban river should be surrounded by three zones:

zone 1: absolute protection of the riverbed and valley from being built up. This zone assumes the restoration of degraded rivers where technically possible. These are areas used for the collection and treatment of stormwater and for recreation. Zone 1 is designated on the edge of the 100-year floodplain with the inclusion of natural habitat zones and

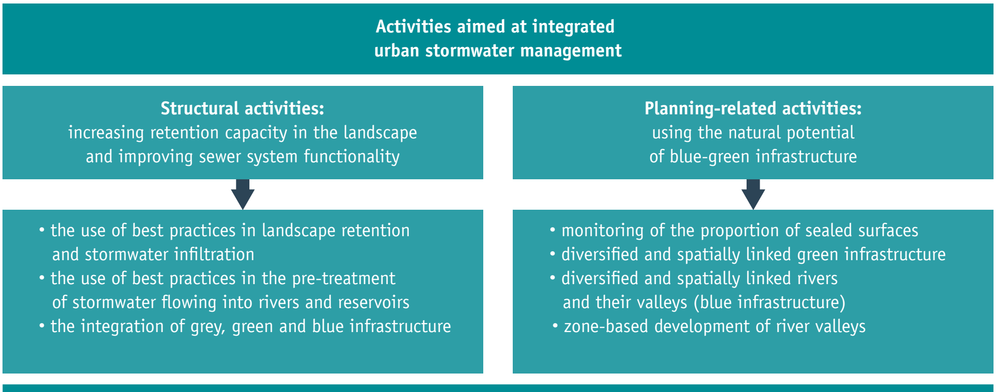

Figure 17. The use of blue-green infrastructure for integrated urban stormwater management

ecological corridors where these coincide with the 100-year floodplain and where allowed by current development.

zone 2: areas temporarily inundated. This zone provides for development with light recreational infrastructure (grassed fields, picnic areas, running paths). This zone is established within 50–100 m from the boundaries of zone 1, including natural landscape and natural/cultural landscape areas where these are continuously linked with the designated zone.

zone 3: zone of low development with strictly defined parameters, a significant proportion of biologically active areas and on-site water retention. This zone is established between the boundaries of zone 2 and the existing development in river valleys or their neighbourhood, and based on the guidelines concerning the natural conditions of the valley and its surroundings.

Ensuring spatial continuity of the urban natural system

Ensuring spatial links between the elements of the urban natural system increases their resilience to external factors and enhances their capacity to provide ecosystem services. This is a challenging task in densely built urban space where "hard" investments are often preferred over the creation of blue-green infrastructure due to competition and the high price of land. However, some rules must be followed when designing the natural system of a city. Green areas should be as big, compact and located as close to one another as possible. Their integration with the structural solutions of best management practices will improve their functioning as more water will be available to plants. If continuity of green infrastructure cannot be ensured, it may be compensated by adequately planned street greenery (cf. previous guidebook in the *Sustainable Development Applications* series), the creation of "green islands" (green roofs or squares located close to one another), and increasing the coverage of pervious surfaces or the use of structural solutions aimed at water retention and infiltration.

Summary

The functioning of blue-green infrastructure in the city is based on sustainable stormwater management. This can be achieved by integrating multiple fields of action that make use of both structural and design solutions (figure 17). Such combinations lead to increased retention capacity in the landscape (even under the pressure of climate change and progressing urbanization), which helps reduce the load on stormwater sewer networks as well as the risk of flooding, temporary inundations and drought (including the heat island effect) and the effects of these. Water accessibility is one of the fundamental prerequisites for the proper functioning of urban ecosystems. The high natural potential of blue-green infrastructure also translates into the ecosystems' ability to provide a wide range of services that are crucial for the quality of life of residents and their ecological safety.

Case study: ecohydrological reclamation of Arturowek recreational reservoirs in Lodz

Small rivers and reservoirs are an inseparable feature of the landscape of Lodz, a city located on the watershed divide between the Vistula and Oder rivers. This location coupled with the lack of any large water body that would receive stormwater, forces the city to seriously consider the use of sustainable stormwater management solutions and the multifunctional use of space (such as combining water retention with recreational and landscape functions and the protection of biodiversity).

The three ponds on the Bzura river in Arturowek together with the surrounding forest complex are one of the most valuable and openly accessible recreational areas for city residents, and even a holiday destination. Designated bathing areas are a popular attraction. However, water quality used to be low due to the inflow of stormwater and the reservoirs' internal load of biogenic substances in the bottom sediments that accumulated over the years. Toxic cyanobacterial blooms that formed on hot summer days posed the biggest threat: bloom intensity significantly exceeded WHO guidelines for bathing waters. Due to the health threat to residents, the bathing areas were closed down on numerous occasions. The improvement of water quality and ecological conditions of the ponds became the prerequisite for maintaining the attractiveness of the site, creating safe public space and recreating ecosystem services.

Within the framework of the ecological reclamation project for the ponds in Arturowek,[4] the threats and opportunities were examined for the restored area (Jurczak et al. 2012). This served to establish action plans aimed at improving water quality where one of the challenges was the pretreatment of stormwater flowing into the ponds. The following solutions were applied (figure 16):

- The ponds in Arturowek are fed by a river with a cascade of seventeen small, dammed reservoirs. Two of these were subject to ecohydrological adaptation: sediments were removed, plants that accelerate water purification were planted and hydrotechnical engineering used to force water flow through the vegetated zones.
- The last reservoir upstream of the ponds in Arturowek receives stormwater from the street. A construction described in this chapter (the sequential sedimentation – biofiltration system) reduces the inflow of pollutants carried by the river to the ponds in Arturowek.
- Most inflowing sediments accumulated in the upper part of the first pond in Arturowek. Therefore, the upper part of its basin was also transformed into a sequential sedimentation/biofiltration system.
- There are also stormwater outlets that convey stormwater to the reservoirs in Arturowek directly from small stormwater basins (such as a hotel, sports centre). At the inlets, plant buffers zones with biogeochemical barriers described earlier in this chapter, were set up.
- In the lowest pond, sediments were removed and floating plant islets were set up that additionally purify the water.

In the first year after the investment was completed (2014), the concentrations of biogenic substances fell 10-fold for the first time in many years, there were no cyanobacterial blooms and the water is now so clear that the bottom can be seen.

The innovative quality of the solutions proposed here is associated mainly with the comprehensive use of multiple, complementary solutions along the entire river system. The application of ecohydrological solutions allowed the achievement of significant benefits at relatively low cost. The natural areas became the basis for the creation of attractive and safe space in line with the city's strategic goals laid out in the Integrated Development Strategy for Lodz 2020+ and the Blue-Green Network concept (Wagner et al. 2013).

[4] The project entitled "Ecohydrological rehabilitation of Arturowek recreational reservoirs (Lodz) as a model approach to the rehabilitation of urban reservoirs" (EH-REK; LIFE08 ENV/PL/000517) is carried out by the Department of Applied Ecology of the University of Lodz in cooperation with Lodzka Spolka Infrastrukturalna and the City of Lodz Office represented by the Municipal Sports and Recreation Center. The project is financed from the European Commission, the National Fund for Environmental Protection and Water Management, co-financed from the Regional Fund for Environmental Protection and Water Management in Lodz and project beneficiaries' own contribution.

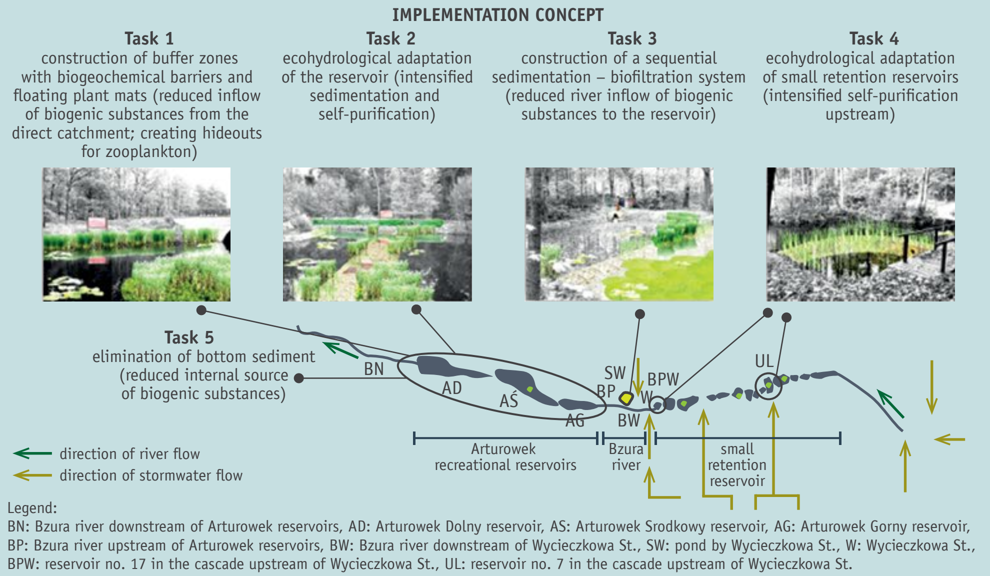

Figure 16. Solutions applied for the reclamation of ponds in Arturowek

References

Burszta-Adamiak, E., 2011. Odprowadzanie wód opadowych systemami do podziemnej retencji i infiltracji. *Rynek Instalacyjny*, 5, pp. 48–51.

EC, 2013. Green Infrastructure: *Enhancing Europe's Natural Capital,* (COM (2013)249), Brussels: European Commission.

Edel, R., 2010. *Odwadnianie dróg*, Warsaw: Wydawnictwa Komunikacji i Łączności.

EPA, 2005. *National management measures guidance to control nonpoint source pollution from urban areas*, Washington, D.C.: U.S. Environmental Protection Agency.

EPA, 2007. *Reducing stormwater costs through Low Impact Development (LID) strategies and practices*, Washington, D.C.: U.S. Environmental Protection Agency.

Geiger, W., Dreiseitl, H., 1999. *Nowe sposoby odprowadzania wód deszczowych. Poradnik retencjonowania i infiltracji wód deszczowych do gruntu na terenach zabudowanych*, Bydgoszcz: Oficyna Wydawnicza Projprzem-EKO.

Jurczak, T., Wagner, I., Zalewski, M., 2012. *Ekohydrologiczna rekultywacja zbiorników rekreacyjnych Arturówek (Łódź) jako modelowe podejście do rekultywacji zbiorników miejskich (EH-REK). Analiza zagrożeń i szans (LIFE08 ENV/PL/000517)*, Lodz: Faculty of Biology and Environmental Protection, Univesity of Lodz.

Kaźmierczak, A., 2013. Innovative ways of supporting the establishment of green infrastructure in cities: collaboration of local authorities with investors and property owners. *Sustainable Development Applications*, 4, pp. 98–109.

Królikowska, J., Królikowski, A., 2012. *Wody opadowe. Odprowadzanie zagospodarowanie podczyszczanie*, Piaseczno: Wydawnictwo Seidel-Przywecki.

Wagner, I., Breil, P., 2013. The role of ecohydrology in creating more resilient cities. *Ecohydrology & Hydrobiology*, 13(2), pp. 113–134.

Wagner, I., Krauze, K., Zalewski, M., 2013. Blue aspects of green infrastructure. *Sustainable Development Applications*, 4, pp. 145–155.

Zalewski, M., 2011. Ecohydrology for implementation of the EU Water Framework Directive. *Proceedings of the ICE — Water Management*, 164(8), pp. 375–386.

Water in the urban space and integrated urban management

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Integrated urban management is based on three pillars: equal access to high-quality environment, efficient use of natural resources for economic benefits, and maintaining ecological balance and the ability of natural systems to regenerate. In each of these pillars, water management is a key aspect because water is a valuable resource, an important element of the landscape and driving force of ecological processes. Thus, integrated urban management requires an interdisciplinary approach, multi-sector, multi-annual planning and extensive cooperation of many groups of stakeholders. Meeting this challenge brings tangible benefits: it allows urban renewal and increasing urban competitiveness, reduces management costs and increases urban adaptability to global changes, not only climate change, but also the demographic or economic changes.

Keywords: integrated management, strategic planning, natural capital, human capital, social capital, spatial and sectoral integration

Introduction

The management of resources such as urban water is a complex matter often referred to as a wicked problem. Wicked problems are not necessarily unsolvable – they may need to be approached differently. The typical features of these problems include the following:

- there is no single, ideal solution: a number of solutions are possible because multiple stakeholders are involved and each of these may hold a different view on the best solution;
- no solution is completely bad or wholly good: these may only be better or worse depending on the spatio-temporal scale and other determinants;
- no solution may be tested beforehand – knowledge is gained as the consequences become known;
- the solution to the problem often becomes a problem in itself because not all cause-effect relationships are known;
- all of the chosen solutions require the stakeholder groups to agree and their needs to be balanced.

Accordingly, the approach to urban water management must be integrated and combine policies and strategies at various levels of decision making to ensure their full compatibility. It is also essential to address all related issues at the same time, e.g. the management of urbanized areas, integrated spatial planning, resident welfare, site competitiveness, social inclusion, environmental protection and a sense of responsibility for the environment.

The concept of integrated water resource management was defined by the Global Water Partnership as "a process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems". This concept became particularly important once Poland joined the European Union.

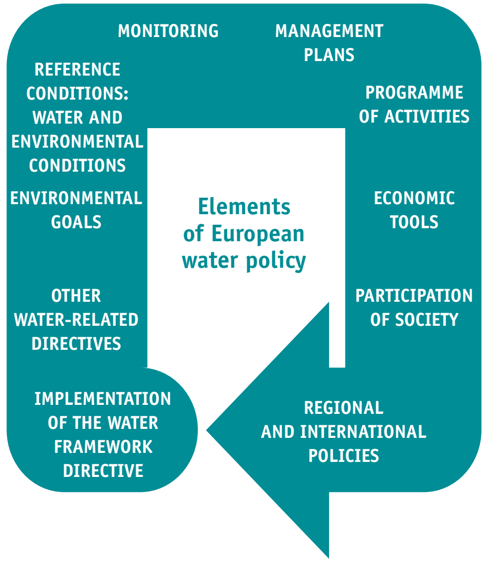


Figure 1. Elements of European water policy implementation that may be achieved only through the adoption of an integrated approach towards water resource management

The implementation of all EU directives (including those relevant for this guidebook, i.e. the Water Framework Directive,[1] the Habitats Directive[2] together with the Natura 2000 network, and the Nitrates Directive[3]) requires an integrated approach. The current and future threats to water quality and availability must be defined. In addition, water-related habitats, species and sectors of the economy as well as the hazards of: business activity; social structure; legal mechanisms; cultural determinants; systemic determinants; technological determinants; and the condition of the environment must all be taken into consideration (figure 1).

Integrated management is based on three pillars:

1. Social equity: everyone has an equal right to access resources to the extent that guarantees dignified life, irrespective of economic status;
2. Economic efficiency: the highest possible number of users should receive maximum

[1] Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy

[2] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

[3] Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources.

Table 1. The benefits of integrated management

Risk	Efficacy	Cooperation	Knowledge
• Comprehensive approach to problems: cause-effect relationships • Decentralization of responsibilities and tasks	• Elimination of incompatible competences and structures • Harmonization and optimization of solutions • Fund acquisition based on natural, human, social and economic capital	• Reliable assessment of objectives and needs • Continuity of activities based on social memory and knowledge • Conditions conducive to public participation	• Conditions that favour knowledge and experience exchange • Adaptive management • Agreement between stakeholders

benefit from resources to the extent feasible and within the available water resources;

3. Ecological equilibrium: ecosystems are to be treated on a par with other water users, therefore ecosystems' right to access the necessary resources to the extent that ensures survival and sustainability must be guaranteed on a level with people's right to use resources.

At the operational level, integrated management requires the application of interdisciplinary knowledge as well as public consultations and participation to design and establish tools and implement good water management practices. Since many sectors of the economy are highly dependent on water, the solutions must also integrate multiple sectors, and stakeholders should be open and flexible in their collaboration. The success of sustainable management depends on:

1. The creation of conditions conducive to the implementation of appropriate strategies, policies and legal solutions;
2. Precisely defined roles and competences of institutions and the creation of the necessary human capital;
3. The establishment of management tools that allow the rationalization of choices and assessment of alternatives.

Other important elements include: political will and involvement, social capital and adequate financing (that provides for long-term planning and the possible returns from investment in infrastructure), and comprehensive monitoring and assessment of the effects of activities on the political and societal fronts as well as implementation-wise.

The benefits of integrated management

The perception of water as a raw material, of rivers as a flood, pollution, and disease-carrying threat, and of small retention as competition for space has led to the degradation of water resources and disappearance of naturally valuable aquatic and water-related land ecosystems (wetlands, ponds, water meadows).

The reversal of the process of degradation and the rehabilitation of degraded aquatic and water-related ecosystems[4] require joint actions by those responsible for water management and its users. In practice, this requires complex databases, expert knowledge and tools that allow the analysis, extrapolation and forecasting of resource dynamics resulting from the current and previous environmental conditions and overall human environmental impacts.

Many cities around the globe have taken on the challenge of integrated water management. Acknowledging the need to use innovative on-site stormwater management solutions is typically the first step. This helps to reduce the load on stormwater sewer systems, increase groundwater recharge, increase the efficiency of waste water purification, and consequently to improve microclimate, supporting the development of green infrastructure, and leading to improved quality of life and aesthetics

[4] These are actions aimed at restoring near-natural processes in heavily degraded ecosystems; rehabilitation does not lead to the restoration of the original, natural system.

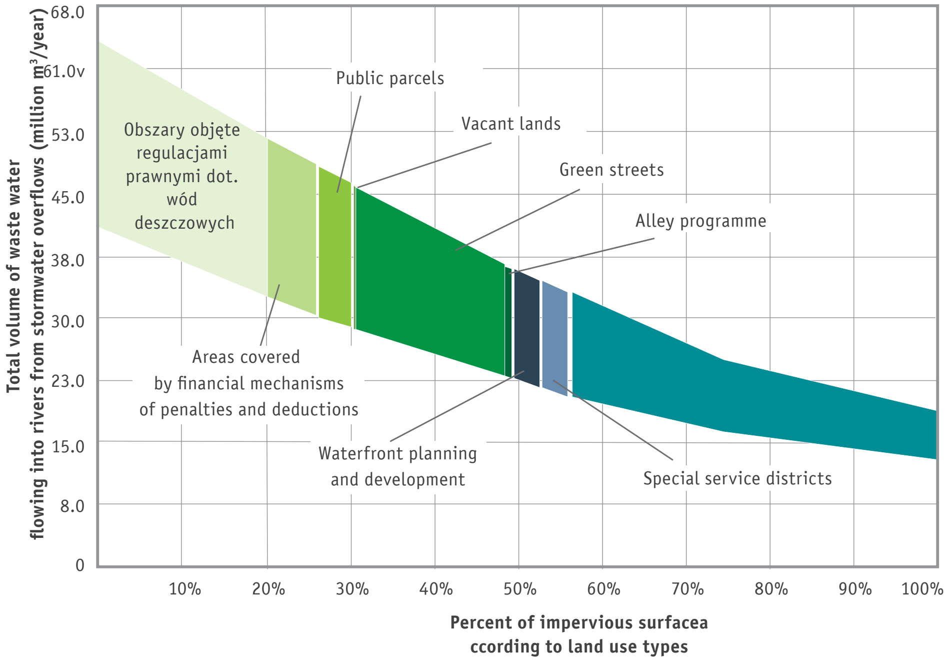


Figure 2. Integrated actions taken on by Philadelphia to reduce the volume of waste water flowing from stormwater overflows into rivers and to reduce urban management costs and promote green infrastructure (EPA 2010)

for city residents (cf. chapter on technical solutions: Wagner and Krauze in this volume).

Figure 2 shows the integrated activities undertaken in Philadelphia with regard to stormwater management. It turns out that legislation directly linked to stormwater management only improves the efficiency of stormwater use on 20% of urban land. Successful management requires the involvement of institutions responsible for establishing the appropriate legal mechanisms of exemptions and penalties (another 6% of the city's surface area), the involvement of private landowners (4%), the creation of an interdisciplinary and inter-sectoral team, a strategy to design and implement a programme of green streets (17%) and urban alleys (2%) and finally cooperation in planning urban development and forecasting and reducing its negative impact on urban water resources (8%). This way, concerted actions and policies allowed 57% of the city's surface area to be covered by integrated management which translates into stormwater runoff being reduced by 65%. At the city level, this saves around 85 million USD annually.

At the same time, integrated urban management based on an interdisciplinary approach allows the city to be revitalized and improve its competitiveness. It is also worth highlighting the reduced urban operating costs: once established, ecological systems increase their efficiency and stability due to plant growth; increasing numbers of species; the intensification of soil formation processes and consequently, improved soil water retention; intensified evapotranspiration; climate regulation; and increasing adaptation to the existing infrastructure (figure 3).

Integrated urban management is about spatial, functional, ecological and social integration. In line with the concept of solving wicked problems, it is a way of defining and comprehensively approaching problems rooted in different aspects of city functioning.

Spatial integration

Cities develop in a way that fosters the creation and accumulation of economic potential and infrastructure that serves this potential. This is how we got to the point where spatial development often negatively affects urban residents' quality of life (Bolund and Hunhammar 1999). Spatial planning too, like environmental resource management, has adopted the command and control model. This model is based on the analysis of the urban spatial structure and making adjustments to the studies of determinants and directions of spatial development in response to, the predicted pace and directions of changes in the city, the need to protect valuable nature, preserve elements of suburban space for recreational purposes and to adapt infrastructure, including road networks. This model is quite static, refers to sectoral visions and strategies, and leaves little room for balancing different elements of the urban space and even less room for balancing the various components within a region. This approach has prevailed in urban management because it can speed up the planning process and uses the existing administrative structures and policies.

With the current challenges of integrated management, a new model of urban spatial arrangement is emerging that is grounded in a visionary and design-based approach. Design thinking focuses on the creation of a coherent vision of the city with rationally located residential areas, business centres, transport networks and other infrastructure. The identification of unique land elements (of both natural and cultural value) and the creation of opportunities to preserve and develop these into areas that will meet the needs of residents on the one hand, and guarantee quality of life at present and in the future on the other by including nature as a full-fledged and mandatory element of blue-green infrastructure, form an integral part of this vision. Planning the urban structure in this way allows the assumption that cities are simple systems that develop in a linear and predictable fashion to be abandoned. The city is perceived as a co-evolving natural/social system where each component is highly and equally dependent on the other. At the level of urban spatial management policy, this new

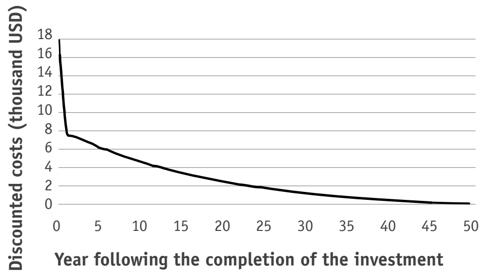


Figure 3. An example breakdown of the discounted costs of a streetside plant infiltration system covering an area of 0.2 ha (SCWS 2012)

approach is associated with the following consequences:

- the spatial management plan is not merely a legal tool and guideline for investments, but above all an operational plan that defines the areas for intervention within the framework of existing urban areas, as well as a tool to design urban policy and create public-private partnerships;
- local administrators play a much larger role in the establishment and execution of local spatial management plans;
- horizontal cooperation between cities and between cities and regions is given a leading role while the role of hierarchical management and vertical decision making is minimized to support greater flexibility of the planning process;
- urban spatial management acquires a long-term dimension if only due to the need to reconcile the needs and interests of multiple stakeholder groups;
- urban residents identify themselves more with the city's space.

At the operational level, this new approach:

- allows for the preservation of links between areas within the city; its natural and cultural elements, both in terms of the road network, alternative (environmentally-friendly) transport pathways, as well as green corridors and green belts around cities that ensure high quality of life. For instance, city residents may be included in the designation of natural/cultural

paths and introduction of green infrastructure in recreational space in a way that opens development possibilities for small service companies;
- determines the city's role in the region as well as the network of interrelationships and interdependencies, including the joint protection of water resources, green infrastructure, and compatible development of satellite cities. For example, this approach allows to establish a common development policy, create metropolitan cultural areas, cooperate on water protection, e.g. to achieve a good ecological condition of rivers, expand and protect green corridors or minimize the negative effect of expanding road infrastructure on nature;
- allows for identification of the best possible urban structure with regard to the age, professional and economic structure of city residents. For instance, authorities in Finland are carrying out activities (backed by social studies) to adapt cities to the needs of parents with small children, while Venezuela and Brazil are making efforts to integrate districts by creating green public spaces; South Korea is recreating cities' historic image to reinstate disappearing traditions and people's relationship with rivers;
- indicates the appropriate allocation of funds for urban revitalization and development that reflects residents' needs and not the system of funds administration and management. For example, the priorities of cities in terms of grey and green infrastructure are now largely determined by the availability of EU funds; this in combination with the centralized and sectoral model of urban management leads to rehabilitation works being carried out simultaneously with the channelling of different sections of the same river. Meanwhile, the establishment of a comprehensive river programme coupled with resident involvement would help harmonize actions and create friendly, coherent and useful space;
- creates the possibility for integrating sectoral activities to achieve common goals, such as combining road design and modernization with the protection of green corridors and the protection and use of groundwater and stormwater;
- prevents the execution of individual needs and achievement of individual benefits at the expense of the local community or long-term public goals, e.g. by increasing the presence of different stakeholder groups both in the design and performance of activities; social control in terms of including the needs of all stakeholders is also enhanced.

Ecological integration

Modern management places high emphasis on the creation of systems with a substantial ability to adapt, i.e. natural systems and the services that they provide and their incorporation in infrastructure. However, as highlighted in this and other sustainable development guidebooks, nature only plays its role when it functions as a system. This is associated with the basic features of these systems which gain particular importance in cities:

- resistance to natural and anthropogenic pressures and the efficiency of service provision (air, water and soil purification; climate regulation; water cycle regulation, water retention) depend on the number of species and their numbers/biomass per area unit. Therefore, all species should be viewed as "insurance policies for the future" in case of changing environmental conditions;
- these systems are dependent on the constant inflow of species and specimens from suburban areas to compensate losses caused by difficult living conditions for urban plants and animals on the one hand and to increase biological diversity with the richer gene pool of out-of-city areas on the other;
- without the inclusion of cities in a system of green corridors and green infrastructure, species diversity in the out-of-city landscape is also under increased pressure due to the expansion of roads (barriers for animals), urbanization processes and intensification of agriculture. Integrated design where the city and landscape are connected allows more effective

nature protection and reduces environmental hazards;
- these systems are associated with water and matter cycling at a particular scale, e.g. that of a catchment. Consequently, self-sustaining natural systems (that do not require significant input such as irrigation, compensation planting, fertilization) are impossible to maintain where these cycles are interrupted by landscape fragmentation (Wagner et al. 2013);
- external pressures may be compensated only by the size of a green area: nature has the greatest self-regulating and regenerative abilities in the central parts of such spaces and these abilities decline towards the boundaries (edge effect). The greater the proportion of surface area to the length of the borderline, the better.

In the context of city functioning, ecological integration is also about preserving the links between the city and the essential resources that it relies on, including the protection of these. The city of São Carlos in Brazil can be used to illustrate efforts aimed at integrated management. Its general development plan (Peres and da Silva 2013) identifies the current and future strategic sources of water. This plan assumes the absolute protection of land surrounding strategic reservoirs already at this point. Therefore, no development permits are issued in the vicinity of the protected areas. In the suburban zone, areas for industrial development and residential development were also indicated far in advance based on the predicted inflow of capital and investor interest. The hydrographic conditions, underground water flow, soil permeability and plant sensitivity to anthropogenic pressures were also taken into consideration. Land for extensive and intensive agriculture was also planned, both to supply the city and to contribute to the development of the region. From the point of view of integrated management, the incorporation of ecosystem services in the urban adaptation system to global changes requires the following:

- absolute preservation of green belts around cities and the prevention of urban sprawl;
- maintenance of green corridors that connect all urban zones with the city's green belt, and the preservation of the high quality and multi-functionality of river valleys, i.e. the protection of their role as animal and plant migration zones (green corridors may include urban parks, alleys, old orchards, community gardens);
- the preservation of naturally valuable land, particularly aquatic and wetland ecosystems, and maintenance of the necessary hydrological conditions;
- the space and time necessary for efficiently functioning green infrastructure, guaranteed in cities' development plans;
- the creation of appropriate conditions for the rehabilitation and renaturalization of green areas and aquatic ecosystems with ambitious goals that go beyond "ecological potential". For instance, the conditions in one of the main streams in Stockholm currently allow the reproduction of 30 fish species, making it one of the most popular angling sites in Sweden (Stadbyggnadskontoret 1995).

Functional integration

One of the functions of cities is to provide residents with healthy space (cf. chapter on the links between water in the city and residents' health: Kupryś-Lipińska et al. in this volume) to meet their needs associated with work, education, leisure, provisioning, aesthetic experience and to establish their identity through contact with nature and culture. At the same time, management is aimed at ensuring sustainable urban development where physical health and welfare goes hand in hand with the quality of nature and ethics of equity. This way, integrated management promotes the multi-functionality of urban space which in turn supports social integration and resident activation.

The concept of social inclusion assumes the establishment of equal living and development conditions for different social groups, residents with different wealth levels and living in diverse parts of the city. It is important not to create closed and spatially isolated enclaves where residents cannot participate in the creation and life of a city for various reasons.

Social exclusion is not only caused by poverty, the associated unemployment and the lack of perspectives, but also by disability, old age, the distant location of residential districts, infrastructure degradation, sense of insecurity, or the dispersal of urban functions that forces residents to travel long distances.

Still, it is poverty that remains one of the greatest challenges because in many cases it is inherited. Districts with a bad reputation fail to attract investors and discourage wealthier residents, further exacerbating the problem (Warzywoda-Kruszyńska and Grotowska-Leder 1996; Warzywoda-Kruszyńska 1998).

A briefing report by the Chartered Institution of Water and Environmental Management in the UK (Grant 2010) suggests that the density of green infrastructure and aesthetic, clean and openly available public spaces is inversely related to the location of areas of social exclusion. In Manchester, for example, green areas constitute at least 10% of wealthier districts that attract capital and only 2% of poorer districts. However, the report emphasizes that efforts to improve the quality and management of urban space will not yield the expected results without resident involvement in the design and implementation of urban programmes, which also helps develop a sense of identity and responsibility for a place.

By opening up high quality public space to all residents, integrated management creates the opportunities to learn, experience culture and tradition, engage in sports, stay in contact with nature and other residents, and to design urban revitalization programmes based on public participation. This can be an effective way to eliminate the sense of alienation. Care for the entire urban space and open access to public spaces facilitate long-term spatial order and cleanness. Integrated management of the city and its nature also makes it possible to designate areas with particular functions for local communities, such as space for urban agriculture/gardening that may be a form of physical activation for seniors, education for children and adolescents, and source of income for poorer city residents.

Urban space is valuable due to its intensive use and the multiple and diverse needs of residents that go with it. Urban spatial management requires the creation of safe living conditions, flood protection, microclimate regulation, protection form temporary inundations and pollutants. The creation of alleys and parks in areas of intense traffic is also crucial to preserve air purity and protect from noise. Due to limited space resources, urban areas should integrate as many functions as possible.

From this standpoint, the protection and efforts to preserve urban green areas are particularly profitable: green areas have greater potential to serve diverse forms of resident activity than e.g. residential districts, commercial and office centres, or industrial areas. Green spaces serve as:

- transport pathways for humans, animals and plants, enclaves of greenery and biodiversity;
- areas of temporary or permanent water retention, flood protection measures;
- areas for relaxation, recreation, physical activity ("health centres");
- areas for biomass acquisition and agricultural production;
- potential areas for the production of renewable energy (water, solar, wind);
- demonstrative projects to promote: the integration of green, blue and grey infrastructure, applied arts and modern architecture; ecological technology and engineering;
- sites for ecological and cultural education as well as good traditions and practices;
- inspiration for new technologies, services, art;
- areas to promote, advertise and sell ideas/services, such as the promotion of local products, mobile cafes, location-based games;
- areas to promote the city and its links with the region.

Sectoral integration

Integrated urban management requires the integration of activities performed by multiple entities responsible for the interrelated urban elements. The key stakeholders that ought to be included at different stages of collaboration are:

- institutions responsible for infrastructure, including sanitary and stormwater infrastructure;
- institutions responsible for the expansion of grey urban infrastructure, including roads and transportation, and urban revitalization;

- municipal departments/facilities;
- departments/facilities/studios for spatial planning;
- departments for strategy and design: the new paradigm for urban water and spatial management can help develop cities' competitiveness if it is reflected in their development plans;
- departments/institutions for promotion and education: to create a new city image, to disseminate knowledge on the progressing changes and the need for these;
- institutions and offices for nature protection;
- institutions responsible for water resources at the regional level (e.g. Regional Water Management Authorities): to maintain the cohesion of policies and strategies for spatial, nature and water management;
- Offices of the Marshal: to ensure coherence of actions within the region;
- institutions responsible for environmental monitoring: these allow the monitoring of the effects of activities in the urban and suburban space, and adaptive management of their resources;
- non-governmental organizations: associations and foundations that help build social capital and include diverse stakeholders in activities that benefit the city;
- funding institutions, such as Regional Funds for Environmental Protection and Water Management that allow the financing of local activities and grassroots initiatives.

The collaborating institutions jointly establish a vision of activities based on a SWOT analysis (strengths, weaknesses, opportunities and threats analysis). With this strategy, the principles of co-operation, scope of responsibilities, and the guidelines for the achievement of short and long-term goals are clearly defined. Changes in stormwater management require actions in different spatial and time frames and hence the need to establish the mechanisms for coherent decision-making at all levels. Additionally, a system of monitoring new investments should be established and the critical boundary conditions for the effective functioning of infrastructure provided.

At the same time, it is worth considering the inclusion of local companies and the academic milieu in this collaboration as their business experience and expert knowledge can help to verify the planned activities.

Integrated solutions

Integrated management promotes the use of integrated solutions that maximize the benefits for all stakeholders and support the equal distribution of costs. According to UN's pyramid of responsible management (figure 4), sustainable development requires first and foremost the use of existing natural potential (capital) and combining it with social and economic capital, as well as constant efforts aimed at its development. When developing a city, authorities should first of all avoid creating pressures on the environment, or at least minimize them. If none of the solutions described above are possible, integrated repair and compensatory activities must be planned.

Each solution must be adapted to the local functions and urban structure as well as the degree of land transformation and ecological potential. Selected solutions for each pyramid level are shown in table 1.

Summary

As one of the elements of sustainable development, integrated urban management is largely based on the integrated management of resources, including water. However, social capital (relationships) and human capital (abilities and awareness) play essential roles. Shifting the approach to management requires the establishment of a system to assess the efficacy of its implementation. Therefore, due to the multifaceted nature of activities, different spatial scales, and multitude of stakeholders, appropriate indicators must be worked out.

Twelve example indicators of successful integrated urban water management were proposed as part of the 2005–2009 SWITCH project entitled

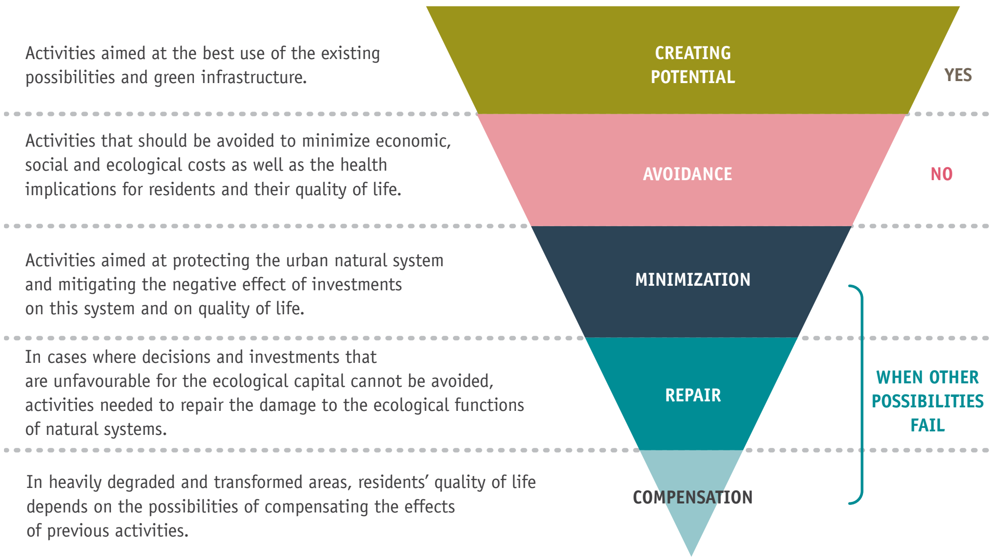


Figure 4. The United Nations-supported Principles for Responsible Investment established and implemented by the UNEP Finance Initiative and UN Global Compact

"Sustainable water management in the city of the future" <www.switchurbanwater.eu>, namely:

- protection of the hydrological cycle (the extent to which the performed activities protect or allow restoration of the disturbed water cycle);
- landscape aesthetics;
- structural and functional integration with neighbouring land (the extent to which the integrated management programmes fit into the design, structure, cultural and historic values of sites);
- correctness of design (the proposed activities, projects and programmes must be designed in a way that ensures the right use of space and human, natural and economic potential, and be adjusted to the local needs and conditions);
- precise long-term maintenance conditions for the constructed infrastructure;
- adaptive qualities of solutions (the adopted solutions should improve the city's adaptation to changing social, ecological and economic conditions);
- usefulness (multifunctional space that includes the protection of ecosystem services);
- public participation (providing for the needs of the maximum number of stakeholders and including these at different stages of management);
- costs (these should not exceed the costs of conventional management);
- combining the needs of different stakeholders;
- interdisciplinary planning;
- societal acceptance.

Gabe et al. (2009) propose an even broader assessment of integrated management. The additional aspects include:

- in terms of environmental impact: increased habitat integrity, increased biodiversity, improved water quality, reduced energy use from non-renewable sources, material reuse, infrastructure recycling;
- in economic terms: economic growth (e.g. the number of new enterprises or projects), economic autonomy of the city and region (the contribution of local enterprises to the region's GDP), job creation, generating returns through integrated projects (rate of return on investment), reduced operating costs for households and enterprises, minimizing the need for vehicle transport (e.g. he length

Table 1. The possibilities for combining activities within different types of land use to build natural capital and carry out a responsible and integrated urban management programme to avoid/minimize/repair/compensate for anthropogenic pressures

	ROADS: DESIGN AND CONSTRUCTION	RESIDENTIAL AREAS	PARKING LOTS AND LARGE INVESTMENTS	RECREATIONAL AREAS AND THE NATURAL SYSTEM
	The designation of areas of absolute protection of nature as a life-sustaining system, and multifunctional areas. The preservation of the critical links between green areas for the protection and creation of natural capital.			
	Defining the true needs for road construction. Prioritizing alternative transportation and creating green walking/cycling paths instead of excessive road development.	Protecting suburban areas from new investments. Establishing financial and legal mechanisms that promote revitalization and adjustments to the existing urban infrastructure. Establishing penalty and tax mechanisms to prevent green and suburban areas from being built up. Including residents in the creation and development of green infrastructure, e.g. cooperation in the design of infiltration basins and infiltration swales along access roads.	Minimization of needs. Designing investments in harmony with the existing green and grey infrastructure. Preserving the adjoining green areas. Using greywater for the maintenance of local greenery. Creating demonstrative and educational projects in commercial centres. Protecting suburban space by connecting large investments with the existing infrastructure.	Designing and creating areas for recreation as buffer zones for valuable nature resources. Including recreational areas in blue-green infrastructure networks. Creating recreational areas in densely built zones. Using nonconventional approaches to create green infrastructure, e.g. High Line Park in New York: a 2.3 km long park on an elevated rail structure.
	Maintaining the links between all elements of urban space and their structural and functional coherence. The creation of a maximally dense network of multifunctional areas based on green infrastructure. The preservation of trees and green areas with the highest ecological potential and sensitivity: aquatic and wetland ecosystems, forests, semi-natural meadows.			
	Planning new investments in place of the existing ones. Avoiding road investments unless absolutely necessary as these contribute to landscape fragmentation, interrupt the continuity of ecological processes and isolate plant and animal species from vital resources. Bypassing aquatic and wetland ecosystems at the stage of road design. Bypassing landscapes with unique cultural features at the stage of road design. Protecting valuable land along roads from being built up as a result of road infrastructure development.	Leaving large (above 1 ha), compact green areas, both forests and land for agricultural use, at early stages of development planning. Preserving links between green spaces and providing residents with aesthetic green areas where they can engage in physical activity. Ensuring the full functionality of housing estates through the development of local services: this helps reduce traffic and prevents residents from migrating to suburban areas. Preserving diversified terrain to benefit from its water-retaining potential and habitat diversification.	Allowing new investments only in urbanized, especially post-industrial areas, inhibition of urban sprawl caused by the expansion of logistical and commercial centres. Planning investments in areas of social exclusion to attract investors and improve overall environmental quality. Leaving large green areas, both forests and for agricultural use. Combining investments with alternative stormwater retention solutions.	Indicating land where recreational functions are secondary to other functions. Protecting aquatic ecosystems, rivers, lakes and ponds by locating them as buffer zones in the vicinity of areas used for recreation.

ROADS: DESIGN AND CONSTRUCTION	RESIDENTIAL AREAS	PARKING LOTS AND LARGE INVESTMENTS	RECREATIONAL AREAS AND THE NATURAL SYSTEM
The creation of local stormwater infiltration, retention and pre-treatment systems. The preservation of maximally large sections of natural and agricultural habitats.			
Metropolitan planning: integrated development design of both central and satellite cities. Expanding systems of passageways and green corridors not only for highways but all roads with traffic exceeding 1,000 vehicles per day to preserve landscape continuity. Preserving unique cultural elements of the landscape.	Establishing detailed requirements and technical guidelines for Low Impact Development. Increasing development density while at the same time ensuring full functionality and the aesthetics of districts. Preserving maximally large urban green areas and enriching these with native species.	Establishing detailed requirements and technical guidelines for Low Impact Development. Constructing small retention systems and other BMPs to serve as habitat for plants and animals and for stormwater collection.	Preserving maximally large urban green areas and the links between them, and enriching these with native species. Creating reservoirs and biofilters in urban aquifers to serve as habitat for plants and animals and/or water sports and angling centres.
Recreating the links between the structural/functional elements of the city and green areas through the rehabilitation of rivers and river valleys and the creation of ecological corridors.			
Individualization of projects for better harmonization with the landscape: recreation of habitats and preservation of the cultural landscape along roads. The use of plant systems for water pre-treatment along roads: infiltration swales, stormwater wetlands etc.	Creating networks of green spaces: parks, squares, old orchards, green roofs. Constructing small retention systems and other BMPs to serve as habitat for plants and animals and for stormwater collection. Creating local waste water purification systems, including stormwater wetlands.	Linking large investments with recreational and residential areas via networks of green transport routes. Constructing small retention systems and other BMPs to serve as habitat for plants and animals and for stormwater collection.	Creating recreational space with the use of unused land, post-industrial areas and municipal parcels after demolition. Creating reservoirs, fountains, ponds.
The use of biologically active areas. Creating green links in the form of stepping stones.			
Preserving additional green areas within city boundaries to compensate for land lost to transport routes. The use of plant systems for water pre-treatment along roads: infiltration swales, stormwater wetlands etc.	Expanding micro-green infrastructure as an architectural element in densely built land.	Constructing small retention systems and other BMPs to serve as habitat for plants and animals and for stormwater collection. Creating multifunctional green areas within investment sites.	Creating leisure areas: squares and alleys that combine local elements of culture, applied arts and native plant species. Creating green pathways for quick access to recreational areas. Creating green corridors for conflict-free (to the extent possible) animal migration and plant dissemination.

Examples of best practices

Integrated management is more than an interdisciplinary and inter-sectoral approach. Due to the features of the integrated systems (social, economic and natural), and the spatial and functional structure of cities, integrated management requires activities in different spatial and time frames. Efforts to combine different types of investment in one system that will help improve residents' quality of life encompass activities at the scale of several metres, an entire district or even metropolitan system. Table 2 shows examples of integrated activities with different scopes.

Table 2. Examples of integrated planning and management at the urban, district and local level

Large-scale programmes: cities	
Grey to Green, Portland, USA (Hoyer et al. 2011; Sustainlane 2010)	
CONCEPT	ELEMENTS OF INTEGRATED MANAGEMENT
	 Photo: Kevin Robert Perry, City of Portland
Redevelopment of the city aimed at decentralizing the system of stormwater management: disconnecting some districts from the stormwater sewer system, introducing rain gardens, infiltration swales, green roofs, greening streets, reducing the coverage of impervious surfaces. Activities have been carried out as part of e.g. the Ecoroof, Green Streets, Downspout Disconnection and Innovative Wet Weather Programmes.	Integrated management allows to consistently reduce the load on the stormwater sewer system by "sensitizing" new investments to water and by restoring the urban water cycle through a coherent approach to spatial planning and revitalization. This consists of establishing links between green areas and creating buffer zones. Green spaces serve stormwater management purposes while at the same time playing the role of public gardens, contributing to the creation of sites' and residents' identity, resident education, and the participatory establishment of the strategy for "the most sustainable city in the USA".

Large-scale programmes: cities	
Waterplan 2, Rotterdam, the Netherlands (Hoyer et al. 2011; Municipality of Rotterdam et al. 2007)	
CONCEPT	**ELEMENTS OF INTEGRATED MANAGEMENT**
 Photo: <www.flickr.com/photos/stmaartenpiloot>	 Photo: <www.flickr.com/photos/isobrown>
The creation of a network of multifunctional green spaces that provide flood protection and increase the attractiveness of the city, especially in densely built areas. The activities were also aimed at: purification of waters and the attainment of the good ecological potential of these required by the Water Framework Directive; combining residential, commercial and recreational functions; rearrangement of the urban sewer system based on alternative stormwater management methods adjusted to local determinants.	Waterplan 2 Rotterdam meets multiple needs associated with city development. The authors decided to combine spatial planning, the city's development and image creation strategies with elements of responsible and innovative water management. The first step was the establishment of a vision for the entire city which was subsequently detailed for particular districts based on their social and cultural characteristics and local environmental conditions. Individualized, local solutions were a smaller-scale reflection of the city's spatial management study (master plan) while at the same time meeting the needs of local communities. Planning was based on long-term predictions with regard to climate change, society and economy. Conditions were created that facilitated communication and cooperation among all interested parties to avoid conflicts and create attractive, multifunctional space.

Medium-scale programmes: districts

Cheonggyecheon Restoration, Seoul, South Korea <www.globalrestorationnetwork.org>

CONCEPT

Integrated revitalization of the city's district based on the rehabilitation of the Cheonggyecheon stream, an element of an underground sewer system. The elimination of a transport artery to bring the streambed above the ground, making it available to residents and nature, and restoring the stream's cultural and historic role. Setting a global precedent by reversing urbanization processes and changing city priorities.

The detailed goals of the programme included:

- the modernization of urban infrastructure in harmony with the area's new functions;
- stimulation of economic development by creating attractive space;
- opening up the stream valley and stream to new forms of activity, such as angling and bathing;
- environmental and historic education;
- restoration of historic and cultural values;
- improving the stream's ecological potential, and air and water quality;
- reducing the heat island effect in neighbouring areas (by 3.6°C).

ELEMENTS OF INTEGRATED MANAGEMENT

The project and its management exemplify a top-down approach initiated by city authorities. A municipal entity called Cheonggyecheon Restoration Centre, made up of experts in various disciplines and sectors was responsible for conducting public consultations as well as information and education activities.

The integrated approach included activities on all levels: cooperation on the removal of one of the city's main transport arteries and monitoring changes in traffic intensity in the city centre, planning flood protection measures, expanding the hydrotechnical engineering solutions that protect the stream from the inflow of stormwater, designating zones for cultural and economic activity, determining the possibilities for plant and animal habitat creation, determining the supplying water sources to maintain an average depth of 40 cm and BOD levels up to 3 mg/l, expanding the city's waste water treatment plant to serve as the future source of water, reuse of materials from the dismantled freeway (100% of steel and iron, 95% of concrete and asphalt were reused) and the use of techniques that minimized dust emissions during construction works. The project was also expanded by the restoration of the historic look of neighbouring streets.

Local project	
Potsdamer Platz, Berlin, Germany (Potsdamer Platz 2010)	
CONCEPT	**ELEMENTS OF INTEGRATED MANAGEMENT**
	
The construction of a commercial/office complex based on full on-site stormwater use. The creation of a site that unites innovative architecture with ecological functionality and shapes the city centre waterscape. The use of a single investment to create a park amid dense urban development with water management as the integrating function.	The integration of activities consisted in combining utility, aesthetics, technical functionality, innovative engineering and ecological premises in one project of multifunctional space. Local-scale integrated management allowed the construction of infrastructure that supports water management: green roofs, underground cisterns (2,600 m^3), above ground reservoirs, including a triangular pond, biofilter and sculpture exhibits, and channels with a system of filters (total capacity of 13,649 m^3). At the same time, water recirculation through purification zones allows it to meet sanitary standards; plant buffer zones not only support water purification but also protect from noise. Vegetation and reservoirs jointly contribute to the aesthetics of commercial, exhibition and recreational space.

of pedestrian and cycling paths; percentage of surface area dedicated only to vehicle traffic);
- in social terms: creating opportunities for local development involving all sectors and social groups, safety, providing all stakeholder groups at all stages of life with access to infrastructure and greenery (e.g. percentage of surface area adapted to the needs of the elderly; the educational value of urban space);
- in cultural terms: creating/preserving the identity and uniqueness of sites (e.g. preserving and exposing the cultural landscape or unique natural phenomena), preserving residents' cultural identity, and the continuity of local traditions (e.g. percentage of preserved and revitalized sites of cultural value; the inclusion of local patterns in modern design).

Irrespective of the adopted indicators, the anticipated time frames for the achievement of results in each category should be specified, bearing in mind that not all activities yield immediate results. Moreover, a cause-effect relationship can be observed for some aspects, e.g. societal acceptance of costs is associated with the achievement of multifunctional urban space.

References

EPA, 2010. *Green infrastructure case studies: municipal policies for managing stormwater with green infrastructure*, Washington: EPA Office of Wetlands, Oceans and Watersheds.

Gabe, J., Trowsdale, S., Vale, R., 2009. Achieving integrated urban water management: planning top-down or bottom-up? *Water Science & Technology*, 59(10), pp. 1999–2008.

Grant, L., 2010. *Multi-functional urban green infrastructure*. A CIWEM briefing report, London: Chartered Institution of Water and Environmental Management.

Hoyer, J., Dickhaut, W., Kronawitter, L., Weber, B., 2011. *Water sensitive urban design principles and inspiration for sustainable stormwater management in the city of the future*, Berlin: Jovis Verlag.

Municipality of Rotterdam et al., 2007. *Waterplan 2 Rotterdam. Working on water for an attractive city (English summary)*, Rotterdam.

Bolund, P., Hunhammar, S., 1999. Ecosystem services in urban areas. *Ecological Economics*, 29, pp. 293–301.

Peres, R., da Silva, R., 2013. Interfaces of urban environmental management and regional management: analysis of the relationship between Municipal Master Plans and Watershed Plans. *Brazilian Journal of Urban Management*, 5(2), pp. 13–25.

Potsdamer Platz, 2010. *History and ecology*, <www.potsdamerplatz.de>.

SCWS, 2012. *In-curb water vaults*, Sarasota County Water Services <www.scgov.net>.

Stadbyggnadskontoret, 1995. *Stockholms ekologiska känslighet*, Stockholm: Stadsbyggnadskontoret.

Wagner, I., Krauze, K., Zalewski, M., 2013. Blue aspects of green infrastructure. *Sustainable Development Applications*, 4, pp. 145–155.

Warzywoda-Kruszyńska, W., ed., 1998. *Żyć i pracować w enklawach biedy.* Lodz: Institute of Sociology, University of Lodz.

Warzywoda-Kruszyńska, W., Grotowska-Leder, J., 1996. *Wielkomiejska bieda w okresie transformacji*. Lodz: Institute of Sociology, University of Lodz.

WERF (Water Environment Research Foundation), 2009. *User's guide to the BMP and LID whole life cost models*. Version 2.0, Alexandria, VA: WERF.

Good practices in stormwater management in cities

Introduction

Similarly to the previous guidebooks in this series, we conclude with a selection of good practices. We focus on examples of innovative practices in urban stormwater management. More good practice examples are available on our website <www.uslugiekosystemow.pl>. The descriptions published on the website provide more extensive information, including more in-depth characteristics, additional photographs, references to literature and links to Internet resources.

Good practices have been compiled by the participants of the e-learning course "Applications of Sustainable Development", organized by the Sendzimir Foundation in spring 2014 as an introductory phase of the Summer Academy "Challenges of Sustainable Development". Joanna Klak – the course tutors' team leader – was responsible for the selection and editing of the good practices selected for this publication.

Keywords: stormwater, infiltration, retention, funding, stormwater management

Contents


Sustainable Stormwater System

Augustenborg, Malmö (Sweden), 1998–2014

Comprehensive revitalization of Augustenborg settlements was based on the idea of sustainable development. One of the main objectives of water management was to minimize flood risk through the construction of a drainage network resembling the natural hydrographic network. Community involvement was an important aspect of the initiative.

The challenge: the neighbourhood of Augustenborg has experienced periods of socio-economic decline in recent decades and frequently suffered from floods caused by the overflowing of the drainage system. Augustenborg suffered from annual flooding caused by the old sewage drainage system being unable to cope with the combination of stormwater run-off, household wastewater and water from other parts of the city. The floods caused damages to underground garages and basements as well as the flooding of local roads and footpaths. Untreated sewage was often discharged into watercourses as sewage treatment plants were not able to purify it.

The solution: the project was implemented by the City of Malmö in partnership with MKB (social housing company) with participation of Augustenborg residents. Thanks to the involvement in the project, the residents raised their awareness about the importance of stormwater and the need to manage it.

One of the main phases of the project was the construction of an open stormwater system that allows the management of stormwater. Rainwater from roofs and other impervious surfaces is collected and channelled through canals, ditches, ponds and wetlands; excess water is directed into a traditional closed stormwater system. An open stormwater system has many advantages: diversifies landscape, creates a living space for plants and animals, and allows spatial arrangement to meet the recreational needs of residents.

Green roofs were also introduced and in 2001 the world's first botanical roof garden was opened. The Scandinavian Green Roof Institute is located in Augustenborg – it is an important research centre for the technologies applicable in the construction of green roofs. The stormwater system and green roofs retain approx. 70% of the rainwater from the 32-acre neighbourhood.

The initiative implemented in Augustenborg was recognized for its pioneering approach to sustainable stormwater system. The studies indicate that Augustenborg has become an attractive, multicultural neighbourhood in which the turnover of tenancies has decreased by almost 20% and the environmental impact was reduced also by 20%.

Investment costs: approx. 22 million EUR
Responsible institution: City of Malmö in partnership with MKB (social housing company)
Author: Deana Jurada

Decentralized Stormwater Management

Hohlgrabenäcker (Germany), established in 2003

Hohlgrabenäcker is a new dwelling on the outskirts of Stuttgart where a decentralized stormwater management was implemented. The main objective was to reduce the costs of water management through the use of green roofs, pervious pavements and tanks collecting rainwater from roofs and paved areas.

The challenge: the sewerage system existing within the area set for new housing had a limited capacity; hence the municipality of Stuttgart required the reduction of stormwater runoff from the Hohlgrabenäcker site to 30% of the existing level. In addition, the soil type in this area was unsuitable for stormwater infiltration, and the steep hillsides precluded the application of surface stormwater infiltration techniques. Since the City of Stuttgart charged the so-called stormwater fee (based on estimated effective imperviousness of the surface), the goal was to reduce the costs associated with this charge.

The solution: different elements of decentralized stormwater management were implemented:

- obligatory green roofs with a substrate depth of at least 12 cm in more densely built areas (serving as a local rainwater storage, they also protect natural resources, reduce air temperature and improve aesthetics, 0.18 ha);
- underground tanks are used in areas where green roofs are not mandatory (they are collecting stormwater from paved areas which can be used for watering gardens, flushing toilets etc., 56 tanks);
- pervious paving applied where possible (16 000 m^2);
- new stormwater sewers in public places which allows direct discharge of stormwater into the watercourse.

The project was expert-led and specialists from various fields were involved e.g. urban planning, civil engineering, landscape architecture, construction. At the design stage, the residents were not involved but they were informed about the requirements relating to green roofs, underground tanks, and now they are responsible for the maintenance of the stormwater facilities located on their private properties. Hohlgrabenäcker makes significant savings through the implementation of water management – the total cost of the implementation of the system was much smaller than the costs of conventional solutions. An additional benefit is that the residents became aware of the presence of stormwater (visible water retention in tanks) and its value (drinking water savings).

Investment costs by 2014: 532,900 EUR
Responsible institution: Municipality of Stuttgart
Author: Gabriela Bieniek

SuDS for Schools Project

London (Great Britain), established in 2013

In 2013, various refinements were introduced in the Hollickwood Primary School in London, as part of the Sustainable Drainage Systems (SuDS) for Schools Project, which aims at improving water quality and stormwater management in the Pymmes Brook Catchment area in North London.

The challenge: the project was designed to solve two problems: flooding and poor water quality. The school grounds are located on different levels thus the water from the higher part flooded the lower area where playing fields and football pitches are located making them unusable after heavy rains. Another problem was the quality of water. Rainfall and groundwater carried sediments from the area into a tributary of the Pymmes Brook degrading its quality and negatively impacting its habitats.

The solution: using the SuDS approach allows the negative influence of urbanization on surface water management to be reduced. The premise of SuDS is to imitate the natural behaviour of the environment with regards to gathering and controlling rainwater, hence, the system incorporates features such as swales, rain gardens, permeable paving, and living green walls and roofs. The SuDS for Schools Project is a joint initiative of the Wildfowl & Wetlands Trust (WWT), Environment Agency, and Thames Water. Ten schools from the North London area were selected to participate in the project, one of which was the Hollickwood Primary School.

The main issues that needed solutions – flooding and water quality – have been taken care of by introducing detention and retention areas. As a result of the improvements, rainfall is now diverted to a newly-constructed raised bog garden planted with native wetland plants (the bog garden is connected to recreational areas around the school and became a common meeting place where kids and their parents can sit and relax). Overflow from this then flows via drainage channels and ditches to be discharched into the stormwater collection system. The Hollickwood Primary School manages the system with the support offered by the WWT.

Students and teachers were all involved in the project including design and planting. Furthermore, the project not only protects the existing play space but also expands it. Thanks to this project students became more aware of the need for sustainable stormwater management and of the importance of wetlands and the benefits they provide to people, fauna and flora.

Investment costs by 2014: 15,000 GBP exclusive of VAT, costs of project management, staff time and planting

Responsible institution: Wildfowl & Wetlands Trust (WWT), Environment Agency, Thames Water

Author: Nina Markowska

Mordialloc Industrial Precinct

Kingston (Australia), 2008–2013

A renewed stormwater management system is one of the outcomes of the revitalization of an old industrial estate. Three industrial roads have been redesigned to harvest 4000 m^3 of stormwater each year from factory roofs and road runoff to help protect Mordialloc River and irrigate adjacent areas.

The challenge: the starting point for the project was the need to upgrade the drainage network and roads.

Kingston is one of the most concentrated industrial areas in Australia with about 4,200 businesses and 27,000 jobs. The authors of the project emphasized that industrial areas contribute to a disproportionately high concentration of pollutants which threatens the health of Mordialloc River and the bay downstream. The goal of the project was also to save potable water.

The solution: the project was initiated and designed by the local Council's engineers in partnership with experts from Melbourne Water who are one of the pioneers of the WSUD (Water Sensitive Urban Design) implementation. Three industrial roads were redesigned: two new drains were installed; 54 stormwater pits were located along the roads to capture sediment and coarse pollutants; a 330 m^2 area of road and parking was covered with porous pavement material.

The redesigned roads enable the collection of water flowing down from the roadway and roofs to protect the nearby stream, watering the adjacent park and street trees and providing increased flood protection. Two gross pollutant traps capture material bypassing the pits before the water enters underground storage system (61 m of 2.4 m diameter pipe). The excess rainwater bypasses the treatment system and goes directly to the river. After initial storage, the water is pumped into a 180 m^2 bioretention system, consisting of layers of engineered soil and sand. The rain garden plants treat the water by removing metals and nutrients. The treated water is pumped up into an above-ground 240,000 m^3 storage tank to be used for irrigation.

Since the beginning of the project several promotional and educational activities have been undertaken, which have resulted in improved community awareness and knowledge of stormwater management. The Council's environmental officers spoke to the owner of every factory located in the catchment area, as part of an educational campaign explaining how to reduce the volume of pollutants leaving their factories. Moreover, newsletters and advertising in the local newspaper and on Council's website provided information about the project and stormwater management.

Investment costs: 2.8 million AUD
Responsible institution: City of Kingston
Author: Elgars Felcis

Sidewalk Garden Project

San Francisco (USA), Established in May 2013

San Francisco's urban watersheds are mostly covered with impermeable surfaces such as concrete and asphalt. As a result, stormwater has no place to go other than the City's combined sewer system. Sidewalk gardens take advantage of the natural processes of soils and plants to slow down and treat stormwater and keep it out of City's sewer system, thus reducing the burden on the sewer system.

The challenge: stormwater runoff is generated when precipitation from heavy rain (and snowmelt) flows over land and does not seep into the ground. As the rainwater flows over paved streets it accumulates chemicals, sediment and other pollutants. The municipal sewer system has a limited capacity thus in the event of rainwater overruns, flooding of building and flash floods can be observed. In addition, if the stormwater overloads the system, sewage is discharged directly into the bay, resulting in large fines for the City.

The solution: the Sidewalk Garden Project is a part of the Urban Watershed Assessment in the Sewer System Improvement Program. The project involved people from public agencies, engineering and design companies, nonprofit organizations, community groups, stormwater experts, and unaffiliated San Francisco citizens. The Sidewalk Garden Project is replacing concrete sidewalks with gardens to capture stormwater and reduce the burden on the sewer system while beautifying San Francisco neighbourhoods and protecting the environment.

Street gardens are formed between the sidewalk and the buildings and streets. Local law states that the pavement should have a width of approx. 180 cm, so wider sidewalks may be tapered to the needs of the garden. The concrete pass connecting the walkway with the street is replaced by permeable surface. A typical sidewalk garden consists of California native and drought-resistant plants, permeable pavers, stone edging and bark mulch.

The residents and non-governmental organizations can submit a design of a sidewalk garden and get a landscaping permit. Property owners in specific areas on the East side of the city may be eligible to green their neighbourhood block for the cost of the sidewalk garden permit (approx. 160 USD). Other costs including the concrete removal, materials and plants are provided free of charge thanks to the support of the SFPUC and FUF.

Responsible institution: San Francisco Water Power Sewer (Services of the San Francisco Public Utilities Commission – SFPUC) and Friends of the Urban Forest (FUF).
Author: Olga Galblaub

FiSH Project – Fitzgibbon Stormwater Harvesting

Fitzgibbon Chase (Queensland, Australia), 2009–2014

The FiSH (Fitzgibbon Stormwater Harvesting) project is designed to harvest stormwater runoff from a catchment area of 290 ha within a residential development and to supply 89 m^3/year of treated stormwater for non-potable uses within the Fitzgibbon Chase estate development. The investment allows for the capturing of stormwater from the urban area, pre-treating it and storing it in a covered reservoir, as well as treatment through filtration and disinfection.

The challenge: the main challenge was very low water resources caused by several year long droughts droughts. There was a need for a big stormwater harvesting system, which will boost the self-sufficiency of urban communities. In addition, the system had to be created for a reasonable cost, allow reduction of stormwater pollution and improve water quality to meet the Australian requirements.

The solution: in the FiSH project the urban stormwater runoff is not directed to the main sewage system running through the development area but is subject to treatment and can be used for example to water gardens, flush toilets, wash cars and to irrigate greenery in public spaces. The stormwater runoff is collected from a catchment area of around 290 hectares, and pumped through a sediment trap to a lagoon of 5000 m^3 capacity. Approx. 10% of the average annual runoff of rainwater is intercepted and impounded there.

The water is purified and its quality is monitored to ensure compliance with the applicable standards. The stormwater system treats approx. 400 m^3 of water per day. Pre-filtering is carried out using an automatic sieve, sand filters provide filtration, and activated carbon removes organic compounds. At the end of the process, a UV disinfection and chlorination take place. The end users approve the project – they believe that stormwater harvesting is a good idea and that the project is an environmentally friendly solution that improves the aesthetics of the area. The project fulfilled expectations and provides additional environmental and social benefits:

- reduced demand on limited water supplies,
- educational benefits,
- improved the aesthetics of the area,
- enhanced usability and increased value of land for development,
- improved the ecological condition of waterways.

Investment costs: aprox. 17 million AUD
Responsible institution: Urban Land Development Authority and Queensland Water Commission
Author: Malgorzata Markowska

Green City, Clean Waters

Philadelphia (USA), Established in 2011

Started in 2011, the Green City, Clean Waters (GCCW) is a 25 year-plan with the vision to "unite Philadelphia with its water environment, creating a green legacy while incorporating a balance between ecology, economics, and equity" through sustainable water management combined with green stormwater infrastructure.

The challenge: constant development of urban areas of Philadelphia affects its watersheds by impairing water quality, degrading ecosystems and waterways. Furthermore, urbanization increases the area of impermeable surfaces that create a barrier for natural retention and infiltration of stormwater.

The solution: in 2011, Pennsylvania Department of Environmental Protection and the Philadelphia Water Department signed an agreement to launch the GCCW program that places emphasis on green stormwater infrastructure that includes "a range of soil-water-plant systems that intercept stormwater, infiltrate a portion of it into the ground, evaporate a portion of it into the air, and release a portion of it back into the sewer system". The GCCW consists of a combination of policy, expert engagement, innovation, regulation and community participation. Furthermore, the GCCW fosters the sustainability concept and analyses environmental, economic and social impacts of the programme. It is expected that the community will have multiple benefits thanks to the implementation of green infrastructure such as creation of green spaces, increase of property values, absorption of CO_2 etc.

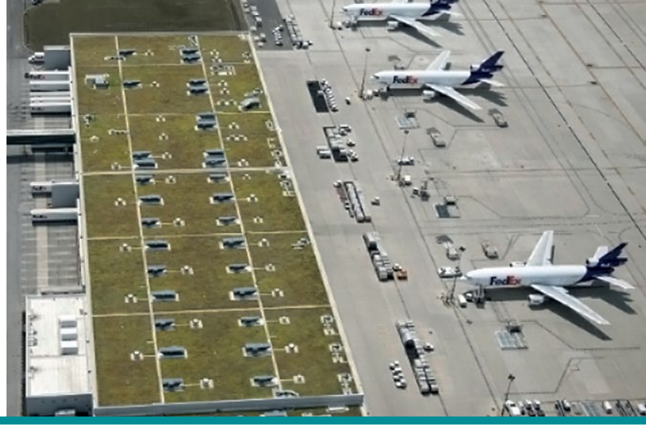
By March 2014, the following elements of green infrastructure were implemented: trees, stormwater planters, stormwater bumpouts, rain gardens, stormwater basins, infiltration/storage trenches, porous paving and stormwater wetlands. In the long term, green infrastructure will include restoration of physical habitats in stream channels, green streets, green schools, green public open spaces etc.

Extra value to the programme is added by local people, businesses, schools and other stakeholders who are invited to take an active role by undertaking different green home projects, green infrastructure projects and green community partnership programmes. The GCCW offers wide a range of events and possibilities for the local community to stay involved.

Investment costs: planned budget for 25 years is 2 bilion USD

Responsible institution: Philadelphia Water Department (PWD)

Author: Iva Valčić



Green Roofs at O'Hare International Airport

Chicago (USA), established in 2006

The project encourages the installation of vegetated roofs on airport facilities. The main goals are to reduce the urban heat island effect, conserve energy and reduce stormwater runoff. The project implemented in Chicago shows that installing vegetated roofs at airports is practical and cost-effective.

The challenge: the O'Hare International Airport is a predominantly impervious urban area so the use of vegetated roofs should increase stormwater retention and filtration. The second challenge is the heat island effect which causes overheating of cities during the summer and can lead to excessive energy consumption for air conditioning and pollution from electric power generation. The vegetated roofs should improve thermal insulation and counteract the heat island effect by helping reduce heating and cooling costs.

The solution: the Chicago Department of Aviation (CDA) has installed over 3 ha of vegetated green roofs on 12 different airport facilities including a lighting control system facility, parking/rental car facilities, and the first vegetated roof ever installed on an airport traffic control tower.

It is estimated that vegetated roofs at the O'Hare airport can retain 70–90 percent of the precipitation that falls on them during the summer and 25–40 percent in the winter. For example, the FedEx Main Sort Building vegetated roof is estimated to retain approximately two million gallons (7500 m^3) of stormwater annually. Energy savings are estimated at around 0.20 USD per square foot per year. At this rate, the FedEx Main Sort Building vegetated roof saves the CDA approximately 35,000 USD per year in energy costs or 1.4 million USD if assuming a 40-year life cycle. Another positive thing is that sound waves produced by construction equipment, vehicle traffic, and airplanes are absorbed or deflected by the soil and plants. It is estimated that a four-inch (2.5 cm) vegetated roof substrate layer can reduce the level of sound penetrating inside the building by around 40 decibels. The vegetated roof installations also support a broader city-wide interest in green roofs.

Investment costs by 2014: approx. 10 million USD
Responsible institution: The Chicago Department of Aviation
Author: Daniela Gluhak

Roof Water Harvesting Project

Warrnambool (Australia), 2010–2011

The Wannon Water Corporation in partnership with central and local authorities have developed a system of harvesting roof water in Warrnambool City. The project involves decentralised collection of roof runoff, diversion of water to surface water basins, and a connecting system with Warrnabool water treatment plant. Treated rainwater is used as a drinking water.

The challenge: ongoing development of Warrnambool city causes two main water challenges: increasing water resource demand and dramatic increase in runoff volume during rainfall events. Satisfying water demand requires increased extraction of the nearest river water, up to established limits and the utilisation of two groundwater basins located 50 and 90 km from the city, which generates costs associated with energy and the necessary infrastructure. Rainwater runoff volume is growing due to the domination of impermeable surfaces in the developing city.

The solution: the Roof Water Harvesting Project required the construction of infrastructure which collected and treated stormwater in three steps. The first step – harvesting stormwater – required connecting the gutters of each house with an individual tank on site (home owners were not required to install an onsite tank but could if they wanted). The second step – storing water – included aggregating water supplies by dedicated pipeline, separated from municipal stormwater system. This included the construction of 2250 m of water mains and 4400 m of smaller collection mains within the new development area. Water collected from roofs flows under gravity to the Wannon Water water storage basin where it mixed with river water. The third step – treatment of water – involves usage of existing Warrnambool water treatment plant connected with water storage, to produce drinking water for the City of Warrnambool. Currently, there are approximately 130 houses built on the 260 lots created as part of this initiative. In 2013, 16 million litres of water from these roofs was harvested which is the same volume that these houses consumed in drinking water.

This solution enables every household to be the source of drinking water and significantly diminishes the natural and economic costs of water supply. The project was a collaborative initiative of the private and public sectors. The project planning and implementation phases were carried out by private agents, whilst its priorities were determined by central and state programmes and also funded by public agencies.

Investment costs: 3.8 million USD
Responsible institution: Wannon Water
Author: Karol Grabias

Houtan Park

Shanghai (China), beginning of designing stage – 2007, commissioning – 2010

The organizers of the World Exhibition EXPO 2010 in Shanghai, held under the theme "Better City, Better Life", faced a challenging task to create a "green exhibition" prepared to accommodate a large influx of visitors. The designers of the exhibition area placed emphasis on the conscious use of green and blue infrastructure. The restoration of the site was supposed to ensure: flood control, water purification, biodiversity, aesthetics of public space, opportunities for recreation and education.

The challenge: a demonstration project, the Houtan Park, was located on a brownfield former industrial site between the motorway and the banks of the highly polluted Huangpu River. The brownfield had been used to store industrial materials and construction debris. The existing concrete floodwall was rigid and lifeless.

The solution: through the centre of the park, a linear constructed wetland was designed to create a reinvigorated waterfront as a living machine to treat contaminated water from the Huangpu River. Thanks to the particular landscape and selection of different species of wetland plants, terraces, cascades and tanks to accumulate contaminants, purify and aerate the water, the treated water can be used safely throughout the Expo Park for non-potable uses. This saves half a million US dollars in comparison to conventional water treatment methods.

The existing concrete floodwall was replaced by a more habitat friendly riprap that allows native species to grow along the riverbank while protecting the shoreline from erosion and creating larger expanses where small groups can gather. In this way, the Houtan Park became a natural floodplain. Wetlands and terraces are characterized by high levels of biodiversity. The greenery located on the site absorbs nearly 250 tons of CO_2 per year. Proximity to water improves the attractiveness of the park as a place for recreation, relaxation and walks. Rice, sunflowers and clover among others are grown in the park – in addition to providing agricultural products, these crops and wetland plants provide opportunities for visitors to learn about Shanghai's agricultural heritage and allow them to witness seasonal changes. To remind the visitors about the recent past, some of the industrial objects have been preserved and integrated into the landscape.

Combining different functions and traditions, the Houtan Park represents a holistic approach to city planning, drawing on the Chinese tradition. Eight techniques used in the design of the park have been patented; many have been amplified during the implementation of other projects. The Chinese authorities officially support a similar action methodology to carry out projects on a large scale across the country.

Investment cost: 15.7 million USD
Responsible institution: Turenscape, Shanghai Landscape Construction Company, Shanghai University of Oceanography
Author: Michał Czepkiewicz


"Human–Nature–Technology" – the concept of sustainable stormwater management

Kronsberg, Hanover (Germany), concept – 1992, beginning of construction – 1997

The concept of sustainable stormwater management for Kronsberg is a part of a comprehensive development project which takes into account equally the economic, social and environmental aspects of the development of urban settlements in Hanover.

The challenge: the Kronsberg settlement, founded in the late 1990s on the western slope of the Kronsberg hill, served as a residential area for people working on the World Exhibition EXPO 2000 – the apartments were later converted into communal flats. As host city to the World Exhibition, Hanover was under a special obligation and thus the new settlement had to follow the requirements of sustainable development.

The solution: the Kronsberg settlement is almost entirely owned by the public and it was one of the factors that contributed to the success of the project. In 1993, the city authorities set up teams in environmental, construction and social affairs departments with a goal to develop a comprehensive approach to sustainable development of the estate. The teams came up with a strategy (*Wasserkonzept*) that presented an action plan for the management of stormwater using a combination of green infrastructure and conventional technical solutions. Proposed solutions were meant to retain as much rainwater in the place of its creation as possible. A decentralized open system was designed to capture and allow retention of rainwater. Rainwater is collected and stored in canals filled with grass, then filtered through a layer of compost to the lower layer filled with gravel, which allows for the retention and effective treatment.

A special part of this concept was the integrated stormwater management system developed for a local primary school. Here, rainwater is entirely captured by a system of channels and stored in an underground tank. Canals, small ponds and areas of increased water storage capacity are located in the area around the school, and create a natural habitat for many plants and animals as well as serving recreational purposes. At the top of school building, there is a green roof that captures water and slows down the run-off. Stored water is used for flushing toilets and watering the school garden. This integrated system can save annually about 550 m^3 of drinking water, and also provides for high school students the opportunity to learn about the importance of water resources and the sustainable management of stormwater.

Kronsberg can serve as a good example not only in the field of water management, but also in other aspects of sustainable development. Currently, Kronsberg is the most attractive housing estate in Hanover.

Investment cost: The total cost of the project, the construction of settlements in 1997–2000, was 500 million EUR, there is no data referring to the water management only.

Responsible institution: City of Hanover

Author: Katarzyna Sabura

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