Methodology of Sensitive Planning and Design of Stormwater Drainage System on Urban Watersheds

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For sustainable stormwater management planning in urban areas a hierarchical approach is needed, from planning on the watershed level, to the implementation on the location level, so a comprehensive approach to planning and designing the improvement of stormwater drainage could be provided with a goal of developing a drainage system, which balances the goals of drainage efficiency maximization and minimizing the negative effects on the environment. But the watershed level, which is relevant to urban hydrology, is almost always ignored while developing stormwater management plans. This paper shows a methodology oriented towards studying of the morphology of the urban watershed in the context of sustainable stormwater management, which consist of five steps and intends to help city planners and engineers choose the right location and make a selection of the best stormwater management practices when defining a sustainable decentralized stormwater management plan.

Key words: urban areas, urban planning, sustainability, infrastructure, integrated stormwater planning and management

1. INTRODUCTION

During the last few decades a trend of increased urbanization is present in almost all countries of the world. The increasing urbanization level and along with it the increasing concern and expectations of the public for control of stormwater runoff control are the elementary driving force for increasing application of modern principles of stormwater management. It is widely accepted today that stormwater drainage must be solved during planinig, designing and development of communities, in a different manner than in the past.

To achieve a development trend which satisfies current needs of the community, with preservation and sustension of natural resources for the future. It is necessary to plan actions in a way which takes into account the quantity and quality of stormwater, the relations between surface water and groundwater and dependency between physical and biological resources.

The processes and methodology for new approaches in stormwater management are always in development with the application of leading principles such as „sustainable development“, „watershed planning“, „ecosystem management“. In an effort to aply these leading systems in solving of concrete problems, environment managers, planners, enginners and scientist will have to use numerous tools, including source control, conservation, control of land use, treatment and best practices of stormwater management.

In the modern practise of stormwater management a concept of dual (major/minor) analysis of the stormwater drainage system and application of objects for stormwater management for control of peak flow and for water quality control were introduced.

Stormwater management demands the use of objects for louding, treating or transforming the stormwater runoff. These objects often must compete for space with the rest of service components and users of land on the watershed. This is why the planning of the stormwater management systems must be in accordance with general development plans on the watershed.

This paper shows a hierarchical approach to planning of the stormwater management and drainage

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system design, with four levels of planning and designing with a particular review of the watershed level, which is relevant for urban hydrology but almost always neglected during the making of stormwater management plans with the application of the best management practices.

Methodology of the sensitive design of stormwater drainage on urban watersheds shown in this paper is oriented towards studying the morphology of the urban watershed in the context of sustainable stormwater management and can be integrated into a hierarchical approach to planning of stormwater management and drainage system design. It consists of five steps and aims to help town planners and engineers choose the right locations and select the best practices of stormwater management while defining the sustainable decentralized stormwater management plan.

2. PLANNING OF INTEGRAL APPROACH TO STORMWATER MANAGEMENT

The term “integral stormwater management” means an all encompassing approach to planning, designing, implementation and improvement of the work of the stormwater drainage system. The purpose of the new approach to stormwater management is to develop an efficient drainage system which creates balance between the contrasting goals of maximizing the drainage efficiency and minimizing the negative effects on the environment.

The basic frame for planning of stormwater management system development encompasses four levels of drainage planning from planning on the watershed level to implementation on the local level.

The advantages of improved stormwater drainage are connected to location and are obvious on a location on which drainage improvements have been done. However, negative effects on the environment generally appear downstream of the location on which improvements have been done and are not always obvious. These influences are problematic because they have a tendency of being accumulated over time and in the area.

Stormwater management planning must be done on a scale which allows the evaluation of the effect on the complete natural drainage system. As a macrounit for planning, the watershed is used. The watershed is too big to be a practical unit for designing specific drainage solutions, but it can be useful in identifying some limitations for smaller units. On the other hand, most drainage improvements are designed and implemented on residential or working areas of a few hectares, which are defined by administrative boundaries and ownership. These units rarely match with natural drainage boundaries and are usually too small for

stormwater management planning. It is evident that, for stormwater management planning, a transient level is needed and a hierarchical approach to planning management and design of stormwater drainage system is necessary. The four levels of planning and stormwater drainage system design, which satisfy the listed requests imply the next: plan of the main water course shed, plan of drainage on the shed/subshed level, drainage master plan and implementation plan on specific location. The geographic relation of those levels of planning is illustrated on figure 1. And the functional relation on figure 2.

Figure 1 - Geographic relationship of the four levels of stormwater management planning and design [2]

Drainage planning on the watershed level has in the last few years, become increasingly dominant as a planned approach which integrates natural systems and change of land use. Drainage planning on the watershed level considers the question of drainage, similar to questions of environment protection as a traditional part of planning, but on a scale on which functions and connections of the ecosystem can be recognized and cumulative influences of resource development/ management strategies can be evaluated.

The watershed concept points to a specific relation between the natural geographical landscape, water, the built environment and the population. The watershed is considered a territorial unit referential to hydrology.

The watershed level, relevant to urban hydrology, is almost always neglected during the making of stormwater management plans, with the application of the best management practices.

As a consequence of that city planners and engineers often cannot demonstrate the true efficiency of the integral stormwater drainage management on urban areas to the decision makers. This also significantly contributes to the fact that city planners, designers and local authorities usually consider the decentralized approach as a possible solution for environment conservation, and almost never as a problem/solution oriented system stormwater drainage in urban environments.

Figure 2 - Functional relationship of the four levels of stormwater management planning and design [2]

However, city planners and engineers seem to forget the natural geography on which urban environments were built, so the making of stormwater drainage plans is mostly determined by conditions on the local level. Having this in mind it is important that city planners, engineers and others interested are provided with the methodology of wastewater drainage design on urban watersheds, which can be integrated into a hierarchical approach to planning of stormwater

management and drainage system design, which could be reproduced anywhere.

3. METHODOLOGY OF SENSITIVE PLANNING AND DESIGN OF STORMWATER DRAINAGE SYSTEM ON URBAN WATERSHEDS

In stormwater management on urban watersheds, numerous decentralized systems are experimented with around the world along with the best management practices and the methodologies of their planning and design.

From the aspect of promoting the decentralized approach to stormwater management on urban watersheds and the integration of this approach in spatial and city planning plans is very interesting methodology of sensitive design of stormwater drainage system, which is applied on the Molenbek watershed in the Brussels Region in Belgium, with the area of 13.5 km² and encompassing the 8% of the Brussels Region [3].

The watershed is defined as a territorial unit which drains water towards a river and which is defined by shed boundary. The urban watershed is an area shaped by water, which is urbanized by urban fabrics towards an agreement (convention) about spatial development granted by the community. The urban watershed is considered a territorial unit which connects three elements and which cannot be viewed without interaction of those elements: landscape, the urban fabric and the territorial development agreements (conventions) [3].

Figure 3 - The methodology of sensitive design of stormwater drainage system on an urban watershed [based on 3]

The landscape consists of the physical base and geomorphology as well as the natural area before human operation on that area. It is a set of physical

characteristics which was already present and which enables and limits the establishing of the urban area. The urban fabric is the common denominator for

public space, collective space and private parcels of land. The urban fabric is defined by a system of blocks and parcels, a system of roads and nodes and a system of buildings.

The convention of territorial development is a set of rules and mechanisms, accepted by the community, which allows the area to be antropized for the forming of a human society. That is the set of processes and rules of spatial development for urban fabric on the watershed.

The effects of stormwater runoff on urban areas directly depend on the morphology of the watershed and human activity on it. To reduce the risk of floods from stormwater and to ensure sustainable stormwater management on the urban watershed, the configuration on the urban shed must be studied and adjusted.

The methodology consists of five steps, shown on figure 3. and it accents the process of studying the urban watershed morphology with a focus on sensitive design of stormwater drainage system [3]. The methodology encompasses the next steps [3]:

- In the first step urban watershed components are analyzed (landscape, urban fabric, convention) based on cartographic analysis of numerous indicators, relevant from the stormwater management aspect,
- The second step focuses on the identification of numerous territorial functions (conservation and enrichment of the biodiversity, promotion of the so called collective management, free surface drainage, integration of levels of the built environment) and the appropriate strategies for decentralized stormwater management,
- Based on the indicated territorial functions and strategies, the third step defines spatial typologies connected to the road network, and urban fabric (blocks/parcels/buildings),
- The fourth step determines numerous scenarios of stormwater management to be applied on spatial typologies,
- The fifth step is designing decentralized stormwater management systems by integrating the best management practices in every spatial typology.

The first three steps of the morphologic study of the urban watershed are realized from the aspect of sustainable stormwater management.

In the last two steps the demanded and efficient development of the urban watershed is realized using the existing and future potentials.

The last step of the methodology is a project of decentralized stormwater management, whose goal is to evaluate and to find available and sufficient space/land for the implementation of the best management

practice for the specific spatial typology (streets or city blocks/parcels/buildings) for the solution of the stormwater problem (retention, infiltration, evaporation) which has fallen on the location of the project.

The choice of the most suitable scenario and the best management practice is a responsibility of the design bureau and town planner/architect/engineer in charge of the project. The decentralized stormwater management project gives advice to the design bureau and the town planner/architect/engineer on the choice of the best management practice, which most suits the location of their project by giving a method, not a specific solution.

The method applies to the scale of a specific project (parcel, street, urban block) but also to the scale of the entire watershed. For the scale of a specific project, the method explains how to choose a project scenario and the best suitable management practice. As a result the evaluation of stormwater management efficiency with the best management practice chosen for that project is received. For the watershed scale, the method is based on the design of decentralized stormwater management with standard elements for every spatial typology identified on the shed. For every spatial typology (streets/city blocks/buildings) defined according to the third step of the methodology a standard element (that is a standard road or a standard urban block, standard parcel or standard building) is chosen from all the elements of the typology. The choice of standard element of the typology is made based on statistical analysis of the characteristic dimensions of a sequence of representative elements for each typology. The standard element is an element whose specific dimension values are closest to the average value of a group of representative elements. The project scenario and best management practice are chosen for the standard element of the typology, as is done for the level of the specific project. It is assumed that the design result for the standard element applies for every element of the typology. The aim of the project on the watershed scale is the evaluation of the operative potential of decentralized stormwater management on the level of the entire watershed.

The process of selection of the scenario and set of best management practices (figure 3.) consist of a few steps organized as a management sequence for a project of a street or city block/parcel/building [3].

The set of best management practices shown on figure 3. is classified according to their shape (punctual, linear or area) and privileged position in the management sequence (retention, transport or control of the pollution source).

It should be recognized that there is no standard solution for stormwater management. Each possible solution has its advantages and flaws. That is why the selection process must be done based on choices from an arsenal of techniques of stormwater quantity control and quality improvement, and based on set demands

for quality and quantity, site conditions, stormwater reception potential, the need for energy use, building maintenance expenses and the experience of the designer. It should also be recognized that in many cases more than one water resource protection technique may be needed.

Figure 4 - Best decentralized stormwater management practices [based on 3]

Contemporary principles imply that, while choosing schemes of stormwater management objects, multipurpose applications should be considered wherever possible. Some stormwater management objects can be aesthetic and recreational content in the environments they are in.

Also the potential of beneficial use of stormwater should be taken into consideration. Besides that, objects whose main purpose isn't drainage, like parking lots, public parks and roofs can be used as components of a system within the general plan of stormwater drainage control.

Proper consideration and implementation of noted techniques, along with other options, as are administrative regulations, restrictions in use, conservation

and improvement of the pollution source control program, will provide adequate standard of stormwater management in the future and will result in future development which ensures human needs with adequate protection of the environment.

Designers and others interested should treat the mentioned methodology and directives as a means of help instead of a rule book for the solution of the stormwater management problem. There are many specific questions regarding the concrete location, which influence the development and planning of stormwater management. The directives give practical and concrete solutions, but there must be flexibility depending on the specific conditions and solutions for stormwater management on a certain location and that must be

recognized when the directives are applied in planning of stormwater management. The shown methodology aims to help city planners and engineers choose the best management practice for the suitable location, but it does not give a universal solution. It should accent the distribution of the best management practices as efficient objects in stormwater management on urban watersheds.

4. CONCLUSION

This paper shows a hierarchical approach to planning and designing management systems of the stormwater drainage system with four levels of planning and design and methodologies of sensitive design of stormwater drainage on urban watersheds. The shown methodology gives advice on designing a decentralized approach to stormwater management on the a scale of the location, taking into consideration the global and territorial roles on the whole watershed.

The methodology can be used for evaluation of the decentralized approach on the level of the watershed, considering, as a starting hypothesis, that the solution (scenario and management sequence of numerous best management practices) which is designed for a standard element of typology (street or city block/lot/-building), can be applied on all elements of the same typology.

Aside from that, the results of the methodology application on the water shed can lead to an improvement in planned regulations and conventions for

urban areas in favor of the decentralized approach to stormwater management. Use of the methodology can show that the realization of the best stormwater management practices need to be given, for certain typologies on the lot level, only a few percent of the road profile. These two applications must lead to a change in city planning regulations with the aim of promoting the sensitive design of stormwater management on the urban shed.

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REZIME

METODOLOGIJA SENZITIVNOG PLANIRANJA I PROJEKTOVANJA ODVODNJE ATMOSFERSKIH VODA NA URBANIM SLIVOVIMA

Za planiranje održivog upravljanja atmosferskim vodama u urbanim sredinama potreban je hijerarhijski pristup, od planiranja na nivou sliva, do implementacije na lokalnom nivou, kako bi se obezbedio sveobuhvatni pristup u planiranju i projektovanju poboljšanja odvodnje atmosferskih voda, sa ciljem da se razvije sistem odvodnje, koji balansira ciljeve maksimiziranja efikasnosti odvodnjavanja i minimiziranja negativnog uticaja na životnu sredinu. Međutim nivo sliva, koji je relevantan za urbanu hidrologiju, skoro uvek je zanemaren pri izradi planova upravljanja atmosferskim vodama. U ovom radu prikazana je metodologija orijentisana na proučavanje morfologije urbanog sliva u kontekstu održivog upravljanja atmosferskim vodama, koja se sastoji od pet koraka i koja ima za cilj da pomogne urbanistima i inženjerima da, pri definisanju održivog decentralizovanog plana upravljanja atmosferskim vodama, izaberu prave lokacije i izvrše selekciju najboljih praksi upravljanja atmosferskim vodama.

Ključne reči: *urbana područja, urbanističko planiranje, održivost, infrastruktura, integrisano planiranje i menadžment odvođenja kišnih voda*