URBAN RAINWATER DRAINAGE MANAGEMENT – KOSICE CASE STUDY

M. Zeleňáková[1]

[1] *Technical University of Košice, E-mail:martina.zelenakova@tuke.sk*

ABSTRACT

Urbanisation is typically accompanied by increases in impervious surfaces such as roofs and roads, construction of hydraulically efficient drainage systems, compaction of soils, and modifications to vegetation. This results are increased flood flows and stream erosion, and the potential for decreased baseflow. New approach towards urban water management includes a number of tools which enable to reduce environmental effects of urbanization and maintain purpose and vision of the area. Although in recent years occurred in Europe and overseas to the implementation of several different types of objects infiltration leads to errors caused by neglected scientific claims in their planning and operation. The paper is focused on the infiltration of water from surface runoff in general and in Košice city, Slovakia. Topic of the paper emerged because of the insufficient information about infiltration systems in the Slovak technical regulations and missing legislative of water infiltration from surface runoff. The foundation for improving and effectiveness of urban drainage will be created by the proposal of conditions for infiltration facilities. The aim of the paper is to expand the body of scientific knowledge in research and solutions of urban rainwater drainage with emphasis on the retention capacity of the selected area considering hydrological and hydrogeological conditions.

Keywords: Hydrogeology, Infiltration facilities, Rainwater, Urban area

1 INTRODUCTION

In many urban areas, drainage is based on a completely artificial system of sewers: pipes and structures that collect and dispose of this water. In contrast, isolated or low-income communities normally have no main drainage. Wastewater is treated locally (or not at all) and stormwater is drained naturally into the ground. These sorts of arrangements have generally existed when the extent of urbanisation has been limited. Recent thinking towards more sustainable drainage practices is encouraging the use of more natural drainage arrangements wherever possible (Butler & Davies 2000). In the last decades it has developed a wide range of approaches to mitigating hydrological impacts as well as impacts on water quality as a result of urbanization. However, there still remains significant controversy over the best approach showing drainage of precipitation and storm water in urban areas and it is still a complex and complicated area of research. There is a new trend towards more integrated approach to dealing with changes in flow regime as well as water quality, and they are trying to treat rainwater as a resource, a means and not an issue that should be discarded (Slys, 2009). Development of integrated models to predict and assess the effectiveness of alternative approaches to rainwater drainage in cities considered to be part of a wider urban water cycle, thus recently got into considerable attention.

Drainage systems are needed in developed urban areas because of the interaction between human activity and the natural water cycle. This interaction has two main forms: the abstraction of water from the natural cycle to provide a water supply for human life, and the covering of land with impermeable surfaces that divert rainwater away from the local natural system of drainage (Butler & Davies, 2000).

Urbanization and growth of megacities are not new phenomena. However, the trend of current urbanization in developing countries differs greatly from that in developed world. Gradual growth rates also enabled these cities to progressively and effectively develop the necessary infrastructure and the capacities to manage their water supply and sewerage services. The current concept of wastewater collection, treatment and discharge is based on centralized sewer systems, which were installed in municipal areas to remove all kinds of mixing polluted liquid streams from the household. In order to limit environmental pollution and to reduce the public health risks in waste and wastewater, wastewater and other waste from household are conveyed far away from residential sites as quickly as possible. To a large degree, conventional centralized sewage system could solve the problems of sanitation very efficiently (Zhang, 2008). This is now regarded as the standard approach in industrial wastewater treatment. Decentralized wastewater systems treat wastewater close to the source, typically providing treatment on the property of individual homes or businesses (Crites, 1998). Decentralized management can be regarded as an alternative, the sustainable strategy and redevelopment of rural and urban human settlement, practically considering ecological, economical and social criteria.

Unlike the other sources of wastewater, infiltration and inflow are not deliberate discharges, but occur as a consequence of the existence of a piped network. Infiltration and inflow have are defined as water that enters the sewer system through indirect and direct means respectively. Infiltration is extraneous groundwater or water from other leaking pipes that enters the sewer system through defective drains and sewers (cracks and fissures), pipe joints, couplings and manholes. Inflow is stormwater that enters separate foul sewers from illegal or misconnected yard gullies, roof downpipes or through manhole covers (Butler & Davies, 2000).

Concerning the proportion of evaporation, infiltration and runoff, rainwater infiltration can contribute essential benefits to the harmonization of natural water balance, and also positive influence for soil, weather, fauna and vegetation (Zelenakova et al., 2014). Hence, they can not only significantly reduce the peak runoff in sewers, but also reduce the size of the sewage pipes required to handle the waste stream, which is important when aging systems have to be rebuilt. In addition, the construction of retention and infiltration systems is usually more economic than the construction of technical rain water utilization system and the related construction work generally does not limit the use of space above ground, since the systems can be also installed underground (Zelenakova et al., 2009).

Systems for rainwater collection, storage and utilization are commonly used in many countries as sources of reduced quality water to be used in a sanitary network system of buildings and for watering, among others (Slys et al, 2012).

The paper deals with the issue of urban hydrology and of the management of rainwater. It presents the results of that research to the problem and case study from Košice City.

2 PRESENT STATE

2.1 Study area

Košice is the primary centre of eastern Slovakia and the second largest city in the Slovak Republic (Figure 1). It is made up of 22 city boroughs, among which is the new project Nová Terasa located on the border of the city borough Staré Mesto in the near vicinity of Košice’s historical centre. The project brings modern architecture, a characteristic feature of which is the exclusiveness of mutually linked buildings, which together form an enclosed interior courtyard. Residents of the flats will thus be able to take advantage of a private rest area intended for free-time activities and including greenery, benches and children’s playgrounds.

The Nová Terasa project (Figure 2) offers a wide selection of different types of flats, for example, flats with an atypically high ceiling under a saddle or flat roof, maisonette flats, as well as a wide selection of layouts of individual flats. In the first phase a total of 199 one- to four-room flats were built with floor space from 31 to 110 m². Each of them has atypical high windows and a terrace, balcony or loggia (interior atrium). The flats are orientated directly on the centre of Košice, in close vicinity of the hospital, or on the slope of the Hills.

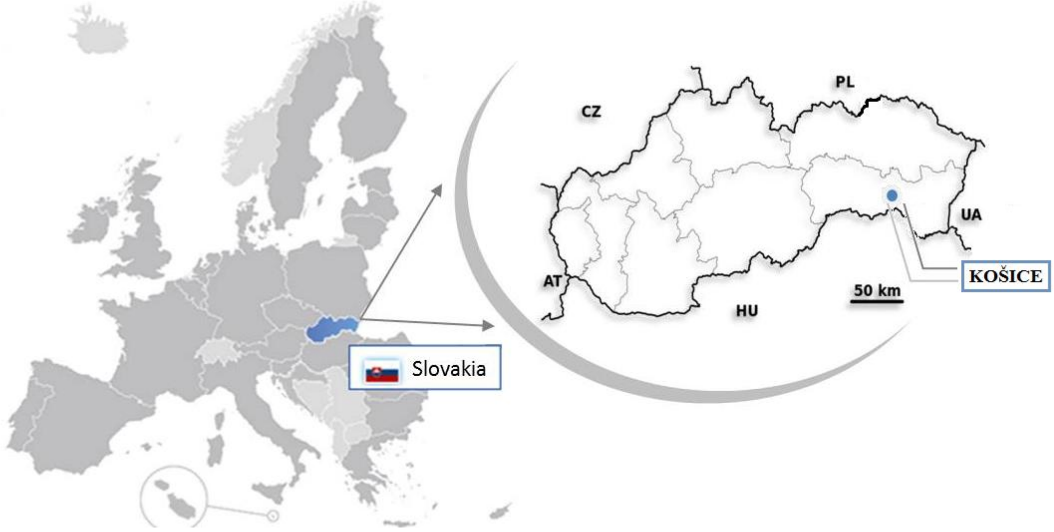

Figure 1. Košice City

Figure 2. Nová Terasa

2.2 Present state of rainwater management

A system for drawing away rainwater from the roofs, car parks and local paths and roads has been designed for the site. Rainwater from roads and car parks from all stages will be harvested using rainwater traps. The water, including rainwater from roofs, will subsequently be carried into a retention tank with throttled discharge using a whirling flow regulator at 25 l/s per one stage. From this it follows that from all four stages the permitted amount of rainwater (100 l/s) will be released into the sewerage system. Rainwater will be taken from the retention tank to an oil-water separator (OWS) with a guaranteed discharge up to 1.0 mg NEL/l.

The original design resolves the possibility of taking rainwater away from the residential area and into the public sewerage system. The pipes will be connected to the existing sewerage network, terminated by a sewerage shaft in the pavement. The route will consist of ribbed sewerage pipes and sewerage shafts of ø 1.0 m will be placed along it. On the request of Eastern Slovakia Water Supply Company, to limit the discharge of rainwater to 100 l/s, a throttling section with a 0.6% gradient will be established on the main path, to which a pipe connected to the existing sewerage system will be led.

Slowing the discharge of rainwater will be resolved in the scope of drainage of roads and paved surfaces by establishing a retention tank with a throttled discharge to 25 l/s.

The calculation of the amount of rainwater for the subject locality is presented in the following section. Table 1 presents the size of the anticipated reduced area. The reduced area is the area of the specific surface reduced by a flow coefficient, which depends on the type of surface according the standard.

Table 1. Reduced areas depending on type of surface

Surface type	Area in m^2	Flow coefficient	Reduced area in m^2
Road - asphalt	2 902	0.9	2 612
Road - tile	3 158	0.8	2 527
Green area	5 756	0.15	863
Roofs - solid cover	3 243	0.9	2 919
	Total reduced area A_r		8 829

The maximum rainwater discharge at $p = 0.5$ is calculated:

$Q_{d,v} = A_r * i = 8829 * 0.0172 = 152.9 l/s$ through the restricted 25 l/s

With respect to the fact that the Eastern Slovakia Water Supply Company permitted the release of only 25 l/s of wastewater (rainwater together with sinkwater) into the sewerage system, it is necessary to retain the excess of wastewater in the volume of the proposed retention tank for a period of 15 minutes, which is the duration of a 15-minute critical rainfall.

$$Q_{d,v}(excess) = 152.9 - 25.0 = 127.9 l/s$$

The amount of rainwater in the retention tank with a rainstorm is:

$$Q_{ret} = 127.9 * 15 \min . * 60 s = 115110\, l = 115.11 m^3$$

From the last calculation it follows that the necessary volume for retaining stormwater is 115.11 m^3.

3 PROPOSED STATE

Proposed alternative management for rainwater managemet is following.

From a geological survey of the site where construction of the first stage of the project is currently taking place, it follows that the territory is not suitable for absorption facilities (Zelenakova & Hudakova, 2014). Therefore, a retention tank was considered in the original proposal. In the subsequent proposal, alternative facilities are proposed for the trapping and accumulating of rainwater, namely (Macurova, 2012):

- Absorption blocks
- Absorption wells

These alternative possibilities for trapping rainwater are proposed for the nearby street, to where the rainwater would be taken. Based on the geological survey performed, conditions on nearby street are evidently suitable for absorption.

3.1 Absorption blocks

Rainwater is led underground into hollow absorption boxes (Fig. 3), where it is temporarily accumulated, and based on the permeability of the soil, infiltrates little by little into the ground. The blocks are also suitable where there is a smaller amount of space for absorption. They are expanded to all sides and combined into optionally large facilities. They also contain a transverse inspection tunnel, which enables inspection by camera or the flushing of the entire system.

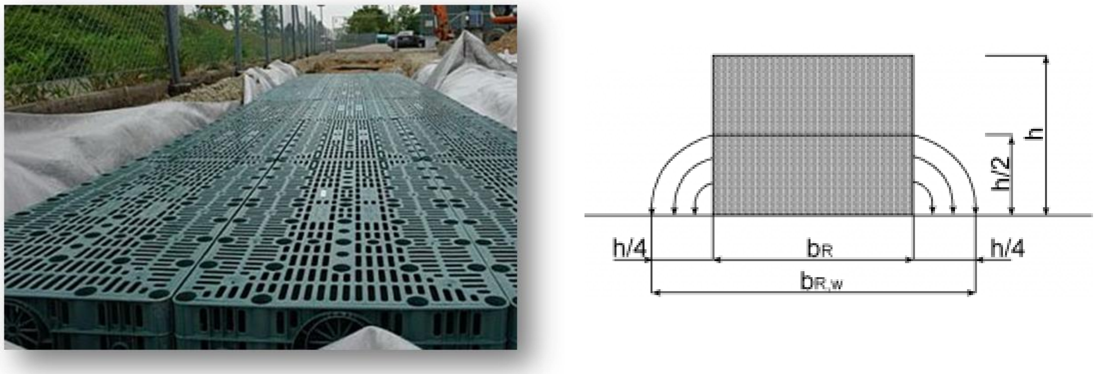

Figure 3. Absorption blocks

Rainwater from car parks will be taken to an oil-water separator, from which, after removal of hazardous substances, it will be fed together with rainwater from the roof into the underground absorption space located near the Elementary School on a street in the vicinity of Kuzmány Street in Košice. The amount of water q which is absorbed, with a value of 0.78 $\mathrm{l/s/m^{-2}}$, is calculated on the basis of the coefficient of filtration known from a hydrogeological survey in the given area. This means that for every 1 $\mathrm{m^2}$ of surface, 0.78 l of rainwater is absorbed into the subsoil. The total amount of rainwater Q_{total} carried for absorption from all stages is known: 695.5 l/s. The absorption area A_{s} is the area which is formed for the most part by the base on which the absorption blocks are placed of 480 $\mathrm{m^2}$: area available for placement of absorption blocks.

The absorption area A_{s} itself is not limited only to the surface A, that is, at the base of the absorption blocks, but is expanded by the width of the side absorption: water rises in the accumulation space to the height of one block h. The middle value of the height of the water level is $h/2$. Since a portion of the absorption is carried out through the side walls of the absorption blocks, namely along both sides of the effective absorption width of $b_{\mathrm{R,w}}$, it is expanded on both sides by the value $h/4$.

Then the effective absorption width is calculated:

$$b_{R,w} = b_R + (2*h/4) = b_R + h/2 = 30 + 0.6 = 30.6m$$

The absorption surface A_{s}, is given by the product of the length L of the absorption surface and the effective absorption width $b_{\mathrm{R,w}}$:

$$A_s = L*b_{R,w} = 30.6*15.6 = 477.36\,\mathrm{m}^2 \rightarrow A_s < A_{s_{total}}$$

The surface which the investor has available for the proposal of the absorption blocks is therefore sufficient.

The amount of rainwater absorbed into the subsoil is calculated:

$$Q_S = A_S * q = 477.36 * 0.78 = 372.3 \text{ l/s}$$

From the previous calculation it follows that the area which the investor has available for absorption is sufficient for the size of these absorption blocks. The amount of rainwater for retention is then calculated:

$$Q = Q_{total} - Q_S = 695.5 - 372.3 = 323.16 \text{ l/s}$$

The volume of retention during a storm is calculated:

$$Q_{ret} = Q*60*t = 323.16*60*15 = 290.84m^3$$

Unlike the current status of the proposed territory, in which a safety overflow is counted on in the case of a storm, the alternative solution counts on having a safety reserve, which represents a larger volume of the absorption blocks. We get this if instead of two rows of absorption blocks over one another with a height of 0.8 m we add a third row, by which we arrive at a height of 1.2 m and the volume is calculated:

$$V_{blocks} = A_{s_{total}} * h = 450 * 1.2 = 540 \text{ m}^3$$

The dimensions of one absorption block are: width x length x height = 15.6 x 30.6 x 0.4 m

3.2 Absorption wells

Absorption wells (Fig. 4) collect rainwater from the roofs of houses, car parks, surfaces, etc. and return it to the groundwater.

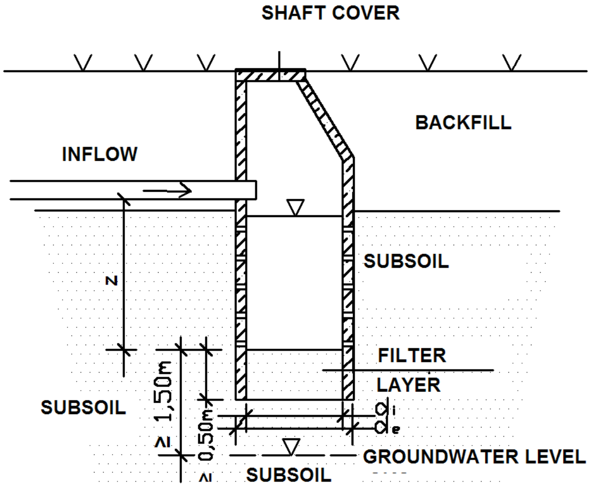

Figure 4. Absorption wells

They have a large spatial volume, i.e. such that each well may absorb a great amount of water. They are usually made from perforated pipes through which rainwater is absorbed into the subsoil. Drilled wells compared with a dug well absorb deeper groundwater, which is not directly dependent on precipitation and its amount remains more consistent over the course of the whole year. The drawn water also wields better quality. In the second alternative solution for trapping rainwater, water from roofs and car parks is taken to a retention container with a throttled discharge. From there it passes through an oil-water separator and is then taken to drilled absorption wells. Only sinkwater is released into the sewerage system. In the scope of the second alternative solution for trapping rainwater 10 absorption wells with a separation of 2 m will be proposed for the selected site. The wells will be mutually interconnected by pipes of diameter DN 150. The absorption capability of one well is 12 l/s. The total amount of rainwater $Q_{\text{total taken}}$ away for absorption from all stages is known to be 695.5 l/s.

The capability of absorption of all wells is calculated:

$$q_{vs} = q_{vs1} * p = 12 * 10 = 120 l/s$$

The amount of rainwater for retention is calculated:

$$Q_{ret} = Q_{total} - q_{vs} = 695.5 - 120 = 575.5 l/s$$

The volume of retention during storms is calculated:

$$Q = Q_{ret} * 60 * t = 575.5 * 60 * 15 = 517.95 m^3$$

Dimensions of the absorption wells: depth of 15 m, diameter of 0.35 m. At a depth from 2 to 13 m is a perforated pipe, through which water is absorbed into the subsoil.

4 EVALUATION OF THE ALTERNATIVE PROPOSALS

This work presents current systems for trapping and using rainwater. The practical part presents a proposal of alternative possibilities for the trapping of rainwater for the newly built project Nová Terasa on Ondavská Street in Košice. This proposal consists in the selection of the most suitable solution from among absorption blocks and absorption (drilled) wells. The proposal of absorption blocks is considered as the most suitable alternative solution for rainwater management, because though they are more expensive, they do not represent a danger to the children living in the vicinity, and an additional playground can be built over them. All alternative methods of trapping rainwater ensure an easing on the public sewerage system, which was also an aim of this work.

5 CONCLUSIONS

The concept of drainage in cities, which aims to mitigate the impact of urbanization on the hydrological regime of the country and on aquatic ecosystems, come from our experiences and knowledge of current method of sewerage. New concept of capture and use water from surface run-off provides a platform for a new technical and non-technical measures, both in drained on each property, as well as the public part of urban drainage area.

The new challenge of rainwater management requires a fundamental change in the way we think about storm water. Instead of thinking of rainwater as something to be collected and treated, then disposed of outside the city, rainwater should be regarded as a resource, and the amount of rainwater introduced into combined system should be reduced. Therefore, decentralized rainwater management can be regarded as an alternative, the sustainable strategy and redevelopment of rural and urban human settlement, practically considering ecological, economical and social criteria.

This work deals with the issue of rainwater management. The practical part presents a proposal for trapping rainwater on the selected territory of the newly designed project Nová Terasa in Košice. This proposal resolves alternative possibilities for taking away rainwater rather than sending it to the public sewerage system. In the original design rainwater is taken for accumulation into a retention tank with a safety overflow and throttled discharge. After passage through an oil-water separator it is taken along with sinkwater into the public sewerage system. For alleviating the sewerage network a system for taking off of rainwater for absorption was proposed for the selected territory, which due to the poor soil permeability at the selected locality will be located on Kuzmány Street in Košice.

These methods for trapping and accumulating rainwater reduce the burden on sewerage networks and thus also relieve the public sewerage network from rainwater.

ACKNOWLEDGMENTS

This paper was written thanks to support from project VEGA 1/0609/14.

REFERENCES

Butler, D. & Davies, J.W. (2000) *Urban Drainage*, 2nd Edition, Spon Press an imprint of Taylor & Francis

Crites, T. (1998) *Small and Decentralized Wastewater Management Systems*, The McGraw-Hill Companies, Inc. United States

Slys, D. (2009) Potential of rainwater utilization in residential housing in Poland. *Water and Environment Journal*. 4, pp 318–325

Slys, D., Stec, A. & Zelenakova, M. (2012) A LCC Analysis of Rainwater Management Variants. *Ecological Chemistry and Engineering S-Chemia i Inzynieria Ekologiczna S*, 19(3), pp. 359-372

Macurova, M. (2012) Rainwater management in urban areas (in Slovak). Thesis. Technical University Kosice

Zhang, D. (2008) *Reuse-oriented decentralized wastewater treatment based on ecological sanitation in fast growing agglomerations*. Thesis. Technical University Dortmund

Zelenakova, M., Balintova M. & Foraiova K. (2009) Rain water management for the purposes of sustainable development. In: *Zeszyty naukowe Politechniki Rzeszowskiej: Budownictwo i Inzynieria Srodowiska*. 266(54), 2009, pp. 119-128

Zelenakova, M. & Hudakova, G. (2014) The Concept of Rainwater Management in Area of Kosice Region. In: Giustolisi, O; Brunone, B; Laucelli, D; et al. Eds. *Conference: 16th International Conference on Water Distribution System Analysis* (WDSA), Bari (Italy), Procedia Engineering, 89, pp. 1529-1536

Zelenakova, M., Markovic, G., Kaposztasova, D. & Vranayová, Z. (2014) Rainwater Management in Compliance With Sustainable Design of Buildings. In: Giustolisi, O; Brunone, B; Laucelli, D; et al. Eds. *Conference: 16th International Conference on Water Distribution System Analysis* (WDSA), Bari (Italy), Procedia Engineering, 89, pp. 1515-1521