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THE UNOBTRUSIVE CHARM OF SMALL WATER RETENTION STRUCTURES IN URBAN AREAS

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Abstract

The utilization the different forms of retention in designing the buildings and spatial management of urban areas, is an the important element of the rain waters management system on urbanized terrain. It can be seen form different perspectives. The authors wanted to introduce retention as interesting, attractive the and functional element of architectural landscape, which can be bound into urbanized terrain structure and as element which has influence on protection of water in shorter time horizon and in longer perspective on balance of water supplies.

One should underline here, that the measurement of influence of spatial management (in scale of given investment) on water resources balance is very difficult, this influence is visible at the larger scale (the housing estate, district, city) and – what is more important it has different borders – not administrative but hydrological area. It the lowering the retention ability of given area influences on: the enlargement the flood areas, increase of the hydrological drought, worsening the quality of waters. The question of small retention has a special meaning in case of urban areas.

Streszczenie

Wykorzystanie różnych form retencji w projektowaniu obiektów budowlanych i zagospodarowaniu przestrzeni jest ważnym elementem systemu gospodarki wodami opadowymi na terenach zurbanizowanych. Na zagadnienie to można spojrzeć z różnych perspektyw. Autorzy niniejszego artykułu chcieli przedstawić retencję z jednej strony jako interesujący, atrakcyjny i funkcjonalny element architektoniczny, który może być wpisany trwale w strukturę terenu zurbanizowanego, z drugiej jako element mający wpływ w krótszym horyzoncie czasu na ochronę wód a w długim horyzoncie czasu na bilans zasobów wodnych. Tutaj należy podkreślić, że określenie wpływu zagospodarowania przestrzeni w skali danej inwestycji architektoniczno-budowlanej na zasoby wodne jest bardzo trudne, ten wpływ jest widoczny dopiero rozpatrując większą skalę (osiedle, dzielnicę, miasto) i to najczęściej nie obszaru administracyjnego a obszaru hydrologicznego czyli powierzchni zlewni. Obniżenie zdolności retencyjnej danego obszaru wpływa stopniowo między innymi na: zwiększenie stanów powodziowych, pogłębianie się suszy hydrologicznej, pogarszanie jakości wód. Zagadnienia małej retencji ma szczególne znaczenie w przypadku terenów zurbanizowanych.

Keywords: **Urbanized drainage basin; Small water retention; Urban runoff; Hydrographs; Stormwater manage.**

1. INTRODUCTION

An important issue in water management, and thus in water resources management (both quantity – and quality-related) is to increase the retention of water drainage basins (the smallest, basic hydrological unit for which a water management balance can be made, or in colloquial terms a balance of water needed for socio-economic purposes and the capacity of the natural environment to provide it. [2]). Drainage basin retention can be defined as the capacity to temporarily store water and, thus, to delay its runoff to surface water streams and reservoirs. This physical and geographic characteristic of drainage basins is essential not only to determine the size of water resources but also to improve the condition of water ecosystems and water-dependent ecosystems (which is one of the priorities in EU countries' water policies) [8]. More and more often, it is also considered as an element of runoff water management in urban areas. It should be highlighted that the traditional approach to the problem of rainwater runoff is gradually changing. For a long time, the dominating principle in planning water and sewage management in cities was to quickly drain rainwater directly to surface water streams and reservoirs: "in a city it is necessary to drain rainwater as quickly as possible as it obstructs motor transportation and has a negative impact on paved surfaces [1]".

Presently, such solutions are (partly) replaced with methods that:

- first limit the drainage of water to the sewers (by increasing absorption by the drainage basin surfaces and by slowing down the runoff of rainwater from the basin by using permeable and poorly permeable surfaces, using harvested rainwater for economic or domestic purposes, and implementing measures to increase surface infiltration and underground infiltration),
- and then make it possible to control the flow of water in the sewerage system (using the retention capacity of storm water sewerage system and retention reservoirs in storm water sewerage system).

The methods in the first group of activities that are based on using the existing natural terrain configuration, proper spatial management, and restoring the natural character of water system elements, are called non-technical methods of small-scale water retention [15].

The authors of this article have two objectives:

First, they intend to present in the paper the importance of small retention measures to water resources in water drainage basins. Thus, they intend to demonstrate that adequate spatial arrangements indirectly affect the size of water resources and, consequently, the hydrological phenomena occurring in drainage basins (to include such socio-economic phenomena as droughts and floods).

The second objective is closely linked with the first one. The authors intend to prove that the use of natural and aesthetic characteristic of small retention structures makes it possible to create a character of a given location in the urban area and has an impact on the local microclimate and the quality of built-over areas.

2. THE IMPACT OF URBANIZATION ON WATER RESOURCES IN AN URBANIZED DRAINAGE BASIN

The social and spatial changes in urban areas have an indirect but important impact on the development of urban technical infrastructure as well as on rainwater runoff management. The main reason for these changes (both in Poland and in other countries) is the process of deindustrialization that results from changing technologies and labour methods [9].

The growing impact of urbanization, with its artificial shaping of open urban spaces, causes a basic change in physical and geographic characteristics of the drainage basin. The results of this process include [5]:

- decreased natural water retention of the area (significant increase of the proportion of impermeable surfaces and those of average permeability, decrease in the ruggedness of the surfaces, and a reduction in the number of depressions),
- changed natural landscape of the water drainage basin (a change in natural inclination of terrain, in transverse and longitudinal drop of terrain and water flow which affects the size and speed of surface runoff, decreases infiltration of the soil and erosion processes),
- increased quantity of rainwater drained by the technical infrastructure to the sewerage system (rainwater is drained to a designated place where it is discharged from the sewerage system),
- decreased retention of river beds and valleys (reshaping of flood valleys, improper regulation of sections of river beds or restoration of river beds), etc.

Of course, there are large variations in the degree of urbanization in different areas of Poland; therefore, the issue that is the subject of this paper concerns most of all areas of high urbanization (to include the area of the Silesia Province [15]) but also areas with high water demand (the central part of Poland with low water resources and minimum water deposits in the first level of aquifers [11]).

The urbanization effect becomes evident when we compare the share of the individual elements in the total balance of water in an urban drainage basin and in the total balance of water in an unmodified natural environment, as depicted in Drawing Fig. 1.

Urbanization leads to a decrease in the natural capacity of the area to collect and store water which, in turn, has an impact on all elements of water circulation in the drainage basin, that is on evapotranspiration, infiltration, surface runoff, etc. An increase of

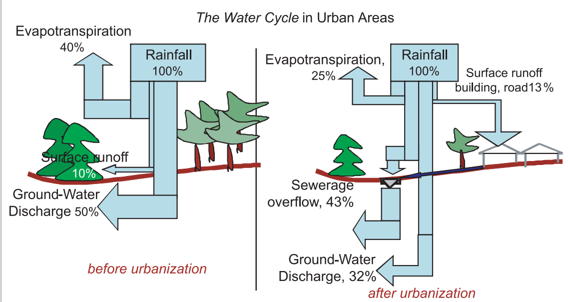

Figure 1.
The impact of urbanization on water resources in an urbanized drainage basin acc. to Rogers and W. Chełmicki [5]

impermeable surfaces to 75% in urban areas causes a nearly three-fold increase of water runoff in the drainage basin (compared with unmodified natural environment), at the cost of underground water outflow (which decreases by approximately 40%) and evapotranspiration (which decreases by approximately 38% [5]). At the same times, the total rainfall in cities becomes approximately 10% higher and the frequency of rains also increases (by 10% in the summer and 20% in the winter [11]) compared with non-urban areas. Also, rains of short duration and higher intensity become more frequent than rains of long duration and lower intensity. This leads to a very uneven runoff in the drainage basin and a change of the surface water regime (changes in long-term tendencies of dynamic flow variability) [2], which are depicted in Fig. 2. The observed phenomena include:

- in a period of freshets (e.g. during or immediately after heavy rains): a significant increase of water flow in rivers in comparison with a natural drainage basin (in the case of a drainage basin where the proportion of impermeable surface amounts to approximately 60% the value of maximum flow, or the culmination of the flood wave, increases 3.5 times [5]),

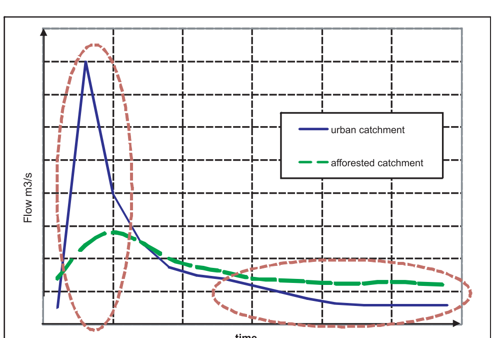

Figure 2.
Influence of process of urbanization on river water flow

- in a period when a river is fed mostly by ground waters: a significant lowering of flow values in comparison with a natural drainage basin and an extension of periods of low flow values, which in extreme cases may lead to a decrease of actual available water resources in any time period.

Changes in the hydrological regime of a river may, in extreme cases, lead to extreme hydrological phenomena of socio-economic nature, such as floods or hydrological droughts. One of the ways to contain such phenomena that is often underrated is using small water retention structures [7]. It should be highlighted that, while a number of solutions (both technological and non-technological) involving small water retention structures are available for flood prevention, the main way to prevent and to mitigate the impact of hydrological drought on soil and water is to build small water retention structures [7]. Small retention structures have various importance to prevention of extreme hydrological phenomena in different parts of Poland, mostly because of the physical and geographic characteristics of the different drainage basins [11]:

- in piedmont areas, the main objective of small water retention structures is to lower the occurrence of floods (good conditions for building small water reservoirs but problems with restoration of forests and regulation of rubble transportation),
- in lowland areas, the main objective of small water retention structures is to store water in order to prevent drought.

The effects of the above processes are not limited to changes in hydrological levels and in surface water flow, but also include degradation of water environment [13] (as a result of impetuous drainage of pollution directly to surface waters: covering 10-25% of the drainage basin with impermeable surfaces changes the quality of surface waters; increasing the proportion of impermeable surfaces to more than 25% of the drainage basin causes degradation of the water environment) [16] and changes in the environment of river valleys and beds (excessive erosion of river beds – the bottom and the banks).

The European Union [8] environmental policies focus on proper management of water resources in river drainage basins, to include implementation of environment-friendly, natural methods of water retention [14]. The following forms of retention can be identified in the natural environment [5]:

a) natural retention – retention by wetlands, forests and parks, soils and turfs, river valleys and beds, snow and ice retention, retention of natural water reservoirs, b) artificial retention – controllable retention (in multipurpose and melioration reservoirs) and non-controllable retention (in dry reservoirs, sand excavation hollows, and fish ponds, etc.). Efforts to increase retention capacity of drainage basins are an important method to balance the impact of uneven distribution of water resources in Poland [9]. Poland is one of the countries of limited water resources, including surface waters [4]. The average availability of water (the per capita quantity of surface waters per year) in Europe is 4,560 $m^3/(M^2$ x year), while in Poland the number is 1,600 $m^3/(M^2$ x year) which is three time less than the European average [4]. The reason for this situation is Poland's unfavourable geographic and hydrometeorologic conditions which result in a relatively low level of rainwater alimentation (the average rainfall in the years 1951-2000 was 620 mm), while the thermal conditions result in high losses of water (the average evaporation in the years 1951-2000 was 444 mm) [4]. It should be underlined that this assessment of water resources is only an estimate, due to its random character, and the presented values are average over many years. Consequently, considering the random distribution of rainfall and drainage over the territory of the country, the availability of water resources at a given time and in a given place may be significantly lower.

3. SMALL RETENTION STRUCTURES IN THE URBAN SPACE

The impact of spatial management on water resources is very difficult to assess on the level of individual construction projects as the impact becomes visible only on a higher level: a square, a block, or a district. In engineering calculations, the degree of surface permeability is determined in the surface drainage coefficient (the ratio between the part of the rainfall that is drained by the sewerage system and the total rainfall in a given area). The value of the coefficient changes from 0.0 to 1.0, depending on the type of surface and on the type of covering on the ground and the ground's inclination, the geological structure of the top layers, the initial moisture of the ground, and the time and intensity of rainfall. The value of the surface drainage coefficient, depending on the surface type [1]: • the lowest values of 0.00 to 0.20 are for areas covered with vegetation, unpaved, and not built-over areas, • average values of 0.20 to 0.50 are for areas of average permeability (dirt roads, pavements, areas with scattered building), • the highest values of 0.85-0.95 are for impermeable surfaces (tight surfaces, asphalt) [1]. For example, by significantly increasing the area covered by vegetation (by 20%) and decreasing the total area of impermeable and poorly permeable surfaces in a sample area of approximately 5 hectares would, in theory, lower the amount of rainwater drained directly into the sewerage system by about 25% [1]. (Assuming that the quarter is located in, for example, Upper Silesia and the duration of rainfall is 10 minutes, then by using the Błaszczyk formula to calculate the intensity of the rain and the terminal intensity method to calculate the flow in the storm water sewerage system [1]).

Including small water retention structures in the spatial architecture is important from the point of view of environmental protection (Fig. 3). It should not be forgotten that in drainage basins with high degree of urbanization a large part of surfaces are covered by technical infrastructure. Thus, the maximum use of any surface that may increase the water storage capacity in cities is essential (Fig. 4, Fig. 5, Fig. 6).

Actions aimed at improving water retention by increasing permeable or poorly permeable surfaces are important to water circulation. Such actions include using special surfaces of increased coarseness and permeability (cobblestones, split rock, small-size paving bricks, perforation of floors, or Japanese gardens – see Drawing Fig. 6) as well as areas covered by vegetation (Fig. 5). These elements can introduce some interesting features to the aesthetic composition of an urban space and may be used to design interesting "social spaces" that entice their users to behave in certain ways that are "programmed" by their authors (by creating the so-called "event space", or "performance space"). Making these spaces attractive to the public indirectly translates into financial gains.

Retention structures can also be a part of small architecture in squares, yards, or parks, and follow patterns present in the natural environment. Such structures can create a unique character of a given place (Fig. 7).

It should be highlighted that the objective for such structures is both to create a friendly architectural and urban space by improving its aesthetics and to slow the rate of rainwater surface runoff. Therefore, one of the most frequent features is open ditches (with meanders that slow down the water stream the same way as in meandering rivers), leading to small intermittent water reservoirs that are often preceded by engineering structures (e.g. settling tanks or filters) that allow an adequate initial purification of rainwater (Fig. 8).

Figure 3.
Spatial arrangement of urban space, Amsterdam, 2000

Figure 4.
Square in centre of city, Amsterdam, 2006

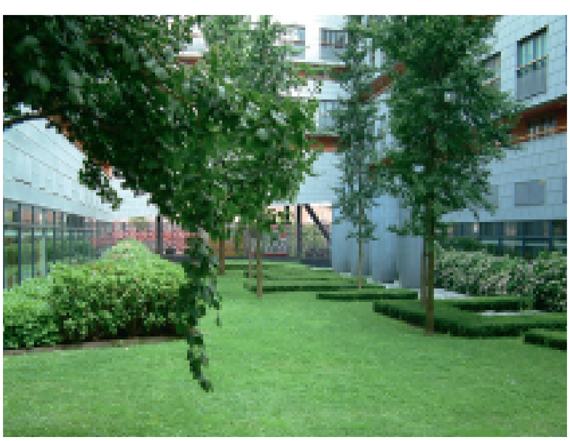

Figure 5.
The inner space of urban block, 2006

Figure 6.
Square near Building of Museum of University, Groningen, 2006

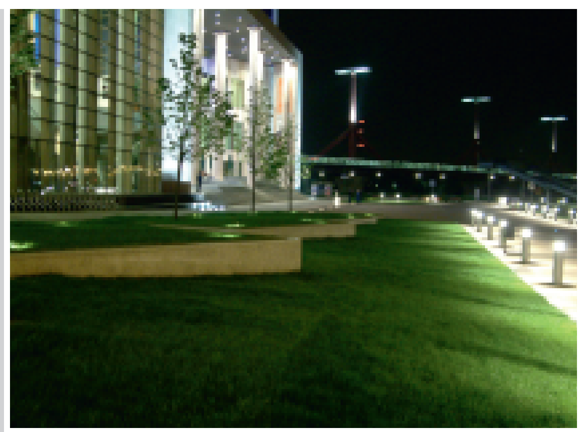

Figure 7.
Square near Museum of Modern Art, Budapest, 2006

Figure 8.
Yang Hae Nam: Seonyudo Park, Seoul, South Korea [17]

Figure 10.
Examples of retention elements which can be used in designig of small architecture elements. Library of University of Technology, Delf, auth. Meccanoo, 2006

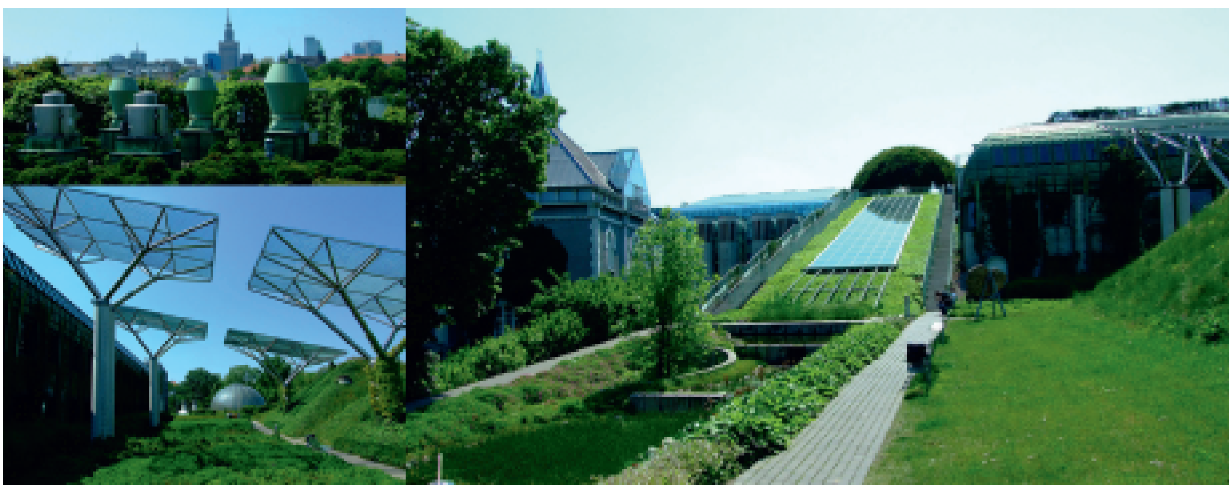

Figure 11.
Examples of retention elements which can be used in designig of small architecture elements. Library of Varsovian University, Warsaw, auth. M. Budzyński, 2006

Figure 12.
Van Nelle, Factory plot (Van der Vlugt, Brinkman, 1925) Amsterdam, fot. 2006

Figure 13.
Transformer box, Amsterdam, fot. 2006

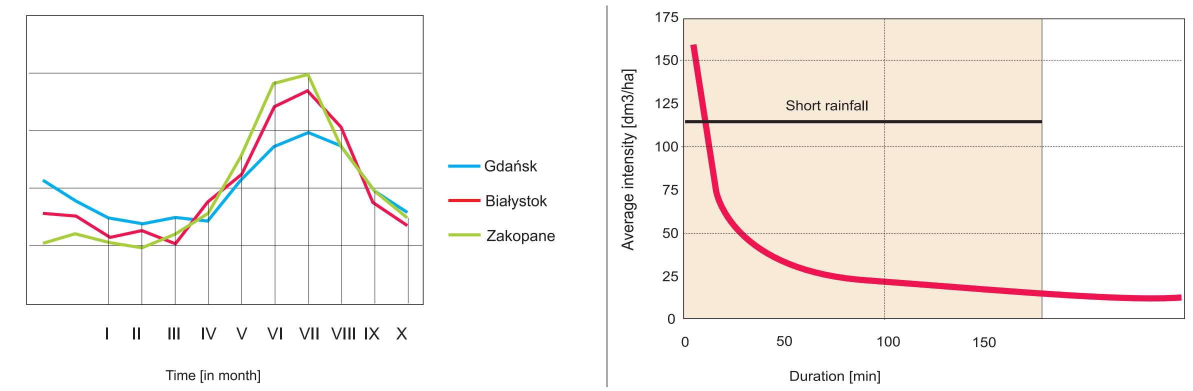

Figure 9.
Changes of monthly rainfall balance and the changes of intensity of rainfall in time for selected of cities of Poland [6]

It should also be mentioned that increasing water retention in drainage basins by using small water retention structures that include the roots of plants (which also lower the heat absorption of surfaces and structures) noticeably improves the microclimate of urban areas by regulating the temperature and humidity, decreasing the amount of dust in the air, and limiting uncontrolled wind gusts.

The possibility to use the natural random nature of rain may turn out to inspire architectural designers. A rainfall may become an element of creation of the architectural space and affect its appearance. Therefore, designers need information on rainfall of short and long duration (their intensity and frequency) as well as knowledge of the basic rules of variability of periodic and seasonal rainfall and snowfall. For example in seaside areas the maximum frequency of rainfall is usually at night or before dawn and in continental climate – in the afternoon. In general, nighttime rains are more frequent and rain occurring during the day has higher intensity, etc [6].

What helps the use of rainfall as an element that makes architectural compositions more attractive is the fact that, as long-term data demonstrates, the highest levels of rainfall in Poland take place in the summer (end of June, beginning of July) which is when open public spaces enjoy the highest number of users (Fig. 9). The knowledge of this fact facilitates the selection of adequate measures related to small water retention.

Another interesting way to take advantage of retention capacity of various surfaces is to build the so-called green roofs (as long as adequate roof covering is applied), such as those in the Delft University of Technology library (Fig. 10) and the Warsaw University library buildings (Fig. 11). In both cases the result was an unique public space. In the former case, the green roof is directly connected with the ground and makes a kind of a grassy slope that is used as a recreational area not only by students (at the same time, "this technical solution makes the least impact on the environment" [12]). In the latter case, the design comprised one of the largest roof gardens in Europe (2,000 m^2) that is connected with a stream with water cascading down from a water reservoir to a garden in the back of the library building (15 000 m^2) [3]. This technical solution has a higher retention capacity than grassy areas as retention capacity depends, among others, on the plant species used (the maximum retention capacity of a plant with coarse surface of horizontally growing leaves is higher than of a plant with smooth surface of slanting leaves and the interception of trees and bushes in the vegetation period equals approximately 10-40% of the total rainfall [5]). The library building and the garden have become a recreational area and a tourist attraction of the city district (thanks also to the fact that Warsaw skyline can be seen from the library's green roof), and an integral part of the cityscape of Powiśle.

A common use of small water retention structures as an element of urban space should occur in all parts of cities, not only in public spaces but also in residential areas (where, for example, small parking lots and driveways can be made from open work slabs or permeable paving brick patterns) and industrial areas (Fig. 12). It is essential that such frequently disregarded architectural elements as the lining and placement of technical infrastructure should also be taken into account at the design stage. These elements should contribute to the creation of a local microclimate and a visual aspect of architecture by resembling sculptures of high aesthetic value (Fig. 13).

4. CONCLUSIONS

During modification of parts of water circulation system by architectural design, town-planning or other activities, the arrangement of connections on whole area (not only on urban area but also in water drainage basin) is modified . In fact to enable consistent policy of small retention systems usage in urban area liability to use small retention has to be contained in Local Plan.

To see it from a different view – designing of public spaces in urbanized areas requires the understanding of way in which works the whole ecosystem in Water drainage basin. It requires recognition of both quantitative and qualitative the relationships between:

– individual physical and geographical parameters of Water drainage basin (the sculpture, litology, soil, vegetation the, meteorological conditions, itp.),
– the engeenering objects and the phenomena (the physical processes) and
– the neighbouring systems [10].

It it should be underlined, that the individual elements of circulation of water are related and mutually correlative, and its change pace is unequal. Designers can not finish their activity on "border of plot" or "range of study", and narrowly seen "specialty". This marks, that responsible design of public spaces requires the architects' and town-planners' education in field of urban hydrology as well as the closest co-operation among architects and the engineers on early stages of design. It requires also the change of routine solutions, utilization of atypical solutions and creating the new technical solutions which can be used to create original beautiful and human-friendly urban spaces.

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