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Perception of ecological aspects as part of flood protection

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Abstract. Modern trends in water management are more than ever inclined towards ecological solutions to avoid technical stream-channel regulation of riverbeds in the design of flood defence measures. Modifications to straighten the riverbeds that were considered in the past, removed the natural meanders of the river, increased the longitudinal slope of the riverbed, and accelerated the outflow from the threatened area. The goals of building protective dams and controlled floodplains are also limited by the negative perception of conservationists and ecologists, which leads to stagnation and discouragement from the proposals. The aim of this article is to compare the given perception of ecological aspects in different countries, how they approach them and how they are applied in studies of flood solutions. Among the ecological aspects, the following points of view will be observed: (1) options for regulation and design of flood areas, (2) duration of flooding time for the ecosystem or the landscape, (3) redefinition of riverfront in cities and (4) concept of resilience.

1. Introduction

According to the terminology of the EEA (European Environment Agency) glossary, flood is defined as an unusual accumulation of water above the ground caused by high tide, heavy rain, melting snow or rapid runoff from paved areas [1]. In Slovakia, the Flood Protection Act defines a flood as follows: a flood is a natural phenomenon in which water temporarily inundates an area that is not normally covered by water [2].

A flood occurs as a result

a) increasing the flow of water in the watercourse,

b) the creation of an obstacle or the creation of an obstacle in a watercourse, on the bank of a watercourse or on a construction, object or device crossing a watercourse, which caused the water to swell and spill over into the adjacent territory,

c) long-lasting precipitation or intense precipitation, snow melting or the simultaneous occurrence of these phenomena,

d) inflow of water from precipitation or inflow of water from melting snow on the surface from the adjacent area,

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e) rise of the groundwater level above the surface because of long-lasting high-water level in the adjacent watercourse or because of long-lasting precipitation.

As in other countries, the literature also describes historical floods. Historical flood marks on the territory of Slovakia date back to 1775 and 1813 on a linden (marks on a tree) in Drahovce, or evidence of the verse chronicle of the village of Cífer from 1813. [3]. Uncertainties in the determination of historical extreme design flows contributed to methods for estimating design values based on measured series of maximum flows. Currently, most of the water gauge stations are managed by the Slovak Hydrometeorological Institute, which provides information, monitoring and warnings related to the water level regime of our rivers.

The aim of the article is to examine the attitude towards ecological aspects in different countries and to describe ecological factors that apply to a given location. However, the narrow specification is the focus on flood protection and its elements precisely in connection with the effects on ecology and the environment.

2. Material and methods

In various countries, the needs, and requirements for the design of flood protection measures differ according to natural aspects such as geology, hydrology, climate, ecology, and so forth, but also due to the influence of the human factor, which is often defined by political agendas, laws, and awareness of the threat of floods as such. For this reason, I will point out different solutions and reasons for the effects of ecological aspects from other countries and how they dealt with them.

2.1 Dike displacement

The Ministry of the Environment, Baden-Württemberg, supported an extensive program called the 'Integrated Rhine Programme' that was ratified in November of 1988. The word "integrated" reflects an interdisciplinary co-operation in which ecological aspects are supposed to be ranked equally with those of water management, agriculture, and settlement needs. The Programme takes the viewpoint that the Upper Rhine valley must be seen as a geological, hydrological, and ecological unit. The reason for the creation of the given program was the public opinion favoured ecological aspects of water and nature management, and that remedial measures, based on flood management criteria alone and with little concern for environmental consequences, did not find general acceptance.

An environmental impact assessment, that was undertaken in this context, found that the previously recommended storage volume was not sufficient to regain the demanded state of flood protection. These findings were based on ecological considerations such as moderate inundations heights and dynamic flooding of the polders ('ecological flooding'). Therefore, the Integrated Rhine Programme launched a survey covering the entire Upper Rhine to identify and evaluate possible retention areas. All potential sites were investigated, essentially following three options: (1) Storage in regulated polders, (2) extending areas of natural flooding by displacing existing dikes away from the Rhine, or (3) 'ecological flooding' [4].

2.2 Duration of the flood

Heavy rain falling in Far East monsoon areas of Russia, can create floods with runoff about 12 – 20 $m^3.s^{-1}$ per km^2 in small river basins. For comparison, the runoff of melting of snow during the spring flood does not exceed 4 $m^3.s^{-1}$ per km^2 in the same river basins. An increasing of volume and frequency of extreme precipitation, particularly in areas with a monsoon climate in the Far East of Russia are forecasted by experts [5]. Preliminary evaluation gave the following results: the frequency of floods caused by heavy rains in the Far East will increase by 1.2 - 1.5 times. So, if now they are repeated 1 time to 10 - 15 years in the future, they will be repeated with time intervals to 7 - 12 years. The number of floods will increase by 45 - 60% in rivers of Far East region of Russia. and that is a big challenge for sustainable urban development in the region [6].

In current studies, the regulation of rivers as a measure to mitigate flash floods flows, proposes a system of self-regulating flood dams (SRFD). These dams are distributed on the river network and can save additional water volume from flash floods in temporary detention reservoirs created by SRFD. The main objective is to develop methods for analysis how the site location of SRFD meets the environmental criterium. Because ecological criterions were in the focus of the research, one of the tasks was to analyse and evaluate duration of flooding time for each ecosystem or landscape for the SRFD parameters during flash floods. Results of modelling in GIS environment were interpreted in raster GIS database which combined the landscape layer and critical time interval formula. This allowed a comparison of locations and possibility to chooses a location that has a minimal impact on the environment [7].

2.3 Waterfront design and redevelopment

When designing flood protection measures for built-up areas of cities, we come across the term riverfront. The "riverfront" stated here represents the water edge area, where the city meets the river. Many developed countries such as the U.S.A., U.K., Japan and have started to ecologically redevelop the riverfront in order to ensure that the rivers are restored to their natural condition [8, 9]. The ecological improvement of riverfronts can be divided into two types: (1) river restoration and (2) river rehabilitation. Restoration has been referred to projects that have a high potential of meeting the natural condition of the river, while river rehabilitation was specific to the river that had been urbanized to the extent that there was limited land available to achieve ecological improvements. This indicates that the implementation of river restoration and rehabilitation depends on the current condition of the riverfront. Riverfront development does not necessarily aim for restoring the natural setting of the riverbank. Improving its ecological setting would be sufficient if processes for full restoration cannot be conducted [10].

2.4 Concept of resilience

The "4Rs" of resilience (i.e., robustness, rapidity, redundancy, and resourcefulness) were adopted as a theoretical basis for the flood-adaptive green infrastructure planning. The 4Rs represent the four attributes included in the concept of engineering resilience, which is the ability to return to the pre-existing state after a disturbance and to maintain a single equilibrium state. (1) Robustness refers to the ability of a system to withstand the impact of floods, while (2) rapidity refers to the time it takes for a city system to be restored to its original stable state after a flood has occurred. (3) Redundancy involves introducing alternative elements or systems to reduce the probability of failure and to better adapt to floods. Finally, (4) resourcefulness refers to the facilities and systems of disaster prevention, such as disaster notifications and shelters, which can identify problems and mobilizing resources.

One way of interpreting the 4Rs is Flood-adaptive green infrastructure design matrix. A design matrix was constructed by classifying the types of flood-adaptive green infrastructure according to the strategy and the scale of the target area. According to the integrated design matrix, small, medium, and large areas were classified based on the size of the target area. Small areas were spaces in residential and commercial areas, and areas around footpaths with green infrastructure types as rainwater infiltration facilities, detention ponds, permeable pavements, trees, bioswales, artificial waterways, green roofs, green walls, and rain gardens. Medium areas were residential and commercial areas in flood-sensitive areas and from the point of infrastructure were defined as green roofs, green walls, rain gardens, urban gardens, parks, wetlands, and green streets (alleys). Large spaces where residential, commercial, and green areas that encounter water or are encircled.

These elements have been applied in several studies and models in South Korea, where the reduction of the rainwater runoff through the expansion of the green infrastructure can minimize the damage due to the urban flood by reducing the peak discharge as Gangnam- u´s park area (6,210,000 m^2) in Seoul [11].

3. Conclusions

In general, the design of flood protection levees (dikes) is one of the most used solutions for the protection of municipalities in Slovak republic. Proposition of the idea about displacing the existing dams, even after proving the improvement of the outflow from the study area, is not taken into consideration and further design stages. Dealing with property rights is probably the most complicated obstacle for offsetting large structures as levees. New proposals try to widen the width of the cross-section profile between protective levees primarily because of the drop in water surface elevation and not because of the creation of a potentially environmental and ecological point of view.

Similar studies of runoff models for sub-basins, with the aim of finding ideal cross-sectional profiles, are also being carried out in Slovakia. Looking at the time intervals and duration of floods in the catchment area does not place much emphasis in the design of dams (like system of self-regulating flood dams). Still the primary parameter in the design of dams with the aim of flood protection is the maximum possible regulated outflow from the dam. The regulated flow must be designed in such a way that the profiles of the riverbed of the area below the dam can safely transfer the mentioned flow. However, this theory could be used in the restoration and design of wetlands, with the goal of regulated floodwater capture. The restoration and design of artificial wetlands is a current topic that deals with the ways of regulating water levels in the catchment areas of wetlands. To what extent it is necessary and possible to divide the given volumes of flood waves so that flood protection measures are met, and at the same time the conditions for the functionality of wetlands are met is questionable, but it is necessary to point out the possibility of creating new valuable habitats.

A partial concept of resilience could be applied to the redefinition of the waterfront. The zone between the river and the inner city is indefinable or even non-existent in most places in Slovakia. The inundation and protected area of the river primarily fulfils the function of water discharge during a flood, but during average and minimum flows, the river corridor is used minimally. Another negative point of view is that functional objects are not proposed in the flow profile of the river, whether they are recreational, sports or even natural elements. Robustness could be the factor, which should be used in the design of stream modifications. The goal should be to redefine the riverfront to fulfil flood protection measures, but restore access to water, whether for people or animals in way, that it is durable and long-lasting.

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