An example of watershed management in Croatia

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Abstract

Activities on the implementation of integrated watershed planning started to bring significant results last year. It is impossible to speak about all watersheds in Croatia, but some of them can be pointed out as examples.

This paper offers an example of improving watershed management. It refers to a small watershed in the River Danube basin in the northern part of Croatia. Beside the two main rivers, Karašica and Vučica, there is a rather developed network of artificial and natural watercourses. In relation to this watershed, there are three major fields of activities.

The first problem that had to be taken into consideration was protection against floods. Within the last decade, the existing flood protection system had malfunctions in 1996, 1998, 1999, 2001 and 2002. Thus a comprehensive flood risk analysis was undertaken, the results of which have defined the priorities in the development and reconstruction of the existing flood protection system using both technical and non-technical measures.

The second topic is related to the river Vučica restoration. Most of the river has been regulated in the past, but certain principles of river restoration were applied recently (restoration of the river’s natural meandering, and application of natural materials for erosion protection).

The third topic is related to river-water quality management. The fact that agricultural fields cover more than two thirds of the total area shows the vulnerability of the surface and subsurface water resources, due to the non-point source pollution. The paper will conclude with a review of further activities on the implementation of integrated watershed planning.

Key words: integrated watershed planning, flood risk analysis, river restoration, water quality.
1 Introduction

The Karašica and Vučica catchment basins have the following characteristics: 75% of the area is typical lowland with average slope of less than 0.01%; 25% is a hilly part with slopes from 2-18% and local medium erosion problems. The most endangered part of the catchment basins are the parts on the contact between the hilly part and lowland. The open watercourses network is very dense. In the hilly part of the catchment basin most of the streams are dry during the summer period, and in springtime they have torrent characteristics. In the lower part of the basin, natural watercourses were regulated in the past. The water regimes of the Vučica River as the primary and the Karašica River as the secondary watercourse are slightly different.

Land use characteristics were developed according to topography. Lowland is basically an agricultural area. There is also a large forest area, rich in wildlife, and what is important, this forested area has increased in the last decade. Vegetation cover of the higher parts consists of vineyards, orchards and forests. A part of this area is protected as Nature Park because of its unique karst formations.

Human impacts are very obvious. Agricultural area covers about 70% of the total area, with a highly developed land drainage system with all related structures (one dam - volume of 2.4 m³, 21 sluices, 2 pumping stations and 32 km of dikes).

Settlements are mostly situated along the rivers. The process of urbanization was very intensive in the last decades and now about 100,000 inhabitants live in the catchment basin.

2 Integrative approach towards the integrative river basin management

Considering natural features, social, economic and environmental aspects of river basin management, some improvements had to be made. The history of water management in Croatia began in this small river basin (more than 125 years ago) with flood protection development. Despite the great experience and a relatively well developed flood protection system, floods appear very often, generating major or minor damage, mostly on agricultural fields and hydro-technical structures, and sometimes on urban areas, too.

Today, many of the natural features have been changed but some of the problems are still present. One of them is flood protection, another one is water quality management which is still on an acceptable level but there are some undesirable processes that need to be stopped (Tadić [2]).

This was a good opportunity for some improvements in the river basin management by:

- application of integrative flood protection;
- watercourse regulation on river restoration principles;
- water quality analysis according to the EU Framework Directives and recommendation for its improvement with an action plan.
3 Flood protection

In the past, the economic aspect of floods was the most common one. The social aspect, considering the uncertainty of investments in agricultural production, drop of estate prices, and quality of life in general must also be taken into account. Development of institutional protection and regulations is very important in this field. The next aspect of flood damages that must be considered is the environmental aspect, which was very much neglected in the past decades. Extreme hydrological events, such as floods and droughts, deteriorate the stability of the ecosystem and induce changes of its original features. Processes of water erosion and sedimentation occur together with biological changes. These changes are opposite to the principles of sustainable development and they indicate inappropriate water management in the catchment basin. Therefore, the integrative approach towards flood protection, based on sustainable development, must involve all of these aspects.

Modern flood protection system must satisfy human needs, protect natural and environmental resources and be justified in the economic sense.

Figure 1: Scheme of integrated flood protection system.
Efficient and safe flood protection can be achieved only by parallel development of all mentioned aspects. The scheme of integrative flood protection system is presented in Fig.1. It shows the complex relation between a number of technical (structural) and non-technical (non-structural) measures. Structural measures are very well known (construction of dikes, dams and other hydro-technical structures) and they have been applied for centuries. Non-structural measures (such as improvement of retention capacity of the catchment basin, improvement of prognosis and information system, mapping zones of high medium-low risk of flood and involving them in the physical planning documents still must be developed or improved (Biondić [1]).

Comparing to the traditional point of view where the excess water had to be conveyed out of the catchment area as soon as possible with minimal damages, the new approach involves keeping water in the area in the natural reservoirs (retentions) to the maximum extent, together with the structural protection of the urban area. In the conditions of extreme hydrological events (floods and droughts), this difference is very significant. Periods of floods and droughts are exchanging more or less every year. In the last decade the average annual precipitation did not change significantly but its time distribution through the year did (Tadić et al. [4] [5]).

In the previous period, attention has been paid to the technical measures and a forecasting and warning system. Today, more activities must be performed in the direction of urban and regional planning towards a more efficient flood protection system and improvement of the water management system, in order to overcome effects of extreme hydrological events (floods and droughts).

4 Water regulation

A part of the flood protection system is the Vučica River regulation. There are several reasons for the river regulation. The latest flood events caused major damages on the river structures, dikes and riverbanks. There are erosion problems on many sections, mainly in the meandering parts.

The major part of the watercourse hasn’t got enough capacity for high discharges during the rain periods. Figure 2 shows the hydrograph of the maximum, average and minimum discharge for the period 1975-1998.

Moreover, most of the river flows through forests and natural meadows with an extremely valuable natural habitat. Figure 3 shows the vegetation along the lower part of the Vučica River (typical wetland). Figure 4 shows an erosion spot in a meander.

So, regulation had to be applied without deterioration of the natural surrounding, including river meanders, and all artificial intakes must be as natural as possible. The proposed regulation works were based on the following constraints:
1. Layout of the riverbed will remain unchanged - the length of the river is constant. Corrections of some sharp meanders had to be done.
Figure 2: Month discharge variations of the Vučica River (1975-1998).

Figure 3: Water vegetation and vegetation along the river.

2. Discharge capacity will be improved by increasing the flow velocity through intervention on the river slope - only by taking out bed sediments. Any other deepening of the river profile was avoided. Increasing of the slope will also slow down the sedimentation process.

3. New dike construction was planned only on the section between the kilometers 5.3 and 28, for the protection of settlements. During the high water periods, water can freely flood the surrounding wetlands, pastures and forests having a function of retentions.
4. Erosion problems of several critical points (mouths of drainage canals, bridges, sharp meanders) are controlled by stabilization of bed sides using natural material (stone and timber).

5. River Vučica is a recipient of a number of drainage canals. Their mouths remained on the same locations, but they have been stabilized and protected from erosion. Figure 5 shows the cross section of designed river stabilization.

The final conclusion is that the main purpose of the river regulation – flood protection without deterioration of the natural habitat and biodiversity – has been achieved. The first part of the solution was approved by mathematical modeling. The potentially endangered areas (settlements, frequently flooded sections due to...
the small cross section profiles, eroded embankments, etc.) are defined on the maps in the scale 1:5000 on the basis of mathematical modeling of water levels by HEC-RAS. Hydraulic calculation was performed for the most unfavorable scenario – coincidence of high water levels in the Vučica River and the Drava River, which is the main recipient. Input data consisted of precipitation intensities and duration, geometry of subcatchment areas, land use maps and geometry of the watercourses. In the second step, mathematical model HEC-1 was used for rainfall-runoff modeling. The results are compared to the measured data and the error was less than 5%, which is acceptable. The second part of the solution is more subjective, but there is no evidence of bad influence on the natural resources (Hidroing, 2003, [6]). Also, Environmental Impact Assessment has been made as a part of the proposed project.

5 Water quality

The analysis of the ecological statement of rivers shows a great quantity of organic material, which can lead to eutrophication. Anthropogenic influences are obvious. Pollution occurs due to the non-point sources from the agricultural fields (mainly nitrogen) and uncontrolled flooding with washing out nutrients from the fields together with soil particles (mainly phosphorus) (Tadić et al. [2], [3]). The process of eutrophication has been detected on the basis of the quantity of phytoplankton and zooplankton and their composition. Apart from the concentration of oxygen, biological oxygen demands (BOD5) also indicate an unbalanced ecosystem. Figures 6 and 7 show the biological oxygen demand and oxygen concentration.

![Graph showing BOD5 vs years for Karašica and Vučica, with max. allowable conc.](image)

Figure 6: Average annual BOD 5.
There is no evidence of point source pollution (urban wastewater) in the river. Reduction of the nutrient pollution of water takes a long time and comprehensive measures to succeed. Efficient control of diffuse pollution sources has not yet been achieved. Usage of mineral fertilizers has decreased in the last decade but according to observed water quality it is still high. The situation is the most serious in the low discharge period, and in dry years (like 2003) in general, so the possibility of enrichment of the water body during summer would be valuable.

6 Conclusion

A synthesis of the previously elaborated analysis, boundary conditions and proposed solutions has been made in the long-term study of the complete river basin management with the definition of priority actions.

Vučica River regulation as a part of the flood protection system, but also a part of the natural ecosystem, has to be carried out. The last part of the activities is related to the improvement of water quality. It is a long process, which has to be funded in the national legislation. Croatian water quality legislation is in the process of coordination with the EU. Along with these, more or less technical implementations, there are several non-structural measures that have to be improved:

- improvement of water management
- improvement of the monitoring system and hydrological analysis of future flood episodes in order to improve the proposed solutions

Positive tradition of river basin management will continue through further activities and improved monitoring. Based on the positive experiences in this
area, some of other smaller river basins develop similar approaches to integrative river basin management.

References