ANALYSIS OF FLOOD FREQUENCY ON THE AREA OF DRAVA RIVER BASIN

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Abstract: In the last five years catchment area of Karašica and Vučica rivers in the Drava river basin there were four huge floods, in 1996, 1999 and in June and September of 2001. They have caused big damages on agricultural fields and hydrotechnical structures. The fact that this catchment area has very developed surface drainage system makes this problem much more serious. The main purpose of this paper is to describe these events from the hydrological point of view and to give some recommendation for the prevention in the future.

This paper will present some hydrological analysis based upon available precipitation data and discharge measurements on the area. They consist of flood frequency analysis, determination of return period of recorded floods and determination of inundated area. According to previous drainage projects of this area, 17 accumulations were planed. The study of the priorities in their constructions is in the preparation and this paper will give some of its results.
Key words: flood, frequency analysis, return period, flood protection

ANALYSE DER ÜBERSCHWEMMUNGSH UFIGKEIT AUF DEM DRAUFLUSSGEBIET

Zusammenfassung: In den letzten fünf Jahren auf dem Flussgebiet von Karašica und Vučica, das zu dem Wasserraum der Drau gehërt, sind vier grosse Überschwemmungen aufgretreten, 1996, 1999, als auh im Juni und September 2001. Sie haben grosse Schäden an den Landwirtschaftsflächen und an den hydrotechnischen Objekten angerichtet. Wegen der Tatsache, dass dieses Flussgebiet ain sehr entwickeltes System der Obertlächenentwässerung hat, stellt eine so erchebliche Häulligkeit der Überschwemmungen ein ernstes Problem dar. Das Ziel dieser Arbeit ist, die schon erwähnten Überschwemmungen von dem hydrologyschen Standpunkt zu beschreiben als auch bestimmte Empfehlungen für ihre Prävention in der Zukunft zu geben. Diese Arbeit wird hydrologische Analyse darstellen, die auf den verflʃgbaren Daten über die Niederschlagsmenge und über die gemessenen Durchtflüsse beruhen. Das sind: Häufigkeit der Überschwemmungen, Berechnung der Wiederholungsperiode, in der die Überschwemmungen registriert sind uns das Definieren des Überschwemmungsgebietes.
Nach den bisberigen Entwässerungsprojekten ist der Bau von 18 Stauseen vorgesehen; aufgrund dieser Analysen wird man die Bauprioritäten festlegen.
Schlüsselbegriffe: Überschwemmungen, Analyse der Häfigkeit, Wiederholungsperiode, vorbeugende Massnahmen für den Überschwemmungs-schutz

1. Introduction

Floods can be defined as a body of water that covers normally dry land. Floods occur when soil and vegetation cannot absorb the water and the runoff cannot be retained in stream, river, ponds or constructed reservoirs. Floods are frequent in the developed countries as much as in undeveloped or developing countries. For example, in United States of America in last 10 years costs produced by flood damages were 3.1 billion US dollars.

Besides the great damages in the economic sense (on agriculture, industry, houses, infrastructure and other properties), sometimes they can cause death of many people. Floods are also one of the most frequent environmental hazards. Recent hydrological analysis shows more frequent occurrence of high precipitation episodes which produce big discharges and flood risk, but the total annual number of rainy days did not increase. Also, frequency of droughts increases, too. Some scientists explain occurrence of these extreme hydrological phenomena by the effects of glasshouse and climate change.

According to the concept of sustainable development, impacts and frequency of natural disasters, like floods and droughts belongs to the group of ecological indicators of sustainability. Frequent appearance of floods and other natural disasters on the certain area or region, indicates that planning and water management of that area is not sustainable according to ecological and economic criteria. It needs a comprehensive analysis and improvement (Tadić, 2002).

There are several types of floods: floods caused by melted snow, floods caused by ice jams and ice breaking up, convectional storm floods, cyclonic storm floods and rain-induced mud flows. Their occurrence depends of climate, geographical characteristics and the period of the year. Very often more than one flood type may occur simultaneously (1).

In this area of continental Europe, and Danube basin, the most frequent are convectional storm floods characterised by short duration on relatively small watersheds. They seldom last very long, but they can produce large loss of property. They are especially serious in the urban areas where urban drainage is not adequate to accept large flows. Very often intensive process of urbanisation is not followed by development of infrastructure. In urban area, most of the surface is impervious, asphalt, concrete and roofs, and runoff coefficients increase. Additionally, occurrence of flood depends on the landscape, too. The most vulnerable point is the area at the contact between mountainous part of the watershed and the lowland.

This paper is going to analyse last flood episodes recorded in the September 6, 2001 in the Karašica and Vučica catchment area in the Drava river basin.

2. Description of the Catchment Area

These floods have all characteristics previously mentioned, they are caused by huge storms of short duration on the relatively small area. Towns and villages that were endangered are located in the bottom of the hill. The average slope is 2.7 %, but the upper region has much more bigger slope than lower part of the region (3).

2.1. Upper Part of the Catchment Area

In the upper part of the region, between 125 and 953 m a.s.l, there are several unregulated watercourses which are not able to accept big runoff in the short period of time. Some of these streams during rainy periods of the year have characteristics of torrent flows. Besides, in the summer part of the year they have very small discharge, bellow biological minimum. The main recipient is Vučica River. Its upper part has a slope between 0.5 and 1.3 %. Because of this big difference in the slope, lower part of catchment area is endangered during high discharges. Land cover consists of forests, orchards and vineyards. Average annual precipitation is about 800 mm with the maximum in June.

In this area, run off coefficients are between 0.33 and 0.49 and horizontal water balance is much more significant than vertical (3).

2.2. Lower Part of the Catchment Area

Lower part of the region, is basically agricultural area, under intensive crop production. It is very flat area, with the slop somewhere less than 0.005 %. Quantity of precipitation is decreasing from the west to the east and from the upper part towards lower part, so average annual precipitation in this lower part is about 680 mm. Due to the small slopes, runoff coefficients are between 0.17 and 0.25. This lowland has very developed land drainage system that consists of surface drainage and subsurface drainage. There is 4356 km of open canals with more than 3760 different hydrotechnical structures. Subsurface drainage is installed on about 30 000 ha of agricultural land. These data shows that lower part of the catchment area is highly influenced by human activities. Natural hydrological regime has been changing for last hundred years. Due to the geographical characteristics and the complexity of the drainage system water management is also complex.

Additionally, last 20 km of Vučica river is influenced by Drava river backwater. In that case the big part of the drainage system is out of function due to the Vučica river backwater (3).

For the hydrological analysis of flood risk, the precipitation of short duration is significant. In this area daily maximum usually occurs in the summer period, from June-September. In the Table 1 there are rainfalls recorded on September 6, 2001 on the 3 rain gauges. Their values are the maximum-recorded rainfall since the beginning of the precipitation measurements in 1961. Besides, there are total flood damages.

Table 1. Recorded precipitation which produced flood

Rain gauge station	Daily precipitation (mm)	Damages (US $)
Čačinci	180	1.2 million
Orahovica	>200*	
Voćin	177	

*Rain gauge bucket was overflowed

Total damages caused by the floods (Table 1) were about 1.0 million US dollars. This big amount of money includes damages on 500 residential and industrial objects, infrastructure of Orahovica city, hydrotechnical structures along the Vučica river and its tributaries, stabilisation of the main road and damages on about 1000 ha of arable land.

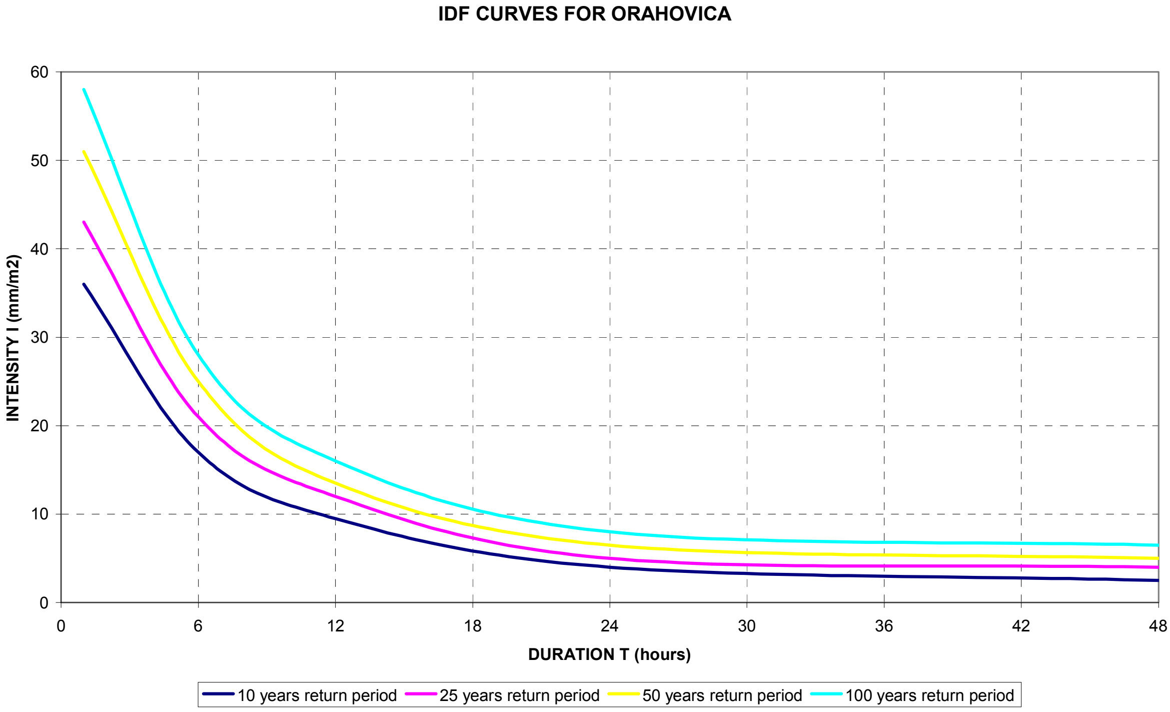
3. Hydrological Analysis

Basic approach to hydrological analysis comes from the main target of the flood protection.

Besides, level of flood protection depends on the direct and indirect damages. There is different level of protection for different type of area – urban, suburban and non-urban (agricultural land and forests). Each area is protected to different return period. Agricultural land and forests can suffer from flood water for several hours without significant damage, while urban area can be heavily destroyed even for few minutes of flood event. Due to the urbanisation, watercourses and streams have tendency to be narrow, what causes much serious hydraulic problems and probability of flood event increases.

According to previously mentioned situation, in Orahovica municipality, basic task of hydraulic analysis was definition of return period of flood event, its recognition on the area and proposal of acceptable solution (depending on costs).

The basic problem was lack of accurate data necessary for calculation. The only available data were daily precipitation (Table 1). The most damaged area was Orahovica city and the first step was rainfall analysis. From the available data IDF curve was defined as a basis of further mathematical modelling (Figure 1).



It is obvious that recorded rainfall of 200 mm/day is in range of 100-years return period and Vučica River cannot accept runoff produced by such a big rainfall. For the comparison, is the table with daily rainfalls recorded on the neighbouring rain gauges (Table 2).

Table 2. Daily values of rainfall for neighbouring rain gauges

Rain gauge station	Period of observation	Max. daily rainfall (mm)
Koška	1980-1994	40.8
Šipovac	1980-1994	43.2
Budimci	1980-1994	34.2
Osijek	1950-1984	101.2
Orahovica	1980-1994	122.6

It was previously explained difference between the protection of urban and non-urban area. Therefore, the problem was divided on the protection of area upstream of Orahovica city (by dam construction) and the lower part, Orahovica city itself. In this stage only the first part of the hydrological and hydraulic analysis were made – for the upper part of the city. Mathematical modelling was made by HEC-1 model. For the mathematical modelling it was used single event (recorded data) versus continuos simulation approach. Basic results obtained by modelling are in the Table 3.

Table 3. Results of mathematical modelling

Return period	Peak flow (m^3/s)	Time to peak (hours)	Average flow from the max. period (m^3/s)		
			6-hours	24-hours	72-hours
10	9.2	9.7	8.7	4.6	2.0
25	12.5	9.0	11.4	5.6	2.4
50	20.7	7.8	17.5	7.8	3.3
100	31.0	7.0	24.6	10.4	4.4

These data were used for the calculation of reservoir volume.

Much more efforts were made for the protection of Orahovica city (population of 8000 inhabitants) was the damages were the worst. Basic concept of Orahovica drainage and sewage system was in division of stormwater and sewage water in the main part of the city (separate system). Only in the centre of the city is mixed system. For the hydrological analysis of this urban area much more complex concept was used. Main approach was defined by PCSWMM mathematical model. Input data for this model consists of 15 – minutes storm sequences. For this purpose rain gauge with data logger was installed, followed by Doppler flow measurer with same time step in sewage canal. Measurements lasted for three months and on their basis calibration for sewage system was done. The same mathematical model was used for open channel calculations.

On the basis of obtained result, recommendation of new overflow in urban sewage/drainage system was made. This overflow should be dimensioned on approximately 7 times bigger flow than in dry period. Its location was defined on the basis of sensitivity analysis of complete system. After the construction of overflow, several storm events of 2-10 years return period occurred and it showed very good results – there was no flooding of the centre of Orahovica city.

Figure 2 and Figure 3 illustrate explained procedure.

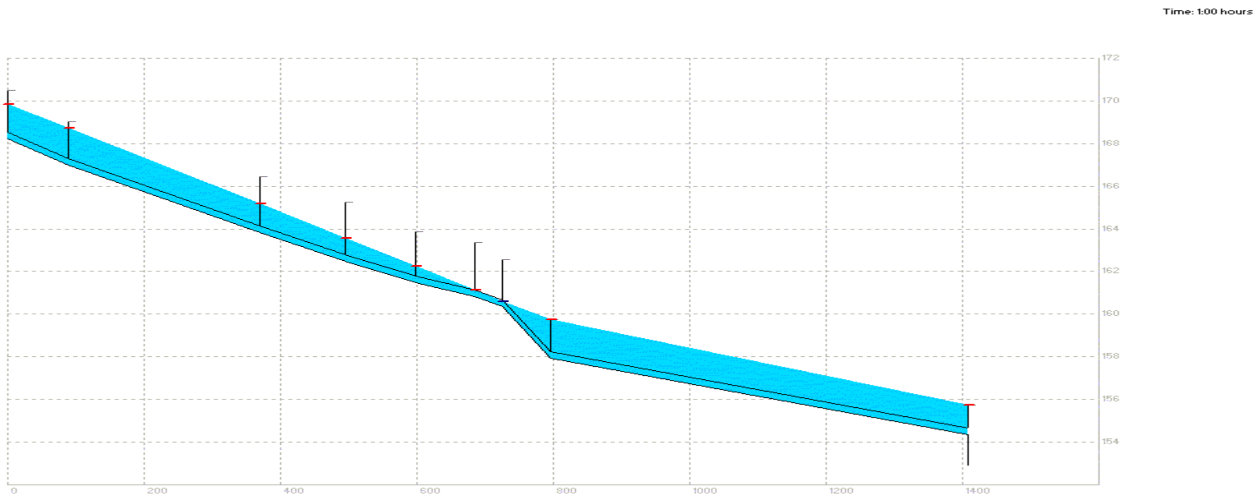


Figure 2. Storm event without overflow

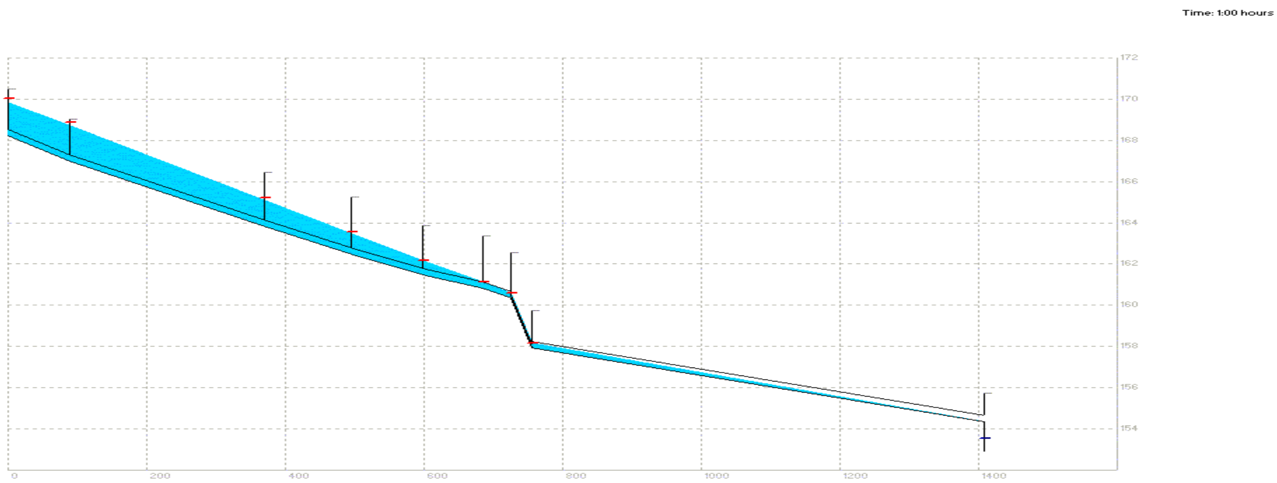


Figure 3. Storm event with overflow

4. Possibilities of Protection

Theoretically, two basic approaches for the flood protection are possible: multipurpose dam construction in the upstream of the watercourse and construction of dikes where the river passes through the city. Both of these possibilities have some advantages and disadvantages. At the catchment area of Karašica and Vučica rivers the first concept of flood protection, construction of dams, has been accepted. The main reason is possibility of using water accumulated in the reservoirs for the irrigation and better possibility of water management in general. The concept of long term development project of the catchment area considers the construction of 18 small dams (Figure 4). Until today, only one has been constructed, Lapovac II. It is located in the vicinity of the biggest town of the area, Našice, and its main purpose is the flood protection of the city. Now, it is used for the sport and recreation, too. The same reasons moved the construction of the second dam in the vicinity of town Slatina because of the same reason – flood protection of the town and its citizens.

Hydrological analysis of the floods recently recorded at the Karašica and Vučica Rivers imply the priorities of dam construction. Analysis shows that most critical points are at the upper part of the Vučica River, Krajina stream, and Voćinka River. All these streams and small rivers pass through the urban areas, small towns Orahovica, Čačinci and Voćin. Therefore, Figure 4 shows the locations of dams which construction has a priority. Besides the flood protection their purpose could be recreational because of their locations, very close to the towns. Also, water accumulated in these reservoirs can be used for irrigation and enrichment of small waters during the summer period in other to preserve present ecosystem in these watercourses.

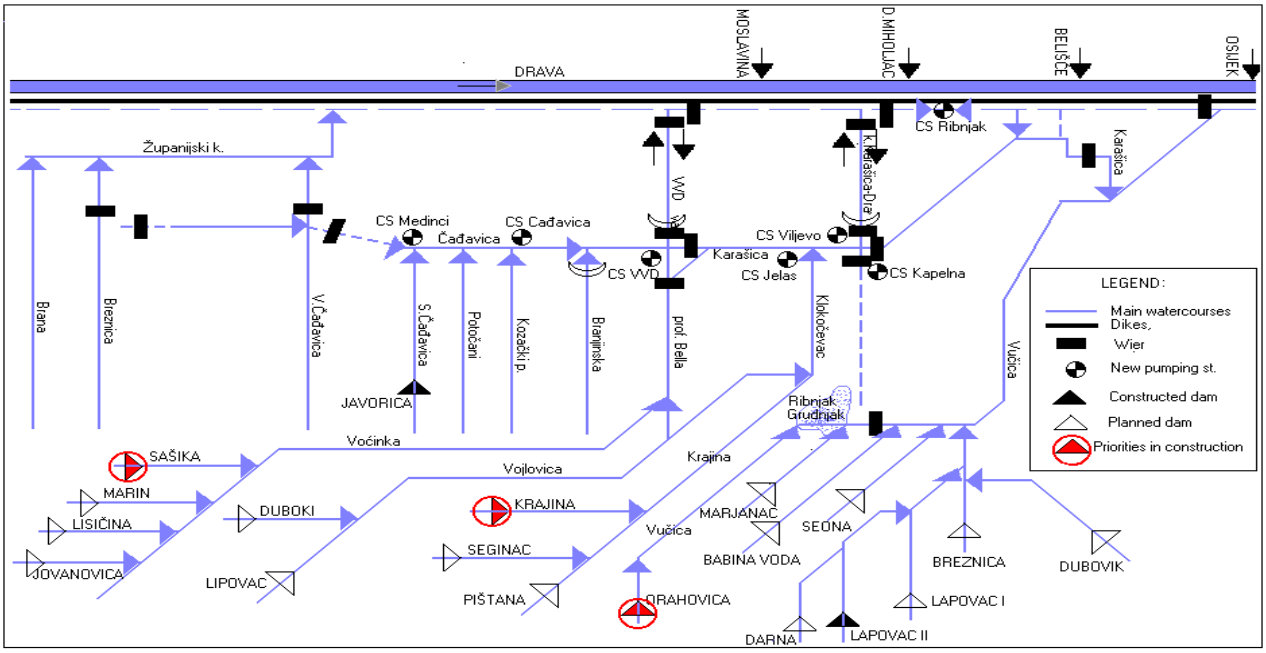


Figure 4. Scheme of main watercourses with dam construction priorities

5. Conclusion

Frequency of the flood episodes has been increased in last few years. Damages in urban and non-urban area are big. Also, there are damages on the environmental equilibrium that usually cannot be quantified. It is important to point out that flood protection is a matter of national concern. Successful flood prevention needs a comprehensive approach. It includes data collection, hydrological analysis, water management development, development of information system, better co-operation among water management agencies and other agencies responsible for economic and social development etc.

Analysis made for the Karašica and Vučica catchment area, specifically for the Orahovica city, showed the complexity of the problem of flood protection. In this case, two solutions were made. The first one for the urban area - overflow construction, and the second one for the non-urban area - dam construction. This solution gives a possibility of solving problem in phases, depending on the needed level of flood protection and available finances.

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