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TWO FLOOD RISK ASSESSMENT METHODOLOGIES FOR THE TERRITORY OF NOVI SAD

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Abstract: *Preliminary flood risk assessment for the settlement of Novi Sad and disaster risk assessment for floods were created by applaying the regulations of the Republic of Serbia. Analysing the past floods, the probability of future floods, the terrain and the hydrological characteristics, the preliminary risk assessment determined that more than 80% of the territory of the Novi Sad is exposed to floods. By disaster risk assessment is founded that the risk of a flood with a return period of 1000 years is moderate (aceptable). A review of the methodologies for both risk assessments revealed that there is a lack of methodology for assessing the harmful effects of floods in dinars/euros, so that the assessments would be realistic.*

Key words: *flood, risk assessment, prevention*

1. INTRODUCTION

Floods represents rising and overflowing of a body of water, especially onto normally dry land, which can threaten people's lives and health, material goods and environment (Directive, 2007/60/EC). Human activities, such as the growth of settlements in the flood area, and climate change contribute to the probability of flooding and their consequences (Directive, 2007/60/EC). Novi Sad was flooded several times in the past, 1770, 1876, 1940 i 1965. This paper describes the floods in 1940 and 1965, during which the stage of the Danube was 706 and 778 cm. In this paper, the flood risk assessment for the Novi Sad was carried out using two different methods. Preliminary flood risk assessment was done according to regulations related to flood protection, and disaster risk assessment for floods was made according to legal regulatons for disaster risk reduction and emergency management. Preliminary flood risk assessment is document which is created to assess existing and potential risks, analyze past flood and factors that increase flood risk. The goal of creating a disaster risk assessment is to identify the risk of catastrophic events and their consequences for people's lives and health, material goods and the environment.

2. BASIC INFORMATION ABOUT NOVI SAD

Novi Sad is city in Republic of Serbia, in the central part of autonomous province Vojvodina (Local economic development office, 2010). Most of it extents on Pannonian plain, at altitude of 72 to 80 m, and lies on the Danube bank at 1255 km of its course (Local economic development office, 2010). It consists of three morphological units: alluvial terrace (altitude of 78 to 80 m), loess terrace (altitude of 82 to 83 m) and former inundation area (altitude of 75 to 77 m) (Milosev, 2005). Inside setlement area, space is intended for public areas, housing, business, agricultural, forest and other purposes (*General plan*, 1999).

3. PRELIMINARY FLOOD RISK ASSESSMENT FOR NOVI SAD

The preliminary flood risk assessment is a document that create Ministry of Agriculture, Forestry and Water Management for the territory of the Republic of Serbia, according to the Water Law („Official Gazette of the Republic of Serbia", no. 95/2019) and Rulebook on determining the methodology for the preparation of preliminary flood risk assessment („Official Gazette of the Republic of Serbia", no. 1/2012), which defines their content.

3.1. Description of past floods

In Novi Sad, on March 23, 1940, flood defense began at a stage of +586 cm, and on April 5, a new absolute maximum of +706 cm was reached (Milosev, 2005). During this flood, the city districts of Adamovicevo naselje (Telep) and Podbara (figure 2) were flooded, 714 houses were demolished and about 3000 residents ended up homeless (Milosev, 2005). The emergency defense lasted till April 21, and the regular defense lasted till the beginning of May (Milosev, 2005).

In 1965, flood defense in Novi Sad lasted 128 days, and the stage reached a level of +778 cm, which exceeded the previous maximum from 1940. (Milosev, 2005). Every meter of the embankment was in danger, especially Novi Sad and places on the alluvial terrace (Milosev, 2005). When the water level reached +650 cm and had intention to rise further, on May 26, the adult population was mobilized and the city headquarters for flood defense was formed (Milosev, 2005). A day later, there was a breakthrough of the embankment near Celarevo, but even before the breakthrough there was a danger that a breakthrough could happen, and that the former inundation area of the Danube and part of the alluvial terrace next to the canal would be threatened, so localization embankments were built (Milosev, 2005). Due to the hard work of all participants in flood defense in 1965, Novi Sad was saved from floods.

3.2. Probability of future floods

In this paper, the probability of future floods was determined by applying a series of maximum annual stages in period from 1916 to 2020. The probability was calculated using the logPearson III distribution, with HEC-SSP 2.0 software. Research has determined that the maximum stage and flow feature has a logPearson III distribution, and the US Water Resources Council (WRC) has declared this distribution as the basis for high water calculations (Kolakovic, 2017). The computed results are shown in table 1.

Table 1: Statistical analysis of the maximum annual stages of the Danube from 1916 to 2020

Probability (%)	Computetd Curve Stage (cm)	Expected Prob. Stage (cm)
0,01	993,50	1021,60
0,1	887,39	902,71
0,5	809,09	817,93
1,0	773,64	780,29

Probability (%)	Computetd Curve Stage (cm)	Expected Prob. Stage (cm)
2,0	736,70	741,47
5,0	684,57	687,36
10,0	641,36	643,01
20,0	592,69	593,48
50,0	509,65	509,65
80,0	438,27	437,69
90,0	405,05	404,01
95,0	379,52	377,98
99,0	335,91	333,06

From the table, we see that the 1% probability stage is 773.64 cm, and the 0.1% probability stage is 887.39 cm. We can conclude that the probability for stage of 706 cm (1940) is ~3.77%, and the return period is about 26.5 years. The return period of the stage of 778 cm (1965) is approximately 100 years, i.e. the probability is 1%.

3.3. Maps of floodplains

Using the Quantum GIS (QGIS) software tool, a map was created showing the location of the flood in 1940, i.e. the floodplains during it (Figure 1). During the flood of 1965, parts outside the settlement of Novi Sad were flooded, so it is not shown on the map.

Figure 1. The floodplain of Novi Sad in 1940

In order to determine the locations of possible future floods, we take into account the stage during previous floods, as well as the stages determined by statistical analysis, characteristics of the terrain and the flood protection system. Considered water levels for future floods are in Table 2.

Table 2. Considered stage for future floods

Scenario	Stage
Flood in 1940	706 cm (78,79 m n.J.m)
Flood in 1965	778 cm (79,51 m n.J.m)
T=100 years	773,64 cm (79,47 m n.J.m)
T=1000 years	887,39 cm (80,6 m n.J.m)

The embankments in Novi Sad are dimensioned for a flood with a return period of 100 years with additional 1.2 m. Based on that, we can conclude that its height is higher than the stage of the return period of 1000 years defined in this paper. Despite this, the function of the embankment may fail, and Novi Sad is threatened by floods, and their consequences must be considered.

Comparing the previously mentioned stages of the Danube (table 2) and the altitude of the terrain, we conclude that the floodplains include the inundation area and the alluvial terrace, because all the mentioned stages exceed the altitude of the inundation area and are in the range of 78.79 to 80.6 m, approximately as alluvial terrace. In all 4 scenarios, the stage exceeds 77 m, which means that in all scenarios the entire inundation area would be flooded.

Using QGIS, floodplains were marked on the map (Figure 2).

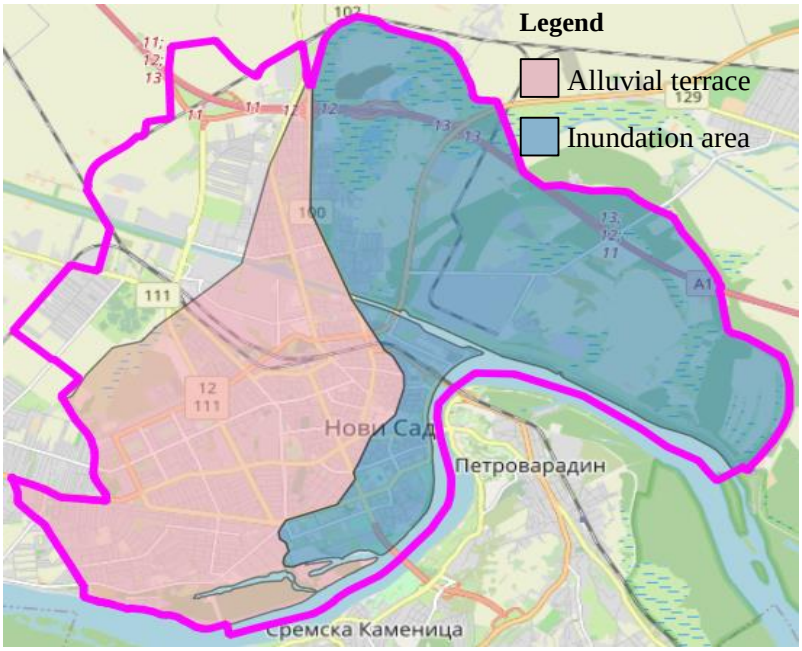

Figure 2. Floodplain in Novi Sad

3.4. Harmful effects of floods

By calculating the area of floodplain using QGIS, we conclude that about 83% of the urban area of Novi Sad is threatened by floods, that is, the area of the inundation area and the alluvial terrace.

The population of the Novi Sad settlement is 258,543 (Local economic development office, 2010), and since the non-threatened part of the settlement is mainly an industrial zone, we can consider that the entire population is at risk. Residential, commercial and public facilities are at risk, and basic infrastructure may also be damaged.

In the Rulebook on determining the methodology for the preparation of preliminary flood risk assessment („Official Gazette of the Republic of Serbia", no. 1/2012), the methodology for assessing the possible harmful effects of future floods is not specified, it is only stated that they are determined based on the topography of the terrain, type and ways of land use, hydrological characteristics of watercourses, efficiency of flood protection systems, location of populated areas and areas of economic activities, long-term development plans and the impact of climate change. It is very important to carry out a detailed assessment of the possible harmful effects of future floods in dinars/euros, so that they can assess the risk.

4. DISASTER RISK ASSESSMENT FOR FLOODS IN NOVI SAD

The disaster risk assessment is prepared in accordance with the Law on disaster risk reduction and emergency situation management ("Official Gazette of the Republic of Serbia", No. 87/2018), Instructions on the methodology of preparation and content of the Disaster risk assessment and the protection and co-operation plan ("Official Gazette of the Republic of Serbia", No. 80/2019). Data on Novi Sad necessary for the assessment are briefly listed in chapter 2.

4.1 Event scenario

For the purposes of risk assessment, a scenario was created for a flood in Novi Sad with the most undesirable harmful effects, according to the criteria from the regulations, which is briefly presented below.

The Danube reached a stage of +887.39 cm, i.e. a stage with a probability of 0.1%, as a result of which the dike's function failed and the water flooded about 80% of the area of the Novi Sad settlement. Residential, business and public buildings are at risk. Flood defense lasted from March 30 to May 15. According to the reports of the Republic Hydrometeorological Institute, intense rains and an increase in the stage of the Danube were expected.

During the flood, 5 people lost their lives, 60 were injured, and 5,000 people ended up homeless. The entire population of Novi Sad was at risk. Harmful consequences for the economy, ecology and social stability exceed 10% of the budget of the local self-government unit.

4.2 Determining the level of risk

Probability statement and assessment of consequences for human life and health, economy/ecology and social stability was carried out according to the methodology, whereby it was determined:

- the probability is less than 1% - negligible,
- consequences for people's lives and health - catastrophic,
- consequences for the economy/ecology - catastrophic,
- consequences for social stability - catastrophic.

The above data were entered into risk matrices, where it was found that the risk is moderate for all segments (life and health of people, economy/ecology and social stability). After determining the risk for individual protected values, the total risk was determined using the

matrix (Figure 3). The overall risk is moderate and acceptable, so risk treatment measures are not necessary, only regular maintenance of existing flood protection systems is required.

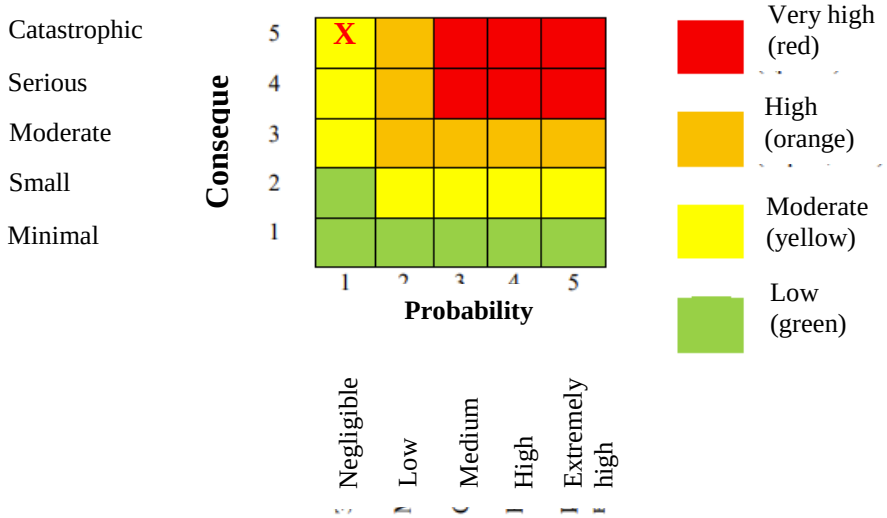

Figure 3. Total risk (Instructions, 80/2019)

4.3. Risk map

After determining the level of risk, the obtained results are shown on the map (Figure 5). A threatened area is marked, where the yellow color represents a moderate (acceptable) risk of flooding with a probability of 0.1%.

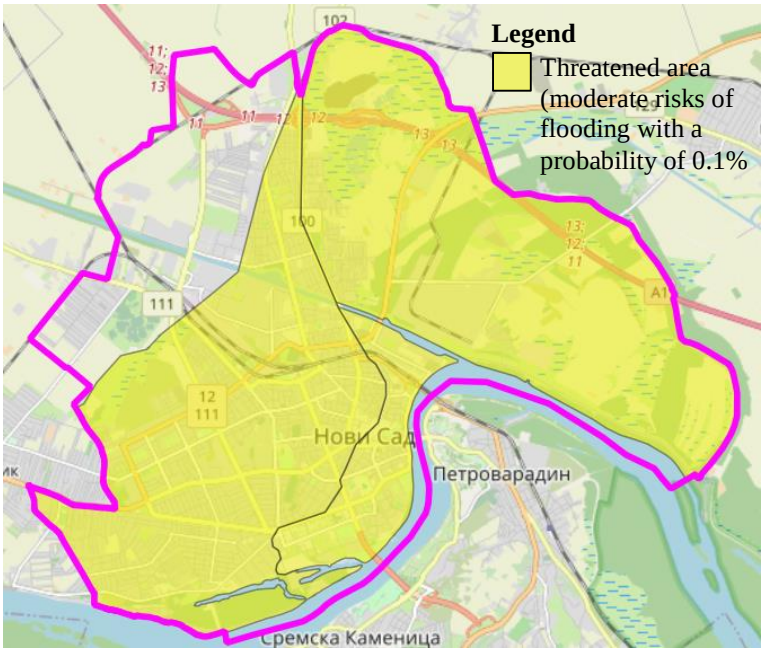

Figure 4. Risk map

5. ANALYSIS OF RESULTS OBTAINED BY RISK ASSESSMENTS

The preliminary risk assessment accurately determines the probability of future floods and maps of the floodplain, which is very important when creating a disaster risk assessment for flood. However, during the preparation of the preliminary assessment, the methodology for assessing the harmful effects of floods was not defined, which is necessary for further analysis. During the creation of scenarios for disaster risk assessment for floods, data related to the harmful effects of floods on human life and health, the economy/ecology and social stability expressed in dinars/euros are necessary, but neither the Instructions on the methodology of preparation and content of the Disaster risk assessment and the protection and co-operation plan ("Official Gazette of the Republic of Serbia", No. 80/2019) have not defined how to determine these effects, nor from which sources to take the values. It would be desirable to determine the harmful effects in the Preliminary Flood Risk Assessment, and to use the obtained results when preparing the disaster risk assessment for floods.

The detailed methodology for assessing the harmful effects of floods should be defined by the Rulebook on determining the methodology for the preparation of preliminary flood risk assessment („Official Gazette of the Republic of Serbia", no. 1/2012). In the following, the procedure for assessing the harmful effects of floods is briefly described, taken from the written material for the preparation of the textbook author Asst. Prof. Slobodan Kolakovic. It is necessary to determine what the harmful effects of floods include and collect the necessary data (Kolakovic, n.d.). Finally, it is necessary to calculate the flood damage by calculating the risk in €/year, according to equation (1) (Kolakovic, n.d.).

$$\bar{S} = \int_{Po}^{Pmax} S(P)dP \sim \sum_{i=1}^{m} \frac{S_i + S_{i+1}}{2} \cdot \Delta P_i \qquad (1)$$

where in:

- $\bar{S}$ – expected average damage in €/year,
- S(P) – individual damage of the planned flood probability of occurrence P,
- P_o и P_{max} – the probability of the smallest and largest flood that caused damage (Kolakovic, n.d.).

6. CONCLUSION

In this paper, the flood risk assessment for the settlement of Novi Sad was carried out using two different methodologies, i.e. using different regulations. A preliminary flood risk assessment was made, which determined the probability of future floods and the floodplain during them. The probability was determined using the HEC-SSP software tool, logPearson III distribution for a series of maximum stages from 1916 to 2020. The 1% probability stages was found to be 773.64 cm and the 0.1% probability 887.39 cm. Analysis of the above results, floods from the past, terrain characteristics and hydrological characteristics determined that about 80% of the Novi Sad settlement is threatened by floods in the event of failure of the embankment function. By disaster risk assessment, through the creation of scenarios and the analysis of the harmful effects of floods, it was determined that the risk of a flood with a return period of 1000 years is moderate (acceptable).

The same problem appears in both assessments, the methodology for assessing the harmful effects of floods is not defined. For flood risk assessments, we need data on damages expressed in money (dinar/euro), so it is necessary to define the procedure for determining them. In the assessments, the determination of the amount of damage is attributed to the expert team that prepares them, without defined requirements on the method of their determination.

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