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Potentially dangerous 24-hour rainfall in the Provadiyska vally system at the end of the 20th and early 21st Centuries

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Abstract*: Extreme rainfalls are of paramount importance for the formation of river springs and, consequently, the occurrence of spills and floods. The article presents the results of a case study of the potentially dangerous 24-hour eruptions in the Provadiyska valley system from the end of the 20th and the beginning of the 21st century. Particular attention is paid to the morphometric parameters and the configuration of the river-valley supply network of the Provadiyska river. On this basis, there are defined areas in which there are favorable conditions for forming high river waves.*

Keywords*: risk, factors, precipitation, catchment, Provadiyska River, floods, prevention*

Introduction

Flooding is one of the biggest natural threats to our country.

Factors affecting flood occurring in drainage basins divide into two categories: natural and socio-economic. Natural factors include: climate, relief shapes, river valleys nature and configuration, slope of sides, rocks emerging on the surface, soil cover, and afforestation. Socio-economic factors include: location of towns and villages, arable land, roads and other infrastructures.

Climatic factors and extreme precipitation in the first place are of paramount importance for the occurrence of river swelling, hence for the events of overflow and flood. Extreme precipitation entails a risk of high waves formation in river drainage basins, regions of narrow river valleys, dry valleys, and sharp changes in side surfaces.

According to Zyapkov, hydrological processes in Bulgaria feature formation of huge amounts of water whose water content is classified as consisting of more rainfalls in comparison to analogous drainage areas in the temperate latitudes of Europe [9].

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Against the background of decreasing annual precipitation sums and discernible tendency to drought in Southern, Eastern and Central Europe [1, 7] in Mediterranean countries, as well as on the Balkan Peninsula, increase in extreme precipitation frequency and intensity has been observed [2] .

Since the beginning of the 21st century, in Bulgaria, as well as in many other countries of Central and Eastern Europe, great number of days with extreme precipitation have been registered, which led to huge economic losses and casualties, especially in 2005, 2007 and 2010. These events arouse great interest in similar events analysis and forecasting methods improvement.

Knowledge of natural and geographic specifics of separate catchment areas, characteristic features of extreme precipitation, as well as recurrence and securing of these events, allows conclusions and recommendations to be made in regard to preventive measures for population protection, technical equipment, production infrastructure and stock of buildings.

The report presents the results from a research into extreme precipitation in Provadiya river drainage basin for a 15-year period (1994-2008).

Materials and methods

Provadiya river drainage basin has surface area of 2132 km^2 and length of the main stem – 119 km. Territory has well marked plain and plateau relief. According to its shape, the catchment area falls into the (dendriform) type of basins, most branched in their upper and middle part.

Provadiya river valley branches in west-east direction in the southern part of Danubian Plain eastern periphery. The borders of its drainage area are marked as follows: ***westward*** – from Shumen Plateau (length from east to west – from 7-8 km southward to 20 km northward; width from north to south 15-17 km; surface area – 73,13 km^2, maximum altitude at Tarnov Tabiya peak – 501,9 m), Hitrino Heights (length – 7-11 km, width – 9 km, surface area – 81 km^2) and Samuil Heights (length – 36 km, width from north to south – 10 km, approximate surface area – 244 km^2, maximum altitude at Kapitan Petkov Sart peak – 501 m); ***northward*** – from the ridge of Samuil Heights and Voyvodsko Plato (plateau) located southeast (length – 11-12 km, width – 5-7 km, surface area – 57 km^2, maximum altitude at Kodzhayuk peak – 475,8 m), Stana Plateau (surface area – 183 km^2), Ludogorsko Plato (plateau) (approximate length – 45 km), Dobrudzhansko Plato (plateau) (length – 60 km, width – from 40 to 60 km, surface area – 2750 km^2) and Frangensko Plato (plateau) (surface area – 360 km^2); ***southward*** – from the rolling hills to the east of Shumen Plateau, Provadiysko Plato (plateau) (length – 70 km, width from 2-3 to 15 km and surface area – 371 km^2), where a few relatively independent units set apart, namely: Madarski (length – 12 km, width from north to south – 2-3 km, surface area – 28 km^2, maximum altitude at Mogilata peak – 374,1 m), Krivnenski (length – 65-70 km, width from 2-3 to 10 km, surface area – 285 km^2, average altitude – 250 m, maximum altitude at Sakar Tepe peak– 476 m) and Dobrinski (surface area – 58 km^2, Bardoto peak – 360 m) and Royakski (length – 38 km, width – from 250 m to 7-8 km, surface area – 163 km^2) and to the most eastern part of Momino Plato (plateau) (length – 28 km, width 18 km, surface area – 410 km^2, average altitude – approximately 200 m, height of watershed – 250 m); **eastward** – through Lake Beloslav (surface area – 3,7 km^2, length – 4 km, average width – 1 km) and Lake Varna (surface area is 18 km^2, length – 14,5 km, average width – 1,3 km, maximum depth – 18 m), Provadiya river waters reach the Black Sea.

Under the name Kamenitsa (length – 44,5 km, catchment surface area 532,2 km^2), Provadiya river takes its source from Samuil Heights, approximately 1 km to the west of the village of Trem (Shumen Region). Total displacement of Provadiya river from spring to flowing into Lake Beloslav is 489,4 m. Its biggest tributaries are: Matnishka Reka (river) (known in its downstream as Madara river – length – 37,5 km, catchment surface area – 147,7 km^2), Kriva Reka (river) (length 47,7 km, catchment surface area – 217,6 km^2), Zlatina river (length – 23,3 km, catchment surface area – 149,3 km^2), Yaztepenska Reka (river) (length 18,2 km, catchment surface area – 128 km^2), Glavnitsa river (length – 40,8 km, catchment surface area – 374,5 km ^{2}), Manastirska Reka (river) (length – 17,5 km) and Mogilska Reka (river).

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National Institute of Meteorology and Hydrology meteorological network stations included in the catchment area are Vetrino, Novi Pazar and Provadiya (Fig. 1).

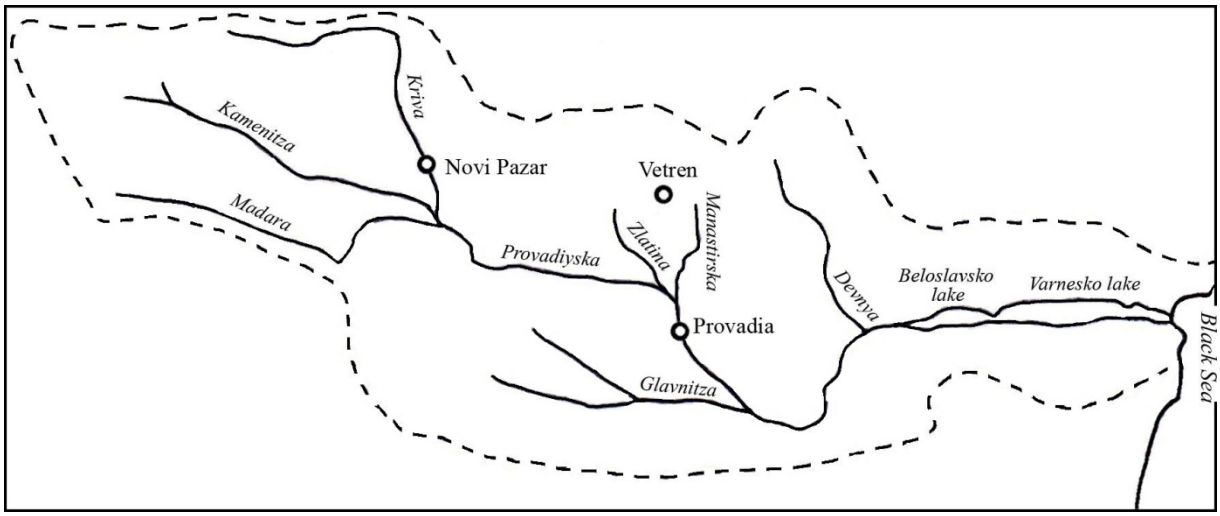

Figure 1. Schematic map of the catchment area of the river Provadiyska.

Output information represents daily data for precipitation amounts for the 15-year period.

Methods used by Bocheva et all. are applied for the research into extreme precipitation [4]. 5 daily precipitation categories have been suggested as follows: Light (A) 0.0-4.9 mm; Light-Moderate (B) 5.0-14.9 mm; Moderate-Heavy (C1) 15.0-29.9 mm; Heavy (C2) 30.0-59.9 mm and Torrential (D) 60.0 mm and above.

Spatial-temporary distributions of days with potentially dangerous and pouring precipitation of C2 and D categories for 15-year period (1994-2008) were presented in this research. Precipitation events of both categories are considered extreme because for the plain part of Bulgaria such 24-hour precipitation amounts represent at least ½ of the monthly norm of precipitation. Research of extreme precipitation events (changes in frequency and their internal annual distribution are of paramount importance, taking into account the established tendency to decline in annual precipitation for the bigger part of country territory [1]. The increase in the number of precipitation of C2 and D categories, even in separate stations, would result in increase of risk of local floods occurrence. According to Bocheva [3], who researches the whole territory of Bulgaria, statistically significant increase in the contribution of precipitation events of both extreme categories C2 and D to annual precipitation amount is observed only in the northeastern part.

Results and Discussion

For the period 1994-2008, in Provadiya river catchment area, the average number of registered events of maximum 24-hour precipitation $\geq$ 30 mm is 29 (Vetrino – 29, Novi Pazar – 33, Provadiya – 27). The frequency of occurrence is the highest at the station of Novi Pazar – 2,2 times a year, followed by the station of Vetrino – 1.9, and at the station of Provadiya such type of precipitation is reported 1,8 times a year.

Differences in the number of events with 24-hour precipitation of categories C2 and D in separate years of the period are presented in Fig. 2.

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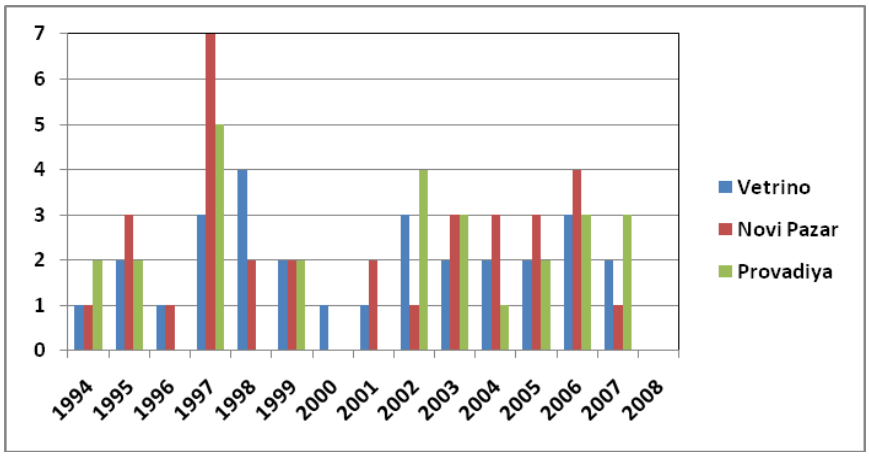

Figure 2. Total number of events with 24-hour precipitation ≥ 30 mm (categories C2 and D)

In 10 of the researched period years, extreme precipitation events were registered in the three stations, while in 2008, there was not even one event of such precipitation.

In the first half of the period (until 2001), well marked contrasts in the course of extreme precipitation were observed in the catchment area by years, while since the beginning of 21st century the course is more uniform. Increase in the total number of days with extreme precipitation for the drainage basin as a whole is observed.

In 1997, in the whole catchment area, maximum number of events was reported as follows: 7 – at the station of Novi Pazar, 5 – at the station of Provadiya, and 3 – at the station of Vetrino. In 10 of the period years, at the station of Vetrino, more than one event of extreme 24-hour precipitation per year were registered. In the other two stations, minimum of two events were recorded in 9 of the years.

Extreme precipitation events are unequally distributed, not only in regard to territory but also in separate months of the year. The annual course of precipitation is closely related to the specifics of atmospheric circulation over Bulgaria.

Based on data of Koleva and Peneva, in the temperate continental climate zone, maximums of 24-hour sums of precipitation within the year are reported in May and June (20-30% of all events), where this recurrence does not depend on altitude [6]. In July and August, recurrence remains relatively high (10-15%), decreasing in autumn months, and in winter months it was barely about 0-5%.

Provadiya river catchment area data indicate shift of this maximum in internal annual distribution of extreme precipitation in the second half of summer and early autumn (July – total of 20 events for the whole catchment area; August–12 events, and September−14 events).

The higher frequency of 24-hour torrential precipitation events in August and September coincides with frequent droughts, which are typical characteristic of Northeastern Bulgaria climate. In the months specified, draughts last an average of 16−19 days, and those over 20 days − 21-24 day-and-nights [8]. These conditions combination is a precondition for the occurrence of swellings with strong negative effect.

Extreme precipitation events are also observed in winter months, but precipitation is primarily in the form of snow and has no risk nature to cause floods or high waves in river beds. Negative effect is however reported at intensive snowmelt.

Consideration of the total number of events with extreme precipitation by seasons indicates increase in their number in autumn since the beginning of 21st century and to a certain extent in winter. On the contrary, their frequency decreases in spring.

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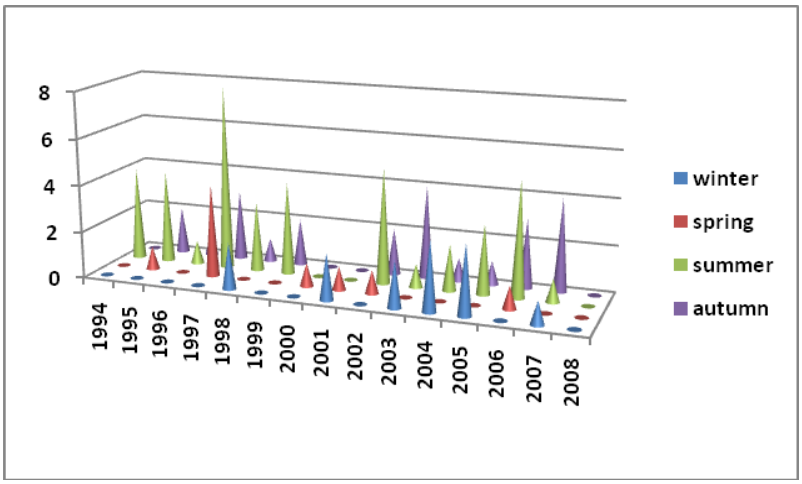

Figure 3. Total number of events with 24-hour precipitation ≥ 30 mm (categories C2 and D) by seasons

Based on data of Bocheva, similar results were obtained also for the southern parts of Europe and for the Balkan Peninsula countries, where the events of dangerous precipitation became more frequent in relatively dry months of the second half of the warm period of six months, from July until October [3].

Extreme precipitation events of category D (over 60 mm/24h) are too rare and local phenomena, besides, the number of stations used in the research is not enough for the registration of all similar events. Precipitation events have very high values at well-developed cyclones or at occlusion as cold front of filling cyclones, when the effect of the cold front is enhanced by intense thermal convection. Sometimes they can be caused by powerful convective clouds. Localization of extreme precipitation in researched territory is also due, to a certain extent, to influence of orography – presence of many plateaus and heights.

At the station of Provadiya, there was no registered precipitation with such value for the researched 15-year period. At the station of Vetrino, one case was registered (4 September 1999 − 75 mm). At the station of Novi Pazar, the cases were three, as in July 2005 in two days in a row record precipitation amounts were registered (3 July – 192.2 mm; 4 July − 99.1 mm), as a result – a few towns and villages were flooded from Provadiya river swollen waters. Great part of the railway lines in that region were flooded and partially destroyed. On the 29th of August 2006, smaller sum was registered – 86.4 mm.

Besides the record precipitation amounts for the researched period, relief is important factor. Between the village of Zlatina and the railway station of Vasil Kolarov, Provadiya river forms deep funnel-shaped gorge with length of 10-12 km. The gorge is wide open to the north and strongly narrowed to the south, towards the station of Provadiya. Zlatina and Manastirska tributaries catchment area waters flow in the beginning of main stem gorge. This combination of factors predetermines possible sharp rise in river level and causing floods at extreme precipitation.

Conclusions

Rise in the number of extreme precipitation ≥ 30 mm (categories C2 and D) has been observed in Provadiya river drainage basin since the beginning of 21st century, for the period 1994-2008.

Internal annual distribution of extreme precipitation events has its maximum in the period July – September. Great precipitation sums, concentrated in short period of time contrast with the extended draughts typical for this season in Northeastern Bulgaria. They are a precondition for the occurrence of river swelling with strong negative effect.

In the course of extreme precipitation by seasons, there was a rise in their number in autumn in the second half of the researched period.

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For determination of places with possible danger following extreme precipitation, a study needs to be carried out in regard to river valleys configuration, type of valley profiles, slopes and afforestation of sides, as well as the places where tributary valleys join main stem valley. Provadiya river gorge section, to the north of the station of Provadiya, appears to be the riskiest region in the river catchment area.

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