STATISTICAL ANALYSIS OF MEAN ANNUAL DISCHARGES OF THE RASINA RIVER

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Abstract: The basin of the Rasina River is situated in the southern part of middle Serbia on the surface of 979.6 km². This study analyzes the trend of mean annual discharges of the Rasina from 1961 to 2016. To determine the trend of discharge alteration we used Mann-Kendall test, whereas to determine the trend of the break point, that is, the year in which statistically significant discharge alteration happened, we used Pettitt test. This study classifies the years by water richness, so as to perform more detailed analysis of the occurrence of dry and wet periods in the basin. The obtained results imply that mean annual discharges in Brus and Bivolje have a declining trend. The break point, that is, the year when significant decrease in mean discharge occurs, is 1981 on Brus station, that is, 1982 on Bivolje station. The most years in both profiles are moderately rich in water. Both profiles have more years dry than rich in water.

Key words: The Rasina River, Statistical analysis, Classification of years by water richness

1. Introduction

Water resources, as well as their quality and availability have been the subject of many contemporary analyses and studies. Due to uneven time and spatial water distribution which is partially conditioned by both global climate changes and irrational anthropogenic activities, about 80% of world's population is exposed to a high risk of water shortage or unsanitary water.

In the times when people realize the importance of rational usage of all the natural resources, when water resources are limited and exhausted, there is a need for constant monitoring and active management of water resources. Planned economy and management of water resources have to be based on solving the problem of water supplying of the population and industry, irrigation of arable areas, but great attention should be also paid to preserving of water quality, flood protection, as well as other water management problems.

All the above mentioned things impose the need for detailed hydrological research, among which are monitoring and alterations in longer hydrological time series. Results obtained in such analyses can be a basis for prevention or solving number of problems (flood defense, irrigation, water supply, water protection, etc.).

Mean annual discharge (Qm), as a basic indicator of the study of water regime of river courses, represents the basic indicator applied to identify water regime trends in long-term intervals (Langović et al., 2017). Statistical analysis of annual, seasonal and monthly discharge trends is the subject of many hydrological studies both worldwide and in our country (Jeneiova et al., 2014; Čanjevac et al. 2015; Zelenakova et al., 2012, Langović et al., 2017; Đokić, 2015; Kovačević-Majkić et al., 2014, etc).

This study analyzes mean annual and monthly discharges of the Rasina River, through analyzing the trend of alteration. The aim of the study is to determine the existence of the alteration trend of this important water regime indicator, as well as if this trend is positive or negative. Apart from defining the alteration that occurred in the series, the aim was to single out the exact year when the alteration happened.

We also analyzed oscillations in mean annual discharges and classified years by water richness, by which we determined how much mean annual values deviate from average multi-annual value, that is, what the frequency of the occurrence of more or less years rich in water is.

2. Research methodology

The Rasina river emerges on east and south-east slopes of the mountains of Goč, Željin and Crni vrh, where its constituents the Velika river (Vranjuša) and the Burmanska river emerge. These two courses meet at Rogavčina, where the Rasina emerges. It flows into the river of Zapadna Morava after the course of 92.3 km as its last significant right tributary, 5 km downstream from the town of Kruševac (Gavrilović et al., 2014). The Rasina basin comprises the surface of 979.6 km^2, it borders with the basin of the river of Ibar in the west, with the Toplica basin in the south, whereas the basin of Južna Morava is situated in the east. In the basin of the Rasina hydrological observations have been done on three stations: Bivolje, since 1922, Brus, since

1953 and Ravni, since 1966. This study analyzes alteration trends of mean monthly and annual discharges on the two stations in the Rasina basin – Brus and Bivolje in the period from 1961 to 2016. The data we used were taken from Hydrological Yearbooks of RHMS (Republic Hydro-Meteorological Service) of Serbia. Calculation was carried out via statistical software for Microsoft Excel – XLSTAT 2014.

The trend of discharge alteration can be checked by various statistical methods. In this study we used Mann-Kendall and Pettitt test, non-parametric tests which do not require any prerequisites related to distribution of time series out of which the data were taken.

Mann-Kendall test was used to determine the existence of the alteration trend in the values of mean discharge, as well as to determine if the trend is positive or negative. It is a non-parametric test which identifies the trend of series on the basis of comparison of relative magnitudes of data alterations (Kendall, 1975). If test results show trend value less than 0, then there is a declining trend; if trend value is higher than 0, there is an increasing trend.

Data analysis by Pettitt test (Pettitt, 1979) was done to determine the existence of trend in data on mean annual discharge, as well as the existence of the moment (year) tc when the obvious mean annual discharge alteration occurs. If the test defines the moment tc, then average discharges in the period before the moment tc significantly differ statistically-wise from average discharges in the period after the moment tc (Radivojević et al., 2015; Stričević, 2015).

Apart from the above mentioned analyses, we classified the years by water richness, which points to the trend in multi-annual water richness regime of a course. Classification of years by water richness for the period from 1961 to 2016 was done on the basis of Log – Person III distribution which proved adequate in hydrological research, as well as classification of years by water richness according to Ocokoljić (1994).

3. Research results

To determine the existance of the trend of mean annual discharge, we used non-parametric Mann-Kendall test. The results of this test imply that there is declining trend in mean annual discharges in both analyzed stations in the Rasina basin. On Brus profile we recorded declining trend of discharge with an average yearly decline of 0.007 m^3/s, whereas in Bivolje we recorded an average yearly decline of 0.028 m^3/s. In the alterations of mean annual discharges on both stations there was a significance values of which are $\alpha > 0.1$, which implies that there is no statistically significant decline of average discharges during time series of 56 years.

Table 1 – Basic statistical data of analyzed stations in the Rasina river basin

Station	**N**	**Minimum**	**Maximum**	**Mean**	**Standard deviation**
Brus	56	1.20	4.60	2.41	0.7214
Bivolje	56	2.60	13.30	7.37	2.7475

Pettitt test was used to determine whether there is a point, that is, a year, in the analyzed period when a significant alteration in the value of mean discharges occurred. The analysis comprised mean annual and monthly values on the Brus and Bivolje stations.

Table 2 – Results of Pettitt test of the values of mean monthly discharges for the period from 1961 to 2016

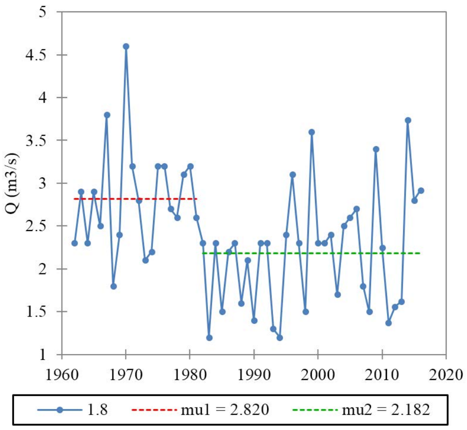
Station	t_c	average value before t_c (m^3/s)	average value after t_c (m^3/s)	p – significance of the test	Difference	
					m^3/s	%
Brus	1981	2.820	2.182	0.0084	0.638	22.62
Bivolje	1982	8.605	6.606	0.0473	1.999	23.23

The results of Pettitt test show that mean annual discharges of the Rasina in Brus and Bivolje have a declining trend.

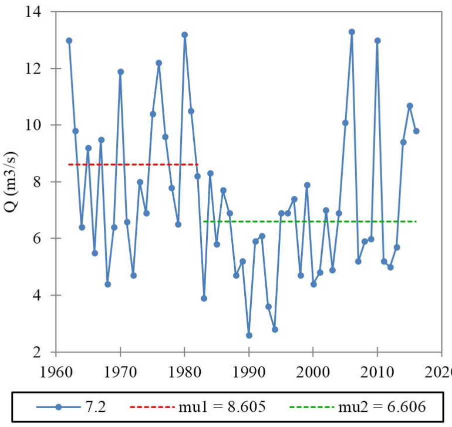
Break point in which there is a decline of discharge in Brus is 1981. Up to that year, average Rasina discharge in the upper part of the basin amounted to 2.82 m^3/s, whereas average discharge dropped to 2.18 m^3/s after 1981. On the most downstream station in the basin, in Bivolje, the year of 1982 was the break point. Average discharge before 1982 amounted to 8.61 m^3/s, whereas it amounted to 6.61 m^3/s in the period after the year of alteration.

When we talk about mean monthly discharges, declining trend occurs in July, August and September in Brus station, while declining trend was recorded in January, February and July in Bivolje station. Since 1982 there has been a significant decrease in mean annual discharges in summer period in the upper part of the Rasina basin, as well as in January in the most downstream part of the basin. In the above mentioned months, mean monthly discharges decreased for almost a third, when compared to the period from 1961 to 1982.

Break points were determined for all the other months, when there was a change in mean monthly discharges, but the obtained values of α significance level are higher than 0.05, which implies that discharge alterations are not statistically significant.



Picture 1 – Mean monthly discharge in Brus from1961 to 2016



Picture 2 – Mean monthly discharge in Bivolje from 1961 to 2016 according to Pettitt test

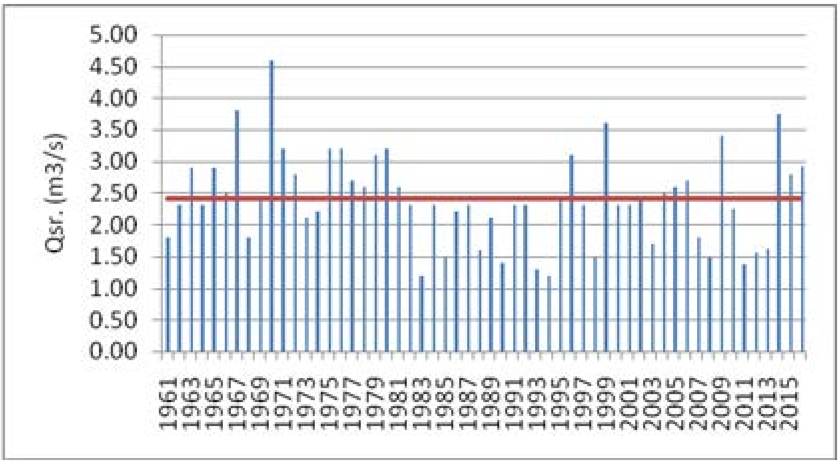
Table 3 – Results of Pettitt test of the values of mean monthly discharges, p values less than threshold α =0.05 for the period from 1961 to 2016.

Hydrological station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Brus - t_c	-	-	-	-	-	-	1979-	1982-	1982-	-	-	-
p value	-	-	-	-	-	-	0.0234	0.0073	0.0136	-	-	-
Qm before t_c **(m^3/s)**	-	-	-	-	-	-	2.31	1.14	1.36	-	-	-
Qsr after t_c **(m^3/s)**	-	-	-	-	-	-	1.58	0.79	0,94	-	-	-
Bivolje - t_c	1982-	1986-	-	-	-	-	1983-	-	-	-	-	-
p value	0.0100	0.0146	-	-	-	-	0.0320	-	-	-	-	-
Qm before t_c **(m^3/s)**	9.31	13.43	-	-	-	-	4.83	-	-	-	-	-
Qm after t_c **(m^3/s)**	5.97	8.94	-	-	-	-	3.74	-	-	-	-	-

The obtained results impose the question of what determines declining trend of mean annual discharges in the Rasina basin. The quantity and water flow of water in a river are conditioned by numerous factors, among which the most important are the amount of precipitation and air temperature. In the analyzed period a trend of air temperature rise was recorded in the Rasina basin, as well as a decrease in precipitation quantity which excretes in the basin. In the upper part of the basin, in stations Milentija, Brus and Kriva River, there has been a significant decrease in mean annual precipitation since 1980 and 1981 (Stričević, 2015; 2016). On the stations in the bottom part of the basin the decrease in precipitation is more prominent in the second half of the 1990s, but “Ćelije“ accumulation in this part of the basin affects the discharge greatly.

When analyzing mean annual discharges we noticed that in some years the rivers are rich in water, and then there are years when waterbeds of some courses ran dry during summer period. To gain insight into how much discharges deviate from certain average, expected values, how often high or low waters occur in the examined period, we classified the years by water richness in the period from 1961 to 2016 in the most upstream and downstream station on the Rasina River.

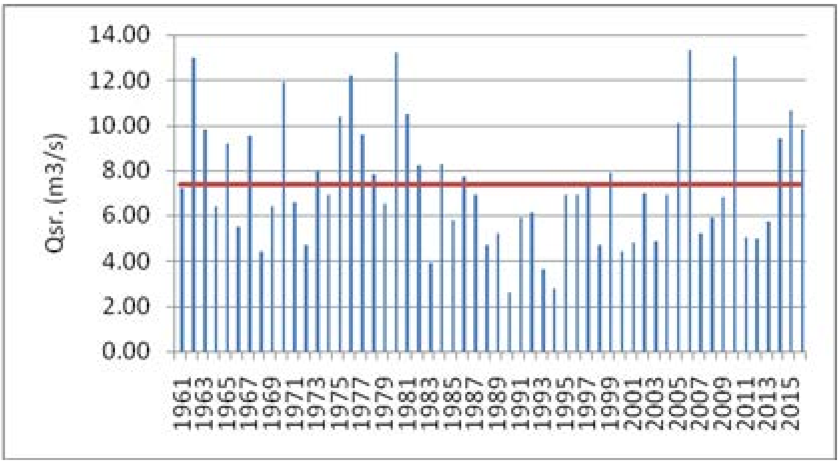
Pictures 3 and 4 show mean annual discharges of the Rasina in Brus and Bivolje, as well as their mean value, as the border which separates the years below and above average rich in water.



Picture 3 – Mean annual values and mean value of the Rasina discharge in Brus (1961-2016)

In the analyzed period, maximum mean annual discharge in Brus was recorded in 1970 and it amounted to 4.60 m^3/s, whereas minimal annual discharge was recorded in 1983 and 1994 and it was 1.20 m^3/s, which is a ratio of 1:3.83. Out of 56 analyzed years, during 23 discharge was above, while it was below average values during 33 years.

Pettitt test determined that the year of 1981 was a break point in the series, when the decline occurred in Brus. Starting from 1982, out of 35 analyzed years, the discharges were below average 25 times, while in the period from 1961 to 1981 discharges below average were recorded only seven times.



Picture 4 – Mean annual values and mean value of the Rasina discharge in Bivolje (1961-2016)

Maximum mean annual discharge in Bivolje was recorded in 2006 and it amounted to 13.30 m^3/s, while minimum mean annual discharge was recorded in 1990, amounting to 2.60 m^3/s, which is a ratio of 1:5.12. Out of 56 analyzed years, during 23 the discharge was above, while during 33 it was below average values.

Pettitt test determined that the year of 1982 was the break point in the series, when the decline in discharge of the Rasina in Bivolje occurred. Starting from 1984, out of 34 analyzed years, discharges were below the average 24 times, whereas in the period from 1961 to 1981 discharges below the average were recorded nine times.

On the basis of Log – Person III distribution, which proved to be adequate in hydrological research, and on the basis of classifying the years by water richness according to Ocokoljić (1994), we classified the years to extremely dry, very dry, dry, moderately rich in water, rich in water, very rich in water and extremely rich in water.

The highest number of years on the river of Rasina in Brus belongs to the group of moderately rich in water (27) and they occur almost every second year, most often two years in a row or more often. Extremely dry years were not recorded in this profile in the analyzed period, while 1970 was extremely rich in water, mean annual discharge amounting to 4.60 m³/s. Years which are dry and rich in water occur every fifth year on average.

The highest number of years on the river of Rasina in у Бивољу belongs to the group of moderately rich in water (23) and they occur almost every second year. Years extremely dry and extremely rich in water were not recorded in this profile in the analyzed period. Years which are dry and rich in water occur every fourth or fifth year on average.

Both profiles show very few years rich in water and extremely rich in water, which is in accordance with the general declining trend of discharge values for all the courses in Serbia (Langović et al., 2017). More dry then rich in water years were recorded on both profiles.

Table 4 – Classifying the years by water richness of the Rasina in the period 1961-2016

Station	Water richness of the year	Discharge (m³/s)	Years	Number of years
Brus	extremely dry	< 1.0	-	0
	very dry	1.0 – 1.34	1983,1993, 1994,	3
	dry	1.34 – 1.89	1961, 1968, 1985, 1988, 1990, 1998, 2003, 2007, 2008, 2011, 2012, 2013,	12
	moderately rich in water	1.89– 2.84	1962, 1964, 1966, 1969, 1972, 1973, 1974, 1977, 1978, 1981, 1982, 1984, 1986, 1987, 1989, 1991, 1992, 1995, 1997, 2000, 2001, 2002, 2004, 2005, 2006, 2010, 2015	27
	rich in water	2.84 – 3.66	1963, 1965, 1971, 1975, 1976, 1979, 1980, 1996, 1999, 2009, 2016	11
	very rich in water	3.66 – 4.31	1967, 2014	2
	extremely rich in water	> 4.31	1970.	1
Bivolje	extremely dry	< 2.21	-	0
	very dry	2.21 – 3.42	1990, 1994	2
	dry	3.42 – 5.45	1968, 1972, 1983, 1988, 1989, 1993, 1998, 2000, 2001, 2003, 2007, 2009, 2011, 2012	14
	moderately rich in water	5.45– 9.06	1961, 1964, 1966, 1969, 1971, 1973, 1974, 1979, 1982, 1984, 1985, 1986, 1987, 1991, 1992, 1995, 1996, 1997, 1999, 2002, 2004, 2008, 2013	23
	rich in water	9.06 – 12.19	1963, 1965, 1967, 1970, 1975, 1977, 1978, 1981, 2005, 2014, 2015, 2016	12
	very rich in water	12.19– 14.73	1962, 1976, 1980, 2006, 2010	5
	extremely rich in water	> 14.73	-	0

4. Discussion and Conclusions

This study analyzes alterations in mean annual discharge of the Rasina River on the stations Brus and Bivolje, as well as defining the trend and years when statistically significant discharge alterations occurred. Non-parametric tests determined that declining trend of discharge values is present on both stations. Break point of average discharge values on both stations was recorded at the beginning of the 1980s (1981-1982), which overlaps with the period of decrease in the quantity of precipitation which excretes in the basin, as well as air temperature rise. Apart from the above mentioned climate factors, water usage of the upper course of the Rasina for water supplying of a part of Brus municipality (water system "Paljevštica"), as well as Ćelije" accumulation which for now supplies 70 settlements on the territories of the municipalities of Kruševac, Aleksandrovac and Trstenik have a big impact on the discharge decrease (Stričević, 2015).

Analysis of the years by water richness implies certain cycles of rotating of dry and wet periods. Few years very and extremely rich in water were recorded, as well as drier than wet years.

Understanding of the alterations in discharge values is very important, because in such a way we gain insight into the state of water richness of a basin. On the basis of the above mentioned data we can conclude that water richness of the Rasina has noticeably decreased in the past thirty years. Because of that it is extremely important to take into consideration the obvious declining trend in discharge, that is, water richness of the basin for future planning, otherwise, if we rely only on average values of the discharge, we might get the wrong impression on the available quantities of water. Apart from analyzing the trends of discharge alterations on annual, seasonal and monthly level, further hydrological research should be focused on detailed analysis of all the factors which condition alterations in water regime of a basin, regardless of how big their impact is.

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