



Minimum runoff in the Ogosta river basin

Borislav Vuchkov*

*National Institute of Meteorology and Hydrology,
Tsarigradsko shose 66, 1784 Sofia, Bulgaria*

Abstract: The object of this research is the river catchment of the Ogosta river - one of the main river basins in the Danube basin. The minimum river runoff is a statistical characteristic of river currents that marks one of the limit states of water volumes. The study covers the Ogosta river catchment, which is located in the northwestern part of the Danube catchment basin. As a river flowing through the temperate continental climatic region, the Ogosta river is distinguished by a moderate continental type of runoff regime, which is characterized by three runoff phases - spring high water, summer-autumn low water and a transition phase in the autumn months, with a runoff maximum in the month of May and a runoff minimum in August. The aim is an analysis and assessment of the spatio-temporal characteristics of the minimum river runoff in the Ogosta river catchment. To achieve the goal, the following are analyzed: previous studies on the minimum river runoff and the methods for studying the runoff characteristics; the factors in the Ogosta river catchment, determining the time parameters of the minimum river runoff; the statistical parameters and temporal characteristics of the annual and monthly minimum runoff in the Ogosta river basin; the values of the ecological runoff, determined according to the methodology of the Ministry of the Environment and Water (MOEW), 95% exceedance probability of the ecological runoff in the Ogosta river basin, the spatial changes of the ecological river runoff. This paper calculates statistical characteristics of the daily minimum runoff for the period 1989–2019, the monthly distribution of the minimum runoff for the period 1981–2019, and the ecological runoff with different exceedance probabilities for the period 1981–2019.

Keywords: Ogosta river basin, minimum river runoff, ecological flow, climate factors, hydrometeorological station (HMS)

* borislav_vuchkov87@abv.bg

1. INTRODUCTION

The geographical study of the minimum river runoff is a challenge to theoretical and applied hydrology for several reasons - the lack of a uniform methodology for identification and unambiguous assessment of this runoff characteristic, the great variability, randomness and uncertainty of extreme hydrological events, the great error in the measurements of the smallest water quantities (Bozhilova, 2024).

The topicality of the topic stems from the need for more information about this natural phenomenon in the individual regions of Europe in order to develop a common policy by the European Commission on the Environment and in particular by the group on water scarcity and drought (Water Scarcity & Droughts in the European Union). The results of the research on the minimum river runoff are also important because of the task of integrating the Strategy for Water Scarcity and Droughts into the European Water Protection Project.

Analyses of the regional manifestation of the minimum runoff are contained in the studies of Nikolov (1973) - "On the minimum runoff in the Maritsa river basin to Belovo", Dakova (1984 a,b; 1994). The winter minimum runoff was studied by Stoychev (1995) and the monthly runoff by Hristova et al. (2011).

The Ogosta river originates northeast of the village of Gorno Yazovo (1573.2 m), Yazovska mountain in the Chiprov region of the Stara Planina, southeast of the village of Vraja Glava (935 m). It borders to the east with the Iskar river, and to the south with the Nishava river catchment. In the southwest it reaches the state border with Serbia, and in the west to the watershed of the Lom River (the watershed of the Tsibritsa River). It occupies an area of 4231.2 km². It covers the northern slopes of the mountains Chiprovska, Berkovska, Koznica, Vrachanska, parts of Vernishko bordo and Veslets, the Pastrina ridge and parts of the Western Danube plain (Figure 1).

The river basin is included in the areas with snow-rainfall (the spring parts) and in those with rain-snow nourishment. In the Chiprovsko-Berkov section of the Stara Planina, the snow runoff forms from 8.0% (catchment of the Chiprovska river) to 12.0% (basin of the Ogosta river) of the annual water volume. Rain runoff forms entirely the surface runoff during the summer and fall months and is almost half and over half of it during the spring months.

The monthly distribution of the river runoff is with runoff maximum in May and runoff minimum in August. A second outflow maximum was registered in December, and an outflow minimum in January. In the entire river basin, the spring runoff volume dominates (Panayotov, 1972). From March to June, they flow from 31.0% to 71.0% of the total annual runoff.

The monitoring network in the Ogosta river basin is composed of eight hydrometric stations (HMS) - Table 1. Three of the water measuring stations are organized on the main river, and the remaining five hydrometric stations - on the rivers Berkovska (16150), Dulgodelska Ogosta (16380), Burzia (16410) and Botunya (16450). The water measuring stations are relatively evenly distributed in the Ogosta river basin - five HMS are in the upper course of the river and three HMS in the flat part of the river basin (Rankova, 2017).

Minimum runoff in the Ogosta river basin

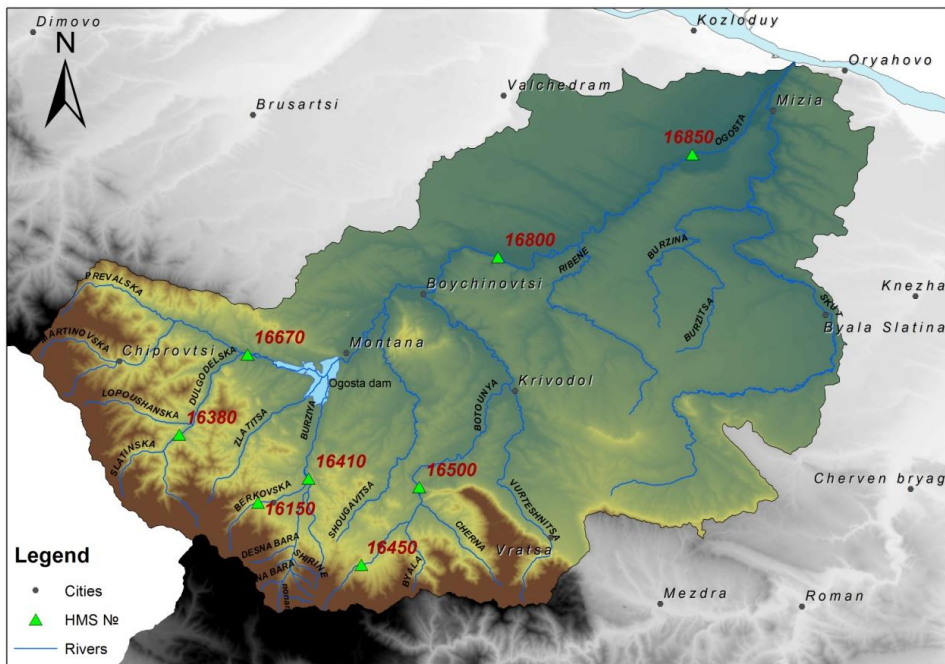


Fig. 1. Scheme of the drainage basin of Ogosta river basin with hydroprometric stations

Climate factors and the distribution of the expenditure water balance components during the year determine to the greatest extent the spatial-temporal characteristics of the minimum river runoff. The hydrogeological, morphohydrographic and geomorphological conditions of the area also influence the values of the minimum river runoff. The hydrography of the watershed, the hydraulic parameters of the riverbeds and anthropogenic impacts are also important in determining the minimum river runoff.

For the period 1988–2018, the average annual air temperature for the low part of the country (for the regions with an altitude of up to 800 m) increased by an average of 0.87 °C compared to the norm for the reference climate period 1961–1990. Because a large part of the catchment of the Ogosta river is in the flat-hilly hypsometric belt, it is expected that there is an increase in the annual air temperature within its borders as well.

Precipitation is the most important factor for the formation of the river runoff and its low values. Their annual value is between 558 mm at Haiderin station and 1200 mm at Berkovitsa station. There is a regular increase in the annual precipitation amount from the Danube bank to the Staroplanina ridge.

Hydrogeological conditions are of great importance for the formation of river waters during periods without precipitation and those with negative air temperatures, when no rainwater or snowwater enters the riverbeds. The groundwater from the flood terraces, which have a hydraulic connection with the rivers - a permanent hydraulic connection and a temporary hydraulic connection - have a large runoff effect.

Large parts of the Ogosta river basin are anthropogenically loaded. The total water use is 157.0 million m³. The anthropogenic impact on river currents is the result of the use of water for drinking-domestic and industrial water supply, irrigation, energy production. The most significant anthropogenic pressure on the runoff regime is exerted by the hydrotechnical facilities and especially the dams, which redistribute the water volumes in the river courses during the year, as well as the derivations to the reservoirs. The effect of hydrotechnical construction on the river runoff is evaluated by the indices of change of the annual runoff, which depends on the place occupied by the dam facility in the water management system and is most often followed by the reduction of the river water volume (Mandajiev, 1989).

Table 1. Data for the hydrometric stations in the Ogosta river basin

HMS №	River	Location	F (km ²)	H (m)
16150	Berkovska	Begovitsa quarter	46,288	1067
16380	Dulgodelska Ogosta	Govezhda village	125,018	973
16410	Burzia	m. Balabanitsa	173,035	864
16450	Botunya	Varshets (Zanozhene)	20,830	1105
16500	Butan	Stoyanovo village	237,968	674
16670	Ogosta	Gavril Genovo village	521,273	
16800	Ogosta	Kobilyak village	2241,383	496
16850	Ogosta	Butan village	3000.743	395

2. MATERIAL AND METHODS

Minimum runoff, determined on the basis of daily water quantities, is the smallest volume of water in river courses recorded during a given year, season or month. It is determined for different time intervals, most often for 1-, 5-, 7-, 10- and 30-day periods with the smallest water volumes and recurrence of a certain number of years.

The minimum one-day river discharge - 1Q, determined on the basis of daily hydrometric data, represents the absolute minimum discharge for a certain period of time. The monthly minimum runoff is defined as the smallest value of the monthly runoff for the period 1981–2019, based on which its intra-annual distribution is analyzed.

A specific feature of the ecological runoff assessment is the need to determine its characteristics at the highest probability of occurrence. For this purpose, empirical probability functions were constructed, which represent the exceedance probability of the ecological runoff in the watershed of the Ogosta River.

To calculate the empirical distribution $P(m)$ corresponding to the terms of the variational series, there are a number of formulas of a general form:

$$P(m) = f(m, n),$$

Minimum runoff in the Ogosta river basin

where m is the sequence number of the term (X_m) of the variational series obtained from the hydrological series by arranging its terms in descending ($X_m \geq X_{m+1}$) or ascending ($X_m \leq X_{m+1}$) order, and n is the total number of elements.

The formula most widely used in practice is:

$$P(m) = (m-0.3)/(n+0.4) * 100$$

The mechanism for constructing the empirical security function is as follows: the hydrological order is converted into a variational order by arranging its members in descending order; the serial number of each member is determined and the empirical distribution $P(m)$ is calculated according to Chegodaev's formula.

In the present work, theoretical distribution functions were also used as a mathematical model of the empirical ones distributions of hydrological quantities. Theoretical functions enable operation over a period of time or allow, on the basis of data limited in volume, to obtain calculated values with some repeatability. They also allow spatial interpolation by constructing them for learned points using their parameters.

One of the many methods of theoretical distributions was used - Pearson III type by the method of moments for 10% of the multi-year average and 95% of the minimum multi-year average water amount, as mentioned in the order of the Ministry of Environment and Water for the minimum allowable runoff.

For this purpose, the average multi-year water quantities of the Ogosta river for the period from 1989-2019 are arranged in hydrological order. Then it is transformed into a variation order. The values of the empirical distribution are determined, here we use Chegodaev's formula (1955).

3. RESULTS AND DISCUSSION

The Annual Minimum Runoff has been calculated for different time periods – one day (1Q), three days (3Q), seven days (7Q), thirty days (30Q) and ninety days (90Q). The dates on which the annual minimum one-day runoff is recorded and the periods during which the smallest water quantities in the river courses are recorded for 3Q, 7Q, 30Q and 90Q are determined.

3.1. The minimum one-day river discharge - 1Q

The annual minimum river discharge is actually the absolute minimum discharge for a given river basin, which makes it possible to calculate the exact date of a weather event. The average annual minimum one-day runoff - 1Q, for the period 1989-2019 has an average value of the lowest in the watershed of the Botunya river – Varshets (16450) and the highest in the river basin of the Ogosta river - Butan village (16500).

The annual minimum one-day runoff is recorded most often in the months of August and September at all river catchments within the boundaries of the Ogosta river basin. The frequency of the absolute minimum runoff for the month of September in the individual watersheds varies from 16.1% (Dalgodelska Ogosta river - Govezhda village

(16380) and Ogosta river - Butan village (16500)) to 38.7% (Berkovska river – Berkovitsa (16150)) . With the greatest frequency in the month of August, the absolute minimum runoff at the Burzia river HMS – Balabanitsa (16410) - 61.3%, and the lowest - 19.4%, at the Dulgodelska Ogosta (16380) (Table 2). The empirical exceedance probability functions of 1Q show smoothly changing values in the time series of the minimum one-day runoff for the Ogosta river - Kobilyak village (16800) and to a lesser extent for the Ogosta river - Butan village (16500) (Figure 2).

Table 2. Incidence (%) in 1Q temporal expression for the period 1989–2019.

HMS	I	II	...	V	VI	VII	VIII	IX	X	XI	XII
Berkovska	3.2	3.2		3.2	3.2	12.9	25.8	38.7	3.2	3.2	3.2
Dulgodelska Ogosta	12.9	3.2		3.2	3.2	3.2	19.4	29	16.1	9.7	
Burzia	6.5				6.5	3.2	61.3	12.9	6.5	3.2	
Botunya	9.7				6.5	16.1	45.2	16.1	6.5		
Butan	3.2				3.2	19.4	35.5	25.8	9.7		3.2
Ogosta - Gavril Genovo	3.2				9.7	16.1	29	29	12.9		
Ogosta - Kobilyak	12.9	3.2		3.2	3.2	6.5	29	22.6		6.5	12.9
Ogosta - Butan	16.1	6.5		9.7			29	16.1	9.7	6.5	6.5

Minimum runoff in the Ogosta river basin

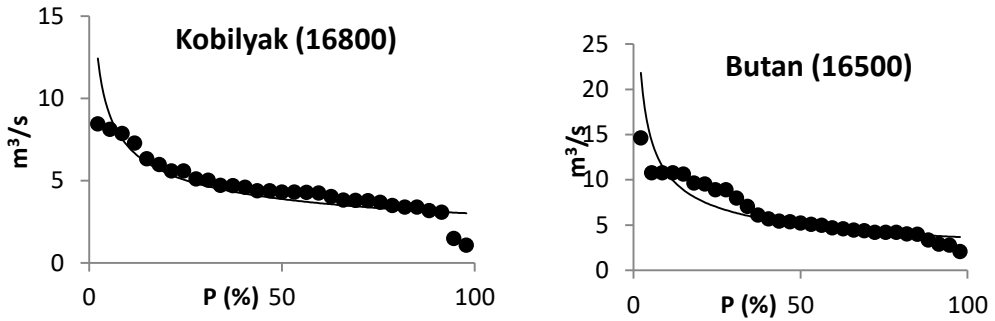


Fig. 2. Empirical security functions in the Ogosta river watershed

3.2. Three days - 3Q

In the case of the three-day minimum runoff, no significant changes in the water quantities from the one-day minimum river runoff are observed. 3Q is reported most often in the months of August and September at all stations within the Ogosta river basin, similar to the one-day minimum discharge. The frequency of 3Q for the months of August and September in the individual watersheds has not changed: for the month of September - from 12.9% for the river Burzia - the city of Balabanitsa (16410) to 38.7% for the river Berkovska – Berkovitsa (16150): for the month of August at HMS Burzia river - Balabanitsa town (16410) - 61.3%, and with the smallest - 19.4%, in the Dalgodelska Ogosta river HMS - Govezhda village (16380) (Table 3).

In the three-day minimum runoff with a guarantee of 95%, the smallest values are recorded on the Berkovska river near the Begovitsa HMS (16150), and the largest in the Ogosta river catchment near Butan village (16850). The constructed empirical functions differ in individual watersheds when arranging the time series values in descending order. As with the one-day minimum river runoff, its values are most smoothly arranged in the lower course of the river and in the catchment of the Botunya river (16450), in contrast to the Staroplaninska part of the Ogosta river, especially distinctly at the Berkovska - Begovitsa river (16150).

Table 3. Incidence (%) in 3Q temporal expression for the period 1989–2019.

HMS	I	II	...	V	VI	VII	VIII	IX	X	XI	XII
Berkovska	3.2	3.2		3.2	3.2	9.7	32.3	38.7	3.2	3.2	
Dulgodelska Ogosta	12.9	3.2		3.2	3.2	3.2	19.4	25.8	19.4	9.7	
Burzia	6.5				6.5	3.2	61.3	12.9	6.5	3.2	
Botunya	9.7				6.5	16.1	45.2	16.1	6.5		
Butan	3.2				3.2	19.4	35.5	25.8	9.7		3.2
Ogosta Gavril Genovo	3.2				9.7	16.1	29,0	29,0	12.9		

Ogosta - Kobilyak	12.9	3.2		3.2	3.2	6.5	29,0	22.6		6.5	12.9
Ogosta - Butan	16.1	6.5		9.7			29,0	16.1	9.7	6.5	6.5

3.3. Seven days - 7Q

Both the annual minimum one-day and three-day minimum outflows, as well as the 7Q, have the highest frequency of occurrence in August and September.

The frequency of 7Q in August for the period 1989–2019 is between 54.8% in the watershed of the Burzia river - the town of Balabanitsa (16410) and 22.6% in the Ogosta river - the village of Kobilyak (16800). 7Q has its maximum frequency in the month of August, along with the Burzia river – Balabanitsa (16410), also in the river basins of the Botunya (Stara) river – Varshets (16450), the Ogosta River - Gavril Genova village (16670) and the Ogosta River - Butan village (16850).

The frequency of 7Q in the month of September for the studied period varies between 48.4% for the catchment of the river Berkovska – Begovitsa (16150) (Figure 3) and 12.9% for the catchment of the river Ogosta - the village of Gavril Genova (16670). The seven-day minimum river runoff has a maximum frequency in this month for the Ogosta river - Kobilyak village (16800), Dalgodelska Ogosta river - Govezhda village (16380).

A seven-day minimum river outflow in the catchment basin of the Ogosta river was also registered in the month of July. The frequency of 7Q in the month of July for the period 1989–2019 is between 16.1% in the watershed of the Botunya River - Stoyanovo village (16450) and 6.5% in the Ogosta river - Kobilyak village (16800). In the lower reaches of the Ogosta river, no observation of 7Q was detected in June.

The analysis of the appearance of the seven-day minimum river discharge over the years does not show certain regularities: no permanent manifestation is observed during a certain ten-day period.

The seven-day minimum river outflow in the catchment basin of the Ogosta river in May and June has an episodic manifestation in separate parts of the studied river catchment. In the month of May, one case was established on 7Q for the Berkovska river – Begovitsa (16150), Dalgodelska Ogosta - Govezhda village (16380), Ogosta river - Kobilyak village (16800) and Ogosta river - Butan village (16850). In the month of June, one case of 7Q was established for Berkovska River – Begovitsa (16150), Burzia river – Balabanitsa (16410), Botunya (Stara) river – Varshets (16450) and Ogosta river - Gavril Genova village (16670).

Minimum runoff in the Ogosta river basin

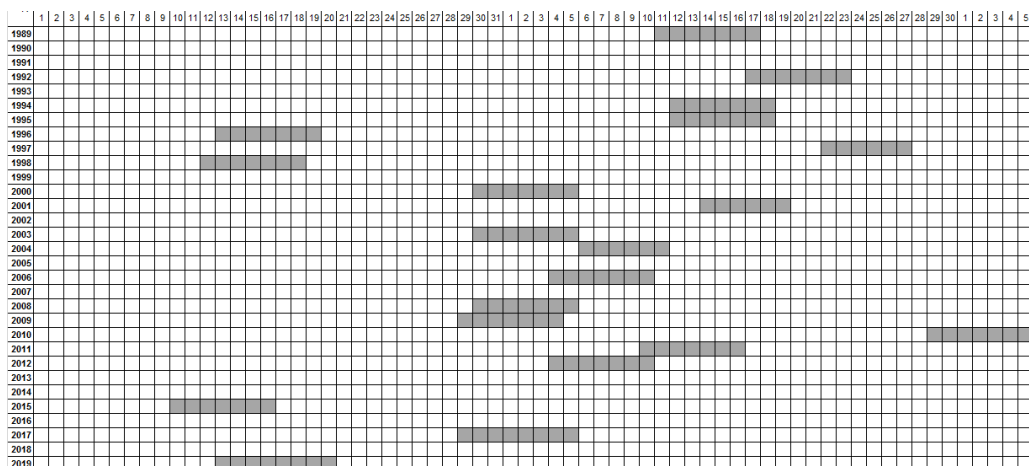


Fig. 3. Temporal manifestation of 7Q in the watershed of the river Berkovska - Begovitsa for August and September for the period 1989–2019.

Comparing the empirical functions of 7Q with the graphical representation of the empirical exceedance probability of 1Q and 3Q shows that the river discharge changes most smoothly in the lower reaches of the Ogosta River.

3.4. Thirty days - 30Q

At the annual minimum outflow for a thirty-day period, the average values of the water quantities are the smallest at the Berkovska River – Begovitsa (16150) and the largest at the Ogosta River - Butan village (16850).

In the month of January 2014, minimum water quantities were registered in all measuring stations for the entire period under consideration. The annual minimum runoff for a thirty-day period occurs most often in the months of August and September, less often in September-October, episodically during the winter hydrological season, and cases are not registered in the months of March and April or during part of the spring hydrological season (Table 4).

The study of 30Q over the years does not show certain regularities: no lasting appearance is observed during a certain ten-day period.

During the analysis of the thirty-day period, it was found that the water quantities with a guarantee of 95% are the smallest at the Berkovska - Begovitsa river station (16150) and the Botunya river station (16450) and the largest at the Ogosta river HMS - Butan village (16850). As with 1Q, 3Q and 7Q, the values in the lower reaches of the Ogosta River are arranged most gradually.

Table 4. Number of cases presenting with 30Q for the period 1989–2019.

HMS	I–II	VI–VII	VII–VIII	VIII–IX	IX–X	X–XI
Berkovska	2	1	5	16	5	1
Dulgodelska Ogosta	4	1	4	10	9	3
Burzia	2	-	8	15	3	3
Botunya	4	1	7	13	4	2
Butan	1	-	5	15	8	2
Ogosta Gavril Genovo	2	2	5	16	4	2
Ogosta - Kobilyak	5	2	3	10	5	6
Ogosta - Butan	6	1	2	9	5	8

3.5. Ninety days - 90Q

The 90-day minimum river discharge is the longest study period and accordingly the highest mean minimum amounts are observed here.

The smallest values of 90Q are observed at Berkovska river – Begovitsa (16150), the largest at Ogosta river - Kobilyak village (16800). Analyzing the 90Q data, as well as the smaller observation periods for the 1-, 3-, 7-, and 30-day minimum water amounts, a dry period was again observed in January 2014 at all hydrometric stations. The annual minimum outflow begins most often in the months of July - August and ends in September - October.

The most frequent appearance of a minimum ninety-day runoff for July-August was observed at the Burzia river HMS - Balabanitsa (16410) and Botunya river HMS - Stoyanovo village - 13 cases each. 12 cases were registered for Berkovska - Begovitsa river, Butan river - Stoyanovo village (16450) - 11 cases, Dalgodelska Ogosta river (16380) and Ogosta river - Butan village (16850) - 9 cases each (table 15) and in the lower reaches of the river Ogosta, the village of Kobilyak (16800) and the village of Butan (16850) - 7 and 6 cases, respectively.

The cases of appearance of 90Q in the period June-July are relatively evenly distributed. There are 7 cases of minimal runoff at the Berkovska river – Begovitsa (16150), 6 cases each at the Dalgodelska Ogosta river - the village of Govedha (16380) and the Botunya River – Varshets (16450), 5 cases each at the Butan river - the village of Stoyanovo and Ogosta - Gavril Genovo (16670) and in 4 cases - Burzia r. - Balabanitsa town (16410), Ogosta r. Kobilyak village (16800) and Butan village (16850) (Table 5).

Table 5. Number of cases presenting with 90Q for the period 1989–2019

HMS	I–II	VI–VII	VII–VIII	VIII–IX	IX–X	X–XI
Berkovska	3	7	12	8	-	1

Minimum runoff in the Ogosta river basin

Dulgodelska Ogosta	2	6	9	11	-	3
Burzia	2	4	13	8	3	1
Botunya	4	6	13	4	1	2
Butan	1	5	11	10	3	1
Ogosta- Gavril Genovo	3	5	9	13	-	1
Ogosta- Kobilyak	6	4	7	8	2	5
Ogosta - Butan	6	4	6	5	5	5

3.6. Monthly minimum outflow

The lowest values of the monthly minimum discharge are registered during the summer-autumn hydrological season: the period of the lowest minimum monthly river discharge usually begins in July and ends in November in all hydrometric stations. Regarding the maximum of the monthly minimum runoff, two groups of catchments are observed - with the highest values of the minimum runoff in April - in the river catchment of the Botunya river (16450), on the Ogosta river - the village of Gavril Genovo (16670) and Ogosta river, Butan (16850), and in May in the rest of the studied river basin (Figure 4).

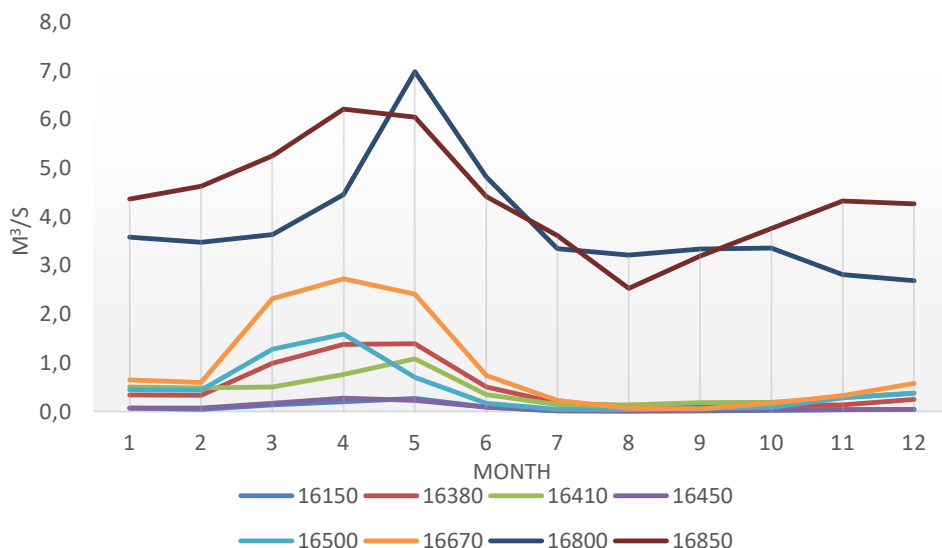


Fig. 4. Monthly distribution of the minimum outflow in the Ogosta river

The percentage, which constitutes the minimum outflow from the monthly average, fluctuates within the limits of 20.63% in the month of September (HMS 16150 - Berkovska - Begovitsa) to 74.91% (HMS Ogosta village Butan 16850). For the Berkovska - Begovitsa river station (16150), this percentage varies between 20.63% in September and 46.58% in January. At Dalgodelska Ogosta village of Govezhda (16380)

in September, the average minimum runoff was 20.63% of the average runoff for the year. As with the Berkovska - Begovitsa river (16150), the highest percentage was observed here in the month of January – 54.92%. The smallest percentage differences are found here - about 24%. HMS Barzia, Balabanitsa (16410) reported the lowest volumes in July - 28.67%, and the highest in November - 53.48%. At the river Botunya – Varshets (16450), the minimum runoff varies between 26.92% (month of July) and 53% (month of January) of the monthly average. Here we see one of the biggest differences in percentage terms – about 26%. The river basin of the Butan river near the village of Stoyanovo (16450) registered the lowest percentage values in the month of August – 24.92% and the highest – m. November – 48.95%, at HMS Ogosta river - Gavril Genovo (16670) 23.39% in September and 47.8% in November.

In the lower reaches of the Ogosta river catchment, the highest values of the average minimum water quantities compared to the monthly averages are registered. The lowest volumes fluctuate around 50% for both stations - Ogosta river, village of Kobilyak (16800) - 50.63% in March and 49.1% - Ogosta river, village of Butan (16850) again in March. The highest were in November for both HMS - Ogosta River village of Kobilyak (16800) reports 74.7%, and HMS Ogosta River village of Butan (16850) - 74.91%

The minimum water amounts form between 20% and 73% of the average runoff amounts during the summer-autumn low water and between 25% and 60% during the spring high water in the individual watersheds.

Comparing the intra-annual distribution of the average monthly and the minimum monthly river runoff shows a similarity with regard to the monthly maximum in the catchments of the Dalgodelska Ogosta River - the village of Govezhda (16380), the Botunya River (16450) and the Ogosta River - the village of Gavril Genovo (16670).

3.7. Ecological flow

The lowest values of 10% Q_{av} . of the ecological runoff in the river basin of the Ogosta River is registered in the Staroplanina part, near the Botunya (Stara) River – Varshets (16450), and the highest in the lower course of the main river.

For the analysis of the temporal manifestation of the absolute minimum and absolute maximum values of the ecological runoff, the high-water and low-water years in the river basins were determined (Table 6).

Table 6. Low-water and high-water years in the Ogosta river catchment

№ HMS	Low-water years >95% Q_{av}	High-water years <5% Q_{av}
16150	1990, 1993	2014, 2010
16380	1990, 1993	2014, 2005
16410	1990, 1993	2014, 2005
16450	1990, 1993	2005, 2014
16500	1985, 1993	2005, 2014
16670	2011, 1994	2014, 2005

Minimum runoff in the Ogosta river basin

16800	1994, 1993	2005, 2014
16850	1994, 1993	2006, 2014

The analysis of the data shows that the minimum values of the ecological runoff in almost the entire river basin for the studied period were recorded in 1993. An exception to the stated fact is the watershed of the Berkovska - Begovitsa river (16150), in which the lowest value of the ecological runoff was recorded in 1990, and the Ogosta river - the village of Gavril Genovo (16670), with an absolute minimum ecological runoff in 1994. The temporal manifestation of the absolute minimum values of the ecological runoff in the river basin of the Ogosta river coincide with the prolonged period of drought established on the territory of the country after the 1980s, and are counted during the least water years for the period 1989–2019.

The ecological runoff 10% Q_{av} shows a strong dependence on the area of the river basin. The correlation coefficient between the two investigated quantities is 0.99 and statistically significant at significance levels of 0.01, 0.05 and 0.10. (Figure 5).

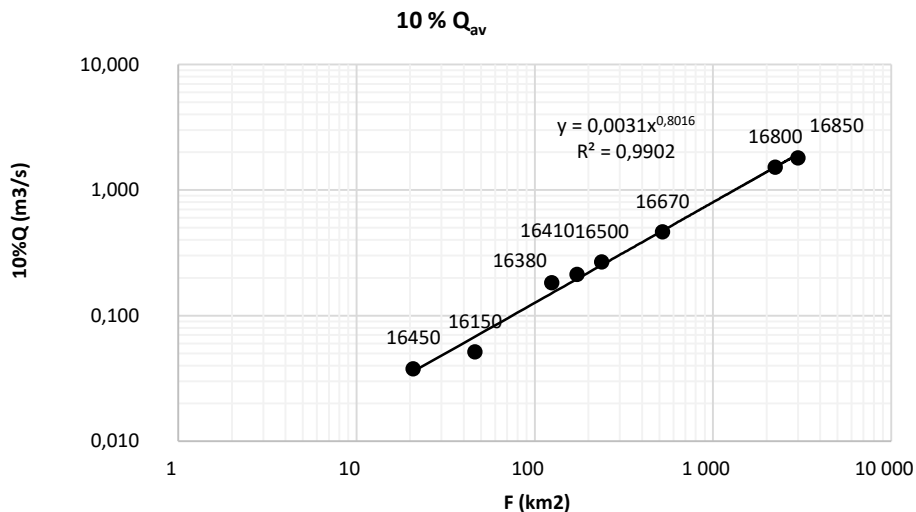


Fig. 5. Dependence between environmental runoff 10% Q_{av} and the area of the river basins in the catchment of the Ogosta river

The methodology for calculating the minimum permissible runoff in rivers requires the determination of a 10% of the multi-year average water quantity, but not less than the minimum monthly average water quantity with a guarantee of 95%. For this purpose, the empirical and theoretical exceedance probability functions are drawn. (Figure6).

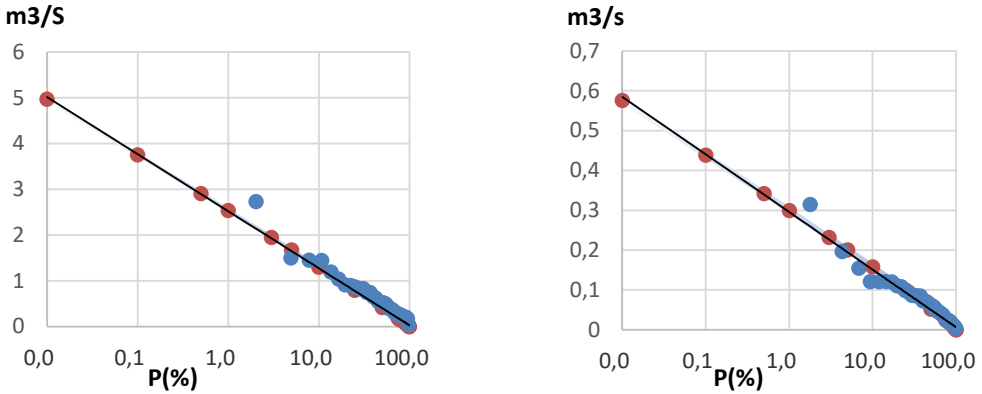


Fig. 6. Empirical and theoretical security functions of 10%Q in HMS 16670 and HMS 16150

The empirical exceedance probability functions of the 10% Q_{av} environmental runoff with 95% are approximated by the theoretical Pearson type III distribution. The ecological runoff 10% Q_{av} with 95% exceedance probability shows dependence on the area of the river basin. The correlation coefficient between the two studied quantities is 0.89 and statistically significant at significance levels of 0.01, 0.05 and 0.10. (Figure 7).

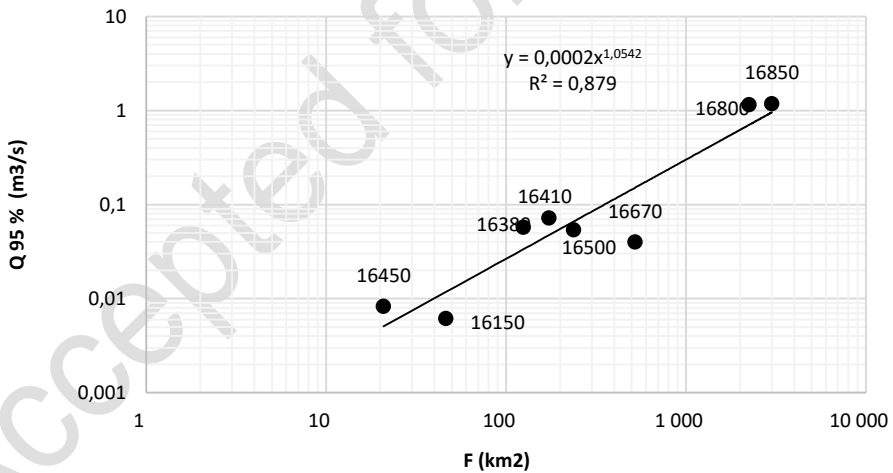


Fig. 7. Dependence between the ecological runoff 10%Q with 95% guarantee and the area of the river basins in the catchment of the Ogosta river

4. CONCLUSION

The river outflow in the catchment of the Ogosta river is formed in the conditions of a moderate continental climate with decreasing air temperature and an increase in the amount of precipitation from the plain to the highland part of the river basin. An increase in the degree of forestation is also observed in the same direction, in the conditions of hydraulic connection between the rivers and underground waters in the lower course of the main river and with feeding of the karst waters with rivers in the middle course of the Ogosta river. Runoff-forming factors determine the appearance in the studied catchment of spring high water, summer-autumn low water and a transition phase in the autumn months, with runoff maximum in May and runoff minimum in August.

The absolute minimum river discharge (1Q) as 3Q and 7Q are recorded most often in the months of August and September at all watersheds within the river basin of the Ogosta river, in August-September and September-October at 30Q and 90Q. The minimum river runoff of varying duration in the Ogosta river catchment has an episodic manifestation during the remaining months of the year and is not counted only in the month of April. In the lower reaches of the Ogosta river, frequent cases of minimum river runoff are found in January. Appearance of the minimum river runoff in the Ogosta river basin do not always coincide with the lowest water years, which is a reflection of the mismatch of the water quantities of the year with the intra-annual distribution of the river runoff and the extreme values of the river runoff.

The dependence of the ecological runoff 10% Q_{av} and the ecological runoff with 95% guarantee on the area of the river basin is the basis for hydrological zoning according to the minimum permissible runoff in the rivers.

In the multi-year course of the river outflow of the Ogosta river for the period 1981–2019, a tendency to increase the annual water volumes that flow through the river is observed. The increase is after 2005.

ACKNOWLEDGEMENTS

The author wishes to express their gratitude to prof. Neli Hristova, eng. Kamelia Krumova and associate prof. Elena Bozhilova.

REFERENCES

- Bozhilova, E. K. 2024 a. Application of Methodology for Ecological Flow for Yantra River Basin in Bulgaria. – Journal of Balkan Ecology, Vol. 27, № 1, 2024. ISSN 1311-0527 (Print) ISSN 2815-3758 (Online). 67-78 (W/S)
- Dakova, Sn. 1984 (a). Minimum outflow of rivers from South-West Bulgaria. – Hydrology and Meteorology, 2, 21–29.
- Dakova, Sn. 1984 (b). Assessment of the minimum runoff from the mountains in Bulgaria. – Hydrology and Meteorology, 1, 7–12.
- Dakova, Sn. 1994. Low Runoff. – In: Limnology of the Bulgarian Danube tributaries. S.: Book Tiger, 43–50.

- Dakova, Sn., Uzunov, J., Mandajiev, D. 1999. Minimum runoff – a limiting factor for river ecosystems. *Meteorology&Hydrology*, 1–2, 56–66.
- Hristova, N., Radeva K. 2011. Geographical analysis of the minimum monthly runoff in Bulgaria. *Year SU, GGF*, 2, 104.
- Mandajiev, D. 1989. River water resources and their change as a result of anthropogenic activity. S.: NIHM.
- Nikolov, Zh. 1973. On the minimum outflow in the Maritsa river to Belovo. Ex. on center. scientific research hydraulic laboratory Studies, XI, 107–118.
- Ninov P., T. Karagiozova, M. Rankova, 2017. Determination of water resources in rivers in the bulgarian basins of the lower Danube
- Panayotov, T. 1972. Variability of intraannual runoff distribution, hydrologic phases, and hydrologic seasons. Ex. *IHM*, XX, 59–80.
- Stoychev, K. 1995. Analysis of the alternation of different water years in the fluctuations of the river runoff in Bulgaria. *Year SU, GGF*, 2, 87, 159–169.

Documents:

- Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, EU (Directive 2000/GO/EC of the European Parliament and the Community Action in the field of Water Policy. 23.10.2000).
- Hydrological atlas of Bulgaria. 1964, S., GUGK, BAS, 48.
- Hydrological reference book of rivers in Bulgaria, 5, 1982. Sofia, State University of Hydrology and Meteorology.
- Hydrological reference book of the rivers in Bulgaria. 1981. S., GUHM-BAN, II.