ASSESSMENT OF RUNOFF DURING THE FLOOD PERIOD OF MOUNTAIN RIVERS BASED ON THEIR EMPIRICAL RELATIONS WITH CLIMATIC FACTORS

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Abstract. The article is devoted to the issues of assessing the flow of mountain rivers during the flood period based on their empirical relationships with climatic factors. For this purpose, a statistical assessment of the multifactorial relationship between the flow of the rivers of the Chirchik basin during the flood period and meteorological factors was made, normalized regression equations were obtained. On their basis, calculated nomograms were constructed and the values of the river flow during the flood period were estimated.

Key words: river, river flow, flood period, climatic factors, multifactorial relationship, regression equations, calculated nomogram, assessment.

Introduction. Nowadays, the shortage of Water Resources is felt more strongly from year to year due to climate warming on our planet, especially in its arid regions. In such conditions, it is of important scientific and practical importance to improve methods of quantitative assessment of water resources of rivers, depending on climatic factors. At the same time, it should be noted that 70-80 percent of the annual flow of rivers of Central Asia, including Uzbekistan, flows during the full-fledged period (Ziyaev R.R. et. al., 2020, Khikmatov F.Kh., 2015). This situation testifies to the fact that in the conditions of our country, the improvement of methods for assessing the amount of flow of rivers during the full-fledged period depending on climatic factors is one of the pressing issues.

The main purpose of this research work is to consider the issues of assessing the amount of flow of mountain rivers of the full-time period on the basis of their empirical connection with climatic factors on the example of rivers of the Chirchik Basin. In the implementation of this goal, the following tasks were identified and found their solution in the research process: 1) collect data on measured water consumption in rivers that maintain a natural water regime in the basin, as well as on atmospheric precipitation and air temperatures recorded at meteorological stations in their basins; 2) draw River hydrographs for each year based on the water consumption data of rivers; 3) using hydrographs to determine the average water consumption during the full-fledged period; 4) statistical evaluation of polynomial connections between water consumption of rivers and climatic factors for different accounting intervals – first base (FBCP, 1961-1990) and current (CCP, 1991-2020) climatic periods; 5) to construct regression equations of polynomial connections and to estimate the full-time flow using nomograms built on them.

As an object of study, well studied from a Hydrometeorological point of view, the rivers of the Chirchiq basin were selected (Table 1). And the subject of the study is the issues of statistical assessment of the links between the flow of the full-fledged period of these rivers and the atmospheric precipitation and (summer) air temperature in different seasons (winter, summer).

Thematic literature analysis. To study the issues of the formation of river flows, their quantitative assessment depending on climatic factors M.Perkins, J.Gibson, T.Edwards, S.Birks, W.Buhai, P.Eachern, B.Wolfe, L.Alfieri, B.Bisselink, F.Dottori, G.Naumann, K.Wyser, Ya.Kong, Z.Pang, dedicated to the research of foreign scientists such as (Kong et. al., 2012, Getu S.A., 2015). T. from scientists of the countries of the Commonwealth of independent states S.Abalyan, S.K.Alamanov, M.N.Bolshakov, M.I.Budico, A.I.Voeykov, V.G.Glushkov, I.S.Sosedov and others studied the processes of formation of the flow of different phases of the water regime of rivers, depending on climatic factors. The first studies in this direction in Uzbekistan were conducted by E.M.Oldecope, L.K. If it was carried out by the davidovs, then with this issue V.L.Shults, O.P.Sheglova, Z.P.Djordjo, A.M.Ovchinnikov, V.E.Chub et al. Currently, research on this problem is carried out by B.K.Sarev, F.Khikmatov, L.M.Karandaeva, B.D.Salimova, S.A.Khaydarov, D.M.Turgunov, R.R.Ziyayev, N.B.Erlapasov, Z.F.Researchers like khakimova continue (Denisov et. al., 1965, Hakimova et. al., 2024, Hikmatov et. al., 2020, Khikmatov et. al., 2016). This study differs from the above works in that it is devoted to considering the problem on the example of the rivers of the Chirchik Basin.

Research Methodology. The article uses methods of geographical generalization, hydrological similarity, modern hydrological calculations. Also, in the statistical assessment of polynomial connections between climatic factors (winter and summer precipitation, summer air temperature) with the flow of the full-fledged period of rivers. The objective equalization and normalization method proposed by G.A.Alekseev was applied (Alekseev et. al., 1971, In-Kyun Jung et. al., 2010, Jain MK et. al., 2004).

The study used measured water consumption as primary data in hydroposts in the Chirch basin rivers of the Autochromet. Climatic factors, namely atmospheric precipitation and air temperatures, were recorded at the Piscom meteostance under this agency.

Analysis and results. The work of calculating the links between climatic factors with the amounts of flow of the full-time Rivers was carried out individually for FBCP and CCP. Computations In the G.A.Alekseev method, performed in the following sequence. Initially, Hydrometeorological variables, namely $\sum X_{X-III}$ (the sum of precipitation in the X-III months of the hydrological year), $\sum X_{IV-IX}$ (IV-IX the sum of precipitation in the months), $\bar{t}_{IV-X}$ (IV-X the average air temperature in the months) was reshaped in ascending order. Based on their color (order) numbers, the normalized values of each variable were determined from a special table. Even multiples of normalized values of variables were calculated to determine the algebraic sums of each pair. These assemblies allowed the calculation of covariation coefficients (μ_{01}, μ_{02}, μ_{03}, μ_{12}, μ_{13} μ_{23}) (Alekseev et. al., 1971, Salimova et. al., 2009, Scheglova et. al., 1960, Schults et. al., 1965, Turgunov et. al., 2022, Ziyayev, 2021). Even correlation coefficients (r_{01}, r_{02}, r_{03}, r_{12}, r_{13}, r_{23}) were defined as the ratio of covariation coefficients to empirical dispersion (σ_u^2) (Table 1).

A system of linear equations consisting of pairwise correlation and unknown regression coefficients determined by the calculations Piscom Formed on the example of the (Mullala) River.

Table 1.

Even correlation coefficients of connections between variables

№	River – hydropost	Score periods	Even correlation coefficients					
			r_{01}	r_{02}	r_{03}	r_{12}	r_{13}	r_{23}
1	Chotqol-Khudoydot q.	FBCP	0,842	0,532	-0,280	0,309	-0,223	-0,607
		CCP	0,704	0,474	-0,329	0,127	-0,196	-0,581
2	Piscom-Mollala q.	FBCP	0,841	0,513	-0,343	0,309	-0,223	-0,607
		CCP	0,726	0,413	-0,367	0,127	-0,196	-0,581
3	Ugom-Khojakent q.	FBCP	0,775	0,659	-0,342	0,309	-0,223	-0,607
		CCP	0,684	0,589	-0,391	0,127	-0,196	-0,581

For this purpose, we used the values of the double correlation coefficients determined above (Table 1) for CCP in the river. As a result, the above System (1) came to the following view:

$$\{\alpha_{01}+0,127\cdot\alpha_{02}-0,196\cdot\alpha_{03}=0,704¿\{0,127+\alpha_{01}\cdot\alpha_{02}-0,581\cdot\alpha_{03}=0,413¿¿¿ \quad (1)$$

The prime and auxiliary determinants of this three-unknown system of linear equations were determined in the Kramer method (Table 2).

Table 2

Head (Δ) and auxiliary determinants (Δ_{01}, Δ_{02}, Δ_{03}) of Calculated values for FBCP and CCP

№	Rivers	FBCP				CCP			
		Δ	Δ_{01}	Δ_{02}	Δ_{03}	Δ	Δ_{01}	Δ_{02}	Δ_{03}
1	Chotqol	0,570	0,429	0,208	0,063	0,637	0,420	0,263	0,025
2	Piscom	0,570	0,430	0,157	-0,004	0,637	0,430	0,184	-0,043
3	Ugom	0,570	0,363	0,307	0,073	0,637	0,398	0,340	0,027

Based on the results of the work on the calculation of Prime and auxiliary determinants, the values of the regression coefficients, which are non-finite, for FBCP and CCP, were determined using the following expressions:

$$\alpha_{01}=\frac{\Delta_{01}}{\Delta}; \qquad \alpha_{02}=\frac{\Delta_{02}}{\Delta}; \qquad \alpha_{03}=\frac{\Delta_{03}}{\Delta}. \tag{2}$$

Table 3.

Calculated values of regression coefficients for FBCP and CCP

№	Rivers	FBCP			CCP		
		α_{01}	α_{02}	α_{03}	α_{01}	α_{02}	α_{03}
1	Chotqol	0,753	0,366	0,110	0,659	0,413	0,040
2	Piscom	0,755	0,275	-0,007	0,676	0,288	-0,067
3	Ugom	0,636	0,539	0,128	0,625	0,534	0,042

Based on the values of the regression coefficients presented in Table 3, the normalized regression equation is structured in general terms as follows:

$$U_0(Q_t)=\alpha_{01}\cdot U_1(X_w)+\alpha_{02}\cdot U_2(X_s)+\alpha_{03}\cdot U_3(t_s). \tag{3}$$

Normalized regression equations have also been constructed based on Table 3 data above for private states, i.e. for each studied river and calculus periods (FBCP, CCP). The full correlation coefficients representing the accuracy of these equations and their errors were determined by all the rivers under study (Table 4).

Table 4

The normalized regression equations of the links between the flow of the river full cycle [$U_o(Q_t)$] and climatic factors [$U_1(X_w)$, $U_2(X_s)$, $U_3(t_s)$,] are

№	Rivers	Accounting periods	Normalized regression equations	$r_0\pm\sigma_{ro}$
1	Chotqol	FBCP	$U_0(Q_t)=0{,}753\cdot U_1(X_w)+0{,}366\cdot U_2(X_s)+0{,}110\cdot U_3(t_s)$	0,927±0,029
		CCP	$U_0(Q_t)=0{,}659\cdot U_1(X_w)+0{,}413\cdot U_2(X_s)+0{,}040\cdot U_3(t_s)$	0,820±0,061
2	Piscom	FBCP	$U_0(Q_t)=0{,}755\cdot U_1(X_w)+0{,}275\cdot U_2(X_s)-0{,}007\cdot U_3(t_s)$	0,882±0,046
		CCP	$U_0(Q_t)=0{,}676\cdot U_1(X_w)+0{,}288\cdot U_2(X_s)-0{,}067\cdot U_3(t_s)$	0,796±0,068
3	Ugom	FBCP	$U_0(Q_t)=0{,}636\cdot U_1(X_w)+0{,}539\cdot U_2(X_s)+0{,}128\cdot U_3(t_s)$	0,945±0,022
		CCP	$U_0(Q_t)=0{,}625\cdot U_1(X_w)+0{,}534\cdot U_2(X_s)+0{,}042\cdot U_3(t_s)$	0,871±0,045

As can be seen from the table 4 data presented above, the values of the net correlation coefficients calculated for FBCP in the rivers of the Chirchik basin were large compared to the CCP. For example, in the Piscom River, the value of the net correlation coefficient in the FBCP was r_0=0.882, while by the CCP, this value decreased slightly to r_0=0.796.

The normalized regression equation, i.e. the contributions of meteorological factors to (4) expression [$\delta(X_w)$, $\delta(X_s)$, $\delta(t_s)$]. Determined using the expressions proposed by G.A.Alekseev (Table 5).

We will analyze the results obtained using the example of the Piscom River. The contribution of winter atmospheric precipitation to the formation of FBCP full-time flow in this river was 81.6%. In CCP, the value decreased slightly to 77.4%. The contribution of summer atmospheric precipitation was 18.1% in FBCP and 18.8% in CCP. In bid, the effect of air temperature on the formation of the full-fledged period on the Piscom River was not at all felt (0.3%), while in Jeddah its share was 3.8% (Table 5).

Table 5

Climatic factors in the formation of the flow of rivers full-time contributions [$\delta(X_w)$, $\delta(X_s)$, $\delta(t_s)$], in percentage

№	Rivers	FBCP			CCP		
		$\delta(X_w)$	$\delta(X_s)$	$\delta(t_s)$	$\delta(X_w)$	$\delta(X_s)$	$\delta(t_s)$
1	Chotqol	73,8	22,6	3,60	69,0	29,0	2,00
2	Piscom	81,6	18,1	0,30	77,4	18,8	3,80
3	Ugom	55,3	39,8	4,90	56,4	41,5	2,10

While in almost all the rivers under study, the contribution of winter atmospheric precipitation compared to CCP and FBCP has decreased, an increase in the share of summer precipitation and air temperature has been noted. These results can be explained by the increased participation of the waters of mountain glaciers and permanent snow in the saturation of rivers, due to climate warming, in the Chirchik Basin studied in our review.

According to the analysis of the results of the calculations performed, the proportion of summer air temperature in the formation of the flow of the full-time flow of all rivers became smaller than the efficiency criterion. Therefore, the normalized regression equation, in the example of the Piscom River, was reformulated, not taking into account the summer air temperature:

$$U_0(Q_t) = 0{,}680 \cdot U_1(X_w) + 0{,}320 \cdot U_2(X_s) . \quad (4)$$

The results of calculations performed using these expressions showed that while the proportion of winter atmospheric precipitation in the formation of the Piscom river full-time flow in CCP was 78.9%, the contribution of summer precipitation was 21.1%. So, the precipitation that the river basin liked in the winter season is of priority in the formation of the flow of the full-fledged period.

The above expression (4), i.e. the rearranged normalized regression equation, makes it possible to determine the normalized value of the piscom river full-cycle flow. At the same time, to determine the value of ushubu, it is also required to determine the normalized values of winter and summer precipitation. In order to get rid of these inconveniences, (4) with the help of an expression, a nomogram for calculating the flow of the fullness period was compiled (Figure 1).

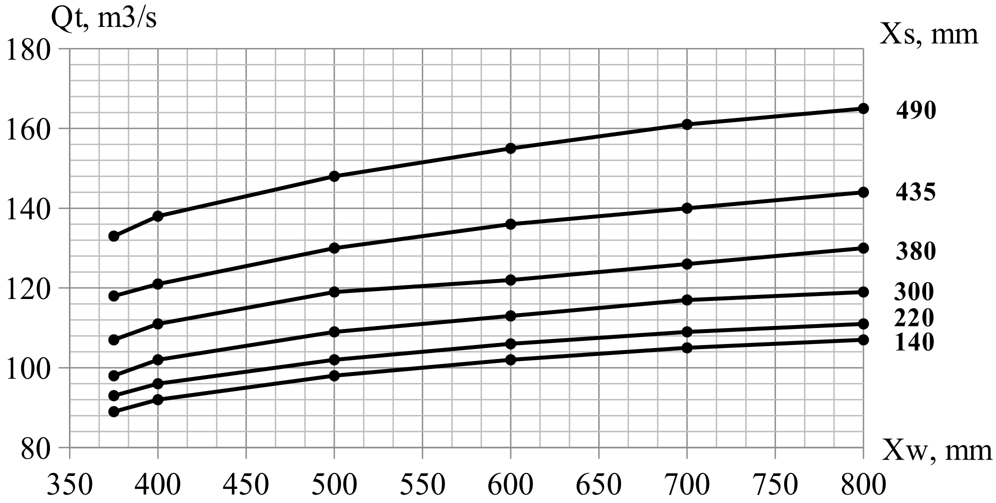

Figure 1. Piscom river full-time flow calculation nomogram

The piscom river flow of the full-time period, depending on the amounts of winter and summer precipitation, was determined from the observed (Q_{to}) and computational nomogram (Q_{ti}) and the values were compared, their absolute (E_a) and relative (E_r) errors were found. Estimates showed that absolute errors averaged 7.75 M3/s, while relative errors averaged 4.64%.

A graphical method was also used to assess the accuracy of the computational nomogram. In this method, a graph of the connection between the water consumption (Q_{to}) observed during the full-time in the Piscom River in Jeddah and their values (Q_{ti}) determined using a nomogram was drawn and analyzed (Figure 2).

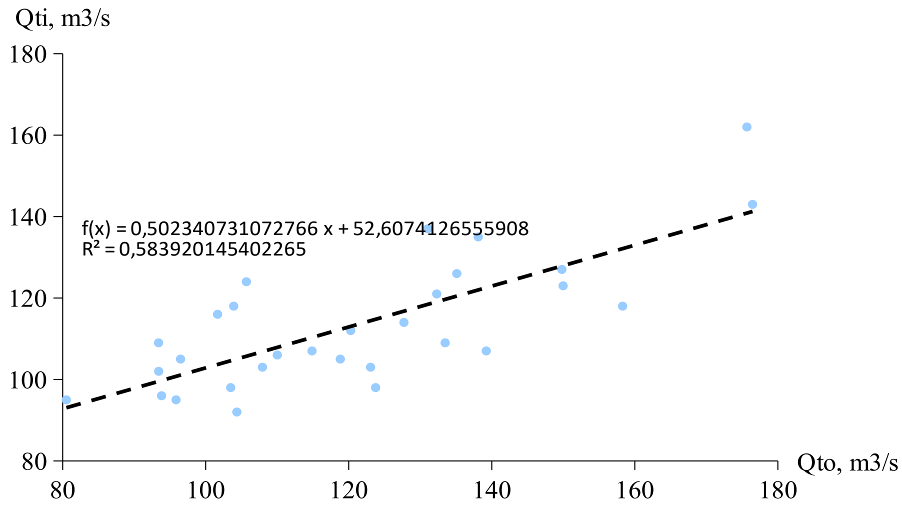

Figure 2. The bond graph between the calculated (Q_{to}) and observed (Q_{ti}) values of the full-time flow

The graph shows that the correlation coefficient and its error representing the correlation of the values of the piscom river full-time flow, determined from the nomogram and observed in practice, was equal to 0.764±0.077. The value of these statistical indicators fully satisfies the requirements for the accuracy of empirical expressions used in hydrological calculations. Due to this, the nomogram developed in the study is recommended for use in assessing the flow of the Piscom river full cycle. In the future, the implementation of assessments in this direction also for other rivers of the studied Basin will allow for more accurate results.

Based on the analysis of the results obtained in the research work, the following conclusions can be noted:

1. Polynomial connections between meteorological factors with the flow of the Chirchiq basin rivers full-time were studied for FBCP and CCP. The values of the full correlation coefficients representing the density of these bonds changed at intervals of 0.882÷0.945 in FBCP and 0.796÷0.871 in CCP;

2. In FBCP, the contribution of winter precipitation to the formation of the chotqol river full-time flow was estimated at 73.8%, that of summer precipitation at 22.6%, and that of summer weather at 3.6%. In this river, the contribution of winter precipitation (69%) in the formation of the CCP full-time flow has decreased compared to FBCP, while in contrast, the proportion of summer precipitation (29%) has increased. Similar results are typical for the Piscom and Ugom rivers in the basin;

3. Normalized regression equations of polynomial connections have been constructed. Their accuracy was evaluated on the example of the Piscom River. They gave an average value of 7.75 m^3/s for absolute errors and 4.64% for relative errors. The bonds obtained in the study are recommended to be used in the practice of hydrological computations.

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