

THE INFLUENCE OF TOKTOGUL RESERVOIR ON THE VARIABILITY OF NARYN RIVER FLOW

Abstract: *The article is devoted to the assessment of the impact of the Toktogul reservoir on the basis of variability of the annual flow of the Naryn River. Toktogul Reservoir is the largest reservoir in Central Asia; its construction began in 1962 and was completed in 1975. The total (designed) water capacity of the reservoir is 19.5 km³, and the useful volume is 14.0 km³. In the study, special attention is paid to the study of influence of the conditions of the reservoir use in the irrigation and energy regimes on the river flow. Statistical indicator of the river flow variability - coefficient of variation (C_v) was determined for three calculation periods.*

Keywords: *river, river flow, natural regime, reservoir, irrigation regime, energy regime, variability, variation coefficient.*

Introduction. The annual flow rates of rivers vary from year to year, that is, if the amount of water in the river is high in one year, it may be less or, on the contrary, even more, in the next year. These quantitative changes depend on climatic factors such as atmospheric precipitation falling on river basins with a natural hydrological regime, changes in air temperature, and they are not subject to a specific law. However, any annual variation in the river flow fluctuates in a range of a certain average value. So, under natural conditions, annual changes in the river flow occur as a result of the influence of meteorological variables - atmospheric precipitation, air temperature and other natural factors.

Besides these, there are also anthropogenic factors affecting the interannual variation of river flows. One of them is reservoirs which were built in the river bed. According to historical data, small reservoirs - ponds were built in the territory of the Central Asian countries at the end of the old era and the beginning of the new

era. The main purpose of their construction was to collect water from small streams and then to use it for irrigation and other purposes.

The main purpose of this work is to evaluate the impact of the Toktogul reservoir on the annual variability of the annual flow of the Naryn River and its distribution throughout the year. To achieve this goal, the following tasks were determined and solved in the research:

- 1) Collecting the data of water consumption measured on the Uchkurgon hydrological station in the Naryn River, their primary processing;
- 2) Dividing the total observation years into different accounting periods, taking into account the operating conditions of the reservoir;
- 3) Calculation of variation coefficients for each accounting period, making relevant scientific and practical conclusions by analyzing the obtained results.

Materials and methods. In the research work, the data of water consumption recorded in the hydrological posts belonging to the Hydrometeorological Service Center under the Ministry of Natural Resources of the Republic of Uzbekistan - Uzgidromet were used. These hydrometeorological data are the results of standard measurements and observations and are therefore considered reliable.

The method of mathematical statistics was widely used to calculate the variability of the river flow, that is, the variation coefficient (C_v) [Rozhdestvensky, Chebotarev 1990]. The values of the variation coefficients were calculated on a computer using standard programs based on the following expressions:

- 1) in the case when the condition of the number of years of observation $n \leq 25$ is satisfied:

$$C_v = \sqrt{\frac{\sum_{i=1}^n (K_i - 1)^2}{n - 1}}; \quad (1)$$

- 2) and when the condition of the number of observation years $n > 25$ is satisfied:

$$C_v = \sqrt{\frac{\sum_{i=1}^n (K_i - 1)^2}{n}}. \quad (2)$$

In the above expressions: n – is the number of observation years; K_i – is the rate of discharge of the river flow, its values were calculated by the following expression:

$$K_i = \frac{Q_i}{Q_0}, \quad (3)$$

where: Q_i – is the average water consumption of the relevant year; Q_0 – is the average multi-year water consumption during the accounting period [Chebotarev 1964].

Results and discussion. The construction of the Toktogul reservoir, located in the upper reaches of the Naryn River, at the confluence of the Big Naryn and the Small Naryn rivers, began in 1962 and was completed in 1975. This reservoir, considered as the largest one in the Central Asia, was put into operation this year. Its total (designed) water capacity is 19.5 km³, and its useful volume is 14.0 km³ [Avakyan et al. 1979]. It is planned to use the reservoir for complex purposes, i.e. for irrigation and hydropower purposes. However, we remind you that during the former Soviet Union, exploitation of the reservoir for irrigation purposes was considered to be the first priority goal.

The following variability of the annual flow of the Naryn River from the Toktogul Reservoir was estimated based on the data of the Uchkurgan hydrological station, as mentioned above. Statistical indicator of river flow variation coefficients were estimated for three calculation periods distinguished above.

The value of coefficient of variation of the annual flow of the Naryn River for the natural water regime, i.e., the calculation period of 1930-1974, was equal to 0.22. This result was compared with the data of V. L. Shults and "Resursy..."

As it was mentioned above, until the beginning of the 90s of the last 20th century, the irrigation regime was the priority goal in the Toktogul reservoir. In the study, taking this situation into account, the variation coefficient was estimated for accounting period II (1975-1994). The variation coefficient of the annual flow of the Naryn River during the second accounting period, when the reservoir was operating in the irrigation mode, was slightly higher than the value estimated in the natural water mode period, and equaled to 0.24. This value showed that during the operation of the Toktogul Reservoir in the irrigation mode, the annual variation of the annual flow values was close to the natural mode.

However, it is worth noting that during accounting period II, a large part of the flow of the Naryn River was used to fill the Toktogul reservoir. In the result of this it occurred that the annual flow of the Naryn River was significantly lower than the norm for several years during this accounting period.

As soon as the Toktogul reservoir began to transit to the energy mode, the annual changes in the flow of the Naryn River and the distribution of the river flow by months during the year began to undergo drastic changes. That is, in the process of the water reservoir transition to the energetic regime, the amplitude of the interannual variability of the river flow was also much lower. The effect of this situation is also reflected in the fact that the value of variation coefficient calculated for accounting period III when the Toktogul reservoir worked in the energy mode is equal to $C_v=0.10$ (Tab. 1).

Table 1

Variation coefficients determined for different calculation periods
of the Naryn River flow

№	Accounting periods (years)	Number of years of observation, n	Variation coefficient, C_v
1	I (1930-1974)	45	0,22
2	II (1975-1994)	20	0,24
3	III (1995-2020)	26	0,10

The exploitation of the reservoir for energy purposes, in turn, had a drastic effect on the distribution of the river flow by months throughout the year. At the next stage of the research, the distribution of the river flow by months during the year was carried out for the calculation periods specified above.

Conclusions.

1. The value of coefficient of variability of the annual flow of the Naryn River in the first accounting period, which belongs to the natural water regime, i.e. 1930-1974, was equal to 0.22. So, during the first accounting period, the annual flow of the river was highly variable from year to year. This result was compared with the data of V.L. Shults and "Resursy...", and their closeness was shown;

2. When the Toktogul Reservoir was put into operation and it worked primarily in the irrigation mode, the variation coefficient representing the interannual variability of the flow of the Naryn River slightly increased as compared with the natural mode, that is, during that period it was equal to $C_v=0.24$. The reasons for this are related to the fact that a large part of the flow of the Naryn River is used to fill the reservoir;

REFERENCES

1. AVAKYAN A.B., SALTANKIN V.P., SHARAPOV V.A. 1987. Vodohranilishcha [Reservoirs]. Moskva. Myisl pp. 326.
2. AVAKYAN A.B., SHARAPOV V.A. etc. 1979. Vodohranilishcha mira [Reservoirs of the world]. Moskva. Nauka pp. 289.
3. BLAGOOBRAZOV V.A., BONDAREV L.G. etc. 1960. Basseyn reki Narin [Naryn river basin]. Frunze. Akademiya nauk pp. 228.
4. CHEBOTAREV A.I. 1964. Gidrologicheskiy slovar [Hydrological dictionary]. Leningrad. Hydrometeoizdat. pp. 223.
5. CHONTOEV D.T., MAMATKANOV D.M. etc. 2022. Vodnie i gidroenergeticheskie resursi Kirgizstana v usloviyax izmeneniya klimata [Water and hydropower resources of Kyrgyzstan in the context of climate change]. Bishkek. Print ekspres. ISBN 978-9967-12-932-0 pp. 400.
6. EDELSHTEYN K.K. 2014. Gidrologiya ozer i vodohranilishch [Hydrology of lakes and reservoirs]. Moskva. Pero pp. 399.
7. KHIKMATOV F., RAPIKOV B.R. 2021. Transfer of the Toktogul reservoir to the energy regime and the problems associated with this process. Scientific and technical journal of Uzbek hydropower. Vol. (2) p. 36-40.

8. KHIKMATOV F., RAPIKOV B.R. 2022. Influence of hydrotechnical facilities on internal runoff distribution of the Naryn river. *Ekonomika i sotsium*. No 10 (101) p. 75-80.
9. MATARZIN YU.M. 2003. *Gidrologiya vodohranilisch* [Hydrology of reservoirs]. Perm. PGU pp. 296.
10. NIKITIN A.M. 1991. *Vodohranilischa Sredney Azii* [Reservoirs of Central Asia]. Leningrad. Hydrometeoizdat pp. 163.