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ASSESSMENT OF THE EFFECT OF WATER RESERVOIRS ON THE HYDROLOGICAL REGIME OF AMUDARYO

Abstract. *The article is devoted to the study of the influence of reservoirs on the hydrological regime of the Amu Darya. For this purpose, the influence of the Norak and Tuyamoya reservoirs on the change in the Amu Darya flow during the year by month and on interannual fluctuations was assessed. The research results make it possible to organize the effective use of transboundary water resources of the Amudarya.*

Key words: *Amudarya, hydrological regime, water reservoirs, hydropower, irrigation, annual flow, fluctuation of river flow, variability, distribution of flow throughout the year, lower bef.*

Introduction. Since the middle of the 20 th century, many reservoirs have been built and put into operation in the Amudarya basin. Among them, the Norak and Tuyamoyin reservoirs are among the largest hydrotechnical facilities in Central Asia. The first of them was built in the upper reaches of the Amudarya, and the second in the lower reaches, for hydropower and irrigation purposes. The Norak Reservoir was fully operational in 1972, and the Tuyamoyin Reservoir in 1979. These reservoirs began to have a great influence on the hydrological regime of the Amudarya, especially on the distribution of the river's flow throughout the year and its interannual variation. But, despite this, studying this issue from a hydrological point of view has been left out of researchers' attention.

The main goal of this article is to study the influence of Norak and Tuyamoyin reservoirs on the hydrological regime of the Amudarya, in particular, on the distribution of the river flow throughout the year and its interannual change, i.e. fluctuation.

Based on the purpose of the research, the following tasks were defined in the article and found their solution in the process of research:

1) Collect and analyze hydrological data about the Norak and Tuyamoyin reservoirs built in the Amudarya basin, as well as the observed hydrological data at the water measuring stations located along the length of the river;

2) Selection of basic hydrological stations that allow to study the annual and interannual changes of the Amudarya flow;

3) assessment of the impact of water reservoirs on the annual and interannual fluctuations of the Amudarya flow based on the data of the selected base hydrological stations.

In accordance with the goals and tasks of the work, the Norak and Tuyamoyin reservoirs, which were built in the Amudarya and its basin and have a great influence on the river flow, were selected as research objects. The subject of the study is the study and assessment of the impact of these hydrotechnical structures, that is, reservoirs on the hydrological regime of the Amudarya, based on the data of the main hydrological stations. In order to achieve the set goal, research methods such as hydrological similarity, geographical comparison, river bed water balance, special hydrological calculations and mathematical-statistical analysis were used in the research process.

Main results and their discussion. It is known that the Norak Reservoir is located in the territory of the neighboring Republic of Tajikistan, and was built in the upper reaches of the Amudarya, more precisely, on the Vakhsh River, which is considered its right tributary. It is one of the largest reservoirs in Central Asia. The water surface area of the Norak reservoir is 98 km^2, the total volume of water collected in it is 10.5 km^3, and the useful volume is 4.5 km^3 (Table 1).

Table 1

Large reservoirs in the Amu Darya basin morphometric indicators

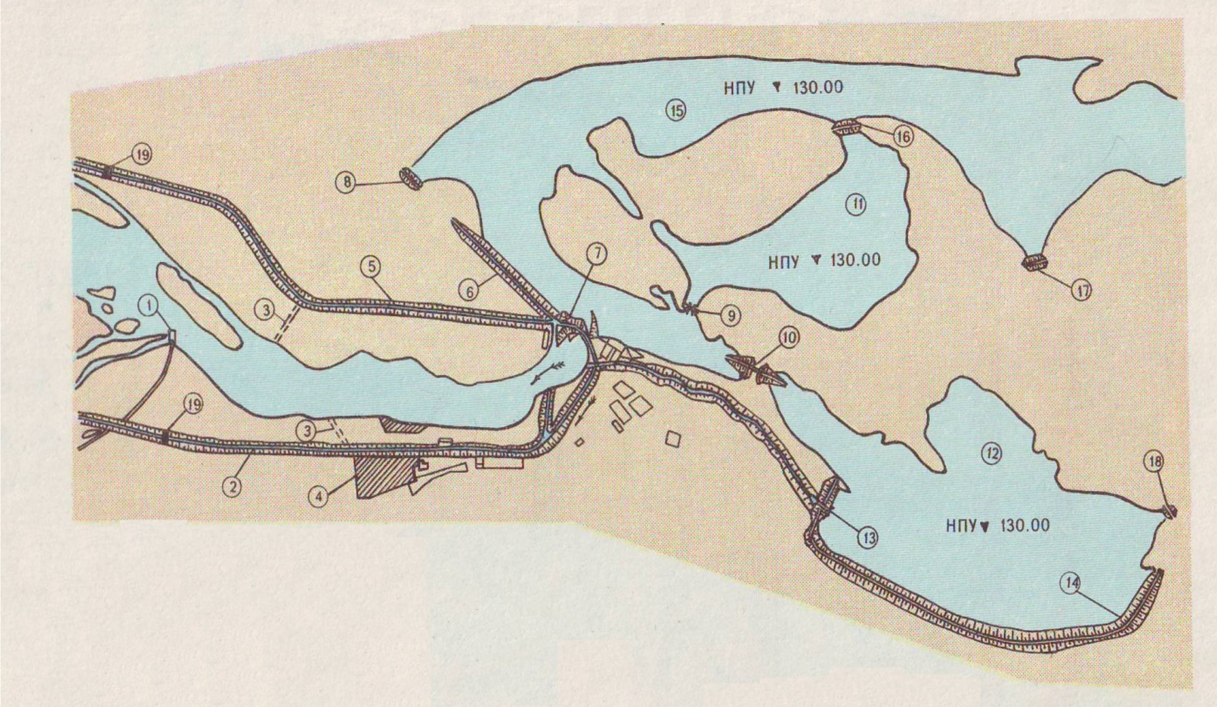
Water reservoir	Dam height, м	Started in the year	Water surface area, км^2	Size, км^3		Power, thousand kW Hour
				Full	Useful	

Norak	310	1972	98	10,5	4,50	2700
Tuyamoyin	130	1979	790	7,80	5,27	150

The Norak Reservoir is designed for seasonal control of the flow of the Vakhsh River, i.e. for regulation and production of electricity. The height of the reservoir dam is more than 310 m, and it is the highest structure in Central Asia. Its gates are able to pass an average water consumption of 645 m^3/s. Currently, the Norak hydropower station produces an average of 2.7 million per year. kWh of electricity is generated.

The construction of the Tuyamoyin reservoir dam in the lower reaches of the Amudarya, in Khorezm region, began in 1970, and the reservoir was fully operational in 1979. This large hydrotechnical facility also serves to seasonally control the flow of Amudarya for irrigation and energy purposes. The reservoir was built in the Amudarya basin and its left bank, in the territory of the neighboring Republic of Turkmenistan, in 3 natural depressions, namely Kaparas, Sultansanjar, Koshbulok (Fig. 1). These depressions, which are the place of ancient lakes, are filled with Amudarya water with the help of special water transfer structures.

The total water capacity of the Tuyamoyin Reservoir is 7,80 km^3 at the standard humidity level, and the water surface area is 790 km^2 (Table 1). An average of 150,000 kWh of electricity is produced at the Tuyamoyin hydroelectric power station per year.



Conventional symbols:

1. The main dam of the Toshsaqa canal 10. Water discharge facility to Sultansanjar
2. Left bank trunk channel 11. Kaparas Reservoir
3. Fishing channel 12. Sultansanjar Reservoir
4. Builders' fortress 13. Deionized water receiving device
5. Right bank main channel 14. Sultansanjar Dam
6. Right Bank Dam, №1 15. Uzan reservoir
7. Hydronodule of the camel's neck 16. Dam, №4
8. Right Bank Dam, №2 17. Dam, №5
9. Kaparas dam 18. Dam, №9

Fig.1. Plan - scheme of Tuyamoyin reservoir

The water collected in the reservoirs described above is used for irrigation, energy, drinking water supply for the population, washing of land and other purposes. Depending on the mode of operation of reservoirs for hydropower purposes and the demand for water, the amount of water stored in them also varies in different values for months and years. In order to study this process, the change of the amount of water collected in the Norak and Tuyamoyin reservoirs by month in 2000-2022 was analyzed (Fig. 2).

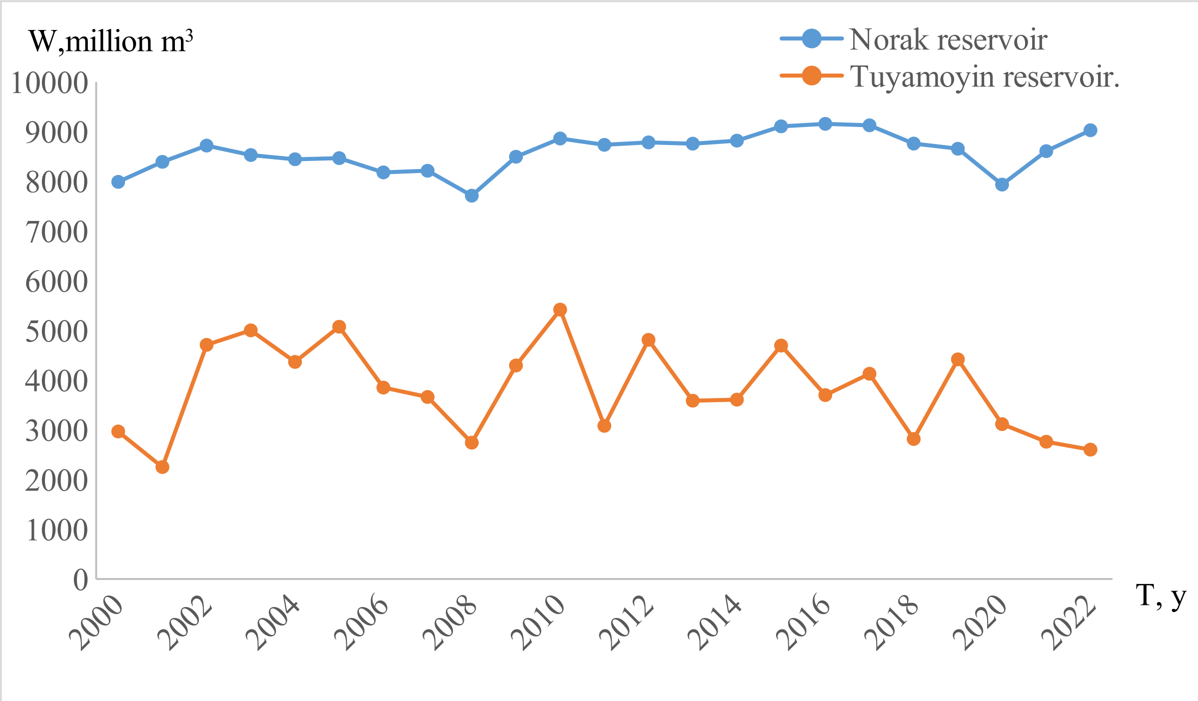


Fig. 2. The amount of water collected in Norak and Tuyamoyin reservoirs Interannual variation of (W).

As can be seen from the diagram, the amount of water collected in the Tuyamoyin reservoir was 2253-3081 million m^3, while the amount of water collected in the Norak reservoir was 8391-8734 million m^3.

It should be noted that during the former Union, these changes were mainly due to the demand for water used for irrigation purposes. For example, in the spring and summer months, that is, during the vegetation period of plants, the amount of water released from them is somewhat larger and is used to irrigate cultivated fields. In winter, water is released from reservoirs mainly for energy purposes. If this situation applies to the Norak reservoir, the water collected in the Tuyamoyin reservoir is also used for the purpose of washing the salt of cultivated fields in the autumn-winter period, as mentioned above.

In the second task set for the realization of the goal set in the article, it was noted the need to select basic hydrological stations. According to this task, Kerki and Tuyamoyin were selected from among the 10 hydrological stations that have been measuring and monitoring the length of the Amudarya. The first of them, i.e. the data on the elements of the water regime measured at the Kerki hydrological station, reflects the influence of the Norak reservoir and the Karakum canal on the

Amudarya flow. It should be noted that the study of the impact of the Karakum Canal on the Amudarya flow is a separate research object. The Tuyamoyin hydrological station located below the Tuyamoyin reservoir of the river is representative in assessing the impact of this reservoir on the Amudarya flow.

Based on the data collected at the Kerki water measuring station, the distribution of Amudarya flow by months during the year was studied for two accounting periods. The first calculation period covers the natural period from 1911 to 1971, that is, the interval until the construction of the Norak reservoir. The second calculation period refers to the years 1972-2022 and reflects the change of the Amudarya flow under the influence of the anthropogenic factor, that is, the Norak reservoir. The distribution of the Amudarya flow by months during the year was studied for the above-mentioned two calculation periods. Calculations were made on the basis of the average multi-year values of monthly water consumption, and the results obtained for both calculation periods were analyzed by mutual comparison (Fig. 3).

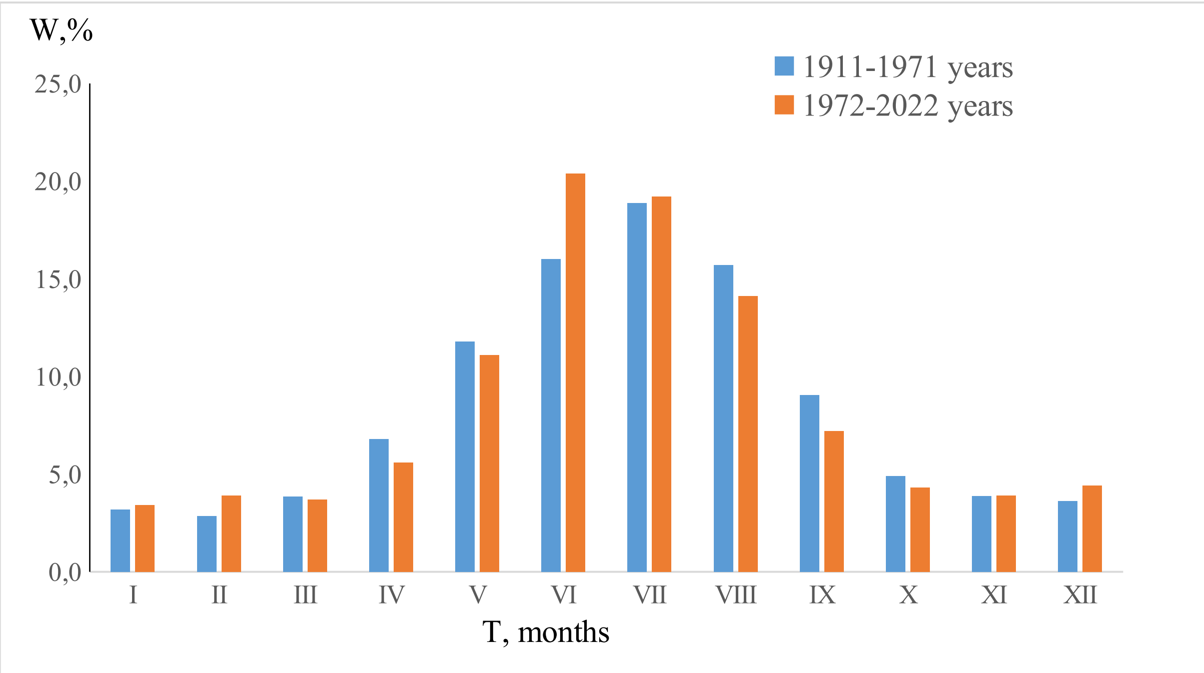


Fig. 3. Distribution of Amudarya flow by months during the year (Kerki post)

As can be seen from this chart, the flow of Amudarya in February was 2,9% of the annual flow in the first calculation period, while it was 16% in June. This indicator increased from 6,8% in April to 15,7% in August. The results of the analysis indicate that in the second accounting period, that is, as a result of the construction of the Norak reservoir, there has been some change compared to the above indicators. For example, in this accounting period, the amount of flow in February was 3,9% compared to the year, and in June it was equal to 20,4 %. So, in the second accounting period, the flow amounts in both months increased compared to the first accounting period.

Based on the data collected at the Tuyamoyin water measuring station, the distribution of the Amudarya flow by months during the year was also analyzed based on two accounting periods. The first accounting period is the natural period of 1953-1979, which includes the period before the construction of the Tuyamoyin reservoir. The second calculation period refers to the years 1980-2022 and shows the change of the Amudarya flow under the influence of the anthropogenic factor, that is, the Tuyamoyin reservoir. The distribution of the Amudarya flow by months during the year was studied for the above-mentioned two calculation periods. Calculations, as above, were performed on the basis of the average multi-year values of monthly water consumption in both calculation periods, and the obtained results were compared (Fig. 4).

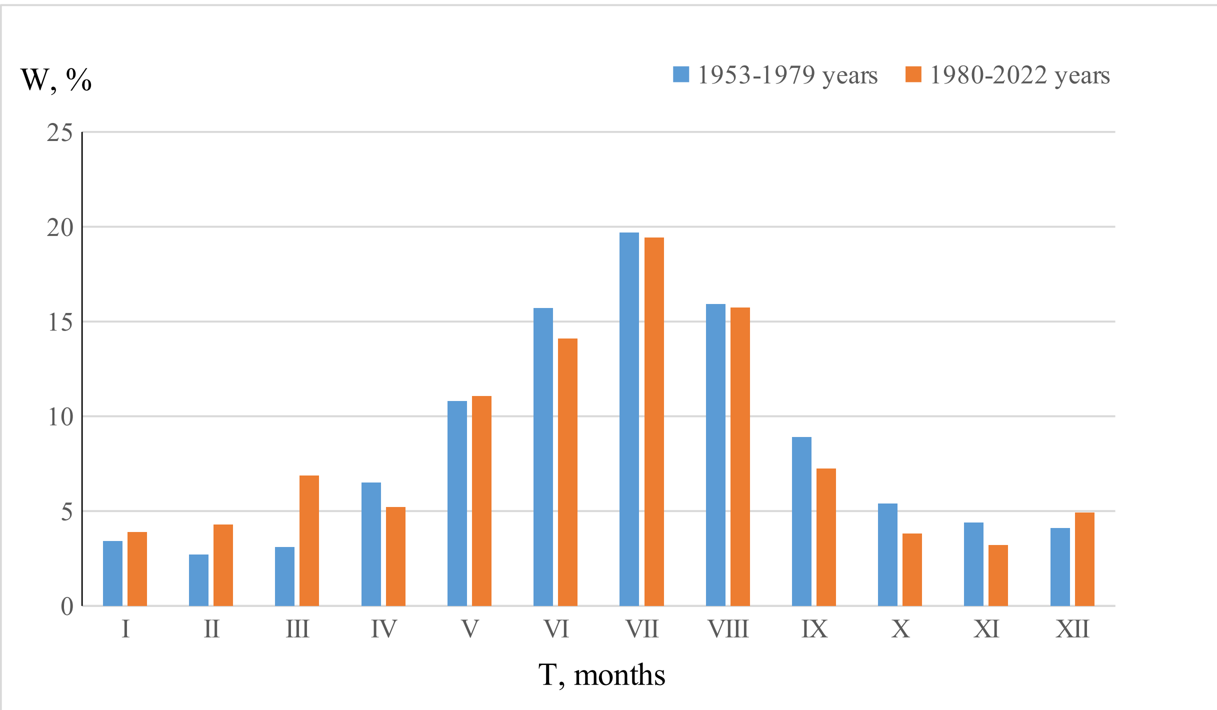


Fig. 4. Distribution of Amudarya flow by months during the year (Tuyamoyin post)

As shown in the above diagram, during the first accounting period, i.e. 1953-1979, before the construction of the Tuyamoyin reservoir, the flow of Amudarya in February was equal to 4,3% of the annual flow, while in July it was 19,7%. This indicator increased from 6,5% in April to 15,9% in August.

In the second accounting period, i.e. after the commissioning of the Tuyamoyin reservoir, the above indicators have changed somewhat. In this period, it was 4,3% in February, and 19,4% in June. So, in this accounting period, the amount of flow in June decreased by 1,7% compared to the first accounting period.

In the article, special attention was paid to the assessment of the effect of Norak and Tuyamoyin reservoirs on the interannual fluctuation of the Amudarya flow. For this purpose, the coefficient of variation (Cv) representing the variability of the river's annual flow was calculated for the aforementioned accounting periods based on the data of both hydrological stations (Table 2).

Table 2

Kerki and Tuyamoyin hydrological stations of Amudarya coefficients of variation of observed annual flow

Kirky		Tuyamoyin	
Accounting period	C_v	Accounting period	C_v
1911-1971	0,18	1953-1979	0,27
1972-2022	0,23	1980-2022	0,41

As shown in the table, the coefficient of variation of the Amudarya flow was equal to 0,18 in 1911-1971 at Kerki post. This value increased by 0,23 for the period 1972-2022. Also, according to the data of the Tuyamoyin hydrological station, the coefficient of variation was equal to 0,27 for the first calculation period, while this indicator was 0,41 for the second calculation period. This result indicates that the flow of the Amudarya is controlled according to the water demand by means of the Tuyamoyin Reservoir. In order to study this issue, the dynamics of flow quantities released from reservoir dams to their lower reaches were studied. The analyzes were performed on the basis of the average annual water consumption recorded in both reservoirs during the years 2000-2022 at our disposal (Figure 5).

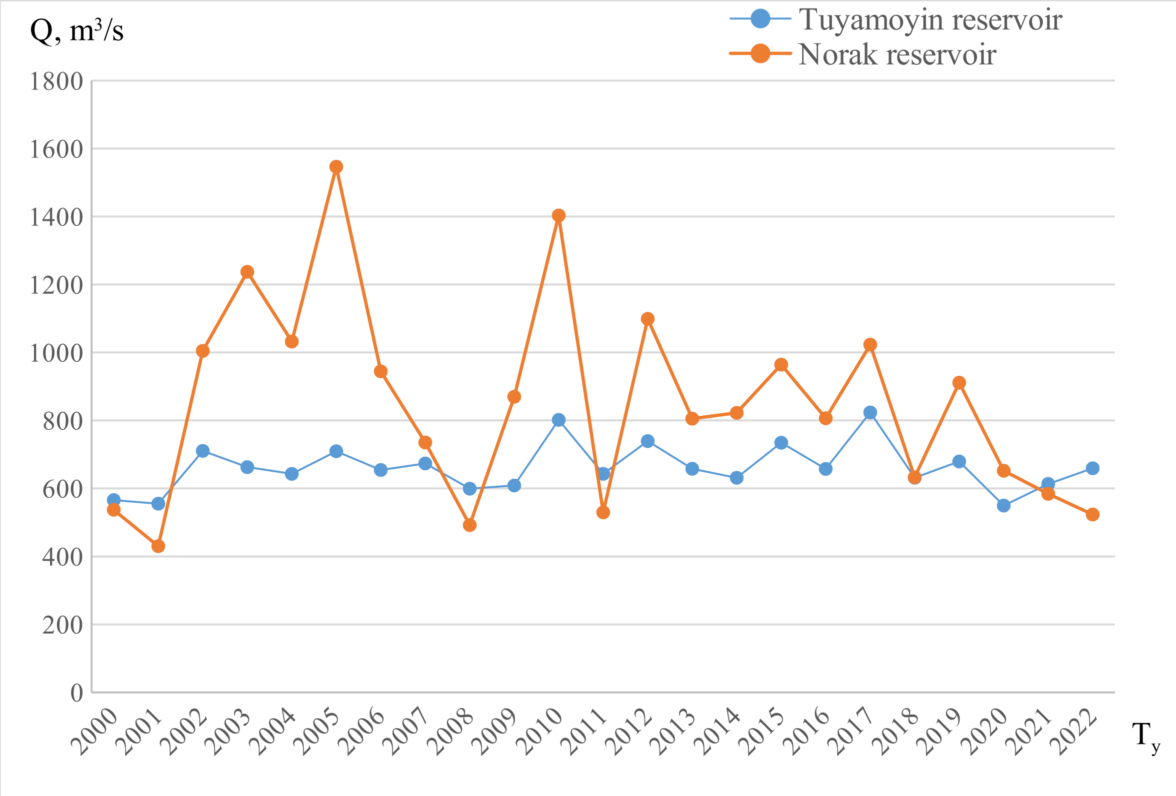


Fig. 5. Changes in the average annual flow from the Norak and Tuyamoyin reservoirs to the lower bef

As can be seen from the diagram, in 2001, 9,8 km^3 of water was released from the Norak reservoir, and 16,6 km^3 of water was discharged from the Tuyamoyin reservoir. The consumption of water from both reservoirs to the lower bef was observed in 2005-2010-2013 at the highest values. These numbers show that these years were full of water in the Amudarya and its main tributaries.

Based on the results of the research, the following can be noted as a conclusion:

1. Hydrological data about the Tuyamoyin reservoir in the Amudarya and the Norak reservoirs built on the Vakhsh River, its right tributary, as well as the

observed hydrological data at the water measuring stations located along the length of the Amudarya, were collected and analyzed;

2. Depending on the goals and tasks defined in the work, basic hydrological observation posts were selected that would allow researching the annual and interannual changes of the Amudarya stream under the influence of the Norak and Tuyamoyin reservoirs;

3. Based on the hydrological calculations and their analysis, the impact of the Norak and Tuyamoyin reservoirs on the change of the Amudarya flow during the year by months and on the interannual fluctuation was evaluated. The results of the research allow to organize the effective use of transboundary Amudarya water resources.

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