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ASSESSMENT OF THE HYDROLOGICAL REGIME OF THE SANGZOR RIVER

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Abstract
This study presents an assessment of the hydrological regime of the Sangzor River basin using a multidisciplinary methodological approach. The analysis is based on long-term hydrological observations (2000-2023) of water discharge, flow volume, and turbidity provided by the Uzbekistan Hydrometeorological Service (Uzhydromet), as well as design and operational data from the Jizzakh Reservoir (2005-2023). Hydrological calculations included the determination of average, maximum, and minimum water discharges, coefficients of variation (Cv) and skewness (Cs), and flow modulus (l/s·km²). Seasonal distribution of flow was evaluated using the Gumbel distribution law, and return periods of maximum discharge (1%, 5%, and 10%) were estimated through probabilistic analysis. The results provide a reliable scientific basis for effective water resource management, irrigation planning, and ecological monitoring in the Sangzor River basin.

Keywords: Sangzor River, hydrological regime, water discharge, flow variability, Gumbel distribution, return period, irrigation, water resource management.

Introduction

Studying the hydrological regime of the Sangzor River basin, located in the western part of the Western Tien Shan within the Central Asian region, is of significant relevance in the context of rational regional water resource management and ensuring ecological sustainability. The Sangzor River is part of the Zarafshan River system, and its hydrological characteristics are determined by the basin's specific geomorphological structure, relief forms, climatic parameters, and a complex of anthropogenic influences. Although numerous studies exist on the hydrology of Central Asian rivers, the hydrological regime of the Sangzor River requires particular attention due to its unique geographic conditions.

Modern hydrological research methodologies, including geoinformation systems (e.g., modeling hydrographic networks and delineating catchment areas using GIS), expand the possibilities for comprehensive assessment of the Sangzor River's hydrological regime. At the same time, anthropogenic factors, particularly the operation of the Jizzakh Reservoir and the development of irrigation systems, have a significant impact on the river's natural flow regime.

The aim of this study is to analyze the geomorphological characteristics of the Sangzor River basin in the context of hydrological processes, evaluate the seasonal dynamics of river flow, water discharge, and turbidity, and systematically investigate the influence of human activities on the hydrological regime, thereby providing a scientific basis for addressing regional water management challenges.

Main Body

The hydrological regime of the Sangzor River is shaped by a combination of its morphometric characteristics, climatic conditions, and anthropogenic influences. The river has a length of 198 km and a basin area of 3220 km² (mountainous region). These key parameters reflect its limited water resources and relatively low average discharge (long-term mean 2,12 m³/s, with some sources reporting up to 4,2 m³/s), classifying it as a low-water river.

Figure 1. Sangzor River (Jizzakh Region)

The river's flow is primarily formed by the melting of snow and glacier masses (source altitude ~3400 m) and atmospheric precipitation (rainfall). The combined effect of these two factors results in a clearly expressed seasonal distribution of discharge. Studies show that 60-70% of the annual water volume flows during March-June, with peak discharge typically occurring in May. This period corresponds to the intensification of spring snowmelt and rainfall. The

Sangzor River has a well-developed hydrographic network, receiving contributions from more than 80 small streams and tributaries, including Khojasoy, Boyqongirsoy, Kokjarsoy, Oqqorgonsoy, Tangatopdisoy, Baxmazarsoy, and others. However, most of these tributaries dry up under semi-arid climatic conditions or are active only during the rainy season. The zones of effective contribution of these rivers can be observed mainly in the upper and middle reaches (in the Baxmal and Gallaorol areas).

Materials and Methods

A multidisciplinary methodological approach was applied to assess the hydrological regime of the Sangzor River basin. The study utilized long-term (2000-2023) observations of water discharge, flow volume, and turbidity provided by the Uzbekistan Hydrometeorological Service (Uzhydromet), as well as design and operational data from the Jizzakh Reservoir (2005-2023).

Hydrological calculations included the determination of long-term average, maximum, and minimum discharges, coefficients of variation (Cv) and skewness (Cs), and flow modulus (l/s·km²). The seasonal distribution of flow was evaluated using the Gumbel distribution law, and the return periods of maximum discharge (1%, 5%, and 10%) were estimated through probabilistic analysis.

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Results

This study presents the main results and their statistical analysis obtained from the assessment of the hydrological regime of the Sangzor River over the period 2000-2023. Data processing and analysis were carried out based on the methodological approach described above.

First, the key hydrological characteristics of the river were analyzed. The main statistical parameters of the Sangzor River for the observation period (2000-2023) include average, maximum, and minimum discharges, the coefficient of variation (Cv), skewness (Cs), and flow modulus (l/s·km²). These parameters are presented in the following table 1.

Table 1. Main hydrological characteristics of the Sangzor River (2000-2023)

Parameter	Value	Description
Long-term average discharge (Q_0)	2,12 m³/s	Average value over the observation period
Maximum discharge (Q_{max})	4,20 m³/s	Highest recorded value
Minimum discharge (Q_{min})	0,34 m³/s	Lowest recorded value
Coefficient of variation (C_v)	0,68	Interannual variability of river flow
Coefficient of skewness (C_s)	1,36	Asymmetry of flow distribution

The above indicators show that the Sangzor River is characterized by a relatively low average water availability; however, its flow regime is highly variable throughout the year (C_v = 0,68). The ratio between the maximum and minimum discharges reaches 12,3 times (4,20 / 0,34), which confirms the sharply continental nature of the river regime. The relatively low value of the runoff modulus (6,58 l/s·km²) indicates the arid climatic conditions of the river basin.

The monthly distribution of the annual runoff volume demonstrates a clearly pronounced seasonality (Table 2). The calculated distribution reveals that the river flow is mainly governed by snowmelt processes and local precipitation patterns.

Moreover, the long-term average monthly discharge of the Sangzor River for the period 2000-2023 was analyzed, and its seasonal variation is illustrated in Figure 2.

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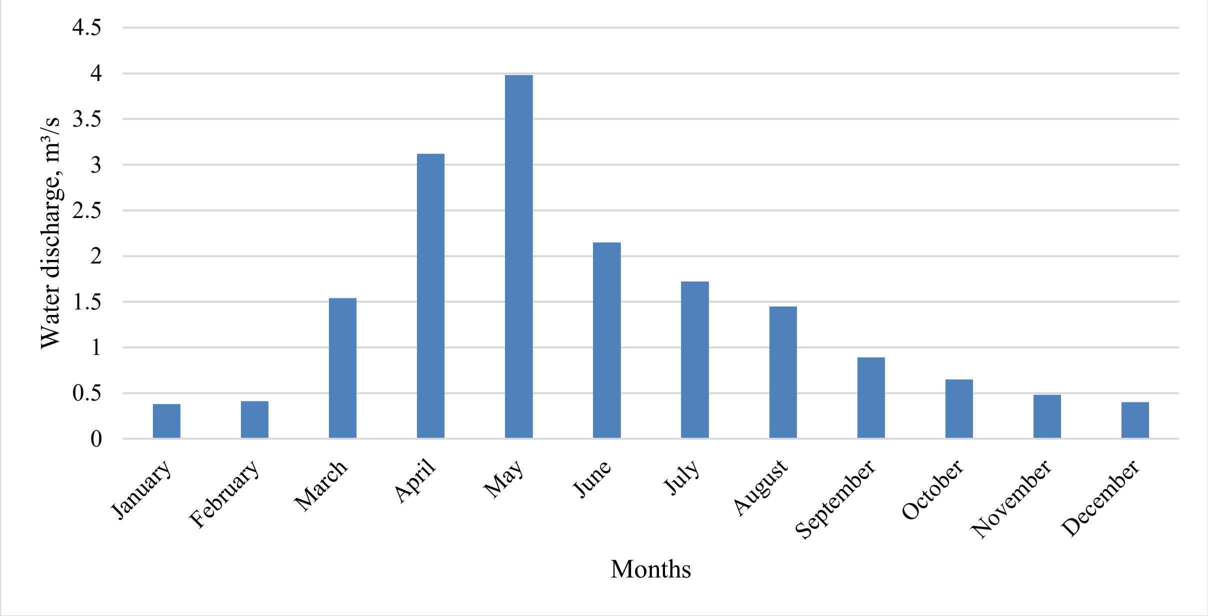

Figure 2. Seasonal variation of the long-term average water discharge of the Sangzor River (2000-2023)

Figure 2 illustrates the monthly variation of the long-term average water discharge of the Sangzor River for the period 2000-2023. As can be seen from the graph, water discharge reaches its lowest values during the winter months (January-February), while a sharp increase is observed in spring, particularly in April-May, with the maximum discharge occurring in May (3,98 m^3/s). During the summer months, water discharge gradually decreases, and in autumn it approaches its minimum levels. This pattern indicates that the river flow is mainly formed by snowmelt and rainfall, reflecting a clearly pronounced seasonal hydrological regime.

Table 2. Average Monthly Water Consumption and Seasonal Share of Flow

Month	Share of Annual Flow (%)
January	2,3
February	2,4
March	9,1
April	18,5
May	23,6
June	12,7
July	10,2
August	8,6
September	5,3
October	3,9
November	2,8
December	2,4
MARCH - MAY	51,2
MARCH - JUNE	63,9

The analysis shows that nearly 64% of the annual runoff occurs during the March-June period, while 51% is concentrated solely in March-May. The maximum water discharge is observed in May (3,98 m³/s), whereas the minimum discharge occurs in January (0,38 m³/s). This clearly indicates that the natural flow regime is primarily controlled by spring snowmelt and summer rainfall. The contribution of rainfall-induced summer runoff (July-August) is also significant (18,8%), indicating a potential risk of local flood events during this period.
The maximum discharges calculated using the Gumbel probability distribution for different return periods are presented in the following table. This analysis is essential for the design of hydraulic structures and for flood risk assessment.

Table 3. Maximum Water Discharge for Different Return Periods

Return Period (years)	Probability (%)	Calculated Maximum Discharge (m³/s)
100	1	6,85
50	2	6,10
20	5	5,20
10	10	4,65
5	20	4,05

According to calculations, the maximum water discharge that may occur once in 100 years can reach 6,85 m³/s. This value is of significant importance for assessing the water conveyance capacity of existing hydraulic structures, particularly the dam and spillways of the Jizzakh reservoir.
The reliability curve for the Jizzakh reservoir, calculated using the Gumbel method, is shown in Figure 3.

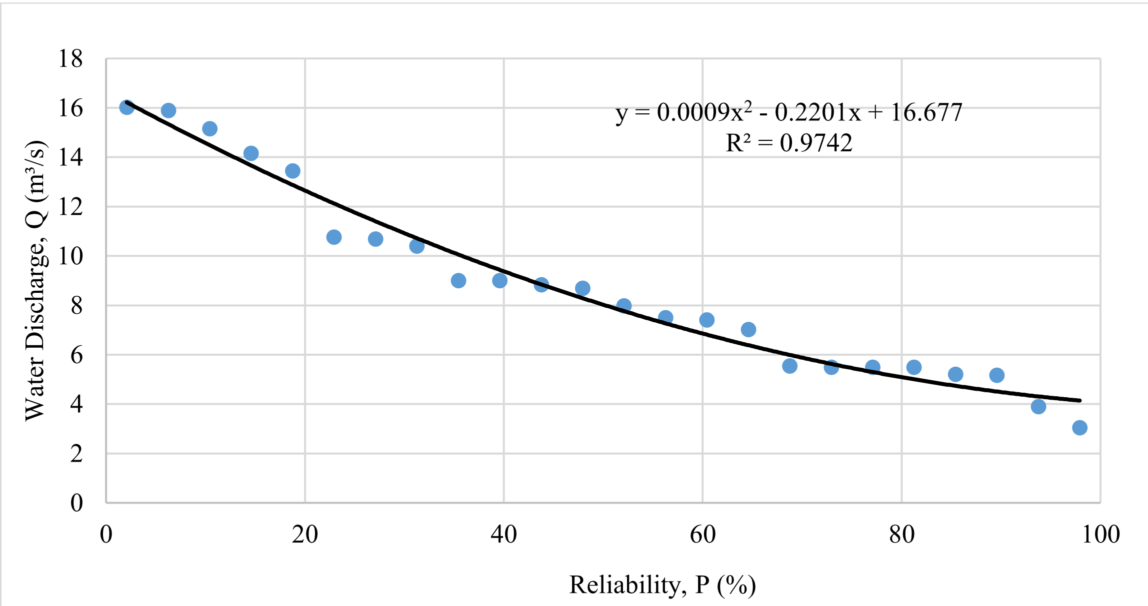

Figure 3. Reliability Curve Calculated Using the Gumbel Method (Jizzakh Reservoir)

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As shown in Figure 3, the reliability curve of water discharge for the Jizzakh Reservoir, determined based on the Gumbel distribution, exhibits a decreasing pattern. An increase in the reliability level corresponds to a consistent reduction in water discharge values. The constructed regression model demonstrates a high degree of fit, with a coefficient of determination of $R^2 = 0{,}97$, confirming the statistical reliability of the calculated hydrological parameters.
The Mann-Kendall trend test was applied to the series of annual average water discharge for the period 2000-2023. The results did not indicate a statistically significant decreasing trend ($Z = -0.95$, $p > 0{,}05$). Nevertheless, seasonal variations were observed, including a tendency for the peak of maximum water discharge to shift earlier in spring (April-May), as well as an intensification of water scarcity during the summer-autumn period. These phenomena may be early indicators of regional climate change.

Conclusion
The conducted study allowed the following main conclusions to be drawn:
– Analyses based on observational data from 2000-2023 indicated that the average multi-year water discharge of the Sangzor River is 2,12 m³/s. During the observation period, the maximum discharge reached 4,20 m³/s, while the minimum was 0,34 m³/s, resulting in a ratio of maximum to minimum values of 12,3. The coefficient of variation $Cv = 0{,}68$ indicates a high interannual variability of the river flow, while the skewness coefficient $Cs = 1{,}36$ confirms that the flow distribution exhibits positive skewness. The flow module is 6,58 l/s·km², indicating a low water availability in the basin.
– Analysis of average monthly discharges showed that 63,9% of the annual flow occurs during March-June, and 51,2% during March-May. The maximum average monthly discharge occurs in May (3,98 m³/s), while the minimum occurs in January (0,38 m³/s). These results indicate that the flow of the Sangzor River is primarily formed by spring snowmelt and precipitation.
– Based on the Gumbel distribution, the maximum water discharges were determined as follows: 6,85 m³/s for 1% probability (100-year return period), 5,20 m³/s for 5% probability, and 4,65 m³/s for 10% probability. The reliability curve constructed for the Jizzakh Reservoir demonstrates a high statistical fit, with the regression model achieving a coefficient of determination of $R^2 = 0{,}97$.
– The Mann-Kendall trend test applied to the annual average discharge series for 2000-2023 did not reveal a statistically significant trend ($Z = -0{,}95$, $p > 0{,}05$). Nevertheless, seasonal shifts were observed, including an earlier occurrence of maximum discharge in spring and an intensification of water scarcity during the summer-autumn period.
The obtained results provide a reliable scientific basis for water resources management in the Sangzor River basin, assessment of the operational regime of the Jizzakh Reservoir, and planning of irrigation systems.

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