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Original paper

Assessment of environmental flow requirements in the transboundary Irtysh River basin for water resources allocation considering ecosystem needs

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ABSTRACT

Relevance. The transboundary Irtysh River basin is characterized by intensive economic development, transformation of the natural water regime, and increasing water demand. This creates a need for scientifically grounded recommendations on water resources allocation among the riparian countries. At the same time, there are no agreed water allocation mechanisms in the basin that take ecosystem requirements into account. In global water resources management practice, such requirements are taken into account through the concept of environmental flow. This study presents an assessment and justification of environmental flow parameters for the Irtysh River to enable their consideration in developing recommendations for water allocation. **Methods.** The study is based on the analysis of water use and the state of the Irtysh transboundary basin ecosystems, as well as long-term hydrological observations including the data on reconstructed conditionally natural flow series. The method of critical hydrological conditions is used to substantiate environmental flow parameters, with floodplain inundation as the key indicator. Calculations are performed for the Irtysh–Tatarka gauging station located near the Russia-Kazakhstan border considering the specific features of flow formation in the river reach under study. **Results.** Functions and indicative parameters of environmental flow are identified. The preliminary environmental flow value is about 80 per cent of the annual conditionally natural flow volume. The importance of maintaining environmental flow during the spring–summer period is highlighted; maintaining May flow volumes above 4 km³ are considered as a hydrological condition necessary for floodplain inundation. These results may provide a basis for incorporating ecosystem requirements into water allocation mechanisms in the transboundary Irtysh River basin.

KEYWORDS: the Irtysh River, transboundary basin, water allocation mechanisms, environmental flow, aquatic ecosystems, floodplain

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INTRODUCTION

The Irtysh River flows through China, Kazakhstan and Russia and is an important source for water supply, industry, hydropower and agriculture in the three countries. Water resources of the transboundary basin are unevenly distributed. Intensive economic activities, including flow regulation by a large cascade of dams and power stations in Kazakhstan, water withdrawal and flow diversions in Kazakhstan and China, have significantly transformed the natural water regime. At the same time, deteriorating water quality additionally reduces the suitability of water resources for use and negatively affects the stability of aquatic ecosystems. In this regard, the problem of coordinated allocation of the Irtysh River flow is of fundamental importance. Increasing water consumption in China and Kazakhstan, predicted growth of wastewater volumes, decreasing flow in certain reaches of the Irtysh River, and climate changes reinforce the need to develop sound recommendations for water allocation.

There are no agreed water allocation mechanisms between countries in the transboundary Irtysh basin. The Agreement in force between the Governments of the Republic of Kazakhstan and the Russian Federation on the Joint Use and Protection of Transboundary Water Bodies (2010) does not set quantitative parameters for water allocation, which, among other things, limits assessment of ecosystem needs in water resources management.

In international practice, ecosystem needs in water resources management are addressed through the concept of environmental flow [1-6]. It is defined as a part of water resources preserved in a water body to maintain structural and functional integrity of aquatic and coastal ecosystems, as well as related ecosystem services of socio-economic importance [3, 4]. The purpose of establishing and implementing environmental flow is generally not to preserve aquatic ecosystems in their natural state. In international practice, it is considered a tool for defining specific water-use rules for each water body based on a balance between ecosystem and socio-economic needs. Despite significant progress in the development of methods for assessing environmental flow, its practical implementation remains a difficult task in many countries of the world [1, 5, 6].

In the Irtysh River basin, environmental flow has not yet been used to solve problems of transboundary water allocation.

The purpose of this study is to assess environmental flow parameters of the Irtysh River to take ecosystem needs into account when developing recommendations for water allocation. The study objectives include analyzing the ecosystem functions of the river and their relationship with the hydrological regime, substantiating goals and parameters of environmental flow, as well as assessing the compliance of the current water regime of the Irtysh River with the proposed recommendations on the environmental flow regime. A distinctive feature of the study is its focus on environmental flow from the perspective of water resources management in a transbound-

ary basin. The study focuses on the water management system of the Irtysh River in its middle reach, a transboundary section between Kazakhstan and Russia that plays a key role in forming the flow entering the territory of Russia.

RESEARCH MATERIALS AND METHODS

The study is based on the analysis of materials on water use and the state of ecosystems in the transboundary basin of the Irtysh River, as well as on processing long-term hydrological observations. To characterize the water regime, average monthly, seasonal, and annual flow values from the Tatarka and Omsk gauging stations in Russia were used. The features of floodplain inundation were assessed based on observations in Pavlodar on the territory of Kazakhstan. Tatarka station (the boundary gauging station on the Irtysh) was chosen to determine the environmental flow.

The study included reconstructing the conditionally natural flow series and adjusting the observations to the boundary gauging station. When reconstructing the conditionally natural flow, features of flow formation were taken into account both in the section from the Shulbinskaya HPP to Tatarka station and in the Tatarka – Omsk section located downstream; the contribution of lateral inflow in these areas may be significant in some years. The lateral inflow between the gauging stations was determined based on data from the joint observation period under the conditionally natural flow regime.

To determine functions of environmental flow, the current state of ecosystems in the transboundary section of the Irtysh River was analyzed. Abiotic and biotic characteristics reflecting the degree of transformation of the hydrological regime and the functioning of aquatic and floodplain ecosystems were taken into account. The features of the water management system in the middle reaches of the Irtysh River were also considered.

Environmental flow was calculated using the method of critical hydrological conditions [7], which allows determination of the minimum allowable (critical) flow volume required to maintain the productivity of river and floodplain ecosystems. Floodplain inundation was used as an indicator of critical conditions because of the high importance and well-developed nature of floodplain ecosystems in the Pavlodar region of Kazakhstan within the study area. According to methodological provisions, calculations of environmental flow should be performed at the basin outlet gauging station. However, in this study, the Tatarka station on the Irtysh is used as a target gauging station. The absence of large tributaries between the Shulbinskaya HPP and Tatarka station minimizes distortions in the estimates associated with the inflow from large downstream tributaries. This adaptation of the method provides a reasonable assessment of environmental flow at the outlet of the section between the Shulbinskaya HPP and Tatarka station.

RESULTS

Substantiation of environmental flow objectives based on an assessment of the state of ecosystems in the Irtysh basin

The section of the Irtysh River under consideration is characterized by low lateral inflow, significant flow losses due to evaporation and water intake, and high dependence on the inflow from the upstream territories. The flow in this section supplies water to the southern arid regions of the Russian part of the basin, including Omsk and the Omsk region.



Fig. 1. Location of the Upper Irtysh reservoir cascade and gauging stations on the Irtysh River

The current state of the Irtysh is determined by significant anthropogenic transformation of the hydrological regime. Kazakhstan has a cascade of large reservoirs – the Bukhtarma reservoir, the Ust-Kamenogorsk reservoir, the Shulbinsk reservoir, which have significantly changed the seasonal flow dynamics since the 1960s. Additional impacts result from water withdrawals in China and Kazakhstan, as well as the diversion of part of the flow through the Irtysh–Karaganda canal (about 1.1 km^3 per year with a design capacity of 2 km^3 per year) (Fig.1). Flow regulation limits the occurrence of ecologically significant floods and related floodplain inundation processes.

The reduction in flood volume limits the frequency and duration of floodplain inundation, which significantly affects the valuable floodplain ecosystems of the middle reaches of the Irtysh, a significant part of which (about 90 per cent) is located in the Pavlodar region of Kazakhstan (Fig. 2) [8]. Despite the specified environmental releases from the Shulbinsk Reservoir, their parameters often do not meet ecosystem requirements, resulting in degradation of floodplain areas, a reduction in inundated area, and decreased bioproductivity.

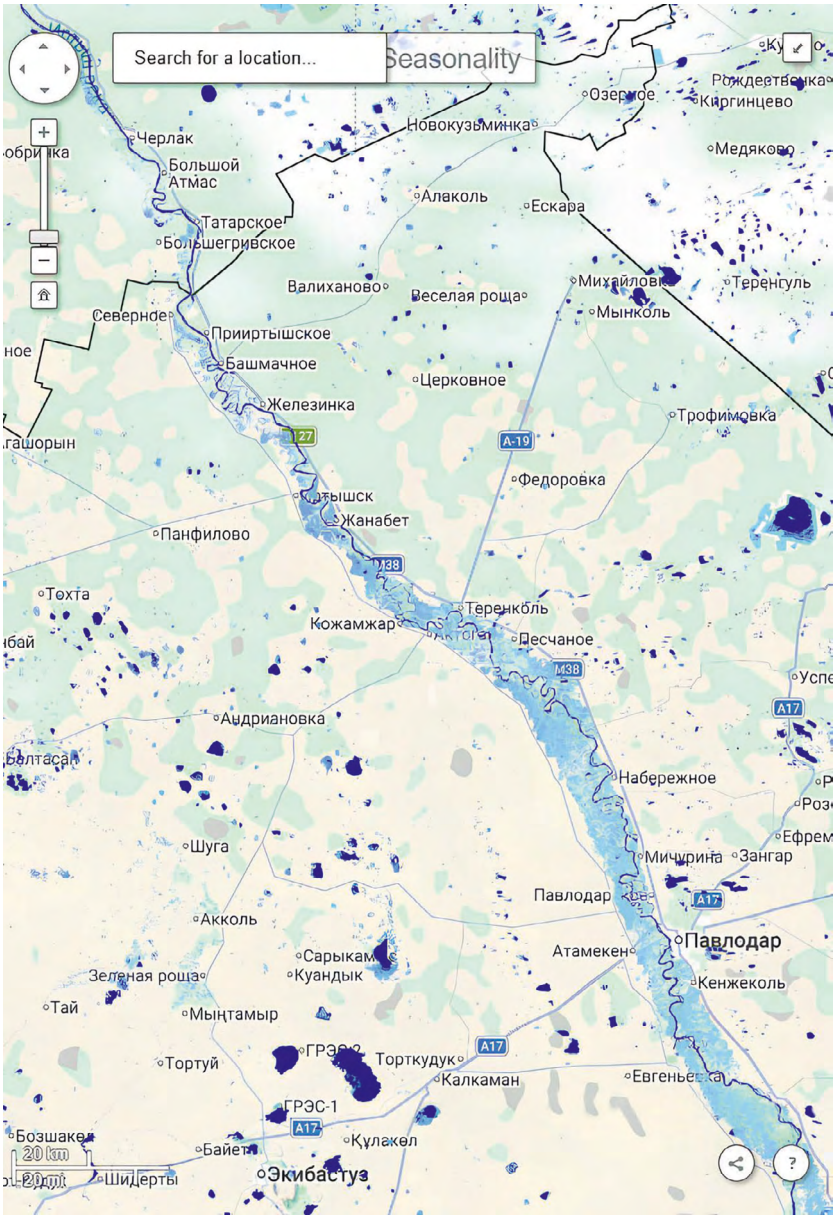


Fig. 2. Well-developed floodplain ecosystems of the middle reach of the Irtysh River in the Pavlodar Region, Kazakhstan[1]

One of the important problems in this area affecting the state and functioning of aquatic ecosystems is the poor water quality of the Irtysh River. In recent years, it has been assessed to be “moderately polluted” or “polluted” in Russia, and “polluted” in the Omsk region [10]. Transboundary pollution with heavy metals remains a significant problem [11]. The river’s self-purification capacity is closely related to the flow volume and regime.

1 https://global-surface-water.appspot.com/map

Despite the high anthropogenic load and the effects of regime transformation, the ecosystem of the middle Irtysh retains a complex structure. A total of 575 species and intraspecific taxa, including 127 rare taxa, have been identified in the phytoplankton of the Russian part of the basin, which indicates a high level of biodiversity. At the same time, the taxonomic structure of phytoplankton reflects an increase in eutrophication processes, while the composition of zooplankton and zoobenthos is significantly depleted. The number of zooplankton species has decreased from 74 to 17, while zoobenthos is represented mainly by chironomids [12]. This indicates a simplification of the structure of aquatic ecosystems and, consequently, a decrease in their stability.

The ichthyofauna of the Irtysh within the Omsk region comprises 19 fish species and subspecies, including valuable and protected species. The Red Book of the Russian Federation lists sturgeon, while the Red Book of the Omsk region lists sturgeon, nelma, spined loach, Siberian sculpin, and two species of lampreys [12, 13]. The presence of protected and vulnerable species highlights the importance of the hydrological regime in providing conditions for fish reproduction and migration.

In the future, an increase in water use and consumption in the Irtysh basin in Kazakhstan and a possible increase in water withdrawals in the upper reaches of the river in China[2] are predicted [14]. These factors increase pressure on the transboundary area and raise the environmental risks associated with water use.

Thus, the Irtysh transboundary area under study is characterized by transformation of the seasonal flow regime, degradation of floodplain ecosystems, deterioration of water quality, and reduced stability of aquatic ecosystems in the presence of protected species. In the context of projected growth in water use in China and Kazakhstan, as well as the high socio-economic importance of the river to the basin countries, the environmental flow regime is of particular importance for limiting excessive water withdrawals and maintaining ecosystem stability.

Under conditions of intensive economic development and a significantly altered hydrological regime of the Irtysh River [15], environmental flow is aimed at maintaining the functioning of aquatic ecosystems under transformed conditions rather than restoring their natural state.

Taking into account the identified features, the main functions of environmental flow for the section of the Irtysh River under study are:

– maintaining the portion of flow that meets ecosystem needs and limits excessive water withdrawals;

– maintaining sustainable functioning of valuable floodplain ecosystems in the middle reaches of the river.

Ensuring the regime of environmental flow can also contribute to maintaining

2 The Concept for the Development of the Water Resources Management System of the Republic of Kazakhstan for 2024–2030 // Legal Collection / International Fund for the Salvation of the Aral Sea Interstate Coordinating Water Management Commission of Central Asia, Scientific and Information Center. Tashkent: SIC ICWC, 2024. No. 59.

the processes of self-purification and improvement of water quality. However, these effects are considered to be secondary outcomes and are not regarded as direct functions of environmental flow.

CALCULATION OF ENVIRONMENTAL FLOW

Definition of critical and limiting conditions

The critical conditions method [7] is based on identifying the parameters of the water regime that determine the maximum permissible (critical) conditions for the functioning of aquatic and floodplain ecosystems, including fish reproduction processes, the existence of near-aquatic biota, and riverbed formation processes. The critical annual flow (W_{cr}) is determined by the years of minimum floodplain inundation and characterizes the lower limit of hydrological conditions under which the ecosystem retains its ability to function. Such conditions, as a rule, are formed in low-water years.

The Irtysh transboundary area under study is characterized by low lateral inflow, which ensures a high degree of consistency in flow between the gauging stations located along this section. The correlation coefficient of maximum water levels between the Pavlodar station and the Irtyshskoye station reaches 0.90 [8]. Since the Tatarka gauging station is located under similar hydrological conditions, the data from these gauging stations can be used together to assess environmental flow parameters (see Fig. 1).

The analysis of observations shows that during flow regulation in the low-water years of 1983 and 2012, the floodplain in the Pavlodar region was practically not flooded. Thus, with an annual flow of 18.9 km^3 in 1983 (Tatarka station), flooding lasted only two days at a depth of 23 cm (Pavlodar station), and in 2012, with an annual flow of about 20.0 km^3, there was virtually no floodplain inundation [8]. Based on these data, the critical annual flow (W_{cr}) is estimated at 19.5 km^3, which corresponds to an exceedance probability of 92% in the conditionally natural series (1923–1961) and can be considered as the threshold value for critical floodplain inundation conditions.

In addition to critical years, years of limiting conditions are identified – periods when floodplain inundation occurred, but was short-term and limited ecosystem functioning. These years include 1984 and 2011. For similar annual flow volumes, differences in duration and depth of flooding show that not only annual volumes, but also the volume of high-water flow and its distribution are critical. In 1984 with an annual flow of 22.8 km^3 and a flood volume of 11.9 km^3, the May flow was 3.94 km^3, which provided only a short-term floodplain inundation lasting about 8 days at a water depth of up to 41 cm. In 2011, despite a comparable annual flow (22.6 km^3), a slightly larger May flow (4.04 km^3) and a different flow distribution during the high-water period ensured a longer and deeper inundation – up to 20 days at a depth of up to 136 cm [8].

The analysis of years with limiting conditions and years with similar flood volumes (1992, 1999) shows that the probability of water reaching the floodplain is determined primarily by the flow volume in May (Table 1). Additional evidence is provided by data from 2011 showing that when May flow exceeds 4 km³, floodplain inundation is deeper and longer-lasting. This allows this parameter to be considered a hydrological indicator of floodplain inundation. The estimates obtained are consistent with recommendations for releases from the Upper-Irtysh cascade of hydropower plants[3], according to which the inundation release has an exceedance probability of 75%, with a volume of about 4.8 km³, decreasing in low-water years.

The established critical and limiting flow volumes serve as the basis for determining environmental flow and clarifying its regime under regulation.

Table 1. Flow characteristics during years of limiting conditions

Characteristics	Year	Flow volume, km³						
		April	May	June	July	August	High-water (May – August)	Annual flow
Years of limiting conditions	1984	1.52	3.94	2.57	1.93	1.93	11.9	22.8
	2011	2.25	4.04	1.89	1.87	1.78	11.9	22.6
Years for verification of limiting conditions	1992	1.85	3.99	2.33	1.81	1.79	11.8	22.4
	1999	1.95	3.91	2.20	1.70	1.47	11.2	22.0

Determination of ecologically allowable irrevocable flow withdrawal

Based on the critical flow, the ecologically allowable irrevocable withdrawal (W_{AW}) was determined as the maximum amount of irrevocable water consumption that does not lead to disruption of sustainable functioning of aquatic and near-aquatic ecosystems. It is calculated as the difference between the critical flow (W_{cr}) and the historically minimal annual flow (W_{his}):

$$W_{AW} = W_{cr} - W_{his}.$$

In this case, the historically minimal flow (W_{his}) is a value close to the flow corresponding to an exceedance probability of 97.4% in the conditionally natural series, which reflects the actual minimum flow values during the period of the conditionally natural water regime of 1923–1961.

For the section of the Irtysh River at the border between Russia and Kazakhstan (Tatarka station) the average allowable irrevocable withdrawal (W_{AW}) is:

$$W_{AW} = 19{,}5 - 14{,}5 = 5{,}0 \text{ km}^3,$$

3 Rules for the Use of Water Resources of the Upper Irtysh Cascade of Reservoirs / Ministry of Energy and Mineral Resources of the Republic of Kazakhstan, Kazgidroproekt, Kazgidro. Almaty: 2001. 63 p.

where $W_{cr} = W_{92\%}$ is the critical flow and $W_{his} = W_{97.4\%}$ is the historically minimal flow, both determined from the conditionally natural flow series.

Thus, for the section of the Irtysh River on the border between Russia and Kazakhstan, the average annual environmentally allowable irrevocable withdrawal is estimated to be 5 km^3, which is 19 per cent of the average annual flow. The allowable irrevocable withdrawal in years of different water availability j (W_{AWj}) is determined by the formula:

$$W_{AWj} = W_{AWav} \cdot \frac{W_j}{W_{av}},$$

where W_j and W_{av} are the natural (restored) flow in year *j* and average multi-year natural (restored) flow, respectively, at the gauging station.

Determination of the volume of environmental flow for years with different water availability

For years with different water availability, environmental flow (W_{EFj}) is calculated based on the established value of W_{AWj}. It is defined as the difference between the annual flow (W_j) and allowable withdrawal (W_{AWj}) for a year with a given exceedance probability *j*:

$$W_{EFj} = W_j - W_{AWj}.$$

Table 2 shows values of annual flow and corresponding volumes of ecologically allowable irrevocable withdrawal and environmental flow for the Irtysh River at Tatarka station in years of different exceedance probabilities.

Table 2. Environmentally allowable water withdrawal and environmental flow of the Irtysh River at the Russia – Kazakhstan border

Flow exceedance probability, %	Annual flow, km^3	Allowable irrevocable withdrawal, km^3	Allowable irrevocable withdrawal portion in the annual flow, %	Environmental flow, km^3	Environmental flow portion in the annual flow, %
25	27.2	5.2	19	22.0	81
50	25.5	4.9	19	20.6	81
75	23.9	4.6	19	19.3	81
95	16.7	3.2	19	13.5	81

Based on the data obtained, the preliminary volume of environmental flow for the Irtysh River at Tatarka station should be about 80 per cent of the natural flow,

providing acceptable conditions for the functioning of aquatic and near-aquatic ecosystems in the long term.

Comparative analysis of conditionally natural and regulated flow regimes

To substantiate the annual volume and intra-annual regime of environmental flow, characteristics of water regime of the Irtysh River near the village of Tatarka were compared for two periods: conditionally natural (1923–1961, 39 years) and the period of flow regulation by the Upper-Irtysh cascade of hydroelectric power plants (1968–2022, 55 years).

Despite the long-term flow regulation, the average annual flow of the Irtysh River at Tatarka station decreased slightly – from 26.2 to 25.0 km³ (about 5 per cent), which indicates preservation of the total volume of water resources. A similar pattern of changes is observed downstream, in the Omsk section (Fig.3). This makes it possible to base the estimate of the current annual environmental flow value on annual values typical of the conditionally natural regime.

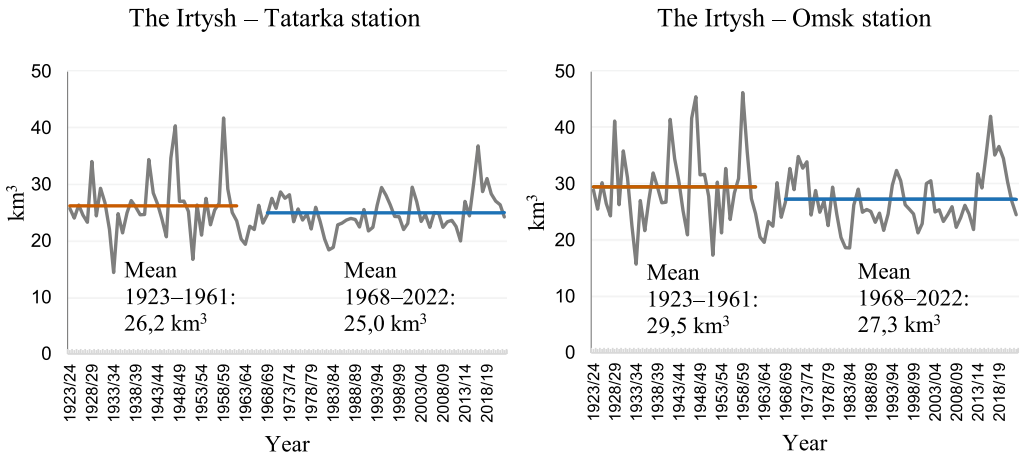


Fig. 3. Changes in the annual flow and its mean values for the transboundary reach under study during conditionally natural and regulated flow periods

At the same time, flow regulation led to a smoothing of interannual (see Fig. 3) and intraannual variability, expressed as an increase in the minimum flow values and a decrease in the maximum flow values (Table 3). The most significant changes were revealed in the intraannual flow distribution. The average volume of the high-water period (April – August) decreased from 18.3 to 14.6 km³, while its portion in the annual flow decreased from 70 to 58 per cent. At the same time, winter flow (December – March) almost doubled from 3.0 to 5.3 km³, which led to an increase in its portion from 12 to 21 per cent. Autumn flow (September – November) changed slightly, remaining at about 5 km³ (see Table 3).

Table 3. Seasonal flow distribution before and after flow regulation at the Irtysh River -Tatarka gauging station

Period, indicator	Annual flow, km³	High-water period (April – August), km³	Autumn (September –November), km³	Winter (December – March), km³
Before 1961, mean	26,2	18,3	4,9	3,0
Before 1961, min.	14,4	9,8	2,6	1,8
Before 1961, max.	41,8	29,1	9,9	5,5
Since 1968, mean	25,0	14,6	5,1	5,3
Since 1968, min.	18,4	10,4	3,4	2,8
Since 1968, max.	36,9	23,9	6,8	7,4

The results obtained show that the key hydroecological consequences of regulation are primarily related to the reduction of the spring-summer high-water period. A decrease in flood volume limits frequency and duration of floodplain inundation and worsens conditions for reproduction of aquatic organisms and functioning of floodplain ecosystems. Therefore, the regime of environmental flow should be focused primarily on maintaining ecologically significant characteristics of the spring-summer water regime.

Recommendations on the regime of environmental flow

With the existing degree of anthropogenic impact, it is impossible to achieve a “reference” regime of environmental flow. At the same time, the environmental flow regime adapted to modern conditions is able to ensure maintenance of basic ecosystem processes and serve as a basis for developing recommendations on flow distribution taking into account ecosystem needs.

Consideration of the identified changes makes it possible to clarify the scope of practical application of environmental flow. Since winter flow in present regulatory conditions already significantly exceeds natural values and its additional regulation is limited by operational requirements of reservoirs, developing special environmental requirements for the winter period seems impractical. Similarly, minimal changes in autumn flow do not require additional environmental requirements.

Based on the identified changes in the hydrological regime, as well as the established critical and limiting conditions for the functioning of floodplain ecosystems, parameters of the environmental flow regime for the transboundary Russian-Kazakhstan section of the Irtysh River are proposed.

1. Annual volume of environmental flow. It is recommended to set it at a level of at least 80 per cent of the actual annual flow. Since regulation did not lead to a significant change in average annual flow conditions, maintaining 80 per cent of the annual volume is justified as a basic value for maintaining ecosystem functions.

2. High-water period (April - August). In conditions of reduced flooding, environmental flow should be focused on restoring parameters of the spring-summer period.

It is recommended to ensure a flow volume of at least 80 per cent of the conditionally natural regime, which makes it possible to bring hydrological conditions closer to the natural seasonal structure and increase the likelihood of floodplain inundation.

3. Peak high-water period (May). The analysis of critical and limiting conditions has shown that the magnitude of May flow is a key hydrological indicator of floodplain inundation. It is recommended to maintain the flow volume in May above 4 km^3 to ensure that water reaches the floodplain and exceeds the limiting conditions for floodplain ecosystem functioning.

Preliminary parameters of the environmental flow regime (Table 4) are aimed at restoring ecologically significant characteristics of the high-water period while maintaining existing flow control conditions and can be considered as a practical basis for coordinating water management regimes in the border area of the Irtysh River.

Table 4. Main parameters of the proposed environmental flow regime for the Russian-Kazakhstan transboundary reach of the Irtysh River

Parameters of the environmental flow regime	Proposed volume	Environmental significance
Annual flow	80 per cent of annual flow	Sustainable functioning of river ecosystems
High-water period (April – August)	> 80 per cent of conditionally natural flow	Approaching the natural regime of the high-water period, which is key to ecosystem functioning
Minimum May flow (Peak high-water period)	> 4 km^3	Floodplain inundation exceeding limiting conditions of ecosystem functioning

DISCUSSION

To assess the compliance of the present water regime of the Irtysh River with the proposed regime of environmental flow, the developed recommendations have been compared with the actual flow regime during regulation. For this purpose, years with characteristic flow conditions (25, 50, 75, and 95 per cent) were selected from the conditionally natural series, as well as years from the regulated flow with similar annual flow values (Table 5). This approach is legitimate, as flow regulation slightly changed the total annual volumes, making the series comparable.

The analysis showed that in a high-water year (2020, comparable in annual volume with the conditionally natural flow of 1937 in annual volume, 25 per cent exceedance probability), the regulated flow volume during the high-water period turned out to be lower than the established environmental flow regime: 15,426 million m^3 against the required 16,578 million m^3. At the same time, the critical May flow was met: 5,785 million m^3 at the required 4,000 million m^3. In a very low-water year, when the flow was regulated (1983, comparable in volume with conditionally natural flow of 1951, 95 per cent exceedance probability), flow volumes for the high-water period and May were lower than required by the environmental flow regime. In the remaining years under comparison – medium high-water (1975 and 1956, 50 per cent exceedance probability), low-water (1988 and 1927, 75 per cent exceedance probability) – the actual flow indicators corresponded to the established values of environmental flow.

Thus, in most of the cases considered, the requirements of the environmental flow regime are met. However, in modern conditions of flow regulation, special attention should be paid to ensuring the regime of environmental flow in very low-water years, since the most critical environmental conditions can arise in such years.

Table 5. Comparison of conditionally natural, environmental, and actual flow for years with different hydrological conditions

Flow characteristics (hydroeconomic year)	Hydroeconomic year, mln m³	High-water period (April – August), mln m³	May, mln m³
Conditionally natural flow 25 % (1937)	28 334	20 723	4604
Environmental flow 25 % (1937)	22 667	16 578	4000*
Actual flow (2020)	27 065	**15 426**	5785
Conditionally natural flow 50 % (1956)	26 016	17 622	4659
Environmental flow 50 % (1956)	20 813	14 098	4000*
Actual flow (1975)	26 296	15 857	4370
Conditionally natural flow 75 % (1927)	23 372	14 827	5732
Environmental flow 75 % (1927)	18 698	11 862	4000*
Actual flow (1988)	23 874	15 101	5055
Conditionally natural flow 95 % (1951)	18 813	13 220	5083
Environmental flow 95 % (1951)	15 050	10 576	4000*
Actual flow (1983)	18 856	**10 395**	**3027**

Note: * – the volume of 4,000 mln m³ is the limiting value to be exceeded to ensure floodplain inundation under the environmental flow regime.

The estimates presented in this paper are preliminary. For a more accurate assessment of environmental conditions, it is necessary to take into account the regime of maximum water levels and features of inundation of floodplain areas. Further research should also clarify the relationship between flow volumes, the dynamics of water levels and characteristics of floodplain inundation, as well as to account for water losses, including evaporation from the surface of large upstream reservoirs.

The estimates of environmental flow parameters obtained in the study can serve as a scientific basis for developing ecosystem-oriented mechanisms for flow distribution in the transboundary basin of the Irtysh River. This task becomes more relevant in connection with the adoption of the new Water Code of the Republic of Kazakhstan (2025), which establishes the concept of environmental flow and the need to maintain it taking into account the specifics of river basins. Such a normative basis makes it possible to compare scientific assessments of environmental flow in Russia and Kazakhstan and their further integration into the practice of water management.

CONCLUSION

The paper proposes an approach to determining environmental flow parameters for the transboundary section of the Irtysh River based on the use of reconstructed

series of conditionally natural flow, analysis of the regulated water regime and characteristics of inundation of floodplain ecosystems.

The functions of environmental flow have been established, including maintaining a portion of flow to meet ecosystem needs and support the functioning of floodplain ecosystems.

The authors propose an adapted regime of environmental flow that makes it possible to take into account key ecosystem needs in further development of economic use of water resources in the transboundary basin of the Irtysh River. For the transboundary section of the Irtysh at Tatarka station, a preliminary environmental flow value of about 80 per cent of the conditionally natural annual flow is proposed, with the spring-summer period (April – August) being of special importance for maintaining floodplain functioning. For May, it is justified to ensure a flow volume above 4 km^3, which is necessary to inundate floodplain ecosystems.

The results provide a scientific basis for integrating environmental flow into distribution mechanisms for transboundary water resources of the Irtysh River. The proposed approach can also be applied to other highly developed transboundary basins where restoration of the natural state is unlikely and solutions are needed to maintain key ecosystem functions.

CONFLICT OF INTERESTS

The authors declare no relevant conflict of interests.

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