Climatic changes and water management in the Ural River basin and their impact on the river water regime

Dmitry Magritsky¹ ORCID 0000-0002-4953-8376, Ayimgul Kenzhebaeva¹, Natalya Yumina¹ ORCID 0000-0002-4815-1356, Lyudmila Efimova¹ ORCID 0000-0003-2733-9680, Vsevolod Moreido² ORCID 0000-0003-1763-4096

¹Department of Geography, Lomonosov Moscow State University, Moscow, Russia
²Water Problems Institute of the Russian Academy of Sciences, Moscow, Russia

E-mail: magdima@yandex.ru

Abstract. The Ural River basin is a transboundary object, which is characterized by a very uneven distribution of water resources, an extensive arid areas and water-intensive socio-economic complex. There are about 3,130 reservoirs and ponds, which are evaporating 0.9 km³/yr. and carry out intra-annual regulation. Water intake peaked in the 1980s. Now the anthropogenic decrease in runoff is <1.6 km³/yr. Climate warming has begun in 1977-1980 and has intensified since the mid-1990s, as well has the occurrence of thaws in winter. In the first half of the current period, annual, summer-autumn, and winter precipitation was higher than the average long-term values. In the second half, spring and winter precipitation increased, while total precipitation decreased due to decrease in summer-autumn precipitation. As a result, the modern water regime of rivers has clearly changed and not in all cases positively. This initiated an inter-State discussion on the efficient use of water resources. Therefore, the goal and objectives of the research were not only to assess the characteristics of the runoff, trends of their changes, but also to determine the role of climatic and anthropogenic factors and the patterns of their long-term behavior. An analysis of data at 56 gauges, 10 meteorological stations, and on water use shows that after 1977 the runoff exceeded by an average of 10–20% 1985-1995 and 2000-2007 were high-water sub-periods. Since 2006/2008, the prolonged water shortage has been registered. The decrease in the precipitation and the increase in evaporation are the main reasons for its formation. The regulation of the Ural runoff and warming have led to an earlier commencement and ending of floods in the lower reaches, a decrease in its volume and maximum water discharges, and the inundation risk reduction. Low-water runoff has increased significantly. This is illustrated by the new data.

1. Introduction

The Ural River is a transboundary river with headwaters and mid-part of the basin situated in Russian Federation, and the downstream part – in the Republic of Kazakhstan. Length of the river is 2,428 km, basin area is 231 km², with 53% on the Russian part. Main tributaries are situated in the upper and middle parts of the basin. The most contributing are right-bank tributaries. The runoff generation conditions of the Ural River are very complex [1-5] due to its location, diverse elevation, vast territories with arid climate and dry steppes. Total precipitation is insufficient. The runoff coefficient value is 0.11. The Ural River basin can be divided into three main zones: 1) main runoff generation zone, 2) runoff generation and natural and artificial uptake, 3) runoff discharge and uptake. Several major industrial centers are situated in the Ural River basin, such as Magnitogorsk, Novotroitsk, Orsk,
Orenburg, Uralsk, Atyrau and Aktobe. There are many mining and manufacturing facilities, power plants, agricultural production. Approximately 3.95 million people live in the basin [6].

Water supply to industry and households in the Ural River basin is limited by high intra- and inter-annual runoff variability, uneven distribution of the water resources within the territory and large arid areas. During the Soviet era the water deficiency issues were addressed by construction of a large number of ponds and reservoirs, water redistribution canals and irrigation systems. Today the modern issues are hydrological implications of climate change, transboundary separation of the basin, intensification of the water consumption and population growth. They are connected with the spatio-temporal water shortage, decrease of the maximum streamflow discharge and water stage during the spring flood, reduction of inundation duration and area size of fish spawning sites on the floodplains, water contamination influence on water supply, fish population and floodplain and river mouth ecosystems’ safety, and small streams’ degradation. These remaining issues have initiated the intergovernmental discussion regarding the fair and efficient distribution and management of the Ural River water resources.

Understanding the contemporary hydrological changes in the Ural River basin requires consistent and relevant runoff assessment, its multi-year trends and spatial distribution patterns, establishing connections between hydrological changes and changing climate, aspects of water management impact. Until recently, only few such assessments were made, mainly due to lack of consistent and up-to-date hydrological, meteorological, water management and socio-economic monitoring data, including the Kazakhstan part of the basin. Having examined these assessments, we are presenting our view on the implications of climate change and water management on the water regime in the Ural River basin.

2. Materials and Methods
Data on water stage and streamflow discharge on 56 gauges were obtained from the hydrological annual books issued by the Russian and Kazakh state hydrometeorological services, and available online in the “Automated information system for state monitoring of water bodies” system (https://gmvo.sknivh.ru). The data covers full measurement period (until 2017/2018), however, a majority of the gauging stations in the basin were established in the 1950-s and in the following years, i.e. after the commencement of the water management. All of the gauging stations’ data were analyzed for consistency, homogeneity and continuity, as well as requirements for data extrapolation. Annual data on water use were obtained from the hydrological almanacs [7, 8], federal and regional bulletins and reports “On the state of the environment”, from “Schemes for the Integrated Use and Protection of Water Resources of the Ural River” of Russia and Kazakhstan [9, 10], and research papers. A significant part of the data were collected by the authors in 2019 during the two field trips in the Uralsk and Atyrau regions. To assess the influence of artificial ponds and reservoirs on the Ural River runoff the data of IRS and Landsat satellite systems data were collected, as well as cartographic data of the General Staff and State GIS Center, Orenburg and Chelyabinsk regional data on water resources, research papers [9-12] and internet sources were accessed. The climatic conditions were analyzed using the data from 10 weather monitoring stations, evenly situated in the Ural River basin. The air temperature, precipitation, snow height and density data were obtained from RIHMI-WDC (http://meteo.ru/data), ECAD project (https://www.ecad.eu/) and KAZHYDROMET service.

The data were analysed using standard hydrological processing techniques [13] such as Fisher’s F-test, Student’s t-test, Mann-Whitney U-test, Spearman’s rank-order correlation (SRCC). A series of different relationships between multiple variables and chronological graphs were plotted, their association and validity were assessed. For the first time, multivariate functions between climatic factors and runoff were assessed as:

\[ Q = a_0 + \sum a_i x_i \] (1)

where \( x_i \) are vectors of predictors (precipitation sum \( P \) and air temperature \( T \) at weather stations Orenburg, Akbulak and Zilair), \( a_0 \) and \( a_i \) are the regression slope and intercept. These relationships possess predicative potential and allow for separation of the climatic and anthropogenic influence on
the river runoff. Mean annual and seasonal water discharges were taken at Orenburg (the Ural River), Kargala (the Sakmara River) and Veseliy #1 (the Ilek River) gauges. The three analyzed hydrological seasons were April – June (hereafter referred to as F), June – October (SF) and November – March (W). The relationship quality and accuracy were assessed with multiple correlation coefficient (R), efficiency criteria (Eff) and reliability of forecast (p%) [14]. For all gauges the assessed relationships for the considered “natural” period show best accuracy (R=0.8–0.9), good efficiency (Eff<0.6) and probability of exceeding (p>75–90%). During next period of changed runoff and climatic conditions the spread of relationship was increased (R=0.6–0.8, Eff<0.8, p=60–80%), especially for winter runoff. We found that annual (A) and spring flood (F) runoff in the lower Sakmara River is highly dependent on the precipitation amount during May – September in the preceding year (first predictor – \(P_{V,IX}\)) and during October in preceding year – April in current year (second predictor – \(P_{X,IV}\)). For instance: \(Q(A)=0.38\times P_{V,IX} + 0.38\times P_{X,IV}-102\) (1937–1965) and \(Q(A)=0.14\times P_{V,IX} + 0.46\times P_{X,IV}-59.8\) (1966–2017), \(Q(F)=1.23 \times P_{V,IX} + 1.32\times P_{X,IV}-382\) и \(Q(F)=0.38\times P_{V,IX} + 1.47\times P_{X,IV}-206.\) Runoff during summer and fall is highly dependent on \(P_{IV,III}\), \(P_{IV,VI}\) and mean air temperature during April – October \((T_{IV,X})\). For instance: \(Q(F)=0.09\times P_{IV,III} + 0.16\times P_{IV,VI} - 15.5\times T_{IV,X} + 157\) и \(Q(F)=0.12\times P_{IV,III} + 0.12\times P_{IV,VI} - 4.3\times T_{IV,X} + 42.5.\) At Orenburg and Veseliy #1 gauges the precipitation and air temperature are the main predictors for runoff in all seasons, so the influence of temperature and evaporation is expectedly increasing southward.

For gauges in the lower Ural River we assessed the dates of commencement (Tc) and ending (Te) for spring flood (F) and low flows in summer and fall (SF) and winter (W), the time of duration and runoff volume during the hydrological seasons (\(W_F, W_{SF}\) and \(W_W\)).

Intercomparison of hydroclimatic and water management data and trends allowed to highlight three main periods for the Ural River: 1) before 1954 – almost intact runoff generation and transit conditions, 2) 1955–1977 – period of anthropogenic influence intensification, 3) after 1978 – nonstationary climate and maximum water management period. The third – contemporary – period is characterized by relatively fast and significant changes in volume and structure of the water consumption (increase to maximum values during 1980s and subsequent decrease), regime of temperature and humidity, and the Ural River runoff volume and regime. It is heterogenous, and can be further divided into sub-periods with main pivot point in mid-1990s.

### 3. Results and Discussion

#### 3.1. Anthropogenic factors of the Ural River runoff alteration

Solving the issue of deficit in water resources, and their even distribution throughout the year required the construction of a large number of water reservoirs and dam ponds, multiple water extraction and withdrawal facilities and extensive channel network [1, 6, 9, 10, 16–21]. Indirectly, landscape alteration contributed to the influence – deforestation, lay land tilling, small streams degradation.

According to our newly obtained data the amount of ponds and reservoirs in the Ural River basin is around 3,130. They include the largest Iriklinskoe reservoir on the Ural River (surface area 260 km², total and live storage 3.26 and 2.76 km³, respectively, filled in 1955–1966), 5 large reservoirs (total area and storage 228 km² and 1.41 km³, respectively), 22 medium-size (201 km² and 0.62 km³), and nearly 3100 minor and very small artificial ponds (~398 km² and ~1.07 km³) of various purposes and bed shape. Only 28% of the reservoirs and ponds (372 km² and ~1.27 km³) are located in the Kazakh part of the basin. The majority of the reservoirs were constructed between mid-1960s and mid-1970s. During the post-soviet period intensive construction emerged in the Republic of Bashkortostan.
The construction of reservoirs leads, in the first place, to one-time losses of runoff for filling the dead storage volume (~0.9 km³ by 2020), and secondly to annual evaporation losses. Total evaporation value (0.89 km³/yr) was estimated by authors from the data on the evaporation intensity in [12, 22, 23]. During drought years the rate is 1.5–2.5 times higher, in humid years – 1.4–4 times lower than the average [21]. However, the actual decrease of runoff due to reservoirs is lower if taking into account only the additional evaporation, which in the Irinkinskoe reservoir is ~0.13 km³/yr. [12], while the total evaporation equals 0.20 km³/yr. In addition, in the downstream of large reservoirs, a reduction in evaporation losses with the floodplain is observed, according to estimates [21, 24], from 0.20–0.30 to 0.14 km³/yr. Thirdly, the reservoirs operate on annual and inter-annual runoff regulation, with the latter influencing the runoff in individual years, as well as annual runoff variance. The actual maximum inter-annual runoff alteration in the Ural River basin is around ±0.55 km³/yr. [7] Annual runoff regulation is one of the main factors of natural water regime alteration. Reservoirs and ponds altogether are capable to accumulate nearly half of the Ural River natural runoff. The least regulated is the Sakmara River runoff (~3%), the most regulated are Gumbeyka, Bolshaya Karaganka, Tanalyka, Or’, Chernaya, Ilek, Utva, Chagan, Barbastau rivers (40–70%). The Irinkinskoe reservoir operational capacity is capable of retaining the whole upper Ural River annual runoff for two average years! As a result, the spring flood is not pronounced downstream from the Irinkinskoe reservoir. However, after the Sakmara River contribution, the influence of the reservoir on the flow hydrograph is significantly lower.

The water consumption has significantly influenced the Ural River runoff since 1950s [17, 20, 21], and reached its peak in 1970-1980s [7, 18]. In the second half of the 1980s the water intake, withdrawal and their difference reached 4.69 (10.5% from groundwater), 2.31 и 2.38 km³/year, respectively. While 60% of the water intake occurred in the Russian part of the basin, 76% of the irretrievable consumption occurred in Kazakhstan. In 1990s the intake abruptly decreased [6, 18]. In the XXI century the water total intake, withdrawal and their difference is ~2.0, ~1.85 и ~0.15 km³/yr., the runoff decline in the Kazakh part of the Ural River is evaluated at ~0.80–0.95 km³/yr.

Therefore, the current anthropogenic reduction of the Ural River annual runoff seems to be lower than 1.60 km³/yr., or around 15% of the natural annual runoff at the outlet of the runoff generation and intake zone [6]. In the 1980s the anthropogenic stress was significantly higher. Given the anthropogenic alteration of the basin surface, this rate can be even higher.

3.2. Climate change

According to climatic indicators, the second period was already warmer than the first by 0.05–0.15 (average annual air temperatures), 0.4–0.8 (spring), and 0.15–1.1°C (winter). Moreover, the warming increased in the southern direction. The summer, on the contrary, was colder than in 1930–1954 (by 0.45–0.65°C). The amount of annual precipitation changed little. The winter precipitation layer increased by 10–40 mm, the spring precipitation layer was 20–40 mm higher, and in summer and autumn, the changes were characterized by multidirectional trends.

Obvious warming in the Ural River basin began in 1977–1980 and has increased since the mid-1990s. As a result, the rise in average annual temperature, average winter and summer temperatures, in comparison with the second period, amounted to 1.3–1.5, 2.3–3.3, and 0.1–0.4°C, respectively. Warming increases towards the middle and southern districts, which are known to have a moisture and water resource deficit. Since the mid-1990s, a significant increase in the sum of positive air temperatures (ΣT+) during the cold period was detected. It indicates an intensification of winter thaws. Concerning precipitation, the situation is not so clear. From the late 1970s - early 1980s, an increase in the annual amount of precipitation (up to the mid-2000s) was recorded at most weather stations. The reason is an augmentation, first of all, in the layer of summer, autumn, and winter precipitation, winter snow storage (from the mid-1980s to 2000s). A similar process in the Volga basin was explained by the southward shift of the trajectories of Atlantic cyclones [16]. Since the mid-1990s, trends in long-term fluctuations of annual and seasonal precipitation values can be characterized as multidirectional and unstable. The obvious increase of precipitation in the spring
(+20...+25 mm in 1996-2018, as compared to 1978-1995) on the territory of their primary falling, maintaining the favorable moisture conditions in the winter months, a decrease in the annual precipitation since the mid-2000s due to a significant reduction in summer (-60...-20 mm) and autumn (-15...-55 mm), in recent years and some parts of the basin, the end of a downtrend has been established. Another important consequence of the change in precipitation regime and value was a reduced variance. This, as the authors believe, is the main reason for the decrease in the dispersion of water runoff.

3.3. Changes in the water runoff and regime of the Ural River and its tributaries
The main features of current climate-induced changes of the water regime of rivers are as follows: 1) an increase in low-water runoff, especially during the winter (main reasons are a decrease in soil freezing, and snow melting during thaws) (table 1), 2) a decrease in runoff volume and maximum streamflow discharges of spring flood due to wasting snow cover during winter thaws for the formation of the channel and underground runoff and increasing of snowmelt water losses for filtration. Similar processes are typical for most of European Russia [25]. The reservoirs enhance these processes since they redistribute runoff between high water and low water seasons.

Table 1. Main characteristics of the runoff in 1936-1957 (1st line) and 1978-2017 (2nd line).

| River, gauge | Runoff distribution by hydrological seasons: in km³ (in brackets – in % of annual volume) | Annual runoff, km³/yr. | Average maximum water discharges m³/sec and C₁ in brackets |
|--------------|---------------------------------------------|------------------------|------------------------------------------------------------|
|              | spring IV–VI summer-autumn VII–XI winter XII–III |                        |                                                             |
| Ural,        | 0.19 (69.3) 0.07 (27.3) 0.01 (3.4)           | 0.27 100               | 0.49 (1.76) 1.97 (1.02)                                      |
| Verkhneuralsk| 0.15 (67.4) 0.06 (25.0) 0.02 (7.6)           | 0.23 72                | 0.93 (0.92) 1.89 (0.64)                                      |
| Ural,        | 0.72 (78.2) 0.18 (19.4) 0.02 (2.4)           | 0.93 686               | 0.94 (1.72) 5.20 (1.39)                                      |
| Kizilskoye   | 0.63 (66.1) 0.24 (24.8) 0.09 (9.2)           | 0.96 393               | 4.93 (0.57) 7.38 (0.74)                                      |
| Ural,        | 2.88 (82.8) 0.45 (12.9) 0.15 (4.3)           | 3.49 2380              | 8.09 (0.85) 28.5 (0.94)                                      |
| Orenburg     | 2.06 (66.4) 0.56 (17.9) 0.49 (15.7)          | 3.11 820               | 23.4 (0.38) 31.6 (0.39)                                      |
| Ural, Kushum | 8.00 (78.5) 1.64 (16.0) 0.56 (5.5)            | 10.2 3350              | 36.9 (0.67) 89.2 (0.54)                                      |
|              | 6.00 (64.4) 2.14 (22.9) 1.18 (12.7)           | 9.32 1460              | 87.1 (0.40) 117 (0.38)                                       |
| Ural,        | 6.41 (72.7) 1.85 (20.9) 0.56 (6.4)            | 8.82 1740              | 34.5 (0.81) 89.5 (0.61)                                      |
| Makhambet    | 4.93 (61.3) 2.14 (26.4) 0.99 (12.3)           | 8.06 1000              | 72.2 (0.47) 93.4 (0.39)                                      |
| Sakmara,     | 3.22 (78.7) 0.58 (14.0) 0.30 (7.3)            | 4.10 1520              | 16.6 (0.85) 28.2 (0.53)                                      |
| Kargala      | 3.43 (74.3) 0.74 (16.0) 0.45 (9.7)            | 4.63 1510              | 27.1 (0.47) 37.4 (0.38)                                      |
| Or, Istemes  | - - -                                             | - - -                  | - - -                                                       |
| Ilek, Veselyi| 0.18 (92.0) 0.005 (2.3) 0.011 (5.7)           | 0.19 164               | 0.15 (0.69) 0.22 (0.56)                                      |
| #1           | 0.51 (70.4) 0.14 (19.0) 0.08 (10.7)            | 0.73 405               | 2.80 (0.61) 7.36 (0.44)                                      |

In the third period, the annual runoff in the Ural River basin has exceeded the annual runoff in 1955-1977 by 10-20% with anomalies from +70% (at the gauges in the Bolshoy Kumak River basin) to -11...-9% (at the uppermost reaches of the Ural River (Verkhneuralsk) and on the Or River (Istemes)). To the Kushum and Makhambet gauges (in the lower reaches of the Ural River), the climatic increasing the annual runoff is leveled by water consumption and is equal to only 2-3%. During the third period, sub-periods with an abundance of water are 1985-1995 despite the maximum values of water intake, and 2000-2005/2007 years too. 1978-1984/1986 was the average sub-period in terms of water content. Since 2006/2008 the long-term low water sub-period (for almost all seasonal and annual values) was observed, but it has already ended for some rivers. The situation with water...
supply since 2006/2008 would have been even more difficult if the water consumption had not decreased. On regulated streams, the runoff of the low-water months has either increased, or overflow water from reservoirs is not carried out at all, as, for example, on the Chagan River. A statistically significant \((F\)-test\) decrease in variance and a change in the pattern of inter-annual fluctuations in the annual and flood runoff, as well as in the maximum streamflow discharges, is another feature of the third period. The coefficient of variation \((C_v)\) of the annual runoff at Kargala (Sakmara River), Mrakovo (Bolshoy Ik River), Aktyubinsk (Ilek River), Verkhneuralsk, Kizilskoye, Orenburg, and Kushum (Ural River) gauges was equal (until 1955) 0.61, 0.58, 0.97, 0.75, 0.95, 0.97, and 0.77. \(C_v\) of the maximum water discharges was 0.71, 0.69, 1.26, 0.91, 1.24, 1.49, and 1.22, respectively. The decrease of dispersion and \(C_v\) of the annual and flood runoff occurred already in the 2nd period, literally at the very beginning. In the third period, it has reached statistically significant values at Kargala, Kushum, and Bulanovo (Salmysh River) gauges, and some regulated rivers. As a result, \(C_v\) has decreased by an average of 1.5-2 times. The main reason is climatic, since the same tendencies are found in precipitation and flow of rivers with natural state. On the contrary, the dispersion of streamflow discharges in the summer - fall and winter low-water seasons has increased since the 1980s. But since the volume of runoff itself has increased significantly, it either did not lead to significant changes in \(C_v\), or \(C_v\) has even decreased.

Regulation of the runoff of the Ural River and some of its tributaries, hydro-climatic changes have most strongly affected the water regime of the lower reaches of the Ural. Here, the main phase of the water regime is the spring flood. 81-83% of the annual runoff and the maximum streamflow discharges \((Q_{\text{max}})\) fell on floods. There were close relationships between the parameters of flood and annual runoff, which simplified the aims of their calculation and forecast [26]: Kushum gauge - \(W_{\text{yr}}=1.07\times W_{\text{fl}}+1.05\ (R^2=0.99)\), \(W_{\text{fl}}=-1.2\times10^{-7}\times Q_{\text{max}}^2+0.003\times Q_{\text{max}}+1.1\ (R^2=0.93)\). In current hydro-meteorological and water management conditions, the share of flood runoff has decreased by 12%, the water stage rise and the risk of inundations during high water have decreased. In the third period, river inundations occurred in 1993, 1994, and 2011. The beginning and end of the flood have shifted to earlier dates: from April 6 to March 27 and from July 23 to July 18 (Kushum gauge), from April 6 to April 1 and from July 30 to July 22 (Makhambet gauge) (figure 1). The duration of the flood water level rising has increased by 16 days, the peak of the spring flood acquired a more smoothed form and a lower height, the duration of the recession of flood has decreased. The type of relationships has changed, their closeness has worsened [26]: \(W_{\text{yr}}=1.15\times W_{\text{fl}}+1.95\ (R^2=0.93)\), \(W_{\text{fl}}=-8.06\times10^{-7}\times Q_{\text{max}}^2+0.0069\times Q_{\text{max}}+1.55\ (R^2=0.85)\). The relation between \(W_{\text{fl}}\) and \(W_{\text{sum-aut}}\) has ceased to exist. At the Kushum gauge, the frequency of floodplain flooding, exceeding the marks of an unfavorable and dangerous phenomenon decreased in comparison with the first period, respectively, from 68 to 60.5%, from 34 to 16%, from 16 to 0%. The duration, depth, and width of floodplain flooding also decreased, which adversely affected floodplain vegetation and sturgeon reproduction [9, 27]. The second important phase of the water regime is the summer - autumn low water with rain floods. Anthropogenic and climatic factors favorably affected the parameters of the summer - autumn low water season and water supply to enterprises, agriculture, and the population. They increased the runoff in July - November by 1.4-1.6 times, its share in the annual runoff (from 12% to 18-20%), the minimum daily and 30-day water discharges. Nevertheless, there are years with a shortage of low-water runoff and "blooming water" (for example, 2015). The low-water season itself has become longer (by 14-17 days). Similar changes, but more significant, are found for the winter low-water season. On the contrary, its duration has decreased (by 9 days).
Figure 1. Long-term changes in the water regime of the Ural River (g. Kushum) with linear trends.
1 – volume of spring flood runoff (shaded bars indicate the restored values), 2 – maximum water discharges, 3 – volume of the summer-autumn low-water runoff, 4 – minimum water discharges, 5 – volume of winter low-water runoff, 6 – winter minimum water discharges, 7 – date of the start of spring flood, 8 – date of the flood end, 9 – date of the start of winter low-water season.

4. Conclusion

The water management complex and climatic conditions are the main factors of the water runoff and regime of rivers in the Ural River basin. Since the late 1970s, obvious warming has been registered in the Ural basin, the intensity of which has been increasing since the mid-1990s. Since the mid-1990s, the frequency and duration of winter thaws have also increased. The response of precipitation was ambiguous. In the first half of the third period (1978-1995), the basin’s moisture exceeds the long-term value due to an increase of precipitation in the summer, autumn, and winter, and it exceeds the maximum indicators of anthropogenic runoff reduction in the 1980s. In the second half of the modern period, the annual amount of precipitation decreased (especially since the mid-2000s), as increased precipitation in the spring and winter was compensated for by a decrease in the summer and autumn. The combination of a decrease of precipitation and an increase of air temperatures in the spring, summer, and autumn seasons led to a prolonged low water period, which began in 2006/2008. It would have been earlier and more difficult, if not for the abrupt reduction of water consumption in the 1990s-early 2000s and anthropogenic pressure on the flow. Climate changes affect not only the value of river runoff but also its dispersion. The influence of the water management complex includes, firstly, a decrease in runoff due to one-time losses of water runoff during the filling of the dead storage of reservoirs (~0.9 km$^3$ by 2020), annual evaporation from the surface of 3,130 reservoirs and ponds (~0.9 km$^3$/yr.), irrevocable water consumption (2.4 km$^3$/yr. in the second half of the 1980s and 1.0–1.2 km$^3$/yr. now), and secondly, intra-annual and inter-annual flow regulation. The effects of intra-annual flow regulation are especially noticeable downstream of the Irikinskoye reservoir. In the lower reaches of the Ural River, it, together with climatic changes of the water regime of the rivers, led to an earlier beginning and end of the spring flood, a decrease in its volume and maximum water discharges,
and the risk of flooding. The damage was caused to floodplain ecosystems [9, 27]. Low-water runoff, on the contrary, has increased significantly, and water use conditions during the important summer-autumn season have significantly improved.

Acknowledgement
The research was carried out within the framework of the state research assignment (MSU).

References
[1] Water of Russia River basins 2000 ed A M Chernyaev (Yekaterinburg: AQUA-PRES) p 536
[2] National Atlas of Russia 2007 2 (Moscow) p 496
[3] National Atlas of the Republic of Kazakhstan 2011 1 (Almaty) p 150
[4] Surface water resources of the USSR 1970 12 (2) (Leningrad: Gidrometeoizdat) p 512
[5] Chibilev A A 2008 The Ural River basin: history, geography, and ecology (Yekaterinburg) p 312
[6] Magritsky D V et al 2018 Changes in the flow in the Ural River basin Bulletin of the Moscow University. Geography Series 1 pp 90–101
[7] State Water Cadastre Surface and underground water resources, their use and quality Annual edition 1981-2018 (Leningrad – Saint-Petersburg – Moscow)
[8] State Water Cadastre Surface and underground water resources, their use and quality Annual edition 2008-2016 (Astan – Almaty)
[9] Scheme of integrated use and protection of water resources of the Ural River (Zhaiyk) with its tributaries Report 2007 The report is in 6 volumes and 11 books (Almaty: Institute of Kazgiprovodkhоз)
[10] Scheme of integrated use and protection of water bodies in the Ural River basin (Russian part) 2013 The report is in 6 volumes (Yekaterinburg: RosNIIVH)
[11] Reservoirs of the USSR 1988 (Moscow: Soyuzvodproekt) p 276
[12] Vuglinsky V S 1991 Water resources and water balance of large reservoirs of the USSR (Leningrad: Gidrometeoizdat) p 223
[13] Determination of the main calculated hydrological characteristics (SP 33-101-2003) 2004 (Moscow) p 74
[14] Borsch S V and Khristoforov A V 2015 Assessment of the quality of forecasts of river runoff Proc. of the Hydrometeorological Center of Russia Special issue 355 p 198
[15] Shevnina E V 2013 Methodology for calculating the characteristics of spring flood according to the data of daily water discharges Problems of the Arctic and Antarctic 1(95) pp 44-50
[16] Water resources of Russia and their use 2008 ed I A Shiklomanov (Saint-Petersburg: State Hydrological Institute) p 598
[17] Grigoriev O M 1981 Evaluation of the impact of industrial and municipal water consumption on the runoff of the Ural River Proc. of State Hydrological Institute 273 pp 45-61
[18] Demin A P 2011 The use of water resources in Russia: current state and prospective estimates (Moscow: Institute of Geography of RAS) p 51
[19] Pavleychik V M and Sivohip Zh T 2012 Water-economic and transboundary aspects of flow regulation in the Ural River basin Izvestiya of the Samara science center of RAS vol 14 1(9) 2367-2371
[20] Rodionov V Z 1977 Influence of economic activity on the flow of the Ural River Proc. of State Hydrological Institute 239 pp 109-122
[21] Shiklomanov I A 1979 Anthropogenic changes in the water runoff of rivers (Leningrad: Gidrometeoizdat) p 302
[22] State Water Cadastre. Annual data on the regime and resources of land surface waters 1984-2017 1 (24) (Obninsk – Samara)
[23] Moskvina E T 1961 Evaporation from the water surface on the territory of the Southern Ural The questions of water management and hydrology of the Ural 1 pp 23-32
[24] Pryakhina G V 2003 Assessment of the impact of large reservoirs on the flow of rivers in the lower reaches (Saint-Petersburg) p 22

[25] Kalyuzhny I L and Lavrov S A 2012 Hydrophysical processes in the catchment area: Experimental studies and modeling (Saint-Petersburg: Nestor-Istoriya) p 616

[26] Magritsky D V and Kenzhetaeva A Z 2017 Regularities, characteristics and causes of variability of annual and seasonal river water flow in the Ural River basin Science Technique Technology (Polytechnic Bulletin) 3 pp 39–61

[27] Vinokurov Yu I, Chibilev A A, Krasnoyarova B A, Pavleychik V M, Platonova S G, Sivohip Zh T 2010 Regional Ecological Problems in Transboundary Basins of the Urals and Irtysch Rivers Izvestiya RAS Geographical Series 3 pp 95–104