Forming of minimum water content in the rivers of the Upper Don basin

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Abstract. The article analyses, on the example of the river Bityug - Bobrov (Verkhniy Don, Voronezh Region), the dynamics of the absolute low water minimums of the low-water run-off. It demonstrates that, in the current century, due to the increase in summer-autumn and winter water content, the dates of absolute minimums of runoff have been shifting (rounded up to a month) for later periods of summer-autumn and earlier periods of winter low water. The highest recurrence of absolute minimums of the winter low water falls on January, and of the summer-autumn low-water - on September.

1. Introduction

The minimum water run-off forming in the rivers of the Upper Don (Verkhniy Don) basin during summer-autumn and winter periods of low water is interesting from various standpoints. In the science of hydrology, the minimum, maximum and average run-off values characterize the general features of the water regimen. The sectors of the economy dependent on the surface water sources, on the other hand, have a very practical interest in it. Since the water levels are uneven over the year, the periods of minimum flow in the Upper Don river basin can lead to water supply shortages. In the realm of ecology, the low water flow can be a risk factor for hydro-logical stability, since the agricultural water usage in drought years can cause a decrease in self-cleaning capacity of the water sources. This can potentially lead to the risk of qualitative water depletion and other extreme situations [8, 12, 15]. Therefore, there are theoretical and practical reasons for researching the seasonal minimums and their changes due to the natural factors, like climate change [9].

The minimum run-off was widely studied in the 1970’s. The studies were done for the whole country [1, 2] and separate regions [6, 7 et al.]. The authors have looked at the major patterns of the low run-off formation and the principles of identifying its components, as well as the boundaries of the hydro-logical seasons within the year. The researchers have introduced methods and formulas to calculate the minimum run-off parameters for rivers in various regions and the country in general [11, 13, 14].

The studying of hydro-logical river basin regimen has become the mainstream in the 21st century. The focus is on the effects of global warming and its potential continuation as well as the causes of low water
levels. This method has resulted in the development of new ways of low run-off calculations and the creation of the Global approach to the usage and conservation of the water object [3-5, 7] etc.

However, the extreme minimums of river water levels have not been deeply researched, despite the fact that such data would be very useful in development of the strategies of rational water usage in low level periods to prevent shortages, as well as risk mitigation for hydro-ecological stability. Our study focuses on the absolute run-off minimums in the Upper Don river basin.

2. Materials and methods
We have analyzed the minimal term water usage data during the winter and summer-autumn low level periods in the Upper Don River basin. It encompasses 19 hydro units of Don, Khoper rivers and their first and second level tributaries. The absolute minimums are illustrated by the example of Bityug river (Bobrov city) in three time periods: 1) From the beginning of observation to 1970; 2) 1971-2000; 3) 2001-2017. This breakdown is based on the water content contrasts emphasizing the dynamics of changes in the current century.

We have employed the mathematical, geographic-hydro logical analysis and graphic representation of the findings.

3. Discussion
The Upper Don river basin is defined as the area between the sources of Don and Khoper rivers to the borders of Voronezh region. The area covers 143 500 km². The basin is mostly in the forest-steppe area, with the exception of the southern part which is predominantly steppe. The spread of the basin and it's landscape variability result in wide range of the time frame, height and duration of snow coverage, flood and low water seasons. For instance, the 21st century flood season in Khoper river in the Voronezh region has 2 distinct phases. The first one is caused by the earlier snow melting in it's proper area, and the second one is due to the influx of melting water from the neighbouring Saratov region. They can be up to two weeks apart.

The low water (minimum run-off) phase in the Upper Don river basin is formed between the end of the current year's flood and the beginning of such in the following year. The low water season lasts between 9 and 10.5 months and depends on the duration of the spring flood. The summer-autumn low level lasts from the end of the spring flood to the formation of stable ice cover in the current calendar year. The summer low water is usually stable and is not interrupted by floods. The autumn low water can be influenced by floods, but it is not an annual occurrence. It is impossible to make a demarcation, therefore they are analysed as a single period. The winter low level starts in December of the preceding year and ends in February of the following year. In the current century it has been frequently interrupted by February thaws. This increases the winter run-off and results in high floods, especially in the small rivers, which recently has been a consistent tendency.

4. Results
The Upper Don river basin regimen has been significantly changing in the recent decades, just like most of the rivers in the European part of Russia. There is a tendency for a decrease in volume and maximum spring flood levels along with the increase in the minimum run-off. There is less difference between the spring flood extremes accompanied by the augmentation of the minimum run-off. There is less contrast in the run-off levels and less disproportion between the spring and the rest of the year.

It's obvious that the minimum water levels are forming differently, namely due to the run-off changes. This can be illustrated by the variations of the extremes in Bityug River (Bobrov city). The data is available for the last 85 years.
The Bityug River originates in Tambov region, runs through Lipetsk region and joins the river Don in Voronezh region. The river is 379 k long and has a 8840 km² catchment area. Before 1950's they used to define 3 hydro units, and currently just 2: Mordovo village (Tambov region) and city of Bobrov (Voronezh region). The amount of available data is sufficient for statistical analysis.

The absolute winter run-off minimum levels are greater than the summer-autumn ones. This is quite natural, since the water levels become much lower after the spring flood and a lot of water is lost due to evaporation. The summer rains don't contribute much either due to about 70% evaporation. The winter run-off is increased due to February thaws; the winter levels had been steadily increasing up to 2006 without significant fluctuations. However, since 2007 there have been stark variations in the winter minimums. The difference between 2007 and 2017 was 6.74 times fold. No such anomalies have been registered in the previous decades. The yearly absolute summer-autumn minimums demonstrated a steady increase up to 2003, but since 2004 there was a sharp variability between the highest values in 2004 and 2012 and the lowest in 2014.

The changes in the winter and summer-autumn run-off minimums lead to the shifts in the dates of the extreme values throughout the calendar year. The increase of the proportion of underground water influx and the decrease of the surface input leads to the shift in the dates (rounded to the month) of winter water level extremes.

January (41%) has become the most prevalent month in the current century, contrary to the month of February (40%) in the previous one. This is quite logical, since the winter run-off is increased due to February thaws. The month of November is slowly disappearing from the low-level cohort; it is not the lowest water level month anymore (figure 1).

August and September (35 and 41% respectively) are now the lowest absolute water level months indicating the depletion of the underground sources. The month of October (6%) is also emerging, just like it used to be in the period from the beginning of observation to 1970 (7%). June is not the least water level month anymore, yielding it's position to July and, especially, August and September (figure 2).
5. Conclusion
The analysis of absolute run-off minimums in the Upper Don river basin based on the example of Bityug river (Bobrov city) between 1933 and 2017 has shown a shift towards earlier (January) onset for winter, and later (September) onset for summer-autumn low water levels compared to the period between 1971 and 2000. The modern mechanisms of water regimen formation and, mainly, the redistribution of the run-off throughout the year along with the increase in low-water level season run-off are the main reasons for such changes in the winter and summer-autumn periods.

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