Generalization of the estimated probabilities of excess the mean annual runoff of the Pripyat River basin within Ukraine

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SUMMARY

Analysis and generalization of the transient ordinates from the average annual runoff to the runoff of the specified exceedance probabilities for the rivers of the Pripyat basin within Ukraine, as one of the indicators of the highest and lowest amount of water for the studied area. For this purpose, the hydrological study was analyzed (series of observations at 28 hydrological gauging section), the empirical and analytical distribution curves (by the moment and highest reliability method) were calculated for 14 values probabilities of excess ranging from 0.01 to 99.9%. Was created the mapps of the spatial distribution of transient ordinates from the norm of the average annual runoff to the runoff of certain probabilities of excess. The work was carried out with the help of basic sets of special tools of several GIS, the main of which was a free cross-platform geoinformation system QGIS.

Introduction. Pripyat is the largest in terms of basin area, length and amount of water of the Dnieper tributary, which flowing through the territory of Ukraine in Volyn, partly in Rivne, Kyiv regions, and territory of Belarus. It flows into the Kiev reservoir. The area of the Pripyat Basin is estimated at 121 thousand km^2, the Belarusian part of the basin accounts for 43% of the catchment area, and the Ukrainian one - 57%. Within the study area were identified about 6,000 rivers, of which more than 70% are more than 25 km long and more than 1/7 are rivers up to 100 km long (Obodovskij et al., 2012).

The water resources of the river and the degree of its variability are important characteristics both for scientific research and for the use of the territory for practical purposes. The generalization of the transitional ordinates from the norm of the average annual runoff to the runoff of certain probabilities of excess (hereinafter $k_{P\%}$), as indicators of the highest and lowest water content for the territory of the Pripyat basin within Ukraine is the purpose of this work. The urgency of the issue is due to several points: the area of the Pripyat Basin is a large, aren`t has dense enough hydrological observations (Sokolchuk, 2019), there are no relevant cartographic materials on the basin. It is also necessary to clarify them in connection with the long period after creation and the rapid changes of the river flow conditions. This necessitates the analysis of river runoff of different levels probabilities of excess to clarify further plans for economic management of the territory.

Method and Theory. Periods of observations average annual runoff (the average duration of time series is 64 years) by analyzing the values of the relative mean square error and checking them for homogeneity can be considered representative for determining the norms of water runoff, so they are sufficiently reliable for practical calculations.

The normals average annual discharge of water and their statistical parameters are clearly correlated with each other and with the basins area. The distribution parameters of the normal annual runoff of the rivers of the Pripyat basin, especially the coefficients of variation, are also reliable and not offset by the analytically calculated values. This allows us to generalize the runoff transitive ordinates for the study territory.

The calculation of the transition coefficients from the normal runoff to the runoff of the set probabilities of excess $k_{P\%}$ was carried out by two methods, moments and highest reliability (Rozhdestvensky et al., 1974; Lukianets, 2010). Observation data of the average annual discharge were used from 28 hydrologic gauging section, for each of which was determined the $k_{P\%}$ of different probability of excess. The estimation of the transient coefficients of $k_{P\%}$ was conducted for 14 values of the probability of excess in the range from 0.01 to 99.9%.
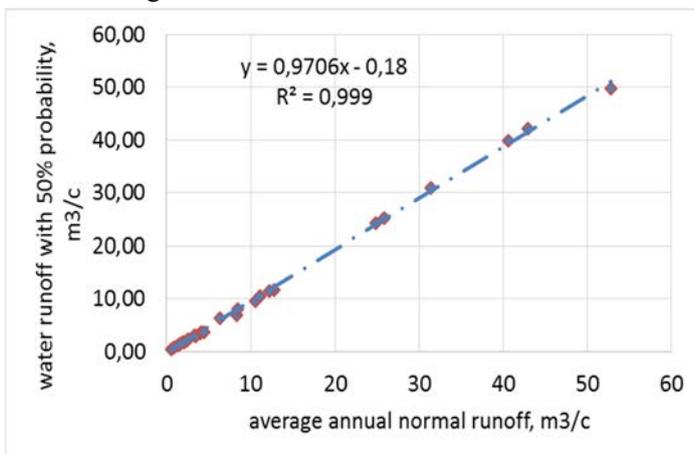

Before generalizing the $k_{P\%}$ by the territory of the Pripyat basin were estimated the deviation of river runoff calculated with the transient ordinates from the normal average annual runoff. The normal average annual of river runoff actually coincides with the value of the calculated runoff of 50% of probability of excess (Figure 1).

Figure 1 *Correlation of the normal average annual runoff of rivers of the Pripyat basin (within Ukraine) rivers (within Ukraine) to the runoff of 50% probability of excess, which calculated by highest reliability method.*

At the same time, in some hydrological gauging section, the values determined by empirical and analytical methods, $k_{P\%}$ may differ from the average three times, especially the difference is noticeable for conditions of extremely rare probability of excess of river resources (0.01 and 0.1% probability of excess) and vice versa, for the 99.0 and 99.9% probability. In particular, the difference is significant for hydrological gauging section of the rivers Pripyat (Lyubyaz village), Goryn (Yampil town), Ubort (Rudnya-Ivanivska village). The method of moments gives a similar distribution, and is characterized

by a slight decrease in the water content of rivers of extreme frequency compared to values of $k_{\text{P\%}}$, calculated by the highest reliability method. To calculate the permissible errors of the model, was calculated the probable deviation of the transient ordinates of the distribution curves for the given probability of excess $\delta_{k_{P\%}}$. Its value was defined as $\delta_{k_{P\%}} = 0,674 \cdot \sigma_{k_{P\%}}$, where $\sigma_{\text{kp\%}}$ is the standard deviation (Lukianets, 2010).

Results. The values of the probable deviations are the highest for the 99.9% probability of excess - 37% for the highest reliability method, 73% for the moment's method. The probable deviations of the transitional ordinates of the distribution curves naturally decrease from the probability of the extreme of excess of 0.01% and 99.9% to the central ordinance with the probability of excess of 50% (Figure 2).
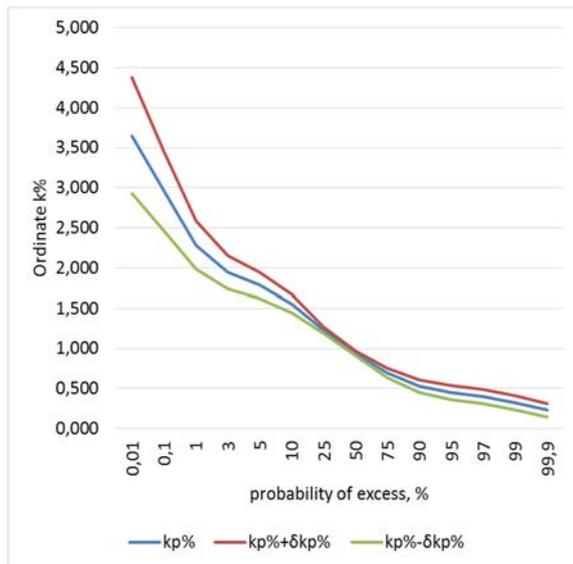
It is worth noting separately two hydrological posts with inappropriate values of the coefficients of variability of river runoff, transitional ordinates of the average annual runoff for the probability of the extreme excess, namely of the river Pripyat (village of Rychytsa), and of the river Noryn (village of Slavenshchyna). The identification of specific impact factors and their areas of action, as well as the errors of the extreme probability of excess defined by the $k_{\text{P\%}}$, will be explored later.

Figure 2 Transient ordinates of the distribution of the average annual water runoff $k_{\text{P\%}}$ of the estimated probability of excess of P% from of the norm and the limit of their probability errors for the rivers of the Pripyat basin (within Ukraine), calculated according to the highest reliability method

Within the study territory, the main trends of changes in $k_{\text{P\%}}$ values distribution of the average annual runoff for the rivers of the Pripyat basin (within Ukraine) are similar, which allows the creation of spatial distribution models of the $k_{\text{P\%}}$.

The $k_{\text{P\%}}$, determined by the highest reliability method, have significantly less probable deviations when used to determine the runoff the probability of the extreme of excess, and similar or somewhat inflated values for the runoff of average probability of excess. So it is expedient to determine the average annual runoff of water of the different levels of probability of excess for the rivers of the Pripyat basine using $k_{\text{P\%}}$, calculated by the highest reliability method, since their probable deviations are even on average 3,4% less than those determined by the moments method.

In view of all of the above, at this stage of the study was selected for presentation the spatial distribution of $k_{\text{P\%}}$ in the form of isolines, determined by the highest reliability method. It should be noted that the general trend of distribution of ordinates $k_{\text{P\%}}$ coincides in both methods. Further work was carried out using the basic toolkits of several GISs, the main of which was the free cross-platform QGIS geoinformation system. Using the basines area, identify by own and by already available data, were gather the coordinates of the basines centers of gravity, which are limited by hydrological gauging section. These coordinates were used to further generalization all characteristics of water runoff.

On the basis of all the collected data, was created a map of isolines $k_{\text{P\%}}$, their visual comparison and identification of anomalous zones and zones with special conditions of river runoff formation. Considering the peculiarities of the hydrological characteristics changing in space, namely the absence of sharp fluctuations in runoff variability insufficient number of hydrological observation points and calculation of errors of the obtained data, it is decided to use interpolation by the IDW method. As a

result of this, isolines have softer contours and are highlighted throughout the basin, not just part of it between basin centers.

Figure 3 shows the spatial distribution of $k_{P\%}$ = 50% probability of excess within the study territory. The actual normal runoff in relation to the average runoff 50% probability of excess is approaching in the south and in the center of the basin, with a maximum $k_{P\%} \approx 1$ for the Goryn river basin (Yampil village). From the center to the northeast and west, the average annual river runoff of the 50% probability of excess decreases relative to the actual normal runoff. The largest deviation on top of the Pripyat basin (Richytsia village), 17% lesser than the norm.

Figure 3 *Spatial distribution of transient ordinates of average annual water runoff of the 50% probability of excess in the Pripyat basin within Ukraine*

Ordinates $k_{P\%}$ =90% probability of excess are characterized by similar trends of spatial change, as of $k_{P\%}$ =50%. However, the smallest relation to the norm is shifted to the northeast, to the basin of the Ubort river (Rudnya-Ivanivska village) (Figure 4).
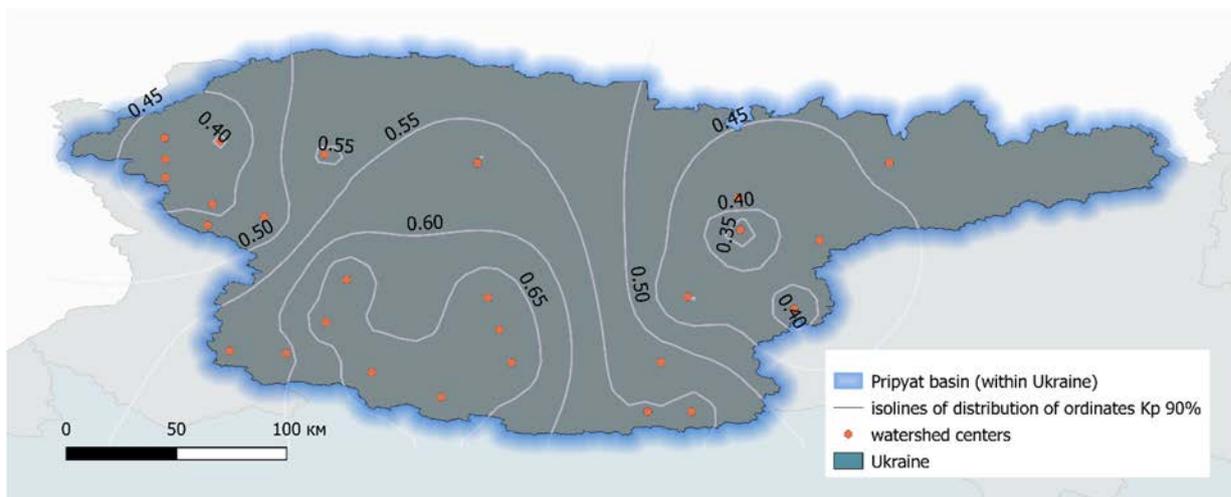

Figure 4 *Spatial distribution of transient ordinates of average annual water runoff of the 90% probability of excess in the Pripyat basin within Ukraine*

In general, all calculated $k_{P\%}$, which have less than 50% probability of excess, are characterized by the inverse distribution of extreme values. It is presented for the river runoff of extremely rare probability of excess, statistical repeatability of which of every 10 000 years (Figure 5).

Figure 5 *Spatial distribution of transient ordinates of average annual water runoff of the 0.01% probability of excess in the Pripyat basin within Ukraine*

The smallest overrun of the normal is observed in the south and central part of the Pripyat basin, with values $k_{\mathrm{P\%}}$ of the 0.01% probability of excess up to 3-4. In the northeast of the basin $k_{\mathrm{P\%}}$ of the 0.01% probability of excess is one of the largest, normal is exceeded 7 times, and in the far northwest largest is higher $k_{\mathrm{P\%}}$ - the norm more than 10 times for the Pripyat river (Rechitsa village). That is, the potential for average annual river runoff of the 0.01% probability of excess varies from 3 to 10 from norms depending on the position of the river.

Conclusions. Pripyat river basin, namely its right-bank part within Ukraine, is characterized by an insufficient number of stationary hydrological observations. In this case, the physical and geographical conditions of the catchment area allow for spatial summarization of data at the scale of the basin. The representativeness of the series of observations is also sufficient.

In the course of the work were created mapping schemes to determine of average annual the river runoff of the necessary probability of excess for the rivers of the Pripyat basin, knowing only the value of the norms of the average annual of the rivers runoff, and determined the permissible errors of the obtained value. Also were pre-allocated two zones with the largest values of extreme of the average annual of the rivers runoff, namely in the extreme northwest of the study area and in the river Noryn basin (Slavenschina village). These territories require a separate research.

Using submitted maps and considering the errors allow you to analyze the economic activity of objects with a statistical average annual runoff. This will help optimize plans for further use of the Pripyat basin water resources. It is also possible to use these charts to supplement long-term river water forecasts and gather information about the current situation.

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