Reconsideration necessity of the water balance equation components.

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The problem of pure water is rather critical all over the world. The concern in shortage of pure water was stated by the United Nations Organization that launched the International Decade for Action “Water for Life” 2005-2015.

The pure water security in the various regions of the world directly depends on the methods of water resources estimation. Today water balance method is considered to be one of the traditional and standard methods for water resources estimation. As commonly known, for the long-term period the structure of the water balance equation is considered to be established consisting of the precipitations spent on evaporation and runoff. To our point of view such an equation having being used for a long time seems to be incomplete. Having such a form the equation does not give an opportunity to determine, for example, the infiltration precipitation losses, not to mention such water balance elements as absorption, runoff and precipitation losses at different stages of water-formation and runoff. Thus, substantial mistakes are made while determining any of the equation components. It is quite clear that the infiltration value determination according to the long-term observations over the underground waters level has become traditional and is used only at the experimental river basins. Mass usage of the traditional infiltration determination method is rather ineffective economically and labour-consuming.

The monograph « World water balance and water resources of the Earth » has being published by the State Hydrology Institute (the Russian Federation) in 1974 under the program of the International Hydrological Decade. Unfortunately, the water balance equation consisting of the same components that are precipitation, runoff and evaporation was used in this monograph. Since there are underground water reservoirs and their infiltration supply, then the infiltration as the component of the water balance equation was used indirectly either in calculations of evaporation or runoff in this monograph. It depended on the hydrological study of the region and on the presence of the survey data. If there were data on precipitation and evaporation and there was not runoff survey then the water balance equation indirectly included infiltration into the runoff, thus increasing it. It means that the water resources calculations were carried out with a certain mistake. If on the contrary, the researchers had survey data on the runoff and atmospheric precipitation, then the evaporation was increased by the infiltration value. In any case of using the data of the monograph the water balance is distorted. It means that the specified monograph requires some corrections.
We hope that the scientific hydrological community will pay attention to this problem promoting researches in this area.

Our long-term researches in the field of water balance have led to the certain results, so we suggest a new linear and correlative model of water balance which could form a basis for reconsideration of the water balance components including that calculated in the earlier mentioned monograph. Our model, unlike the traditional one (precipitations, runoff, evaporation) lets us distinguish analytically, according to the atmospheric precipitation and river runoff observation not only the infiltration value, but also evapotranspiration and evaporation from the water surface, absorption, runoff losses at the drop of each flood, precipitations losses at the surface slowing up at the reservoir. Application of the model considerably raises the accuracy of pure the water stocks determination in any region of the world. The linear and correlative model is checked up on the survey data of supervision on the rivers of Cuba and Russia and it shows good correlation of the calculated and the observed water balance equation components. The model is practically applied at definition of the annual runoff of some rivers in Peru.

The suggested linear and correlative model is based on the fact that on consideration of runoff formation conditions, there are processes at which the falling precipitations form a certain share of losses, and as the result of the precipitations accumulation on the reservoir surface a new quality appears that is the process of water formation. As the cause and the effect are fixed in dependences of the runoff on precipitations, the research of the structure and quantitative expression of the losses uniting the precipitations and the runoff in cause and effect relationship is of a certain interest.

Despite a rather long history of the water balance equation usage, that starts with the work of P.Perrault (1674), the question of use of the correlation of the runoff and precipitations for definition of the runoff and precipitations losses is reflected neither in domestic, nor in foreign publications. Let's consider shortly the linear and correlative model.

Let's accept the water balance equation for the long-term period in the following structure:

$$P = Y + E + U_{n+1} \qquad (1)$$

In which the atmospheric precipitations P are spent on the runoff of the rivers Y, evaporation E and infiltration into underground waters U_{n+1}. The equation (1) can be compared to the equation of the straight line connecting runoff and precipitations:

$$Y = kP - b \qquad (2)$$

At $k = 1$ we have the equation

$$Y_3 = P - b_3 \qquad (3)$$

representing the runoff generated by the precipitations minus some of their part.

Coming out of the physical sense of the phenomenon, we shall note that the runoff starts and comes to an end with some delay in relation to the moment of the beginning and the end of a rain that is connected with accumulation of the certain quantity of losses. As $k_3 = 1$, formally it is possible to establish, that losses during the process of running off are absent.

The considered case corresponds the water balance equation if we accept that b_3 is equal to the evaporation. Thus it is supposed, that on the given pool there is a full interception of the infiltration stream, or the infiltration processes are absent and the runoff is carried out from the surface that is impossible from the physical point of view.

Without coming into the detailed reasons we shall note, that b reflects not just the losses, but more definite - the layer of absorption and the layer of accumulation of the falling precipitations at the reservoir prior to the beginning and after the termination of water formation. Speaking about the identity of the equation (3) and the generally accepted water balance equation (precipitations, runoff, evaporation), it is necessary to state, that the last (3) is a special case of the equation (1) at the factor of regress equal to one. It means that, the equation $Y = P - E$ is valid at absence of losses during the runoff i.e. when the tangent of the angle of the straight line $Y = f(P)$ is equal to I. As such conditions in the nature of the river reservoirs are not met, we shall consider a more typical case:

$$Y_4 = k_4 P - b_4 \qquad (4)$$

In comparison with the variant $k_3 = 1$ and $b_3 \neq 0$ using the equation (4) it is obviously important to consider a problem of correlation between the parameters a_4 and b_4 and to define the physical sense of parameter a_4.

It is obvious, that b_4 is a part of a_4. It is possible to prove, that the the quantities $P(1-k_4)$ and $Y_4 \frac{1-k_4}{k_4}$ are also the components of a_4.

$$a_4 = b_4 + \left[P(1-k_4) - Y_4 \frac{1-k_4}{k_4} \right] \qquad (5)$$

Thus, there are three parameters that are the components of a_4. As for b_4, it has been already mentioned, that it is the quantity of losses on absorption, the losses prior to the beginning and the termination of water formation, spent in a consequence on the evaporation. I.e. it is a part of the total evaporation.

If to consider, that k_4 is a factor of the runoff from the active layer of precipitations, and $(1-k_4)$ is the factor of losses, then $P(1-k_4)$ is the losses of precipitations during the runoff. As some part of evaporation is in the form of the parameter b_4 then the remaining part of the expression (5) also represents evaporation, and the expression in the square brackets is easily converted to $b_4 \dfrac{1-k_4}{k_4}$.

It is easy to demonstrate, that $Y_4 \dfrac{1-k_4}{k_4}$ is nothing other but the infiltration.

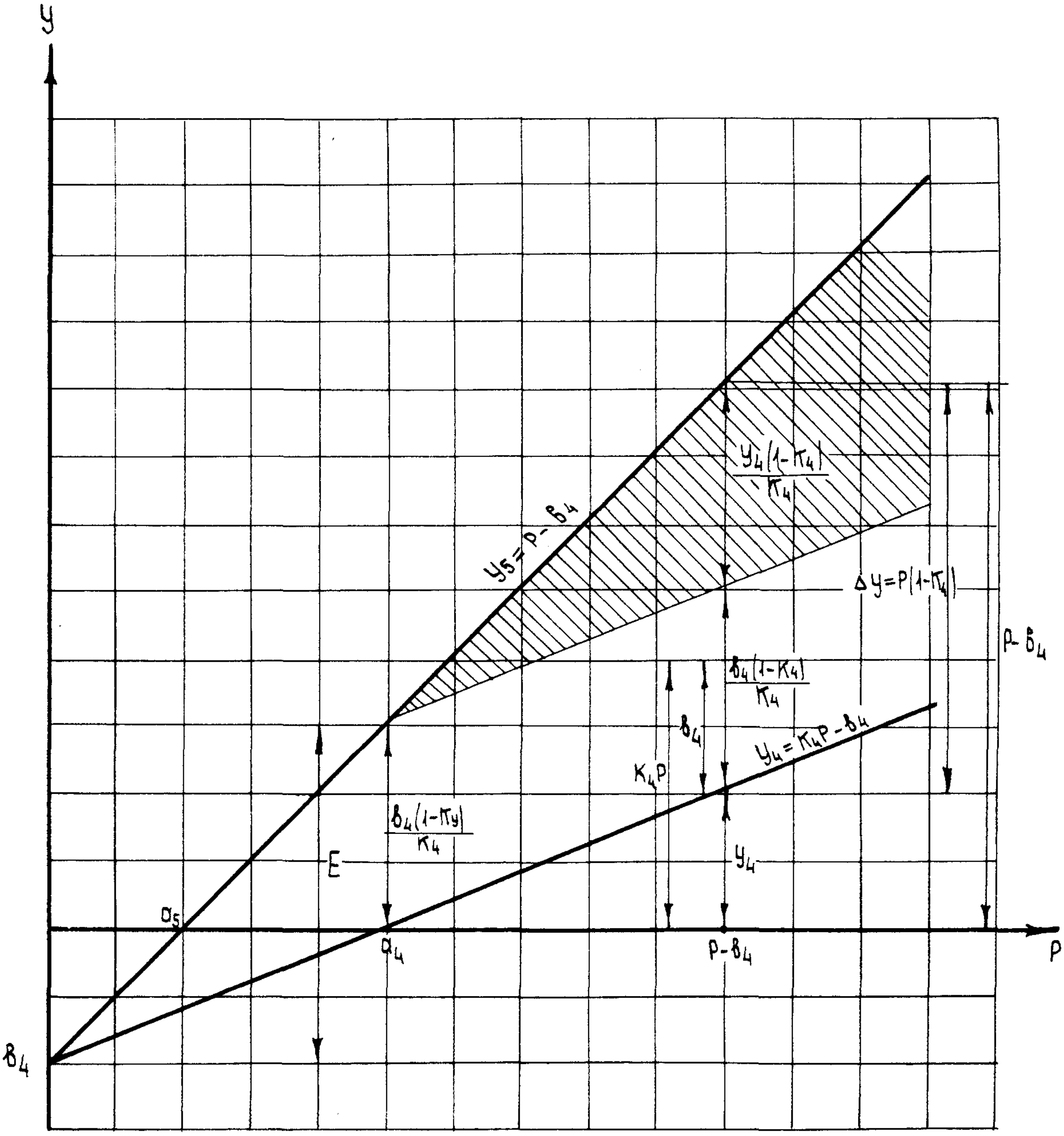

Рис.1. Graph of the members of the water balance equation.

The water balance equation in the obtained interpretation, with the reference to the graph of dependence of the runoff on the precipitations will be as follows:

$$P = Y_4 + a_4 + Y_4 \frac{1-k_4}{k_4} = Y_4 + b_4 + b_4 \frac{1-k_4}{k_4} + Y_4 \frac{1-k_4}{k_4}. \qquad (6)$$

The offered linear and correlative model is checked on the survey data on the experimental basins of the State Hydrology Institute (the Russian Federation).

№	River point	F km^2	Elements of the water balance according to the survey data			Calculated values of the water balance components		Correlation factor	Regression equation $Y = f(P)$
			Y, mm	P, mm	E, mm	E alcu-lated, mm	U_{n+1}, mm		
I	**2**	**3**	**4**	**5**	***6***	***7***	**8**	***9***	***10***
1	Usadievsky gully	0,36	103	459	335	314	42,1	0,86	Y=0,71P-223
2.	V. Usadievsky gully	0,016	33,4	462	300	283	152	0,67	Y=0,18P-51
3.	Siniaya Gnilka gully	0,015	52,3	451	**207**	**400**	2,2	0,83	Y=0,96P-384
4.	Taiozny gully	0,45	57,7	477	**197**	**345**	79,7	0,77	Y=0,42P-145
5.	Elovy gully	0,0023	66,4	491	207	222	99,6	0,69	Y=0,40P-89
6.	Polomet river Dvorets village	432	113	476	179	209	150	0,70	Y=0,43P-90
7.	Polomet river Iazelbitsy village	631	120	463	214	233	102	0,79	Y=0,54P-126
8.	Polomet river Sominka village	776	115	453	228	200	140	0,76	Y=0,45P-90
9.	Polomet river Lychkovo village	2203	106	458	231	241	110	0,74	Y=0,49P-118
10.	Lonnitsa river Mosolino village	48,3	103	480	214	283	91,3	0,83	Y=0,53P-150
				average	231	273			
Comparison of the elements of water balance to S.F.Fedorov's data (1961-1973)									
I.	Taiozny gully	0,45	58.0	473	401	345	71	0,78	Y=0,45P-155
2.	Usadievsky gully	0,36	94,4	448	384	320	33	0,85	Y=0,74P-236
3.	Polomet river Dvorets village	432	109	458	**398**	**252**	97	0,79	Y=0,53P-134
4.	Siniaya Gnilka gully	0,015	69,0	451	404	317	64	0,63	Y=0,52P-165

The results of comparison of the calculated elements of the water balance equation and according to the survey data on the experimental basins specify the following: the divergence in the quantities of evaporation does not exceed 18 %.

If we do not consider the infiltration parameter in the water balance equation, i.e. the equation including the atmospheric precipitations, evaporation and runoff, the maximal divergence with the equation (6) at defining, for example, evaporation can reach 175-190 %.

The linear and correlative model is been used on the rivers of Cuba Republic where division of the volumes in parameter b_4 on the direct absorption and surface slowing up is executed. Using the geomorphological factor that is the correlation of the length of a slope to the square root from the bias of a reservoir $\varPhi = \frac{l}{\sqrt{i}}$ we managed to state the degree of the absorption reduction from the relief on the rivers of Cuba and Russian Federation.

The analytical expression of the losses of the runoff for the surface slowing up is obtained. Besides, we obtained the dependence of evaporation from the water surface on the evapotranspiration.

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