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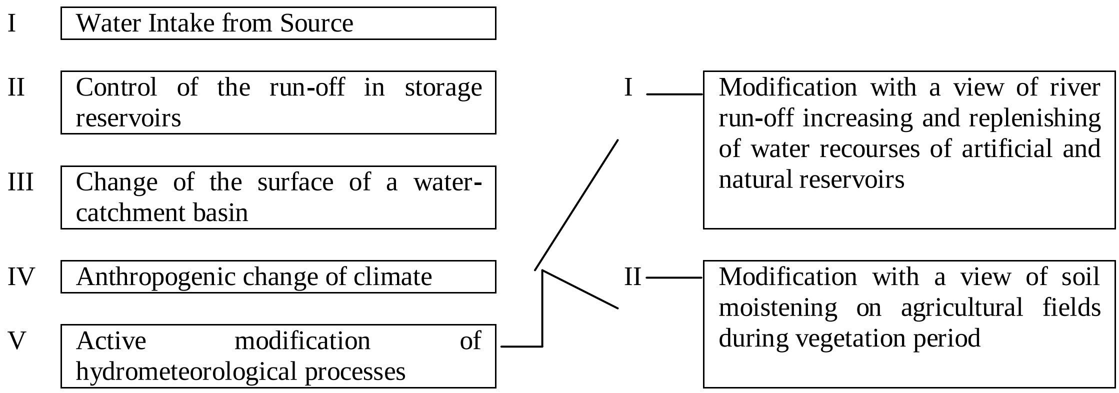
A MATHEMATICAL MODEL OF FORMATION OF THE RIVER RUN-OFF IN THE CASE OF ANTROPOGNIC INFLUENCE ON CLOUD SYSTEMS

1. Introduction

Man's activities throughout the entire period of the existence of the earth's civilization have produced a certain influence on hydro-meteorological processes and phenomena. This influence was essentially different at different times and in different regions of the earth. The contemporary period and especially the period expected in the nearest future are characterized by many-sided human activities which are constantly and rapidly increased in scale and affect all the natural processes on which characteristics of hydrometeorological phenomena depend.

Man's influence on the river run-off and accordingly, on the information on this run-off can be classified into five types listed in (Table I). At present particular attention is given to the fifth type of the influence which can be divided into four groups (Table I). The last two anthropogenic influences are based on making precipitation more intensive with the aim to increase water supply of some southern rivers. Such work is especially effective in the basins of rivers already having control reservoirs. In this case work on increasing precipitation can be carried out all the year round in the entire water-catchment area located above the discharge site of the reservoir. This results in an artificial increase of the run-off of rivers supplying a given reservoir and makes it possible to use stored water whenever necessary.

Table I. Classification of the influence of man's economic
Activities on the river run-off regime



For numerical experiments, allowing to estimate possible changes of run-off parameters as a result of anthropogenic influence upon hydrometeorological processes (in particular artificial increasing of liquid precipitation), models of separate hydrological processes (water motion along the slope, moisture transition on soil, shifting of water masses in river beds, etc) are applied. These models may be served as the basis for the construction of a general model of river run-off formation. The main problem have is to choose an adequate detailing of the process. The latter may be ensured by necessary information and corresponds with the role of some of the processes for the specific hydrological phenomenon or watershed. An important factor in construction of the model is that fact, that a number of run-off parameters must be selected according to the observations upon water regime.

Extraordinary spatial heterogeneity of conditions in the catchment area, sensitivity of run-off parameters to the variations of meteorological and morphometeorological factors make the construction of adequate mathematical models of run-off formation as one of the most difficult problems. Solution of this problem depend upon not only the extent of the evolution of knowledge about the main physical processes but upon the possibility of obtaining of information in the catchment and space-time variability of these processes, as well.

2. Strycture of a physic-mathematical model

To study the quantitative estimate of anthropogenic changes of the run-off expected in prospect in eastern regions of Georgia we constructed a physic- mathematical or statistical regression model showing the relation of the ET river run-off to the mean territorial precipitation that occurred in the basin. Within the framework of the proposed model the process of rainfall run-off formation is randomized experimental (a random chaise a 12-hour interval during which the cloud seeding or gauging was carried out 1, 2, 4) can be schematically described as follows. Precipitation occurring in ET is partly or totally absorbed by the soil and transferred to deeper horizons. Precipitation which is the difference between the rainfall intensity and the absorption rate forms a run-off layer which moves along the slope and gets into the river bed network. When modeling a melted snow run-off, we additionally take into account the snow-melting process and water loss caused by the filling of surface depression and by evaporation.

In the simplest case the model can be represented as

$$W = Q\Delta t = (1 - K_1 - E_2)HF \qquad (1)$$

Where

$$H = \ddot{x}_1 = \sum_{j=1}^{S_{1i}} x_{ij}/S_{1i}$$

The coefficients E_1 and E_2 are used to take into account factors influencing the evaporation and percolation processes such as air temperature, air humidity, a basin slope, structure and composition of the ground

Therefore the water volume formed at the expense of precipitation in the j-th ET and passed through the design water discharge site is equal to

$$W_j = \sum_{i=0}^{n_i} \frac{(Qi-Qo)+(Q_{i-1}-Qo)}{2} \qquad (2)$$

The run-off increase in the hydrograph is expressed in the form of a flood crest the beginning of which is a value of the water discharge ordinate at the moment when the counting of EU began. The crest volume is calculated by expression (2). If water discharge was less than Q_0, i.e. $Q_i<Q_o$, and the run-off decrease was observed for the j-th EU, then we assumed W_i=O. In that case, if within the j-th EU the cloud seeding was carried out, it was regarded as having no results from the hydrological point of view, though the cloud seeding cloud produce an increase of precipitation, but the precipitation amount and the conditions of run-off formation were such that they did not lead to the increase of water discharge in the discharge water gauging station.

Depending on the conditions of run-off formation, the flood crest length in the hydrograph can be different. The crest existence time can be several times greater than EU. That is why the crest can be the result of several EU; in that case it is necessary to know the contribution of each EU to the crest volume so as to be able to determine components of the total run-off amount of the experimental and control groups. To this and we use the genetic method of plotting hydrograph by the know behaviors of rainfall in the catchment area. This method consists in summing up successively elementary run-off volumes which were formed in different parts of the basin and pass simultaneously through the gauging installation. In that case the time during which elementary run-off volume reach the considered river discharge gauge site and which is know as the lag time is taken into account by plotting in the catchment area map a diagram of isochrones, i.e. Lines of points which are equidistant from the closing discharge gauge site with respect to the lag time. The isochrones diagram can be used for determining the distribution of individual water catchment areas giving the run-off within the given time. The method can be expressed analytically by the formula

$$Q_i = \int_0^{t_1} h \frac{\partial f}{\partial z} d\tau \qquad (3)$$

Which shows the regularity with which water runs off the catchment area to the closing discharge gauge site? Here Q is water discharge at the i-th moment of time from the flood beginning, h is the surface inflow at a given moment of time; t_1 is the lag time; f is the water catchment area contained between the adjacent isochrones; r is the integration variable.

Thus, having the lag time, the corresponding water yield graph (a rainfall pluviogram), physical and geographical data, and taking into account the volumetric run-off coefficient characterizing each flood crest, we can determine the run-off volume formed as a result of the rainfall of an individual EU bt the expression

$$W_j = \alpha_j H_j F \qquad (4)$$

The volumetric run-off coefficient contained in expression (4) is determined by the formula

$$\alpha_j = \frac{V_j}{\sum_1 H_1 F} \qquad (5)$$

where V_j is the flood crest volume calculated by integration of the observed hydrograph; $\sum H_1$ is the total layer of precipitation bodies of EU which have formed this crest.

3. An example of calculation

The model of rainfall run-off formation was tested in the water catchment basin of the Iori River (in the hydrometeorological polygon of the Trans-Caucasian Research Institute of the USSR State Committee for Hydrometeorology). The basin area is 494 km^2; the water-course length is 43 km; the calculated mean rate of river bed lag is 12 hours. Fig 1 shows the hydrograph comparing the observed run-off and the run-off calculated by the model. In these calculation we used data on precipitation of q1982 (the 5-th month), data on 13 EU of which 0 were with and 4 without cloud seeding; the water discharge was measure by the discharge gauging installation on the Iori river near the village of Lelovani. To check the accuracy of calculation we compared the values of all flood crest volumes obtained by integration of the observed hydrograph on the basis of (2) and calculated by expression (4). The discrepancy was not greater than 1-2 and therefore the accuracy was quite acceptable. Calculation shows that the total experimental run-off formed at the expense of precipitation of EU with cloud seeding was W_1 =5196.4 10^3 m^3; the total run-off was W_2 = 3417.2 10^3 m^3, the mean experimental run-off volume per one EU was equal to 371.1 10^3 m^3, while the control one was V_2=342 10^3 m^3. The run-off increase was V = 29.4 m^3 or 10% of the control mean run-off of one EU.

For performing calculations on computer the ANSTOK program is used 3.

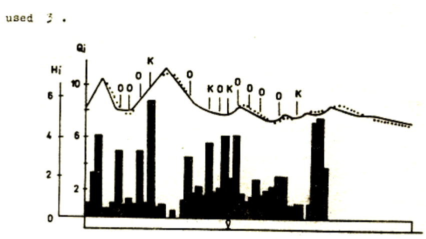


Fig.1. The hydrograph of the observed (1) and calculated
(2) run-off values for may 1982.

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Математическая Модель Формированмя Речного Стока При Антропогенном Воздействии На Облочние Системы

В работе рассмотрены вопросы антропогенного воздействия на режим речного стока и оценки эффективности эксаериментальных работ по увеличению водных ресурсов для горных районов Восточной Грузии. Для этой цели расмотрена возможность исползования физико-математической модели формирования речного стока и прмводятса результаты анализа гидрометеорологического полигона ПЕЬ ЗакНИИ.

ცინცაძე თ.

ღრუბელთა სისტემებზე ანთროპოგენური ზემოქმედებით მდინარის ჩამონადენის ფორმირების მათემატიკური მოდელირება.

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