Geophysical Research Abstracts,
Vol. 11, EGU2009-950, 2009
EGU General Assembly 2009

The concept of runoff elements as a basis of scale-free approach to runoff formation modelling – the experience of the model "Hydrograph" development and implementation

Yu.B. Vinogradov and O. Semenova

State Hydrological Institute, Department of Experimental Hydrology and Modelling of Hydrological Processes, St. Petersburg, Russian Federation (omakarieva@gmail.com)

The concept of runoff elements used in proposed model as a base for calculating routine describing slope runoff transformation gives the opportunity to avoid the scale problem in hydrological modelling which, to our opinion, mainly refers to mathematical approaches (the framework of Navier-Stokes equations) widely used for description of water movement within the basin.

River basin is a system of elementary watersheds of surface and underground ones of various layers. The topography of river basin surface conditionally can be presented by a system of the inclined surfaces each of them being an elementary slope. Within a surface elementary slope water flowing down is realized over non-channel rill system and within the underground elementary slope – over the underground drainage system. The elementary slopes and watersheds in their turn consist of a system of runoff elements – limited by micro-divides areas of the surface and underground elementary slopes and watersheds exposed with their open part to the slope non-channel or underground drainage system. Runoff elements are not the kind of idealization but they can be easily identified with the natural formations. Surface runoff elements depending on natural conditions but mainly on inclination can be measured from shares and ones up to tens of thousand square meters. Underground runoff elements can be much greater.

For each runoff element there is a balance ratio

$$dW/dt = S - R \tag{1}$$

There is the unique nonlinear relation between $W$and outflow discharge$R$:

$$R = b[\exp(aW) - 1] \tag{2}$$

Then, the corresponding equation of the outflow hydrograph from runoff elements of a given layer is the following**:**

$$R = (S + b)/\{1 + [(S - R_0)/(R_0 + b)] \exp[-a\Delta t(S + b)]\} - b \tag{3}$$

Here R_0 is the initial value of runoff R and S is the runoff rate (m^3s^{-1}); Δt is the computational time interval (sec) during which S is constant; a, b – hydraulic coefficients (which determine the conditions of outflow) with dimension m^{-3} and m^3 s^{-1}.

In the general case, we assume that the number of runoff elements is proportional to the basin area $F(m^2)$, and then $a = a^* \times F^{-1}$and $b = b^* \times F$.

A lot of surface, soil and underground runoff elements of different level make a river basin. And the total hydrograph of inflow to the channel system is described by an equation system such as [3] for the surface, soil and various layers of underground waters when values S, Q, a and b are different.

The types and peculiarities of runoff elements determine the character of transformation of runoff formation hydrographs (runoff in the point of its origin) into hydrographs of inflow to the channel system. By transformation we understand runoff redistribution in time being determined by regulating impact of runoff elements and described by equation [3].

The existing runoff types and the types of runoff elements connected with them are listed below. Simultaneously the order of the values of the determining coefficient a^* (when the average value of the parameter $b^* = 10^{-6}$m s^{-1} is constant) and of the typical outflow time corresponding to it (relaxation time)$\tau^* = 1/(a^* b^*)$. The real relaxation time depends on water amount in a runoff element and is always less than the typical time.

1. Direct runoff realized with liquid precipitation to the surface of flowing waters ($a^* \rightarrow \infty$,$\tau^* = 0$).
2. Surface runoff at the submerged territory. It is formed when underground waters come to the soil surface, basically, at plains, especially in river flood beds and within wide and flat valley bottoms and intermountain depressions, at slope base ($a^* = 1000m^{-1}$,$\tau^* = 17\,\mathrm{min}$).
3. Classical surface runoff. It is formed with the excess of storm rain intensity or water yield from snow over infiltration intensity ($a^* = 1000m^{-1}$,$\tau^* = 17\,\mathrm{min}$).
4. Soil and swamp runoff, runoff in taluses (through runoff). It is realized in various situations with presence of obstacles for free infiltration ($a^*$is from 100 up to 10 m^{-1}, τ^* from 3 hours up to a day).
5. Various kinds of underground runoff. The runoff regime changes depending on the kind of the underground waters causing it: irregular temporary water, ground, fissure, karst, artesian, supra-, intra- and sub-permafrost waters. The abundance of rocks in water and mobility of underground waters generally reduce with the depth. Therefore, we assume the vertical stratification of underground aquiferous structures:
   - rapid ground (a^* is from 10 up to 1 m^{-1}, $\tau^*$is from 1.2 to12 days),
   - ground (a^* is from 0.32 up to 0.032 m^{-1}, $\tau^*$is from 1.2 months up to a year),
   - upper groundwater (a^* is from 0.01 up to 0.001 m^{-1}, $\tau^*$is from 3.2 up to 32 years),
   - deep ground water (a^* is from 0.00032 up to 0.000032 m^{-1},$\tau^*$is from 100 up to 1000 years),
   - historical groundwater (a^* is from 10^{-5}up to 10^{-6} m^{-1},$\tau^*$is from 3200 years and more).

The concept of runoff elements and the results of successful use of the proposed system for runoff modelling at basins regardless of their scale and situated in different natural conditions would be presented.