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MAXIMUM RUNOFF OF THE FLOOD ON WADIS OF NORTHERN PART OF ALGERIA

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ABSTRACT

Wadis of Algeria are characterized by a very irregular hydrological regime. The question of estimating the maximum flow of wadis is relevant. We propose in this paper a method based on an interpretation of the transformation of surface runoff in streamflow. The technique of account the maximal runoff of flood for the rivers of northern part of Algeria based on the theory of channel isochrones is offered.The realization of this method is performed on the basis of hydrometeorological data standarts.

Key words: wadis, maximum flow, runoff, streamflow, flood.

1. NTRODUCTION

Algerian territory can be conditionally divided into three geographical zones, situated from north to south: 1) coastal Tel – fertile, high cultivated and sown zone; 2) territory of Atlas Mountains, consisting of Small Atlas on the north (the highest point – 2308 m) and Big Atlas (the highest point – 2328 m) – on the south, and the extensive plateau, droughty and fruitless, spreads between them; 3) Sahara desert zone, which is located deep into continent, with not numerous oases, transforming into mountain range Ahaggar in the South with the highest point of Algeria – Tahat mountain (2918 m).

Hydrography of the country is poor: some rivers flow into Mediterranean Sea, whereas only parched river-beds and dried up salines are often found in Sahara zone. All Algerian rivers belong to wadis type.

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Wadis of Northern Algeria are similar to rivers of Mediterranean type with prevalence of rain feeding. Only in near-shore zone the wadis' runoff is directed to

Mediterranean Sea. In the rest of Algeria the drainage network is represented by closed basins of internal runoff. The biggest wadi is Shelif (L=700 km), the others rarely exceed 100 km at length (El-Hamman, Isser, Summam, El-Karib, etc.).

Maximum runoff of the flood on wadis of northern part of Algeria is examined in this work. This is mountain territory with difficult and various relief. Amplitude of height variation (from 0 up to 2328 m) defines variety of climatic zones, soils and vegetation, which have an influence upon genesis of maximum drainage of adjacent wadis.

2. PROBLEM STATUS

Rainy floods on the concerned territory are observed during cold period of the year and formed as a result of liquid fall-out; in mountain areas the snow-resources, accumulated on the top, also participate in their formation. Result of rain falling is often short-term but too high floods. The dams, water reservoirs and hydroelectric power stations are built on the wadis of Northern Algeria. During the previous years the disastrous floods in different areas of Algeria were registered, as a result of which influence many hydraulic structures were destroyed, local population suffered, and in general the country suffered significant economic damage.

The problem of investigation of maximum runoff of the rainy flood in small and medium Algerian rivers is of current importance, however due to insufficiency of hydrometric data it is not always possible to determine its value. Thus the territorial generalization of characteristics of the maximum runoff is necessary, allowing quantitative evaluation of maximum expenditures of the unstudied rivers.

The purpose of the work is development of methods of calculation of the maximum runoff of wadis in Northern Algeria, based on standard hydrometeorological data.

Analysis of investigations and publications. World experience in the sphere of calculation of the maximum runoff characteristics allows classifying of the methods, being used in practice, into few groups:

1. So called formula of maximum intensity or "rational formulas"
2. Volume formulas
3. Empirical, mostly reduction formulas
4. Methodology of "peak-peak"

5. Formulas, based on theory of bed isochrones

In the first case the empiric dependence between maximum intensity of precipitation for some calculation period and maximum modules of drainage is established.

Volume and reduction formulas in their base depend on single-mode floods, at that the common decision is only volume structure, since variant of reduction formula represents only private case, when duration of water influx from the slopes to the channel net through the territory is changed a little. It is very difficult to realize volume structure for normalization of characteristics of maximum drainage, since duration of flood depends not only on size of basins, but also on factors of hillside regulating of drainage (under the influence of forest-cover and waterlog) and river-bed – floodplain regulation of floods. Because of this the formulas of volume type are not widespread in world practice. To the contrary, too simple methods of generalization of data in structure of reduction formulas and methodology of "peak-peak" for long years displaced development of modern theoretical base for normalization of maximum drainage characteristics.

3. METHOD OF INVESTIGATION

The authors proposed the variant of calculation scheme, realizing principal model of drainage formation, shown in the figure 1.

Examining the figure 1, it easy to come to a conclusion that the idea of formation of formulas of maximum intensity (rational method) is not well-founded in theoretical respect, as in the model "precipitations-channel flow" the operator of precipitation transformation in hillside drainage is missed.

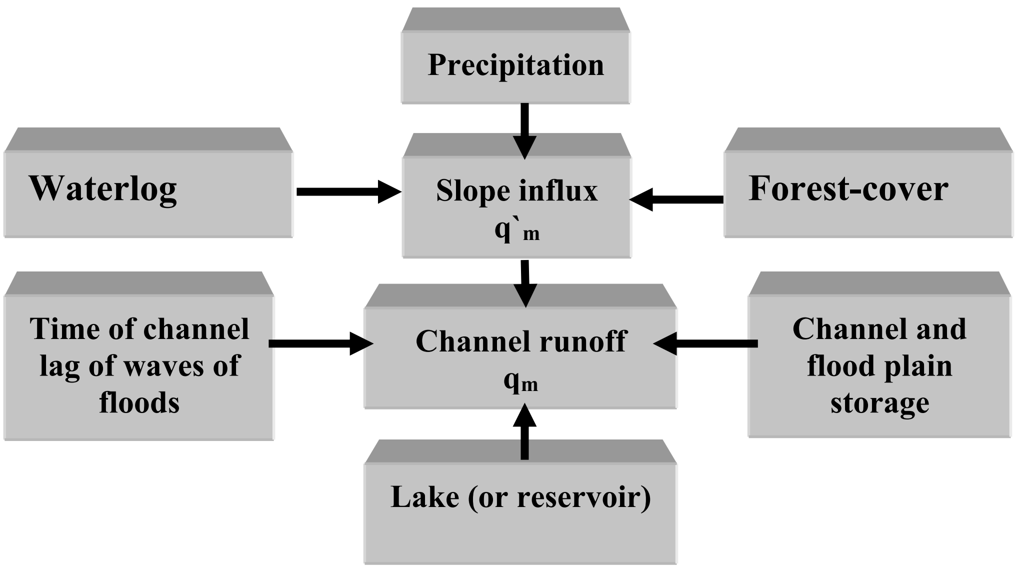

Fig.1. Scheme of formation of bed flowing-off

It is obvious that two operators must describe the process of formation of channel runoff: "precipitations – slope influx" and "slope influx – channel runoff". Just such shall be the theoretical and methodical base of problem solving, concerned, for example, with forecasting of hydrographs of channel runoff under atmospheric precipitates. However in practice of hydrological calculations, on solving of a whole series of problems, the great interest is given not to the whole hydrograph of channel runoff, but to its maximum ordinate, moreover, to infrequent exceedance probability.

In such case the problem of formation of theoretical base may be simplified considerably. In particular, it is possible to confine oneself only to consideration of operator "slope influx – channel runoff", which is described by the balance equation according to studies (2,3):

$$\frac{\partial Q}{\partial x}+\frac{1}{\varepsilon_F}\frac{\partial \omega}{\partial t}=q'_t\,B_t \qquad (1)$$

Where Q – discharge of water;

ε_F - coefficient of channel and flood plain storage;

ω - total area of water section in a plane of the channel lag isochrones;

q'_t - any function of inflow of water from slopes in the bed network;

B_t - width of a watershed by the channel lag isochrones at the moment of time t.

If within the equation (1) the problem only concerning maximum discharge of Q_m is resolved, than according to (2,3) functions q'_t and B_t may be represented in reaming from maximum value, i.e.

$$q'_t = q'_m\left[1-\left(\frac{t}{T_o}\right)^n\right], \qquad (2)$$

and

$$B_t = B_m\left[1-\left(\frac{t}{t_p}\right)^m\right]. \qquad (3)$$

where q_m - maximal module of slope influx;

B_m - maximal width by the channel lag isochrones;

T_o - duration of slope influx;

t_p - time of channel lag of waves of floods.

n and m – exponents in equations of slope influx and isochrones, correspondingly.

Expressing discharge of water Q through speed of channel lag V and area of water section ω, and, inserting (2) and (3) into (1), we will obtain

$$V\frac{\partial\omega}{\partial x}+\frac{1}{\varepsilon_F}\frac{\partial\omega}{\partial t}=q'_m B_m\left[1-\left(\frac{t}{t_p}\right)^m-\left(\frac{t}{T_0}\right)^n+\frac{t^{n+m}}{T_0^n\ t_p^m}\right] \tag{4}$$

Provided that $t_p \langle T_o$, integration (4) brings to expression

$$q_m=\frac{Q_m}{F}=q'_m\left[1-\frac{m+1}{(n+1)(m+n+1)}\left(\frac{t_p}{T_0}\right)^n\right]\varepsilon_F \tag{5}$$

Under invert correlation, i.e. when $t_p \geq T_o$,

$$q_m=\frac{Q_m}{F}=q'_m\frac{T_0}{t_p}\frac{n}{n+1}\left[\frac{m+1}{m}-\frac{n+1}{m(m+n+1)}\left(\frac{T_0}{t_p}\right)^m\right]\varepsilon_F \tag{6}$$

As evident from (5) and (6), the modules of slope influx q'_m and coefficients of channel and flood plain storage, and also transformation functions $\Psi(t_p/T_o)$ enter into their right parts, which are equal correspondingly:

a) under $t_p \langle T_o$

$$\psi\left(\frac{t_p}{T_o}\right)=1-\frac{m+1}{(n+1)(m+n+1)}\left(\frac{t_p}{T_o}\right)^n; \tag{7}$$

б) under $t_p \geq T_o$

$$\psi\left(\frac{t_p}{T_o}\right)=\frac{n}{n+1}\frac{T_o}{t_p}\left[\frac{m+1}{m}-\frac{n+1}{m(m+n+1)}\left(\frac{T_o}{t_p}\right)^m\right]; \tag{8}$$

Combining (5) and (6), taking into account (7) and (8), it is possible to write generalized equation for q_m :

$$q_m = q'_m \ \psi\left(\frac{t_p}{T_o}\right) \varepsilon_F \, . \qquad (9)$$

If the river basins have lakes or reservoirs of stream-handling type, then it is necessary to bring coefficient of lake (or reservoir) regulating r ≤ 1.0 into right part (9), i.e.

$$q_m = q'_m \ \psi\left(\frac{t_p}{T_o}\right) \varepsilon_F \ r \qquad (10)$$

In (10) the parameter, which determines the upper limiting value of maximum runoff on water collection, is module of slope influx q'_m, which is equal on the basis of integrating (2):

$$q'_m = \frac{n+1}{n} \frac{1}{T_o} Y_m , \qquad (11)$$

Where $\frac{n+1}{n}$ – irregularity coefficient for slope influx; Y_m – layer of slope influx.

It is obvious that q′m represents complex characteristic, which is coordinated with other elements of slope hydrographs - their form – by means of $\frac{n+1}{n}$, volume – by means of Y_m and duration of influx - by means of T_o. On the other hand, being the characteristics of slope influx, T_o and Y_m allows taking into account regulating effect of such local landscape-hydrological factors, like forest-cover, waterlog, etc. [2,3,5,6,7].

4. INVESTIGATION MATERIALS

43 gauging-stations of National Hydrometeorology Service were used for substantiation of design parameters of operator model of maximum runoff of floods of Algerian rivers. Areas of reservoirs of investigated rivers fluctuate within 77 km^2 and 8735 km^2. Period of observations on concerned reservoirs is since 1967 till 1997 years; the shortest line has 9 years of observation (wadi Ksob-Medjes), the longest one is 29 years (wadi Bu-Handan – Medjes Amar).

It is significant to note that in most cases the maximum discharge was determined under extrapolation of discharge curves $Q = f(H)$ and checked by means of hydraulic calculation under the tracks of high flood waves.

5. RESULT OF INVESTIVATIONS

The authors of present article realized operator model for calculation of the maximum runoff of wadis' floods of the Northern area of Algeria. All parameters, included in design formula (10), are established.

Layer of flood runoff of 1% provision is represented in the form of isolines' chart (figure 2). Character of isoline distribution over the territory is enough complicated, that is mainly concerned with relief, in particular, location of mountain ranges toward direction of principal moisture transfer. In general, $Y_{1\%}$ values naturally decrease in the direction from north to south, from 64 to 24 mm. The maximum values (50-64 mm) may be observed on coastal, well-moistened territory that corresponds to physiographic zoning. Nevertheless, the decrease of flood runoff up to 32 mm is possible in the north-east of coastal Tel that one can observe in such cases, when flat lowered territory is bordered with mountain ranges. To the extent of south movement, to the zone of Atlas Mountains, the runoff decreases and reaches minimum (24 mm) on the territory of internal arid hollows (figure 2).

On the basis of analysis of literary resources and taking into account longevity authors' investigation concerning determination of coefficients of form of slope hydrograph and duration of influx of floods to the bed network for different territories (1,2,4), it is proposed to average and to assume $\frac{n+1}{n} = 3.5$ and $T_o = 3$ hour as equal these parameters for Algerian rivers.

Investigations of one of the authors of this article (8) can be confirmation of accuracy of accepted values, in particular, $\frac{n+1}{n} = 3.5$. On the basis of analysis of the parameters of volume formulas Ladjel Mahmoud proposes to use empiric dependence between the coefficient of the form of channel hydrograph $\frac{m+1}{m}$ and area of spillway, which looks like:

$$\frac{m+1}{m} = a + b \lg\left(\frac{Y_{1\%}}{T_n}\right) \quad (12)$$

Where a and b - hydraulic characteristics of channel.

Value $\frac{n+1}{n}$ is the maximum value $\frac{m+1}{m}$ under $F=0$, i.e. coefficient of the form of slope hydrograph. For wadis of Northern Algeria value $a'=0.55$ (figure 3), wherefrom $\frac{n+1}{n}=3.55$, that well conforms to value $\frac{n+1}{n}=3.50$, accepted by us.

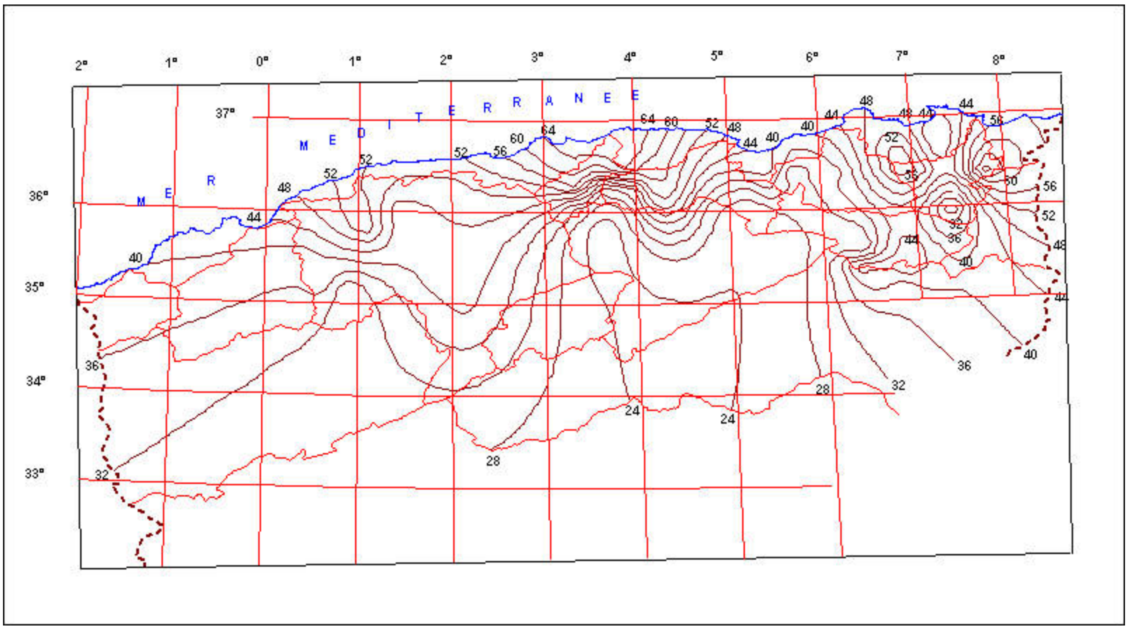

Fig.2. Map of distribution of the maximum layers of floods runoff of 1% provision for Algerian rivers, mm

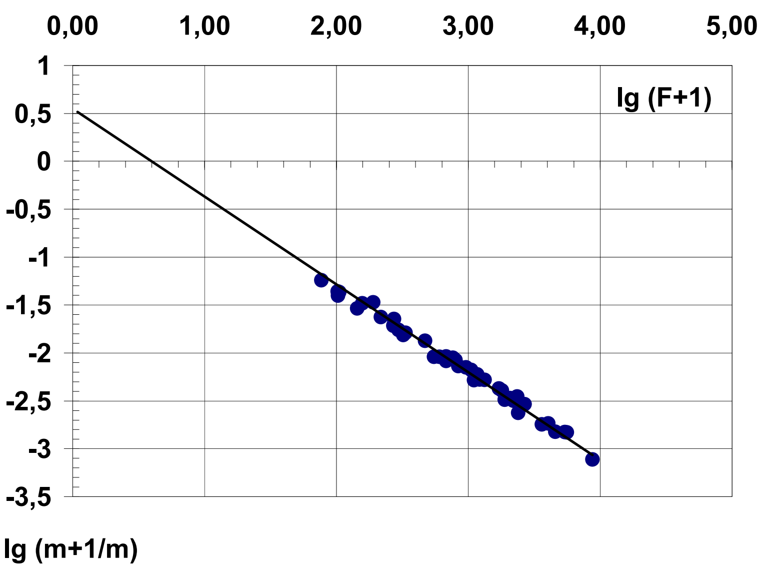

Fig.3. Dependence of coefficient of the form of channel runoff on area of watershed for wadis of Northern Algeria.

Design maximum models of slope influx $q'_{1\%}$ for concerned territory change in the range from 20.3 m^3/s km^2 - in the northern, coastal area, and up to 7.3 m^3/s km^2 – in the south.

Transformation function $\Psi\left(\frac{t_p}{T_o}\right)$ may be claculted according to equations (7) and (8) depending on proportion t_p and T_o. With the purpose of determination of t_p it is necessary to dispose of the data about areas of watersheds, lengths and slopes of rivers, since

$$t_p = \frac{L}{v_\partial}, \qquad (13)$$

where L - river length (km); v_∂ - speed of channel lag $(km/hour)$.

It is proposed to calculate the speed of channel lag v_∂ under the regional formula, worked out for rivers of steppe zone

$$v_\partial = 1.19\ F^{0.14}\ I^{0.33}; \qquad (14)$$

where $F-$ area of river watershed (km^2); $I-$ weight-average slope of river ‰.

Taking into account the fact that runoff for rivers of this territory in practically all cases is formed under the type of slowed $(t_p > T_o)$, and assuming $m = 1$, it is possible to write the following design equation for $\Psi\left(\frac{t_p}{T_o}\right)$- under $\frac{\mathrm{n}+1}{\mathrm{n}} = 3.5$ and $\mathrm{T_o} = 3\,\mathrm{hour}$:

$$\Psi(\mathrm{t_p}/\mathrm{T_0}) = \frac{0.855}{\mathrm{t_p}}\left[2.0 - \frac{1.74}{\mathrm{tp}}\right]; \qquad (15)$$

then $t_p \leq > T_0$

$$\Psi(\mathrm{t_p}/\mathrm{T_0}) = 1 - 0.59\left(\frac{\mathrm{tp}}{3}\right)^{0.4}. \qquad (16)$$

Analyzing the values of $\Psi\left(\frac{t_p}{T_o}\right)$, obtained under 43 watersheds, one can note that they change in too wide range – from 0.05 to 0.52 (fig.4). The minimum values of $\Psi\left(\frac{t_p}{T_o}\right)$ correspond to small watersheds with areas approximately up to 350 km^2, and the maximum values correspond to watersheds with area more than 4000 km^2. The upper limit value of $\Psi\left(\frac{t_p}{T_o}\right)$ is the unit, corresponding to $\frac{t_p}{T_o} = 0$ or $F = 0$.

The last parameter, included in design formula, is the coefficient of channel and flood plain storage ε_F. Under certain q′m and $\Psi\left(\frac{t_p}{T_o}\right)$ its value may be calculated in the inverse way from equation (10). Obtained values of ε_F are generalized in the form of dependence on area of watersheds F, which is represented on the figure 4. There are also curves of common reduction of maximum runoff $\frac{q_{1\%}}{q'_{1\%}}$ and transformation function $\Psi\left(\frac{t_p}{T_o}\right)$ are represented on the same figure. Extrapolation of all three curves in the range of small areas is carried out taking into account their physical boundary, equal to 1.0.

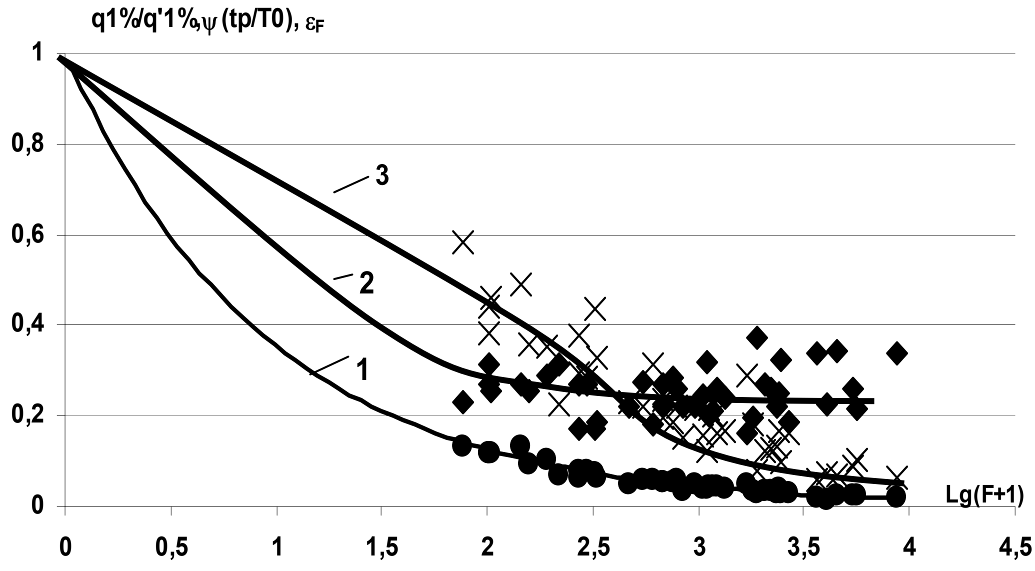

Fig.4. Dependence of coefficients of common reduction (1), channel transformation (2) and channel and flood plain storage (3) on area of watersheds of wadis of Northern Algeria.

Analyzing the figure 4, it is possible to note that channel and flood plain storage plays leading role for rivers with watershed area approximately up to 350 km^2, and for larger watersheds the transformation occurs mainly at the expense of time of channel lag t_p.

For convenience of use the coefficient ε_F may be represented in the form of table, given below (table 1).

Table 1. Coefficients of channel and flood plain storage ε_F of maximum module of flood runoff for wadis of Northern Algeria

F, km^2	0	10	25	50	100	500	1000	≥5000
ε_F	1.0	0.65	0.45	0.35	0.33	0.32	0.31	0.30

Checking calculations demonstrated that accuracy of method is ±15,7%. Taking into account the fact that accuracy of basic data under maximum runoff of the rivers of concerned territories is ≈ 20%, one may consider the results as quite satisfactory.

6. CONCLUSIONS

- Under the active hydraulic building, ongoing during last time, the calculation of maximum runoff of floods for Algerian wadis is too actual problem;
- For calculation of maximum runoff of Algerian rivers it is supposed to use two-operator genetic model of precipitation transformation into channel runoff, which, according to authors' opinion, takes into consideration all runoff factors the most completely;
- All parameters, included into proposed scheme, are determined and generalized for concerned territory;
- Checking calculations demonstrated good conformity of actual and design modules of maximum runoff, and, therefore, the method can be recommended for practical application.

7. PROSPECT OF FUTURHER INVISTIVATIONS

Proposed theoretical model may be used for working out of the method for calculation of maximum runoff of floods within Algerian territory.

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