THE ANALYSIS OF FLOOD WAVES

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ABSTRACT. The floods are an important phase of the hydrologic regime. Based on both genetically and influential factors, it can be identified several types of floods. The main criterion of analysis is the identification of flood that can be achieved using many methods. The type of flood, the morphology and the goal of analysis are taken into account for the identification of the flood. Then, parameters of the flood hydrograph can be specified, those parameters characterizing the laws of maximum water flow in given section of the river. The parameters estimation implies a careful analysis of flood identification method. The flood's parameters are used for hydrologic analyses, for defense against flooding, for water management and for prognostication activity.

Keywords: flood, flood wave types, flood wave delimitation, flood hydrograph parameters

INTRODUCTION

Both, flood and high flow form the maximum flow phase of the rivers. The analysis of this phase is important for both scientific point of view (for hydrologic calculations) and defense against flooding activities (flooding risk reduction), water management (dam lake harnessing), hydrologic prognostication (maximum water discharge, maximum level of the river, volume of the water).

There are many ways to state a flood, but all of them take into account the supply sources and abruptly increase of water level/debit. Besides all these primary features, some others can be mentioned:

- rapid concentration of flow in time (Diaconu, Şerban, 1994),
- the features of levels/discharge decrease (Sorocovschi, 2002).
- setting over regular debits (Zăvoianu, 1999),
- overlapping of main flow (Vladimirescu, 1984),
- correlation between over ground flow and others types of flowing (Linsley, Kohler, Paulhus, 1958),
- relation of water and the river banks (Mustăţea, 2005),
- the hydrologic basin extension (Sorocovschi, 2002),
- this is not only a hydrologic event (Starosolszky, 1987),
- unpredicted events, catastrophes (Minea, Romanescu, 2007)
- hydrotechnic accidents (Zăvoianu, 1999, Minea, Romanescu, 2007).

In a general acceptance a flood can be describe as a sudden increase of level/river discharge due to a rapid concentration of rainwater or/and of water resulted from snow melted, followed by a slight diminution of level/discharge.

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It can be stressed that the differentiation between flood and high flow does not consist in the maximum level/discharge value, but the way of formation and the elements of hydrograph (mainly duration and shape).

Of course other meanings in the definitions make the notion more accurate. Sometimes these are necessary, since the genesis of a flood is a very complex process. Along with genetic factors there are many other influential factors which are interfering.

First of all we have to stress that is a distinctive flood formation area, placed in the upper part of the hydrographic basins, at the average altitudes, forming a band characterized by maximum pluviometric or/and abrupt increase of spring temperatures.

Rapid concentration of water in river bed and the flow speed are allowed by many factors: geological (low permeability rocks, monocline stratification), morphological and morphometrical (a developed basin in the lower sector, high gradient and concave slopes, high gradient of the longitudinal river bed profile), pedological (low permeability soil or moistened), vegetation (areas without forest), and not in the last place, the shape of hydrographic network (dendritically design).

TYPES OF FLOOD

The floods can be classified and typified using several criteria. Most of them refer to the genesis and shape of hydrograph.

The floods occur in the periods of the year when the hydrographic network is highly over filled, as a result of huge amount of water inputs in the system. The rivers overflow can be a consequence of high intensity rainfall and/or sudden melting of the snow, differentiate on climatic features of the region. It can be identified pluvial floods and nival floods depending on alimentation type. Characteristic monogenetic floods have a pluvial origin and only rarely nival. Within the temperate-continental climatic zone, the most floods have a mixed origin.

Apart from the mentioned natural floods, artificial floods can occur. The best known are the floods due to uncontrolled discharge from reservoirs, passing water through hydroelectric power stations turbine and those resulted from dams breaking.

Based on the number and characteristic peaks it can be differentiated „mono wave" floods (simple, having a single peak) and „multiple waves" floods (composite, having many peaks). The single wave floods are generated by continuous and intense rainfall, snow melting does not produce such floods because the heat intensity is different between day and night. For simple floods, rising limb and the recession limb are continuous, just the variation rate is different. General shape approximates a triangle.

Multiple wave floods have many types. Before or after the main peak it follows a secondary peak that is not significantly smaller. There are floods where on the recession limb smaller and non-important growth peaks are in range. The floods characterized by many peaks occur due to the oscillation of the genetic phenomena intensity (rain or snow melting). The water contribution of the tributaries river, when it is not overlapping the flood wave of the main stream, is a contributor of the composite floods.

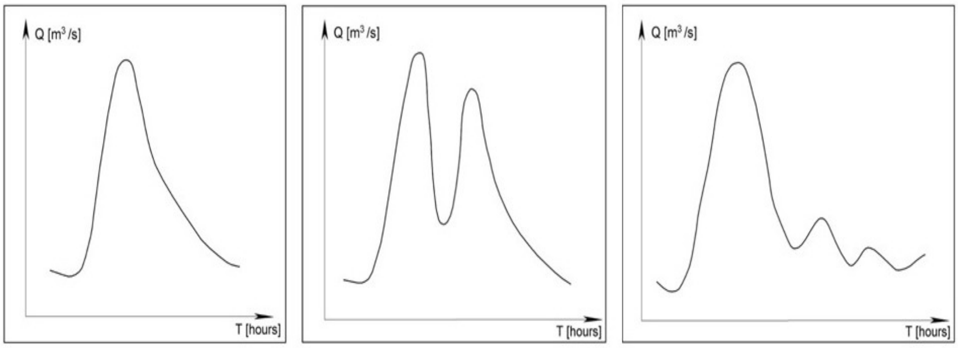

Fig. 1. ***Mono wave floods and multiple wave floods***

The shape of artificial floods can be very varied, based on the way in which they come out from the reservoir. In many cases, their shape approximates a rectangle rather than a triangle.

FLOOD HYDROGRAPH DELIMITATION

The floods, along with other hydrological and meteorological elements, are tracked and recorded within sections of hydrometric stations. During the maximum flowing period, the river level recording has a high frequency, in order to have the best image of its variation. The flood hydrograph is obtained by plotting the graph of these levels, or of correspondent discharges.

To give a definition of flood hydrograph elements the main problem consists in its delimitation.

The „flood cutting line" delimitates the variation interval of level/discharge with significant characteristics, as it results from its definition. This operation settles the flood period, but influences the volume, the shape coefficient, and the relations between periods, respective volumes, too. Therewith the delimitation line separates the flood volume of the surface runoff from the base volume of the flood, which includes the underground alimentation.

In theory, the delimitation line realizes the connection between both inflexion points, one located on rising limb, the other located on recession limb. If the first one is easy to find, the plotting of the second one is difficult and is the subject of many discussions. The recession limb, has in many cases, several inflexion points, choosing one being difficult, or in some cases the drawdown can be almost even without any inflexion point.

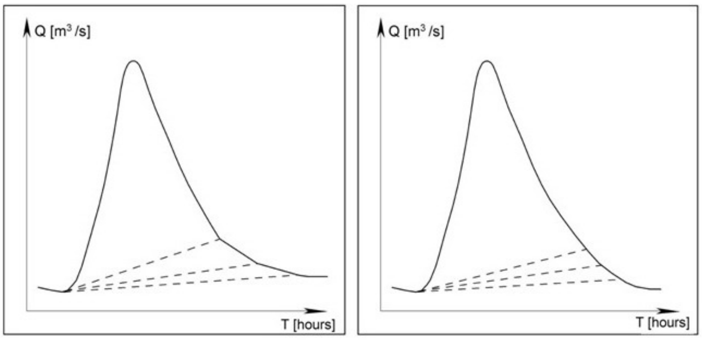

Fig. 2. ***The inflexion points find***

The process of plotting this point involve others criteria, as example the correlation of flood total time to average altitude and hydrographic basin area, or to length of the river.

$$T = f\,(H, A) \qquad \text{or} \qquad T = f\,(L) \tag{1}$$

Delimitation of the flood wave can be made with a straight line, a broken line or a curve line. The most frequent method used is „cutting" by a straight line; this can point to three directions.

- ascendant to the rising limb. This is logically because underground alimentation prevails at the end of flood period in comparison with its start.
- parallel to X axis. In some hydrographic basin, during the flood period, there is no modification of underground alimentation intensity.
- downward to the recession limb. This is a rare and a special situation.

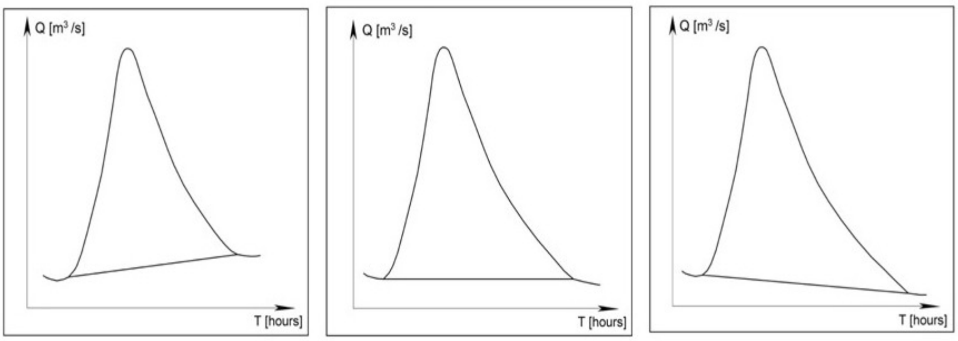

Fig. 3. ***Flood wave delimitation by straight line***

Delimitation using a broken line takes into account a continuous decrease trend of underground alimentation to the moment of reaching maximum level/ discharge, thereupon it starts to grow. Using the method of cutting with a curve line is particularly theoretic and takes into consideration various underground alimentation designs. This depends on the relationship between water level in river and level of ground water at the beginning of the flood, and other local influencing factors, too.

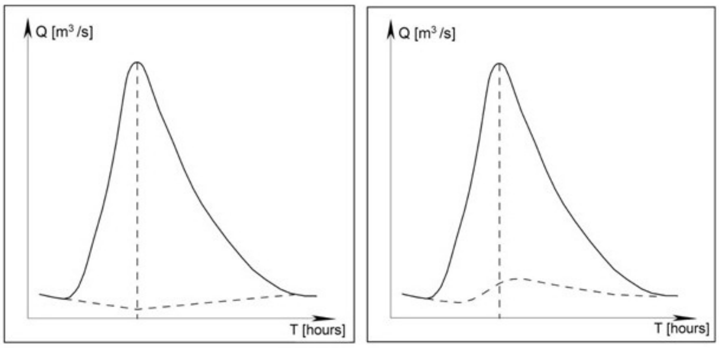

Fig. 4. ***Flood wave delimitation by broken and curved line***

In case of a flood with two peaks, delimitation implies not only separation of underground alimentation. If the analysis asks, it might be possible to separate two simple floods by extrapolating the rising limb or the recession limb. The design of extrapolated segment approximates the variation trend of the part that was cut. Of course, the method implies some errors, because it assumes unknown regularities of variation.

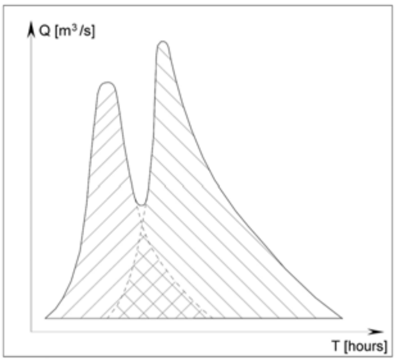

Fig. 5. ***Two peaks flood wave separation***

The surface under the „cutting line" that represents water volume of underground alimentation is another problem of flood delimitation taken into account. For the floods waves where the distance between the „cutting line" and X axis is small, and the correspondent surface is negligible in comparison to the hydrograph surface, it is considered that the flood start and end having zero discharge. It is not considered as a part of flood wave if the distance, and related to it the surface is big. The above findings are very important for flood volume calculation and for the shape coefficient.

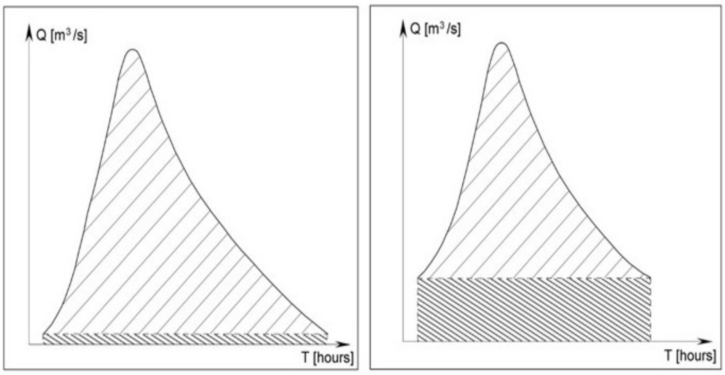

Fig. 6. ***Flood wave with negligible and with important base volume***

CHARACTERISTIC PARAMETERS OF THE FLOOD HYDROGRAPH

Interconnections between floods genetic factors and influential ones are reflected within flood hydrograph geometry. It is given by rising limb and recession limb design, limited at the upper part by maximum level/discharge.

The flood wave parameters are related to points, distances and surfaces. On the flood hydrograph they are established by direct reading or by calculation.

The hydrograph can be analyzed as function $H = f(T)$ or as a function $Q = f(T)$. The shape of hydrograph levels is not similar to discharges hydrographs, for intervention of the limnimetric key $Q = f(H)$ function.

Whereas discharges hydrographs are more frequently used, its elements are analyzed.

1. Initial discharge (Q_{in}). This point represents the inflexion value of the rising limb base, where abrupt discharge change ratio starts, due to overlapping of surface and underground alimentation.

2. Maximum discharge (Q_{max}). This represents the highest point value between hydrograph rising limb and recession limb.

3. Final discharge (Q_{fi}). This point is the inflexion value placed on the recession limb, where the surface alimentation ceases and the flow is sustained only by underground alimentation.

4. Time of growth (T_{gr}). This represents the period of abrupt growth of discharges, between the moment of initial discharge and maximum one. The design of rising limb are related to rainfall or snow melting characteristics, and the hydrographic basin characteristics that influence the flow concentration in the riverbed, provided by slopes and tributaries, to the cease of rainfall.

5. Time of decreasing (T_{des}). This represents the discharge decreasing period from the moment of maximum discharge to the moment of final discharge. The design of this segment is a consequence of the way that runoff concentrate on the slopes of the basin and the tributaries contribution after the rainfall cease. As a result of the flood formation regularities the time of growing is reduced compare to the time of decrease.

6. The total time (T_t). Named also the „flood duration”, is the period between the moment of initial discharge and that of the final discharge. This is the sum of increase and decrease time.

$$T_t = T_{gr} + T_{des} \qquad \text{[hours]} \qquad (2)$$

7. Base discharge (Q_b). In theory this represents the value of drainage discharge without superficial flow contribution due to the flood trigger rainfall. Base discharge of a flood varies with the time, as it results from the delimitation methods analysis. Base discharge can be established in many ways, using the flood wave characteristics and the delimitation method:

- the base discharge is considered equal with initial discharge: $Q_b = Q_{in}$
- it can be calculated as the arithmetic mean of the initial discharge and the final discharge:

$$Q_b = \frac{Q_{in} + Q_{fi}}{2} \qquad [\mathrm{m^3/s}] \qquad (3)$$

- it can be calculated as weighted mean of discharges placed on the hydrograph delimitation line, at equal segments of time:

$$Q_b = \frac{\sum_{1}^{n} Q_i}{n} \qquad [\mathrm{m^3/s}] \qquad (4)$$

where: Q_i - discharges placed on the hydrograph delimitation line;
n - number of values taken into consideration.

8. The growth volume (V_{gr}). This element represents the outline surface between rising limb, the vertical of maximum discharge and delimitation line of initial and maximum moments of discharge. If the elements placed on both axes (discharge and time) are taken into account, the surface represents a water volume. Analytical calculus relation is:

$$V_{gr} = \frac{Q_{in}}{2} + \sum_{2}^{n-1} Q_i + \frac{Q_{\max}}{2} \qquad [\mathrm{m^3/s}] \qquad (5)$$

where: n - number of discharges taken into account placed on the flood rising limb, included Q_{in} and Q_{max}.

The water volume can be plotted, by surface (in cm^2) planimetration and multiplying with scale product.

9. The decrease volume (V_{des}). Represents the area delimited by the recession limb, vertical of maximum discharge and the delimitation line between the moments of maximum discharge and final discharge. With the same reasoning of analytical calculation, can be written:

$$V_{des} = \frac{Q_{\max}}{2} + \sum_{2}^{n-1} Q_i + \frac{Q_{fi}}{2} \qquad [\mathrm{m}^3/\mathrm{s}] \qquad (6)$$

where: n - number of discharges taken into account in the recession limb, including Q_{max} and Q_{fi}.

It can be used the same graphical method for determination.

10. Flood wave volume/Total volume (V_t or V). This represents the total volume of water, expressed by hydrograph. Several methods can be used for determination:

- as the sum of growth and decrease volumes

$$V = V_{gr} + V_{des} \qquad [\mathrm{m}^3/\mathrm{s}] \qquad (7)$$

- using general analytical formula, which may be the sum or the integral equation

$$V = \sum_{1}^{n} \frac{Q_i + Q_{i+1}}{2} * \Delta t \qquad [\mathrm{m}^3/\mathrm{s}] \qquad (8)$$

where: Q_i - discharges from the hydrograph limbs;
Δt - time interval (s);
n - number of values

or $$V = \int_{0}^{Tt} Q_i * dt \qquad [\mathrm{m}^3/\mathrm{s}] \qquad (9)$$

where: T_t - total time of the flood
Q_i - discharge on the Y axis
dt - very short time intervals, when the discharges are to be taken into account

- by graphic method: hydrograph surface is planimetered and it is multiplied with the scales product.

In the above method the base volume of the floods wave is neglected, namely all discharges have been considered from zero. If the base volume is significant, from all discharge on hydrograph is subtracted a constant discharge or the basic discharges appropriate to each discharge of hydrograph. Therefore, the general formula becomes:

$$V = \sum_{1}^{n} \frac{\left(Q_i - Q_{b,i}\right) + \left(Q_{i+1} - Q_{b,i+1}\right)}{2} * \Delta t \qquad [\mathrm{m}^3/\mathrm{s}] \qquad (10$$

Also, during the planimetration process, is taken into account the real surface of the hydrograph.

11. The shape coefficient (γ). Represent the ratio between the volume of the flow wave and the equivalent volume of a rectangle with Q_{max} and T_t as sides.

In other words, expresses the way in witch the flood's hydrograph fills the rectangle it fits in.

$$\gamma = \frac{V}{Q_{\max} * T_t} \qquad [m^3/s] \qquad (11)$$

If the basic discharge is not equal with zero, then the formula is:

$$\gamma = \frac{V}{(Q_{\max} - Q_b) * T_t} \qquad [m^3/s] \qquad (12)$$

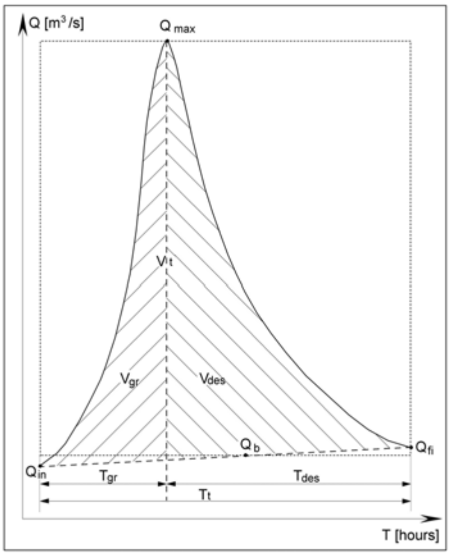

Fig. 7. ***Flood hydrograph parameters***

12. The ratios between parameters. To characterize the flow hydrographs and in order to check the correctness of delimitation, there are used some ratio computations. These refer to times and volumes:

$$\frac{T_{gr}}{T_t}, \frac{T_{gr}}{T_{des}} \quad \text{sau} \quad \frac{V_{gr}}{V_t}, \frac{V_{gr}}{V_{des}} \qquad (13)$$

For the rivers of Romania, the ratio value T_{gr}/T_t is about 1/2 - 1/3 for the small hydrographic basins (50 - 100 km²) and about 1/3 – 1/5 for the big ones. The ratio V_{gr}/V_{des} is about 0,5 for the river basins where the flow concentration is very fast and around the unit where the development of the flood is slower.

A flood flow can be expressed in several ways, identical to the expression of average flow. Along with the discharge and volume, the specific flood discharge or the layer of floodwater can be used. Also, can be calculated the flood flow coefficient. All of these are useful in regional generalizations, comparative studies, water management etc.

CONCLUSIONS

Analysis and assessment of the excess situations of rivers runoff has very extensive theoretical and practical implications. Speaking about floods, to carry out calculations, the flood delimitation has major importance. If this operation is wrong, all subsequent calculations are involving mistakes, some of them fundamental.

The delimitation method used for different flood hydrographs depends on purpose. There is a difference in cutting a flood wave for hydrologic analyses, and for flood protection activity and for water management.

Sometimes, the construction of a type hydrograph or medium hydrograph is used for a riverbed section, which results from the mean values of several hydrographs of that section.

The ratios of times or volumes, and other parameters of flood hydrographs, are used to build theoretical hydrographs on ungauged rivers.

Regional generalizations can be obtained using the parameters of flood waves. When they are used, should be taken into consideration that they are valid only for relatively homogeneous geographical regions.

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