A SIMPLIFIED MODEL FOR DETERMINING FLOOD WAVES IN SMALL BASINS UP TO 100 KM^2

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Abstract: A simplified model for determining flood waves in small basins, based on the relations between the elements of the floods (increasing and decreasing duration, maximum discharge, volumes in the increasing and decreasing periods) and the characteristics of the rainfall which cause them (duration, amount, intensity) are presented.
The relations have been obtained on the basis of the data from hydrographic units within the representative and experimental catchments with surface which have varied between 72 m^2 (runoff parcels) and 76 km^2.
Keywords: flood, increasing and decreasing duration, maximum discharge, increasing and decreasing volumes, base discharge.

EIN VEREINFACHTES MODELL, UM FLUT-WELLEN IN KLEINEN BASSINS BIS ZU 100 KM^2 ZU BESTIMMEN

Auszug: Ein vereinfachtes Modell, um Flut-Wellen in kleinen Bassins, gegründet auf den Beziehungen zwischen den Elementen der Fluten (zunehmende und abnehmende Dauer, maximale Entladung, Ausgaben in der Erhöhung und Verringern-Perioden) und den Eigenschaften der Niederschlagsmenge zu bestimmen, welche sie (Dauer, Betrag, Intensität) verursachen, wird präsentiert.
Die Beziehungen sind auf der Grundlage von den Daten von hydrographic Einheiten innerhalb des vertretenden und experimentellen Auffangens mit Oberfläche erlangt worden, das sich zwischen 72 m^2 (Entscheidungslauf-Pakete) und 76 Km^2 geändert hat.
Schlüsselwörter: Flut, vergrößernd und Dauer, maximale Entladung vermindernd, vergrößernd und Ausgaben vermindernd, stützt Entladung.

1. Introduction

The paper presents a simplified model for the determination of the increase and decrease branches of the flood waves in small catchments with surface of up to 100 km^2, based on the correlation between the elements of the flood wave (the rising and falling duration, the maximum flow, the rising and falling volumes) and the characteristics of the rainfalls that generated them (duration, amount, intensity).

As regards the more detailed analysis of the characteristics of the flood wave falling branch, this is justified from more reasons.

In most cases, the falling duration contributes with the largest share to the total duration of the flood wave and also conditions the most its shape coefficient.

Another reason is also that it best expresses the role that the catchment has in evacuating the incoming water over its surface, the flood wave falling duration being so much longer as the catchment surface is larger. Previous analyses have shown that in the case of the flood wave rising duration, the role of the catchment surface is much smaller.

Knowing the flood wave rising and falling duration in different catchments and in certain precipitation variation circumstances also has an obvious practical role that needs to be disclosed.

2. Data and methods

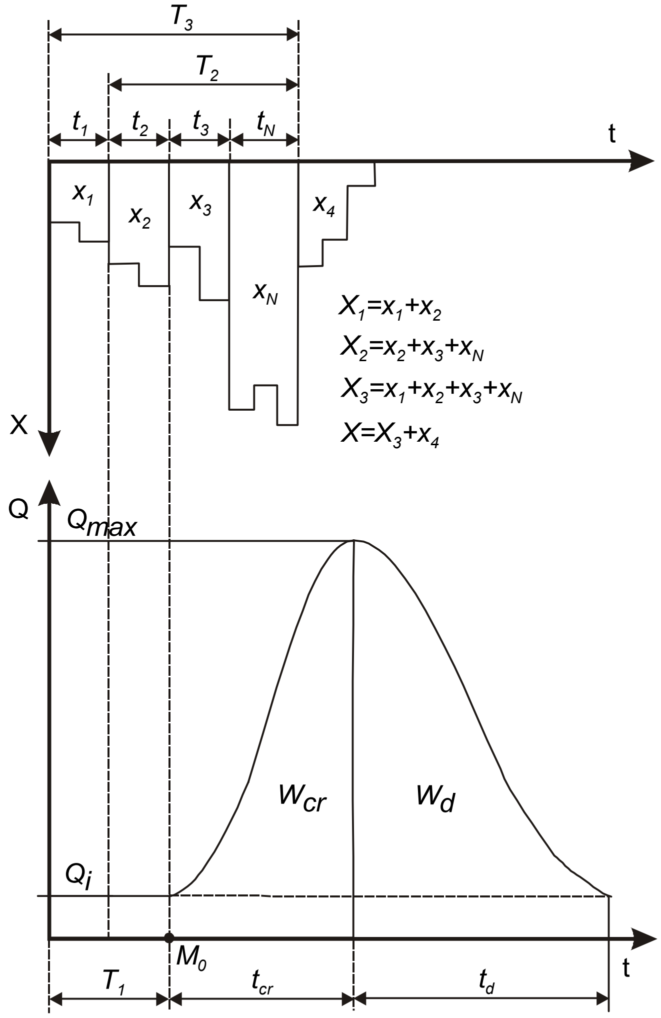
At the basis of elaborating this paper were the data from the gauging stations within the representative catchments, to which catchment surfaces correspond ranging from 72 m^2 (discharge plots) to 76 km^2, precisely to highlight the role of the surface on the studied parameters also.

The method used with the aim to construct the model for the determination of the flood wave rising branch is based on the relations between the elements of the flood rising branch (rising duration, flood volume during the rising period, maximum flow) and the characteristics of precipitation that determine these elements, i.e. the rain duration from the beginning to the end of the rain's nucleus, the precipitation amount and the rain intensity within the same time interval.

The elaboration of the model for the determination of the flood falling branch utilized as the main method the use of the relations amongst the main elements of the falling branch (falling duration, flood wave volume within the falling period, maximum flow) and the characteristics of the precipitation determining them.

3. Determination of the flood wave characteristics

At the basis of achieving the flood wave determination model were the relations between its elements and the characteristics of the rainfall determining it, rendered as a scheme in figure 1.



x_1 - amount of precipitation totally infiltrated in the soil at rainfall start;
t_1 - time interval corresponding to x_1;
x_2 - amount of precipitation falling after interval t_1 till flood wave start;
t_2 - time interval corresponding to x_2;
x_3 - amount of precipitation falling from high flood start till the start of the rainfall nucleus;
t_3 - time interval corresponding to x_3;
x_N - precipitation amount corresponding to the rainfall nucleus;
t_N - rainfall nucleus duration;
x_4 - amount of precipitation fallen after the rainfall nucleus has been recorded;
T_1 - time interval corresponding to X_1;
T_2 - time interval corresponding to X_2;
T_3 - time interval corresponding to X_3;
W_{cr} - flood rising volume;
W_d - flood falling volume;
M_0 - flood starting moment;
t_{cr} - flood rising duration;
t_d - flood falling duration;
Q_i - flood basic flow;
Q_{max} - flood maximum flow.

Figure 1. The scheme with the flood wave elements and the characteristics of the rainfall determining them.

3.1. Rising duration

The first of the relations was between the flood rising duration, t_{cr}, and the rainfall duration from its start till the end of the rainfall nucleus, from which the time interval was extracted when the total infiltrations occur from the rainfall start. This interval is noted as T_2, therefore t_{cr}=f(T_2).

Whereas t_{cr} is obviously clearer from monitoring the flood hydrograph, for the determination of T_2 there must be known first the duration of the t_1 interval, when the total infiltrations occur from the start of the rainfall: $T_2=T_3-t_1$.

The solution of determining interval t_1 was adopted through using the relation between the runoff coefficient, α and the precipitation that has generated the flood X, taking into account the precipitation fallen 10 days before, API_{10}: α=f(X, API_{10}) (Miță, 1994).

Figure 2 displays this type of relationship in the case of Rănuşa gauging station along Moneasa River.

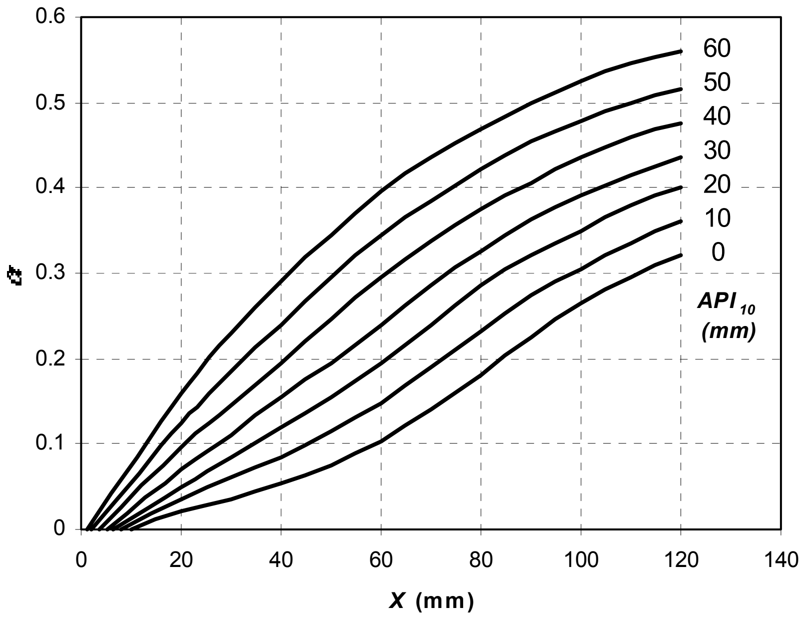


Figure 2. Relation α=f(X,API₁₀) at Ranusa gauging station within Moneasa representative catchment.

Such a relation shows at its lower side, at what values of X and API_{10}, α=0 is recorded. The crossing point of a certain API_{10} curve with the X abscissa, for which α=0 is noted x_1 and represents the total precipitation infiltrations from the beginning of the rainfall (fig. 2).

Once the value x_1 is known, the time duration will be determined when this amount might be recorded, i.e. t_1, according to the pluviogram. Consequently, there can also be established the value of T_2 from the relation $T_2=T_3-t_1$.

It is noteworthy that, at the same values of API_{10}, the value of the total infiltration at the beginning of the rainfall, when α=0, is longer in the catchments characterized by soils with textures favorable to infiltration (light textures), through high afforestation coefficients and reduce slopes, as resulted from the analysis performed within this paper.

As regards relation t_{cr}=f(T_2), that one resulted to be quite tight, in the case of all the analyzed gauging stations. Figure 3 displays such a relation in the case of Rănuşa, Boroaia and Ruja gauging stations.

It is noteworthy that the T_2 interval includes the rainfall nucleus also, being many cases delimitated by this nucleus alone.

3.2. Rising volume

The flood volume during its rising period was analyzed aiming to determine the shape of the rising branch.

The analysis of the rising volume W_{cr}, materialized through relations established between this parameter and the flood rising duration t_{cr}; W_{cr}=f(t_{cr}). Such relations yielded on the grounds of analyzing a large number of floods recorded at the gauging stations within certain representative catchments.

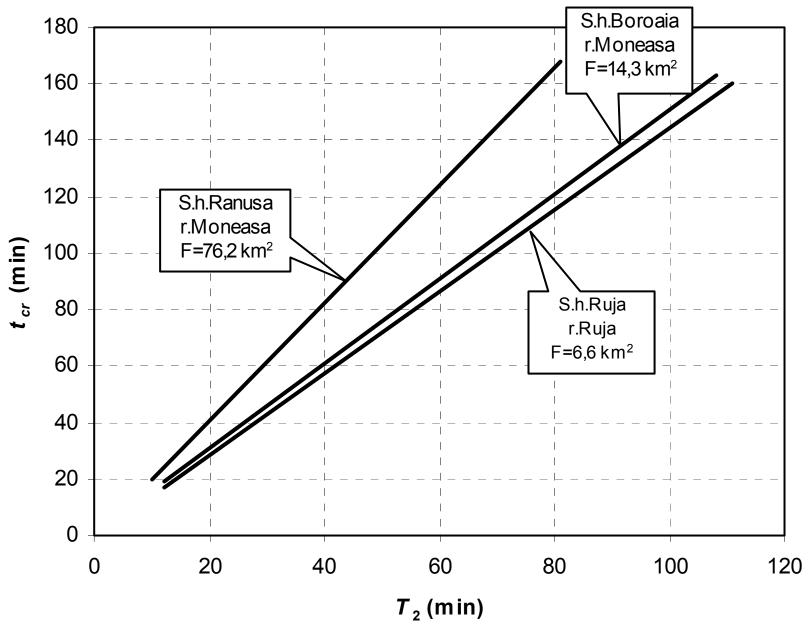


Figure 3. Relation t_{cr}=f(T_2) for Rănuşa, Boroaia and Ruja gauging stations within the Moneasa representative catchment.

Figure 4 renders relation W_{cr}=f(t_{cr}) in the case of certain gauging stations within the Moneasa representative catchment, where a rise of these volumes is noticed as the duration of the flood rise grows larger, but also their rise in agreement with the catchment surface rise.

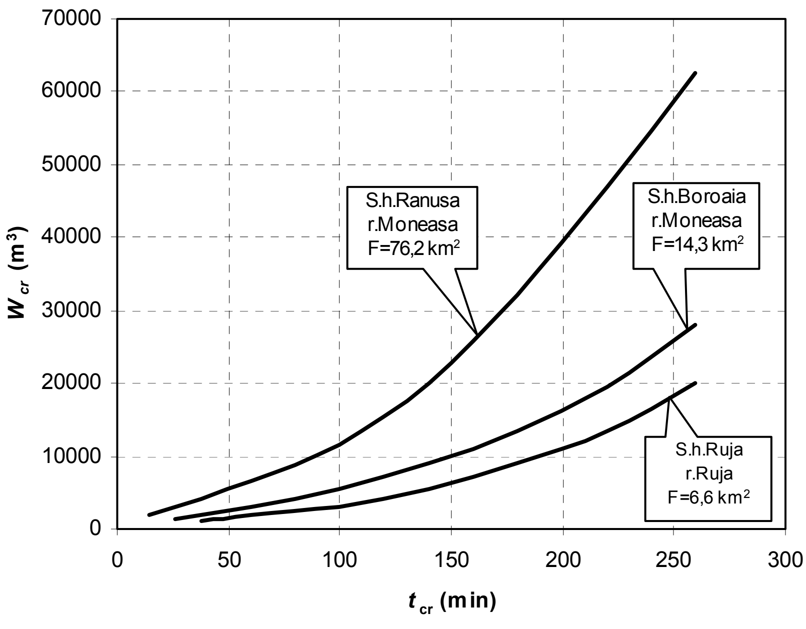


Figure 4. Relation W_{cr}=f(t_{cr}) for Rănuşa, Boroaia and Ruja gauging stations within the Moneasa representative catchment.

3.3. Maximum flow

As regards the Q_{max} maximum flow, this was first analyzed within certain gauging stations, function of the precipitation intensity, i_{X2}, fallen in the T_2 interval and of API_{10}: Q_{max}=f(i_{X2}, API_{10}). Figure 5 displays such a type of relation in the case of Rănuşa gauging station on Moneasa River (F=76,2 km^2).

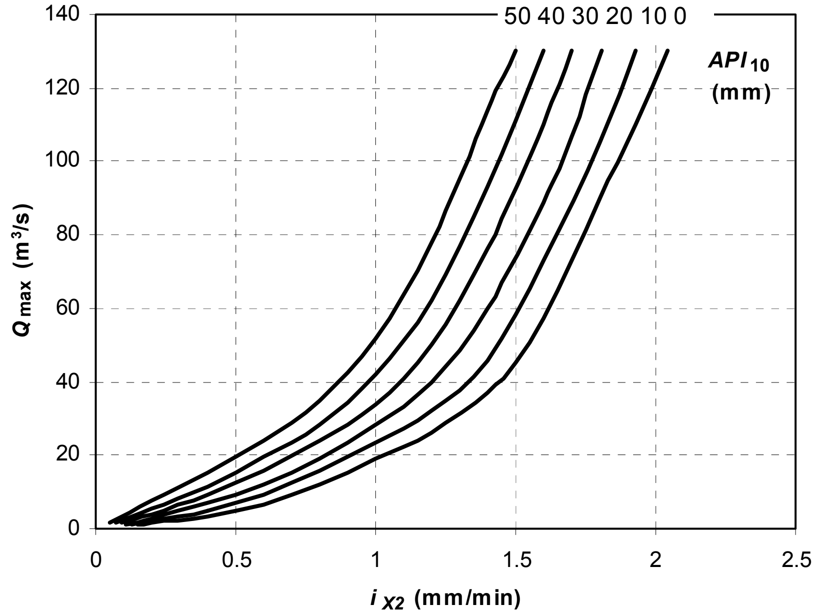


Figure 5. Relation $Q_{max}=f(i_{X2}, API_{10})$ at Rănusa gauging station on Moneasa River.

As results from Figure 5, the flow in agreement with the increase of the rain intensity, but also with the increase of precipitation fallen 10 days before, API_{10}.

When analyzing the maximum flow, relations also yielded at some gauging stations between this parameter and the precipitation intensity, i_{X2}, fallen in the T_2 interval, taking into account the duration of this interval (Miță şi Corbuş, 1996; Miță şi Corbuş, 1998). An example of such a relation is displayed in Figure 6.

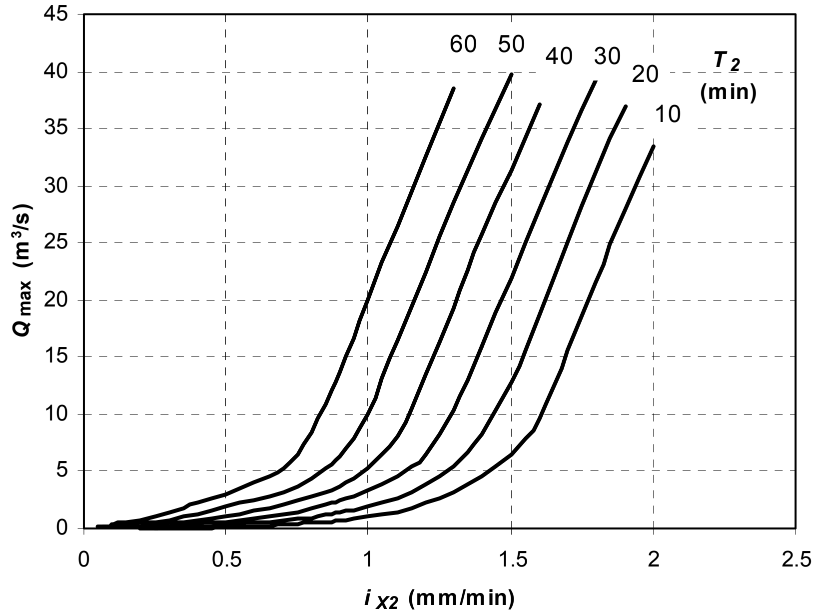


Figure 6. Relation $Q_{max}=f(i_{X2}, T_2)$ at the Stâna de Vale gouging station on Iedut River.

As results from Figure 6, the flow increases in agreement with the increase of the rain intensity, but also with the increase of the T_2 interval duration.

It is remarkable, as noticed when drawing the relation in Figure 6, that the highest flows were recorded certainly in the case of high intensities, but at duration of T_2 of 40 - 50 min, i.e. at duration close to those of the maximum flow concentration time in this catchment. At smaller duration of T_2, for instance of just 10 or 20 min, flows were unimportant, although the precipitation intensity within this interval was quite large. The explanation is that precipitation falling in a time interval smaller than the concentration time does not ensure the participation of these precipitation at the occurrence of the maximum flows for the whole catchment surface.

This type of relations that yielded with a rather high degree of certainty in the case of the analyzed gauging stations are recommended to be also used to the operative forecast in the case of knowing of the precipitation forecast.

Also, by using such relations it can be precised in what circumstances of intensity and API_{10} or T_2, the rarely probable maximum flows may occur.

3.4. Mean variation of the rising branch

In order to precise the shape of the flood rising branch, relations were determined of the form Q_c/Q_{max}=f(t_c/t_{cr}), where (t_c,Q_c) are the characteristic points on the flood rising branch. Figure 7 displays such a relation, determined for Rănuşa gauging station on Moneasa River.

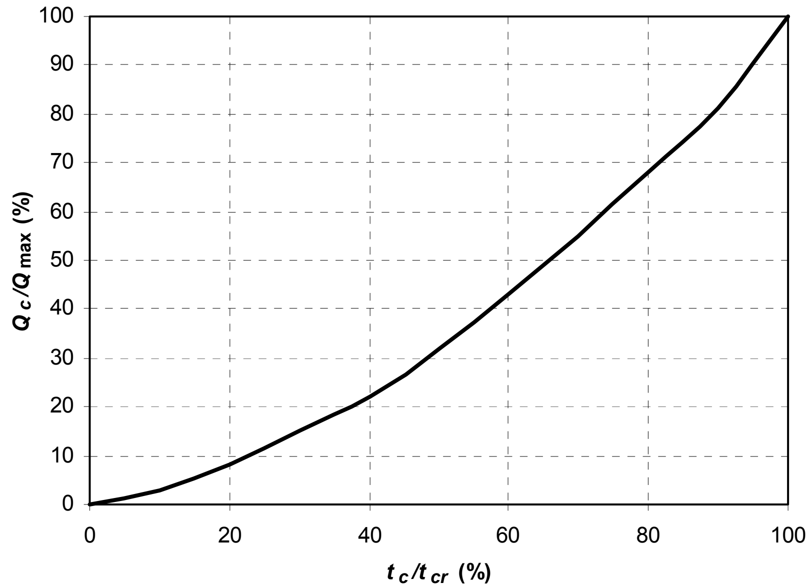


Figure 7. Mean variation of the flood rising branch at Rănuşa gauging station on Moneasa River.

3.5. Falling duration

The main element of the flood falling curve, the falling duration (t_d) was determined depending on the total X (mm) precipitation amount that had generated the flood, also taking into account the precipitation fallen 10 days before, API_{10}; t_d=f(X,API_{10}).

Figure 8, where such a relation is displayed for Rănuşa gauging station on Moneasa River, within the Moneasa representative catchment, highlights the dependence of t_d on the precipitation that had generated the flood, as well as on precipitation fallen previously.

The analysis of this type of relation for gauging stations characterized by catchments with various surfaces reveled that at similar values of X and API_{10}, the t_d falling duration increases in agreement with the increase of the catchments surface.

3.6. Falling volume

So as to establish the shape of the falling curve, there yielded for gauging stations within the representative catchments, relations between the volume from the W_d falling period and the t_d falling duration: W_d = f(t_d).

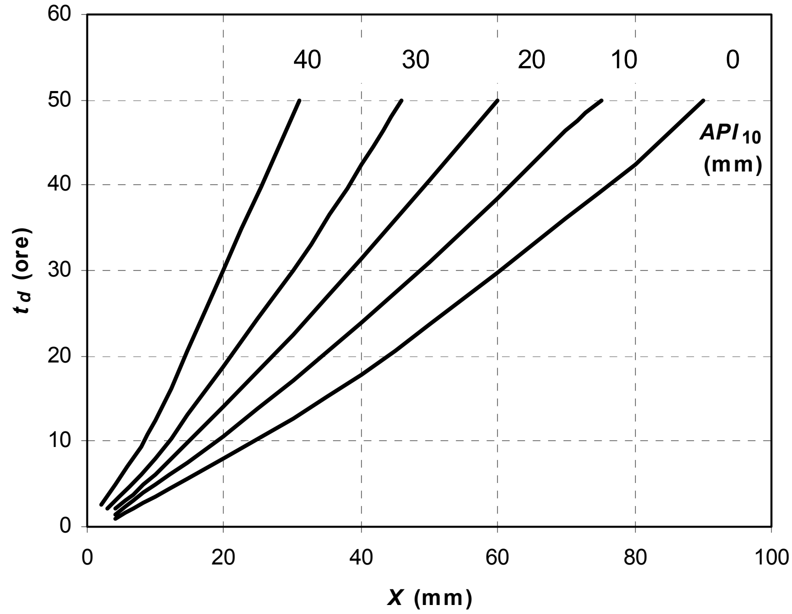


Figure 8. Relation t_d=f(X, API_{10}) at the Rănuşa gauging station on Moneasa River.

Such relations, yielded for gauging stations whose catchment surfaces are different are displayed in Figure 9, highlighting that at equal duration of t_d, the volumes within this time interval increase with the increase of the catchment surface.

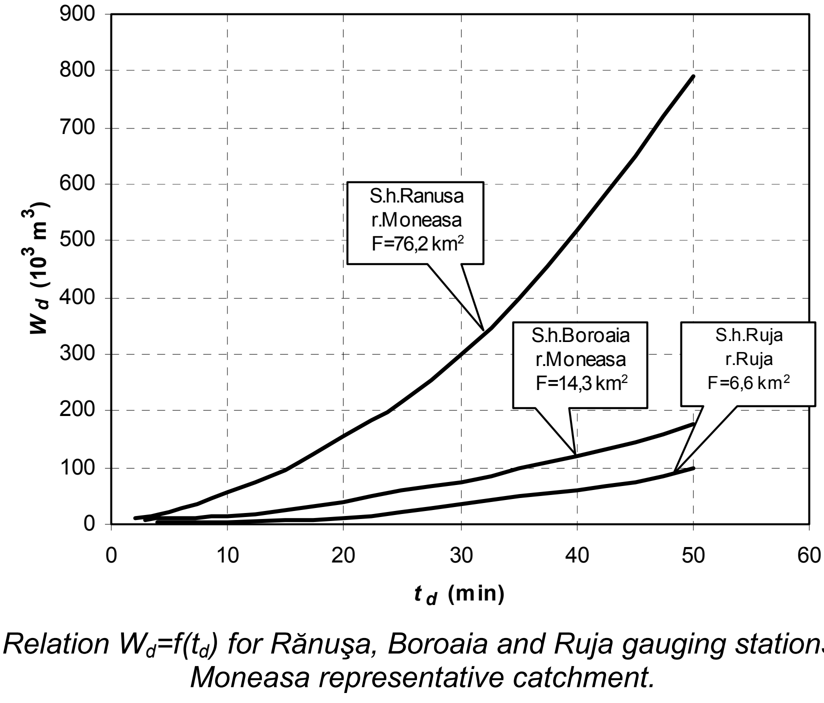


Figure 9. Relation W_d=f(t_d) for Rănuşa, Boroaia and Ruja gauging stations within the Moneasa representative catchment.

3.7. Mean variation of the falling branch

So as to represent the shape of the flood falling branch, there were determined relations of the form Q_c/Q_{max}=f(t_c/t_d), where (t_c,Q_c) are characteristic points on the flood falling branch. Figure 10 renders such a relation, determined for Rănuşa gauging station on Moneasa River.

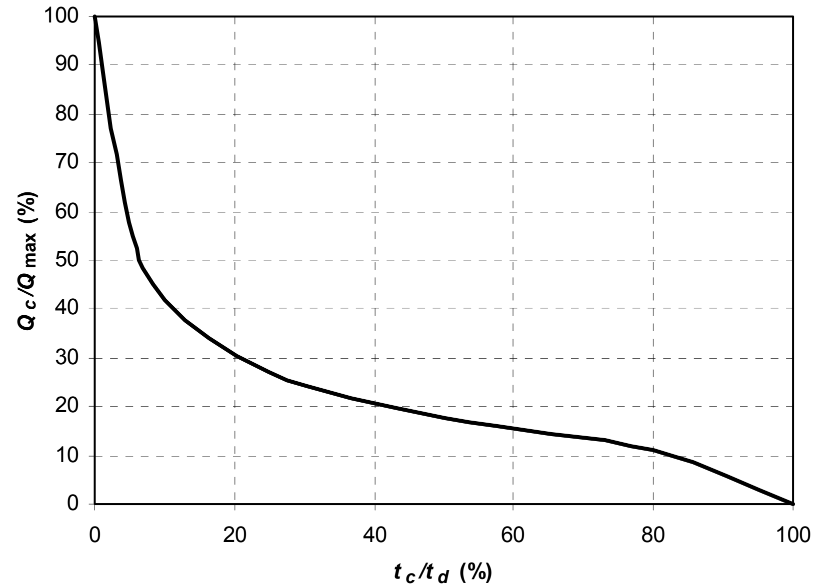


Figure 10. Mean variation of the flood falling branch at Rănuşa gauging station on Moneasa River.

4. Applications

4.1. Determination of the rising branch

In order to exemplify the method presented in this paper the flood of 1-2 August 1976 was considered, as recorded at Rănuşa gauging station on Moneasa River. Knowing the characteristics of the precipitation that generated the flood: T_3=130 min and X_3=36,8 mm, as well as API_{10}=30 mm, x_1=5 mm was first determined from Figure 2, then t_1=38 min from the pluviogram of the event. Then the $T_2=T_3-t_1$=92 min value resulted, with which t_{cr}=192 min was determined from Figure 3. The rain intensity was further determined as $i_{X2}=(X_3-x_1)/T_2$=0,4 mm/min, with which the maximum flow Q_{max}=9 m^3/s yielded from Figure 5, function of API_{10}.

So as to precise the shape of the flood rising branch the corresponding values of the 1,1 m^3/s, 3,2 m^3/s and 6,7 m^3/s flows were then determined from Figure 7, for 25%, 50% and 85% of t_{cr}=192 min.

A final adjustment of the shape at the flood rising branch was performed taking into account the flood rising volume W_{cr}=36000 m^3, determined from Figure 4 function of t_{cr}.

Figure 11 displays the result obtained.

4.2. Determination of the falling branch

To exemplify the method presented in this paper, there was considered the flood occurred on 22-23 June 1984 at Rănuşa gouging station on Moneasa River. Knowing the X=39,6 mm total precipitation that generated the flood and API_{10}=30 mm, t_d=41 hours was determined from Figure 8. Further, knowing the rain intensity i_{X2}=0,85 mm/min, the maximum flow Q_{max}=29 m^3/s yielded from Figure 5, function of API_{10}.

In order to precise the shape of the flood falling branch, the corresponding values of the 16,6 m^3/s, 13,3 m^3/s, 8 m^3/s, 5,1 m^3/s and 3,1 m^3/s were further determined from Figure 10 for 5%, 10%, 25%, 50% and 85% of t_d=41 ore.

A final adjustment of the shape of the flood falling branch was performed, taking into account the W_d=546 10^3 m^3 flood falling volume, determined from Figure 9, function of t_d.

Figure 12 renders the result obtained.

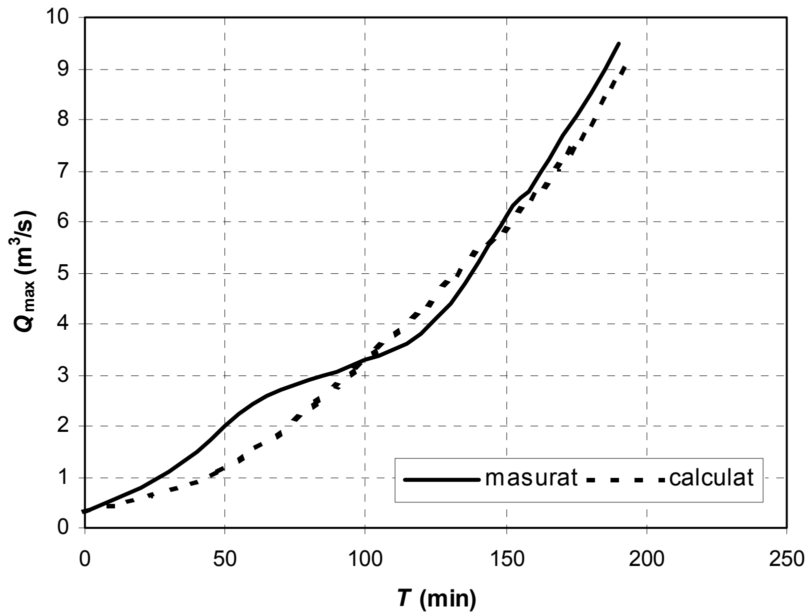


Figure 11. Simulation of the 1-2 August 1976 flood rising branch at Ranusa gauging station on Moneasa River.

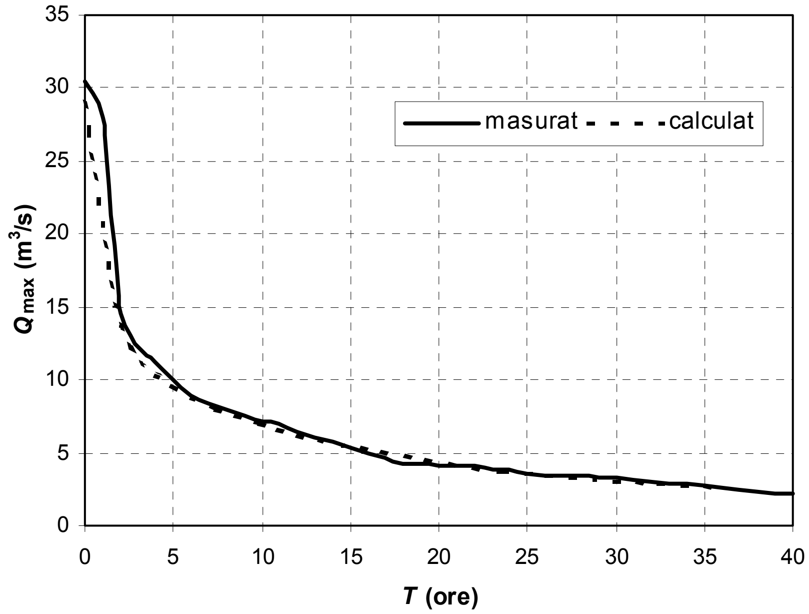


Figure 12. Simulation of the 22-23 June 1984 flood falling branch at Rănuşa gauging station on Moneasa River.

5. Conclusions

The main conclusions and ideas evident after the carrying out of this study are the following:

- The paper displays a simplified model for the determination of the flood waves which takes into account the rising and falling durations, the maximum flow, the rising and falling volumes, each determined function of the generating rainfall characteristics.

- The analysis performed for certain gauging stations with various surfaces also highlighted the role of the surface on the variation of the elements of the rising and falling branches, as well as of the maximum flow.

- The application of the model led to fair enough results, which ascertains its reliability with catchments with a surface smaller than 100 km^2.

- The proposed model may be used successfully for flood forecasting in small catchments. Results will be so much better as the forecast share of the total rainfall is smaller, and certainly, as the rainfall forecast is better. Thus, the best results yield after the maximum nucleus of the rainfall is reached.

- Using the proposed methodology to determine the shape of the rising and falling branches of the flood hydrographs in the practical activity displays advantages mostly in the computer modeling technique, applied in the field of hydrology and water management.

6. Bibliografie

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