HYDROGRAPH OF THE FLOWS OF THE MOST IMPORTANT HIGH FLOODS IN VASLUI RIVER BASIN

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ABSTRACT. – Hydrograph of the flows of the most important high floods in Vaslui river basin. Most of the rivers in the Eastern part of Romania are influenced by the excessive continental climate. That is why torrential rains are frequent and the possibility of high floods occurrence is extremely high. The Vaslui river is not an exception, and this is the reason why a series of measures to prevent floods have been taken in this river basin. The most efficient constructions for diminishing high floods consisted in damming the main water courses on certain sectors, building up of an accumulation in Solesti and slope forestation. The measures have as a main purpose the diminution of the negative impact on the town of Vaslui. The maximum flows in the Vaslui river basin can be recorded in any season, but most frequently they register during spring, sometimes at the end of winter, when snow melting is accompanied by high amounts of rain. The high floods in the Vaslui river basin, as a manifestation form of the maximum flow, are mainly generated by the torrential rains in summer, but they can occur in other periods of the year as well. In order to analyse the high floods the most representative maximum flows recorded on the Vaslui river and on the course of the main tributary have been chosen.

Keywords: high floods, maximum flow, reference flow, water volume, barrage**.**

1. INTRODUCTION

The main characteristic of the rivers in the Eastern part of Romania is the uneven flow, with extremely high flows during high waters. As a result of the fact that the Vaslui river has often over flown its banks, measures of regularization of the river course and barrage construction in order to diminish the high floods have been taken. From this point of view the Vaslui river basin is insured and the frequency or intensity of the floods has diminished significantly. Nevertheless, the phenomena with hydrologic risk start to have a special importance for the small river basins, tributaries to the main course.

The importance of the main high floods on the Vaslui river is pointed out, and their consequences, as well as the measures necessary to reduce the effects.

The intrinsic connections between the amount of precipitation (especially those with torrential character), and the occurrence of the flood phenomena are pointed out. Therefore, the climatic data stored at the Moldova Meteorological Center in Iasi have been correlated with the hydrological data obtained from the Prut Water Headquarters in Iasi.

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2. GEOGRAPHIC LOCATION

As a left tributary to the Bârlad river, the Vaslui river is situated in the Eastern part of Romania. The area of the hydrographical basin represents 9.58% of the Bârlad river basin, which is the greatest river basin and the longest river in the Siret river basin (Fig. 1). The Vaslui river has its source under the Repedea – Păun plateau, at 340 m altitude, and the river flows into the Bârlad river, at 80 m altitude.

From a morphologic point of view, the Vaslui river basin is situated in the central-eastern part of the Moldavian Plateau, more precisely in the central - eastern part of the Central Moldavian Plateau. It is limited by the Rebricea and Telejna river basins to the west, by the Crasna river basin to the east, and by the Bahlui and Jijia river basins to the north. It has a length of 81.0 km and a basin area of 692 km^2 (The Atlas of Water Cadastral Survey in Romania, 1992). It has a length of 81.0 km and a basin area of 692 km^2 (The Atlas of Water Cadastral Survey in Romania, 1992).

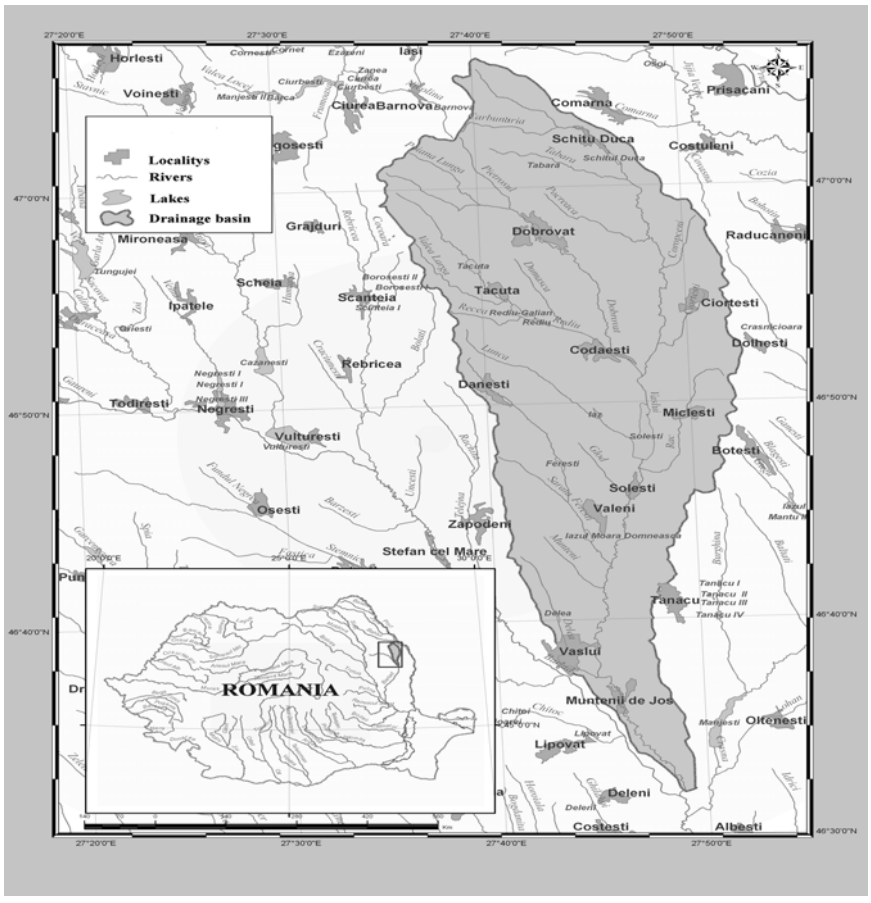

Fig. 1. ***Geographical location and mathematic coordinates of the Vaslui river basin***

3. RESEARCH METHODS

In the present study the hydrology specific methods have been used, especially those referring mainly to high floods and high waters. From this point of view, the following parameters have been analysed: maximum flow (Qmax, m^3/s); reference flow (Qb, m^3/s); increase time (Tc, hours or days); decrease time (Td, hours or days); water volume (W, m^3); flown layer (h, mm); shape coefficient of the high flood (y).

The maximum flow, the increase time, the total time and the high flood volume are the main elements defining the high flood hydrograph and represent the basis for its calculation and construction.

4. RESULTS AND DISCUSSIONS

The maximum flow is extremely complex, being influenced by a multitude of factors: the river basin shape and size, lithology, vegetation cover degree, slope inclination and river bed, flood plain width and configuration, presence of lakes etc. (Romanescu, 2003) (Table 1).

The maximum values can be produced in any season, but most frequently they are recorded in spring, sometimes at the end of winter. when the snow melting is associated with high amounts of rain. Analyzing the causes of the highest annual maximum flows, lead us to the conclusion that rainfall has a main role in producing them, either alone or accompanied by snow melting. Consequently, when calculating the maximum flows, the starting point is represented by the analysis of the annual maximum flows.

The annual maxim values on the Vaslui river are recorded in Satu Nou in the months of June, March and April; in Codăeşti in the months of April, May and June; in Soleşti in March, June, April and May. On the Dobrovăţ river, at the hydrometric station in Codăeşti, they are recorded in March, April and June.

Table 1. ***The date when the historical maximum flows were recorded at the hydrometric stations in the Vaslui river basin***

River	Hydrometric station	Qmax (m^3/s)	Date
Vaslui	Satu Nou	217	25.VIII.1970
	Codăeşti	222	19.VI.1985
	Soleşti	13,2	9.VII.1985
Dobrovăţ	Codăeşti	47,1	27.V.1991

Prut Water Headquarters, 2009

In the analysis of the main high floods in the Vaslui river basin, for each hydrometric station, 5 high floods (the greatest) will be included. In this case, the data from Soleşti will be only partly treated as this hydrometric station is located

very close to the downstream barrage - Soleşti. Consequently, the flows recorded here are not relevant, as they are artificially controlled.

In the profile of Satu Nou hydrometric station the maximum flow is 217 m^3/s, recorded in 1970. A special situation occurs here: the 5 greatest high floods were registered in consecutive months, in different years, in the interval April – August. The lowest maximum flow was 105 m^3/s. This hydrometric station was set up on 1 September 1961, but measurements of liquid flows were performed only starting with 1968. Until then, only level measurements were done.

At the hydrometric station in Codăeşti, on the Vaslui river, the maximum flow was 222 m^3/s, recorded in 1985. The maximum flows were recorded in the interval April – June and September. A characteristic is represented by the fact that in the month of May two of the maximum flows were recorded: 115 m^3/s in 1991 and 79.1 m^3/s in 2005, the latter one being the lowest maximum flow of the five.

The recording of maximum flows in different years at the hydrometric stations in Satu Nou and Codăeşti (on the Vaslui river), in 1970 and 1985 respectively, is explained by the different time when these hydrometric stations were set up (1968 and 1977). This aspect is emphasized by the months and by the years in which, in these two sections, multiannual monthly maximum flows were recorded in the same month and year, except the months of July, August and December. Considering this aspect, the Vaslui river had probably a higher flow in 1970, than in 1985 (when the historic maximum was recorded) in Codăeşti.

In Soleşti, the maximum flow of 9.96 m^3/s in the month of June is not the annual maximum in 1985, but it is the multiannual maximum flow of the month of June. In 1985, in Soleşti, two of the highest multiannual monthly flows were recorded: 9.96 m^3/s and 13.2 m^3/s. The flow of 8.30 m^3/s in 1991 is the lowest of the 5 multiannual maximum flows.

Even if the section in which measurements are taken is situated downstream the accumulation, some multiannual monthly maximum flows are in accordance with those recorded at the hydrometric stations upstream This is caused by the manoeuvre from the accumulation. In this section the multiannual monthly maximum flows occurred in three periods: March, the interval June-August and in November.

Along the Dobrovăţ river, the main right tributary of the Vaslui river, there is only one hydrometric station, in Codăeşti. This was built after the Soleşti barrage was constructed. At this hydrometric station, the multiannual monthly maximum flows were recorded in the months of May, June and September. The multiannual maximum value was 47.1 m^3/s, recorded in 1991, in May. In this month, in 2005, another annual maximum flow was recorded, with the value of 35.0 m^3/s. In September, two of the highest multiannual flows were recorded: 31.4 m^3/s in 1989 and 39.5 m^3/s in 1996. The lowest flow of the 5 multiannual maximum flows was 30.8 m^3/s in 2001.

The maximum flows recorded depend on the precipitation with torrential character. It is not compulsory that a high annual amount of precipitation lead to a significant annual maximum flow, but to a significant average annual flow.

In Satu Nou, on the Vaslui river, the multiannual variation of the maximum flows, indicates the fact that the interval 1997 – 2008, the maximum flows had values under 37.5 m^3/s. This is the period with the most reduced flows, even if the lowest maximum flow was 1.76 m^3/s, in 1987. This period starts in 1992, with 16.1 m^3/s, and the flow with the value of 68.8 m^3/s, in 1996, interrupts it. This is a period which raises a lot of questions, considering that it is a recent one, and the flow trend is decreasing. On the other hand, this evolution emphasizes the torrential character of the river and the continental character of the climate. Year 2007 was also important, characterized by meteorological drought, with impact on the river flows in 2008. The percentage of years with maximum flows under 50.0 m^3/s is of 73.2%.

Considering the fact that 2009 was a droughty year, the period started in 1997 is continued, the decreasing tendency is maintained, with influences on the surface flow in the years to follow, according to the precipitation regime, of course.

In the multiannual variation of the flows at the hydrometric station in Codăeşti (Fig. 6), located on the Vaslui river as well, the trend is decreasing, but not so significant as upstream, in Satu Nou. Anyway, it is normal to find such a tendency in Codăeşti as well, while it is manifested upstream, but in this case, the period 1997 – 2008 does not have the same evolution. At this station, the flows exceeding 50.0 m^3/s are: 68.4 m^3/s in 1999; 65.0 m^3/s in 2001; 79.1 m^3/s in 2005.

Although the area of the of the hydrographical basin (up to the hydrometric station), is much greater (362 km^2) that upstream (105 km^2), in 68.8% of the situations, the annual maximum flows do not exceed 50.0 m^3/s.

At the hydrometric station in Codăeşti, on the Dobrovăț river, the multiannual maximum flow is 47.1 m^3/s, which means that the multiannual variation of the flows runs under this value. It is normal that the flows are lower than those recorded at the hydrometric stations on the Vaslui river, considering the fact that the river basin is smaller (184 km^2).

For this hydrometric station, in the multiannual variation of the maximum flows, three periods with flows under 20.0 m^3/s are noticed: 1992 – 1995; 2002 – 2004; 2006 – 2008 (and they represent 69.6% of the annual maximum flows).

The first period, 1992 – 1995, is important, with reduced flows, and this is characteristic to the other two hydrometric stations too. It is a well defined period, with constant flows on the Dobrovăț river, between 8.42 – 16.7 m^3/s. In the second period the flows have values between 4.30 – 19.6 m^3/s, and in the third, between 3.26 – 12.0 m^3/s. These emphasize the manifestation of the periods in the other hydrometric stations, with reduced maximum flows as well, as compared to the whole evolution period. The evolution trend of the maximum flows in this case is decreasing as well.

Due to the fact that data of the high flood in 1971 at Satu Nou is not found in the Water Management System of Vaslui, the high floods recorded in 1969 was analysed, as this was the second greatest in terms of flows. The high flood recorded in 1969 in Satu Nou was caused by the combination of the precipitation periods in the month of June, when they registered the monthly maximum of that year (125.4 mm) and 86.3 mm in July, in Poeni.

The flow of 90.4 m^3/s was reached on 12.VII.1969. The high flood started the same day, with a reference flow of 0.250 m^3/s, under the conditions of a saturated soil, as a consequence of the previous precipitation. This high flood had a unique character as the maximum flow is preceded, on 11.VII.1969, by an amount of precipitation of only 4.4 mm, before which 8 days without precipitation were recorded. But the effect of the precipitation fallen in July is manifested later, and to this, the precipitation on 12.VII.1969, of 20.0 mm, are added, and therefore the maximum flow is recorded. Starting with 13.VII.1969 the flows are continuously decreasing, but due to the precipitation recorded on 13 – 14.VII.1969 (20.0 mm in each day), the high flood flows register a slight increase and the hydrograph of the high flood got a different shape, with a prolongation until 16.VII.1969.

For the interpretation of the high flood in 1970, only the data for the months of August and September are missing from the data provided by C.M.R. (in the month of August the historic maximum flow was recorded). This fact is not a coincidence, the lack of data is probably a proof of the fact that measurement conditions or instruments were deteriorated in that period, as these two months are the only in which precipitation data are missing.

In Poieni, for the year 1970, only the precipitation amount of 443.6 mm is represented on the graph, and this does not include the monthly amounts of August and September. The high flood in 1970 recorded the historic maximum flow in Satu Nou hydrometric station, with the value of 217 m^3/s, on 25.VIII.1970, with a start value of 0.039 m^3/s in the same day.

The maximum flow in 1971 (105 m^3/s), is due to the high amounts of precipitation recorded in Poieni in the month of July (210.9 mm). The maximum amount on 24 hours had the value of 105.0 mm on 2.VII.1971, when the maximum flow was also recorded. This amount was supported by the previous ones, in the interval 12.VI. – 1.VII.1971 (114.5 mm). In the period 3 – 4.VII.1971 other 25.5 mm were recorded, supporting the flow.

The high flood in 1979 has a reference flow of 2.37 m^3/s on 8.IV.1979, due to the combination of several precipitation amounts in Poeni: 53.0 mm (3 – 5.IV.1979) and 30.2 mm (7 – 8.IV.1979). Under the circumstances of such precipitation and flows, on 9.IV.1979 other 80.1 mm were recorded, followed by a flow of 108 m^3/s, the high flood ending on 11.IV.1979.

In 1985, at the hydrometric station in Satu Nou, the high flood with the second greatest multiannual maximum flow was recorded (Fig. 2). This has a sudden increase, from 1.42 m^3/s on 18.VI.1985, a day in which the amount of precipitation in Poeni was 80.1 mm, to 125.0 mm in 19.VI.1985, when the maximum flow of 174 m^3/s was also recorded.

The last high flood of the 5 ones, but not the one with the lowest flow, was recorded in 1991, a year for which there is no precipitation data for Poeni at the Moldova Meteorologic Center of Iaşi. That is why we used only the precipitation measured in Soleşti pluviometric station, situated downstream. In the beginning, the high flood in 1991 has a flow of 1.76 m^3/s on 26.V.1991. On 27.V.1991, the amount of precipitation is 127.5 mm, causing a maximum flow of 122 m^3/s (Fig. 3).

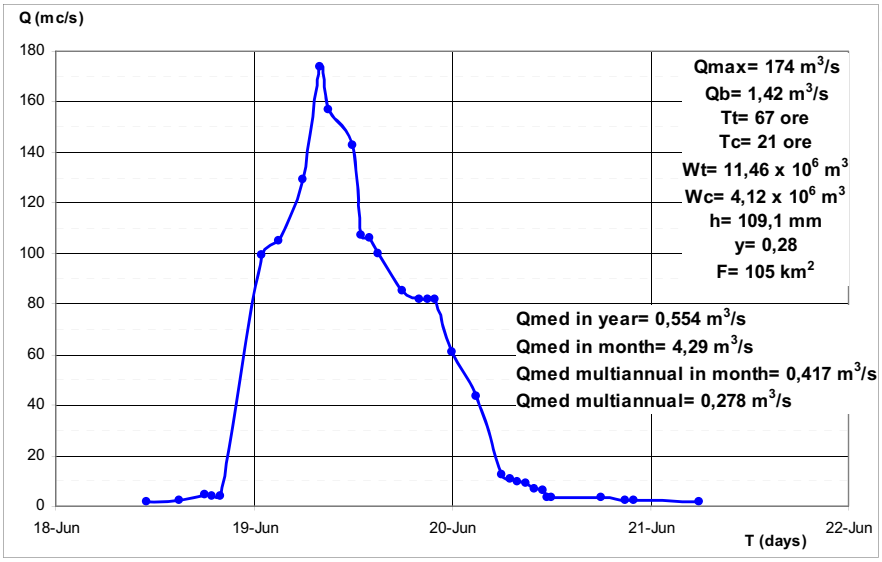

Fig. 2. ***Hydrograph of the high flood on 18 – 21.VI.1985, on the Vaslui river, at the hydrometric station in Satu Nou and the main characteristics***

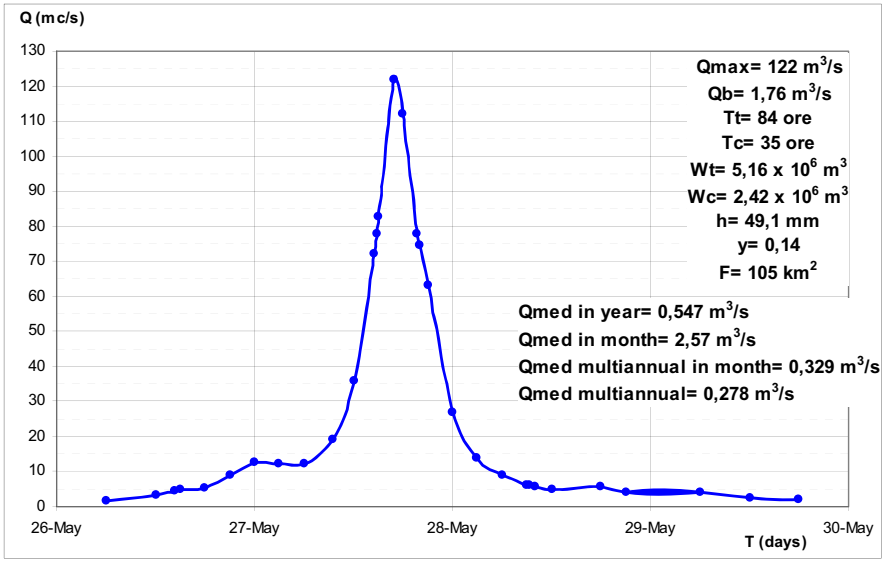

Fig. 3. ***Hydrograph of the high flood on 26 – 29.VI.1991, on the Vaslui river, at the hydrometric station in Satu Nou and the main characteristics***

Of the 5 high floods, those recorded in 1970 and 1985 can be distinguished. The high flows were recorded in a very short time. In 1970, the flow increased from 27.8 m^3/s to 217 m^3/s in only 7 hours, and in 1985, from 4.19 m^3/s to 99.5 m^3/s in only 4 hours.

What draws our attention is also the total volume of the high flood in 1985, of 11.46 mil. m^3 and the volume of high flood increase of 4.12 mil. m^3. These volumes exceed the values of 1970 high flood, when the multiannual maximum flow was recorded. The flown layer is also significant, exceeding 109 mm, and also the high flood shape coefficient (0,28), as compared to the value of the flown layer and of the shape coefficient of the other high floods, with values between 49 – 70 mm, 0.14 – 0.22 respectively. This fact is due to the sudden increase and decrease of the levels, and of the high flood flow implicitly.

The high flood in 1979 is the direct consequence of the precipitation amount of 23.7 mm in the period 3 – 4.IV.1979, 17.3 mm in the interval 7 – 8 .IV.1979 and 20.5 mm on 9.IV.1979, the date when the maximum flow of 133 m^3/s was recorded. The reference flow of the high flood is 4.08 m^3/s, on 8.IV.1979, the high floods being over on 14.IV.1979.

The high flood in 1985 has a similar character to the previous one. The high flows, the high amounts of precipitation recorded in the upper basin and the area of the river basin, caused the recording of the maximum flow at the same date with the one in Satu Nou. The amounts of precipitation are important, 27.7 mm on 8 – 9.VI.1985, and 43,3 mm on 18.VI.1085 and 31,3 mm in the day when the multiannual maximum flow was recorded, 222 m^3/s, as they induced a very low decrease rate to the high flood. Its start, on 17.VI.1985, had a reference flow of 0.361 m^3/s and the end was recorded on 5.VII.1985 (Fig. 4).

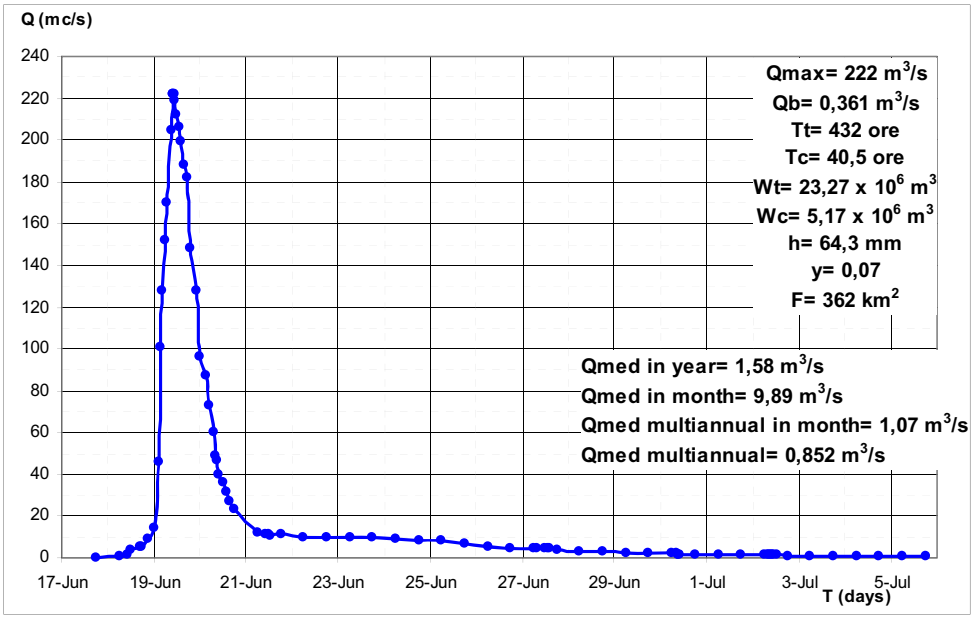

Fig. 4. ***Hydrograph of the high flood on 17 – 5.VI.1985, on the Vaslui river, at the hydrometric station in Codăeşti and the main characteristics***

The high flood in 1991 has a special character, with a maximum flow of 115 m^3/s, recorded on the same date with the maximum flow in Satu Nou hydrometric station, on 27.V.1991, higher than the value recorded in Codăeşti (Fig. 5). As in the case of the other high floods, the high flows are caused by the significant values of the flows and precipitation in the upper river basin. At the pluviometric station in Soleşti, the amount of precipitation cumulated for the month of May, until the date when the maxim was registered, is 127.5 mm. Due to its distribution in time, it did not cause significant flows from a quantitative point of view.

This high flood is of a composed type, and it manifests in the period 25.V. – 7.VI.1991, with a reference flow of 0.480 m^3/s. The second important peak of the flow has a value of 38.6 m^3/s, on 30.V.1991, its beginning occurring the same day.

The high flood in 1996 occurred in the period 22.IX. – 5.X.1996. The value of the reference flow was 0.592 m^3/s, reaching the maximum flow of 106 m^3/s on 24.IX.1996. It has a normal increase time, but the decrease is very slow, similar to the high flood in 1985. There are no precipitation data for this high flood either.

A high flood of a composed type, but with another manifestation way, is the high flood in 2005. It presents three peaks with flows of 79.1 m^3/s, 28.8 m^3/s and 14.9 m^3/s. The high flood manifested in the interval 7 – 19.V.2005, starting with 0.876 m^3/s, and reaching a maximum flow of 79.1 m^3/s on 8.V.2005.

The high flood in 1979 and 2005 are characterized by higher shape coefficient than other high floods (0.14 and 0.12 respectively), due to the fast increase of the flows, with significant values in a short period of time, and with a decrease which happens also fast.

As compared to the multiannual maximum flows recorded at the other hydrometric stations, reaching 217 m^3/s in Satu Nou, 222 m^3/s in Codăeşti, both situated on the Vaslui river, in Codăeşti, on the Dobrovăț river, the 5 multiannual flows included in the present analysis are much lower. The multiannual maximum flow is 47.1 m^3/s, representing 21.7% of the multiannual maximum flow recorded in Satu Nou and 21.2% of the multiannual maximum flow in Codăeşti. In the case of the Dobrovăț river basin, due to the high vegetation cover degree and to its large area, the measured flows of the river are much lower.

As compared to the high floods analysed before, on the Dobrovăț river, 3 of the 5 maximum flows are of a composed type.

The high flood in 1989 has a unique evolution, due to the precipitation that are detected rapidly in the measured flows of the river (Fig. 18). It has a significant reference flow, of 0.664 m^3/s on 5.IX.1989, due to the precipitations on 30.VIII – 4.IX.1989, measured in Soleşti pluviometric station, of 30.8 mm, a flow which was followed by a small increase in the same day, under the circumstances of another amount of precipitation, of 31.8 mm, followed by 4 days of rain, of 20.7 mm, 24.9 mm, 14.7 mm and 28.3 mm on 9.IX.1989. On 8.IX.1989 the maximum flow is recorded, with the value of 31.4 m^3/s. Before this, on 7.IX., two important peaks were recorded, of 29.1 m^3/s and 28.9 m^3/s, with a lower flow of 23.5 m^3/s between the two peaks.

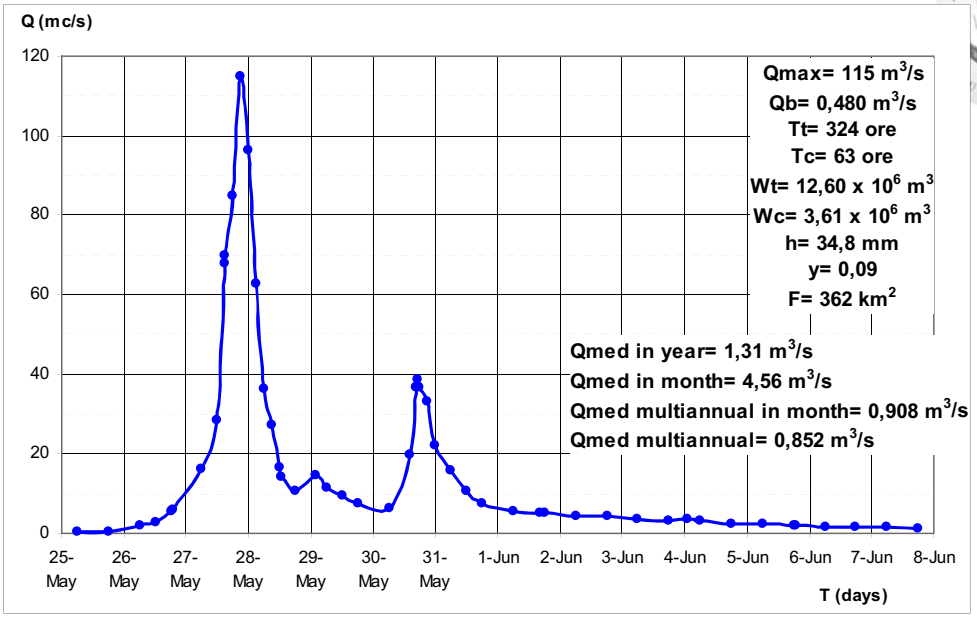

Fig. 5. ***Hydrograph of the high flood on 25 – 7.VI.1991, on the Vaslui river, at the hydrometric station in Codăeşti and the main characteristics***

Due to the distribution over a longer period of time of the precipitation, after the maximum flow was recorded, another increase of the flow was registered, but not so significant (7.40 m^3/s), the high flood ending on 11.IX.1989.

In 1991 the multiannual maximum flow was registered, with a value of 47.1 m^3/s, on 28.V.1991, when the maximum flows at the other two hydrometric stations were recorded on 27.V.1991. The reference flow of the high flood has the value of 0.300 m^3/s on 26.V.1991, and its end is recorded on 8.VI.1991.

After the maximum flow on 31.V.1991 another peak of the flow was recorded, with the value of 18.2 m^3/s, starting from a value of 3.20 m^3/s on 29.V.1991, under the circumstances of precipitations recorded at the pluviometric station in Soleşti, mentioned in the case of the other high floods in 1991.

The high flood in 1996 is a simple one. It occurred in the interval 22 – 30.IX.1996, it has a reference flow of 0.540 m^3/s and a maximum flow of 39,5 m^3/s on 24.IX.1996. It has a slow increasing time and a much slower decrease.

There are no data for the precipitation accompanying this high flood, same as in the case of the high flood recorded in the same month, in the same year, on the Vaslui river, at the hydrometric station in Codăeşti.

The high flood in 2001 is of simple type, but with a lower maximum flow, of 30.8 m^3/s on 5.VI.2001. The high flood manifested in the interval 4 – 14.VI.2001, with a very slow decrease, as compared to the increase, which was sudden, with a reference flow of 0.099 m^3/s. The peak of the high flood was recorded on the basis of the significant precipitation, measured at the pluviometric

station in Soleşti, on 5.VI.2001, with a value of 44.7 mm, to which, the precipitation of the previous day were added, that is 21.5 mm.

The high flood in 2005 is a composed one. It occurred in the period 6 – 24.V.2005, with a maximum flow of 35.0 m^3/s, recorded on 8.V.2005. The high flood has a significant reference flow, of 0.576 m^3/s. The peak has a flow of 13,4 m^3/s on 7.V.2005. The maximum flow is followed by three other peaks, the first with a value of 10.7 m^3/s on 9.V., and the next ones, of 5.25 m^3/s and 5.93 m^3/s respectively, both recorded on 10.V.2005.

The high flood in 1989, even if it does not have a very high flow, it has a high volume while increasing. It also has the highest shape coefficient (0.28).

In the hydrological practice, the knowledge of the elements characteristic to the high flood waves, presents a special importance. These elements are determined by using the hydrographs of the single high floods, recorded at the hydrometric stations, and on the basis of the analysis of the most important high floods. Afterwards, the average characteristic elements of the high flood waves, which represent the basis of the type hydrographs of the single high floods with different probabilities, can be calculated.

5. CONCLUSIONS

All the river basins in the Moldavian Plateau undertake climatic conditions favourable to the genesis of torrential rains. In this case, the hydrological risks are very frequent and the material damage or human toll can reach immeasurable values. The detailed analysis of the hydrographs of the maximum flows on the Vaslui river and its tributary, Dobrovăţ, emphasizes the fact that most of the works that have been accomplished on the water courses are efficient. The exception belongs to the sector upstream of Soleşti barrage.

Besides of the precipitations with torrential character and the shape of the upper river basin, another decisive factor in producing floods in represented by deforestation. The barren slopes became more and more in number after 1990, when the agricultural land was given to the small land owners.

The basic characteristic of the high flood waves on the Vaslui river is represented by the existence of a clear modulation, very often vertical, in a relatively short time. The sharp waves are similar to those produced in the urban areas. This particular thing is caused by the existence of the barren slopes.

The barrage in Soleşti, with a multiple purpose, has a very important role in diminishing floods. From this point of view the town of Vaslui is well protected against floods, and the hydrologic risk is no longer existent.

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