PARTICULARITIES OF PERIODS WITH MAXIMUM WATER FLOW ON THE RIVERS FROM THE SUCEAVA HYDROGRAPHIC BASIN (1981–2005)

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ABSTRACT.- Particularities of periods with maximum water flow on the rivers from the Suceava hydrographic basin (1981 – 2005). Suceava river basin gets its tributaries from the eastern slopes of the northern group of the Eastern Romanian Carpathians, situated under the influence of Baltic air masses, which bring rainfalls and cold weather, felt into the water flow regime of rivers in the region studied. This water flow regime varies from month to month, with the maximum flow having the most important role in the restoration of underground water reserves. This study examines the temporal (frequency, duration and intensity) and quantitative (volume and flow) parameters of periods with maximum flow, at monthly and seasonal level, revealing the differences in the water flow regime induced by the relief's morphometric particularities (altitude, fragmentation degree, exhibition). For the evaluation of mentioned parameters was appealed to the TML 2.1 extension from the HydroOffice software package, which uses quantitative thresholds, depending on which it is set the appearance, and disappearance of periods with maximum flow.

Key-words: maximum flow, quantitative threshold, frequency, floods.

1. INTRODUCTION

There can be differentiate two phases into the water flow regime of rivers: maximum flow and low flow. In the phase of maximum flow appear two distinct periods: high waters and floods, each with its special characteristics and which can sometimes overlap (Ujvari, 1972).

The maximum flow in a river basin is characterized by several parameters: temporal parameters (duration, frequency, time of appearance, return period), quantitative parameters (discharge and volume of water drained).

Suceava river basin includes two major forms of relief: the Ridges of Bukovina as part of the Eastern Carpathians in the west and Suceava Plateau in the east. Between the two forms of relief there is a transition sector, represented by a series of depressions and sub mountain hills (Fig. 1).

The period of maximum flow is the temporal interval when the river's

discharge exceeds certain quantitative thresholds, generating a number of negative effects on bordering regions.

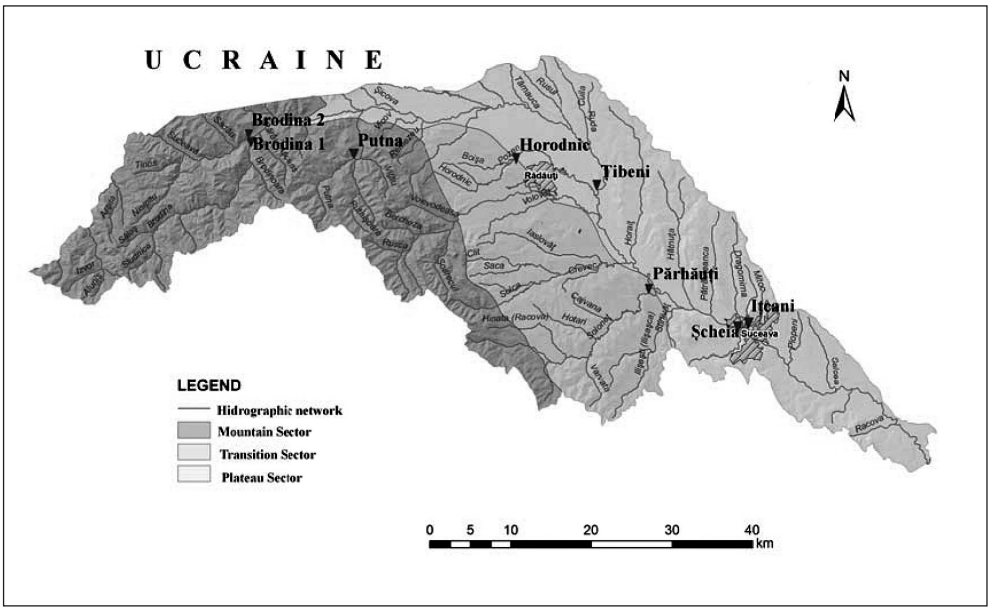

Figure 1. Hydrographic network and hydrometric stations from Suceava river basin

2. DATA BASE AND METHODS

The database used in this paper includes daily maximum liquid flow values, from eight hydrometric stations, three of which are located on the main five tributaries (Fig. 1). Data were obtained from the "Siret" Water Basin Administration and the Bacău Water Management Service. The interval taken into consideration was from 1981 to 2005.

To interpret meteorological data, daily rainfall respectively, there were used data from the National Meteorological Administration in Bucharest.

For the interpretation and graphical representation of hydrological data, it was used the method of quantitative threshold (Hisdall et al., 2000), using the TML 2.1 extension of the HydroOffice software package. With this extension, there were identified the periods with maximum flow, analyzing the river's discharge values. These periods are delimitated using annual, seasonal, monthly, N-day, daily thresholds, or can be chosen a pre-defined value. Within each type of threshold can be used average values, medians, percentiles (as percent values) or direct values liquid discharges. For this study we considered most appropriate the threshold

values of 20% (20 percentile) from the daily flow, recorded in the period 1981-2005, calculated for each hydrometric station in the basin (Table 1).

Table 1. Threshold values for the determination of periods with maximum flow at the hydrometric stations from Suceava river basin

River	Station	Threshold values for maximum flow (in m^3/s)
Suceava	**Brodina 2**	5
Suceava	**Ţibeni**	13
Suceava	**Iţcani**	19,3
Brodina	**Brodina 1**	2,3
Putna	**Putna**	0,7
Pozen	**Horodnic**	0,6
Soloneţ	**Părhăuţi**	1,2
Şcheia	**Şcheia**	0,2

3. RESULTS AND DISCUTIONS

The period of maximum flow are an important phase of a river water regime through multiple effects that may have on the environment components and on the riverine residents. It has different sizes, intensities and durations, which manifests itself in flowing regime of rivers as high waters and floods.

3.1 Genetic factors of periods with maximum water flow

As phase of the drainage system of rivers, periods of maximum flow are generated by heavy rainfall fallen from March to October, the melting of snow in winter or overlapping of the two during winter - spring crossings.

The quantities of water fallen in 24 hours show that rainfall intensity in a given region can generate large floods. Lowest amounts of precipitation fell in the winter (January), when the studied region is under the influence of the Siberian Anticyclone, which generates very low air temperatures (Table 2). Precipitation values increase during summer, when moisture values grow, intensifying convective and frontal processes peaking in July in the entire basin.

Table 2. Monthly average rainfall quantities and maximum rainfall quantities fallen in 24 hours (in mm)

Station	Value	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Brodina	Med.	33.0	39.8	43.6	71.4	109.5	138.0	146.4	112.3	73.1	44.0	35.2	34.1
	Max	26.8	24.1	38.7	61.6	51.9	91.6	93.3	94.8	70.7	33.8	31.7	31.5
Izvoarele Sucevei	Med.	33.6	41.8	53.8	80.8	119.9	153.6	158.1	120.2	80.7	54.4	43.5	42.2
	Max	20.6	20.2	36.2	58.9	58.6	79.1	90.7	75.0	55.7	40.5	30.5	31.6
Marginea	Med.	28.2	30.6	37.4	57.0	86.4	114.6	116.5	87.3	59.0	41.1	34.5	33.1
	Max	19.3	21.0	31.8	41.4	57.3	61.6	64.4	55.2	40.3	29.7	32.3	29.7
Pârhăuți	Med.	22.9	24.1	29.2	49.9	74.7	98.7	103.0	76.2	49.2	32.8	28.2	24.3
	Max	18.7	18.7	28.0	33.3	56.3	57.2	69.5	57.3	42.0	28.7	30.7	20.2
Suceava	Med.	23.1	24.2	32.4	53.6	76.6	98.0	102.9	73.2	51.9	36.2	30.0	27.3
	Max	20.1	19.8	30.3	38.8	62.9	60.2	63.7	57.7	47.9	32.4	30.8	25.6

A significant water reserve for rivers is the snow layer that contributes to the formation of large floods, especially when snowmelt is superimposed over the fall of rainfall. The maximum thickness of the snow is reached during February, even March in the highest sectors of the basin (Table 3) as a result of very low temperatures recorded in January and February. The time interval of snow layer appearance varies (on average) between 138-146 days in the mountain sector, with 113 days in the transition sector, reaching 78 days in the plateau sector.

Table 3. Monthly average thickness (in cm) of snow cover

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Brodina	27.5	39.7	37.5	7.2	0.04	0.004	0.00	0.00	0.001	0.4	4.6	15.0
Izvoarele S.	32.3	45.3	47.4	11.9	0.11	0.005	0.00	0.00	0.006	0.7	5.5	18.4
Marginea	17.9	21.6	15.5	1.4	0.00	0.00	0.00	0.00	0.00	0.08	2.9	9.7
Pârhăuți	8.1	9.5	6.4	0.2	0.00	0.00	0.00	0.00	0.00	0.01	1.2	3.9
Suceava	7.4	8.8	5.9	0.2	0.00	0.00	0.00	0.00	0.00	0.01	1.1	3.6

3.2. Manifestation forms of periods with maximum water flow

To analyze the particularities of manifestation forms of periods with maximum flow, there were made daily flow hydrographs for each of the 25 years taken into account in the eight hydrometric stations in Suceava River basin.Periods of maximum flows are represented by floods and high waters that occur with different durations and frequencies in time-space profile. There is a lower frequency of overlapping periods for high waters over the floods.Summer floods, of pluvial origin, have the highest frequency (between 32.4% at Ițcani station and 45.1% at Brodina) .(Table 5). Follows the floods with pluvial – snow origin from spring, which hold between 32.4% (Brodina 2) and 40.5% (Ițcani). Lower weights present the

floods in autumn (between 7.1% at Țibeni station and 23.6% at Horodnic station), the lowest being recorded in winter (between 3.8% at Brodina and 16% at Pârhăuți). The values of flood hydrograph elements are directly proportional to the size of river basins, the highest values being recorded at the Iţcani station (Table 4).

Table 4. Flood hydrograph elements for the hydrometric stations of Suceava river basin

River	Station	H med (m)	S (km 2)	Q max (m3/s)	Wc (mil. m3)	Wt (mil. m3)	Hs (mm)	Ga-mma	Tc (h)	Tt (h)
Suceava	**Brodina 2**	990	366	70,1	3,2	13,5	29,9	0,5	36,1	130,8
Suceava	**Tibeni**	730	1228	165,1	10,3	32,4	26,4	0,4	56,2	161,0
Suceava	**Itcani**	629	2377	225,3	13,0	41,5	17,6	0,4	43,2	139,7
Brodina	**Brodina 1**	989	142	53,9	1,8	6,6	45,9	0,4	28,1	108,7
Putna	**Putna**	847	53	14,7	0,6	1,8	33,1	0,4	33,5	98,8
Pozen	**Horodnic**	488	67	17,0	0,6	4,3	23,2	0,5	37,4	88,9
Solonet	**Parhauti**	467	204	36,0	0,8	2,8	13,7	0,3	33,5	94,5
Scheia	**Scheia**	388	33	4,3	0,2	0,5	13,7	0,4	35,4	97,1

H med – basin's average altitude
S – basin's surface
Q max – flood's maximum discharge
Wc – flood's increasing volume
Wt – flood's total volume
Hs – flood's flown layer, where: Hs = Wt / S
Gamma – flood's shape coefficient, where Gamma = Wt / (Qmax • Tt)
Tc – flood's increase time
Tt – flood's total time

High waters present a similar frequency succession to the floods, with differences between the mountain, transition and plateau sectors (Table 5), but with lower number of cases than floods. The lowest values were recorded in the mountain, where such phenomena rarely occurred in the period under review (1 case). Values rise in the plateau sector, reaching a peak on the Şcheia River (7 cases), due to the reduced of the scale basin, which have reacted very quickly to climate pulsations.

Table 5. Monthly frequency (absolute and relativă) of high waters and floods

Station	Winter floods		Winter high waters		Spring floods		Spring high waters		Summer floods		Summer high waters		Autumn floods		Autumn high waters	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Brodina 2	10	6,9	1	1,5	47	32,4	27	41,5	60	41,4	30	46,2	28	19,3	7	10,8
Țibeni	7	6,5	1	2,4	41	38,3	17	40,5	40	37,4	21	50,0	19	17,8	3	7,1
Iţcani	12	10,8	2	3,3	45	40,5	28	45,9	36	32,4	24	39,3	18	16,2	7	11,5
Brodina 1	5	3,8	1	2,0	44	33,1	21	42,9	60	45,1	22	44,9	24	18,0	5	10,2
Putna	6	5,3	1	1,8	40	35,1	21	37,5	47	41,2	25	44,6	21	18,4	9	16,1
Horodnic	16	13,9	6	10,9	39	33,9	21	38,2	38	33	15	27,3	22	19,1	13	23,6
Pârhăuţi	21	16,0	6	8,7	44	33,6	24	34,8	44	33,6	24	34,8	22	16,8	15	21,7
Şcheia	13	13,0	7	13,0	34	34,0	19	35,2	34	34,0	17	31,5	19	19,0	11	20,4

3.2 Parameters of periods with maximum water flow

Maximum flow from a water basin is characterized by many parameters such as: temporal parameters (duration, frequency, time of appearance, return period), quantitative parameters (discharge and volume of water drained).

3.2.1.Temporal parameters

For the analysis of temporal parameters of periods with maximum flow were considered together both high waters and floods periods, which resulted in a longer duration of period with maximum flow, in some cases the two phenomena overlapping, making it impossible the temporal differentiation between them.

The duration of periods with maximum water flow. Analyzing periods with maximum flow on certain time intervals (10 days) it is noted that the percentage is higher for the interval below 10 days (75% at Iţcani station and 84.6% at Putna station of the total number of cases) (Table 6). The percentage values decrease more at the following intervals, with weights between 8.7% at Şcheia station and 13.8% at Brodina 2 station.

Table 6. Frequency (in %) of periods with maximum flow of certain time durations (in days)

Station	< 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 - 90	90 - 100	> 100
Brodina 2	79,1	13,8	4,0	1,2	2,0	0,0	0,0	0,0	0,0	0,0	0,0
Ţibeni	79,3	9,7	4,1	4,1	0,5	1,8	0,5	0,0	0,0	0,0	0,0
Iţcani	75,0	12,3	7,1	3,3	0,9	0,9	0,5	0,0	0,0	0,0	0,0
Brodina 1	79,5	11,9	4,5	1,6	2,0	0,0	0,0	0,4	0,0	0,0	0,0
Putna	84,6	9,7	4,1	0,9	0,3	0,3	0,0	0,0	0,0	0,0	0,0
Horodnic	78,9	10,6	5,5	1,8	1,4	0,9	0,5	0,0	0,0	0,5	0,0
Părhăuţi	80,8	9,6	6,0	2,0	1,2	0,4	0,0	0,0	0,0	0,0	0,0
Şcheia	77.0	8.7	8.7	2.6	1.0	0.5	0.0	0.5	0.0	0.5	0.5

The remaining intervals show very low percentages, under 10% of total cases, as isolated phenomena caused by high waters which were spread out over long periods of time or overlapped with floods. An example is Ţibeni station, where in the summer of 1998 succeeded a series of floods and high water periods that lasted two months (Fig. 2).

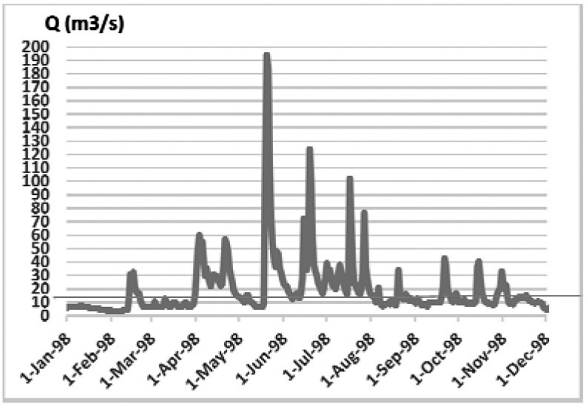

Figure 2. Hydrograph of daily discharges for Țibeni Station in 1998

The frequency of periods with maximum water flow. To study the frequency of periods with maximum flow were analyzed the monthly and seasonal frequency of water flow from Suceava river basin.

The annual variation of the number of days when the threshold value of maximum flow has been exceeded in Suceava river basin in the interval 1981-2005

Between 1981 - 2005 (Fig. 3), maximum annual flow varied, in number of days, from one year to another, in some years completely lacking at all stations, and in other years occurring in most hydrometric stations with different durations (1981, 1984, 1988, 1999, 2002 and 2005).

If it is made an analysis of maximum flow variation over the years separately on the main course and tributaries, it can be seen that on the main course, the annual number of days with maximum flow was lower than on the tributaries, rarely exceeding 100 days / year (Figure 4a). Instead, on the tributaries, this number has varied much more (Figure 4b), in some years being registered no daily maximum flow, while in others a large number of such days, the biggest change being at the Şcheia station, where appeared the highest number of days with maximum flow, but there have been six consecutive years without maximum flow (1993-1998) (this happened because the river basin has small dimensions and discharge values, and it develops only in the plateau sector, with lower water supplies, which makes it respond more quickly to climate change).

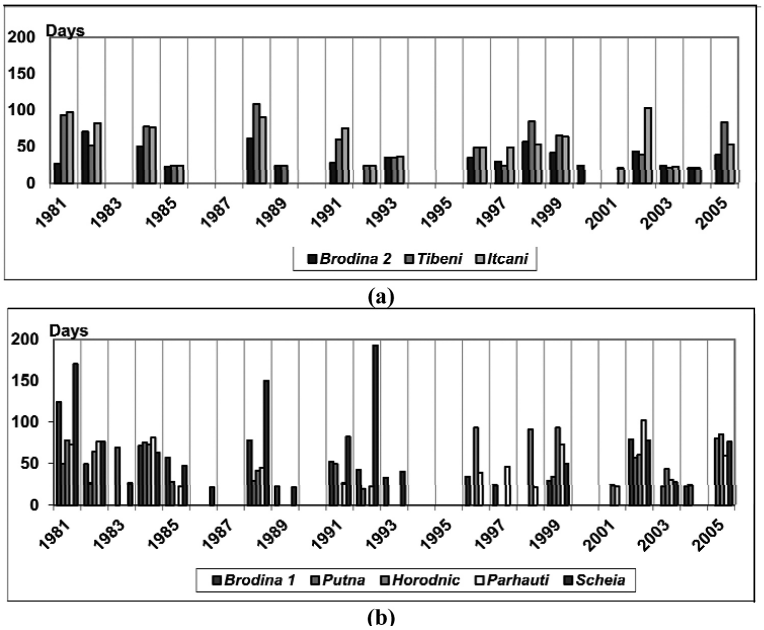

Figure 3. Number of days/year with maximum flow registered at the stations from: (a) main water course, (b) main tributaries in the interval 1981-2005

Monthly frequency. The highest monthly frequency of periods with maximum flow was recorded in April, from 17.5% at Şcheia station and 30.2% Brodina 2 station (Table 7). The explanation is that in this interval occurs widespread melting of snow layer in the mountain area, which contributes to the volume of water carried by rivers. The second month with maximum flow frequency is May for stations in the mountain and on the main water course, where the flow is delayed by the slower melting of snow (between 19 and 24% of annual frequency). Maximum frequency appears also in March, with values of over 15%, especially at stations located on tributaries of the middle and lower water basin.

Then comes July and June, with maximum frequencies that reach 17.5% in July at Putna station. The months from October to November show low values, below 10% from the multiannual flow value. In the months from December to February appear rare cases of maximum flow (below 7%), due to very low temperatures in these months that do not allow the melting of snow and the formation of high waters or floods. A special case is Horodnic station, which recorded 10.9%, this being the third month in frequency (5 cases of floods and high waters recorded in the period 1981-2005).

Table 7. Monthly frequency of cases with maximum at the hydrometric stations from Suceava river basin (in %)

River	Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Suceava	**Brodina 2**	0.0	0.0	11.6	**30.2**	**23.3**	9.3	**14.0**	9.3	2.3	0.0	0.0	0.0
Suceava	**Țibeni**	0.0	0.0	**14.5**	**21.8**	**23.6**	10.9	14.5	12.7	1.8	0.0	0.0	0.0
Suceava	**Ițcani**	3.5	1.8	**14.0**	**19.3**	**19.3**	10.5	12.3	10.5	7.0	0.0	0.0	1.8
Brodina	**Brodina 1**	0.0	0.0	12.0	**24.0**	**22.0**	8.0	**16.0**	14.0	4.0	0.0	0.0	0.0
Putna	**Putna**	0.0	0.0	**17.5**	**20.0**	12.5	15.0	**17.5**	12.5	5.0	0.0	0.0	0.0
Pozen	**Horodnic**	6.5	6.5	**19.6**	**19.6**	10.9	6.5	0.0	2.2	4.3	4.3	8.7	**10.9**
Soloneț	**Părhăuți**	0.0	4.7	**20.9**	**20.9**	**16.3**	7.0	4.7	9.3	7.0	2.3	4.7	2.3
Șcheia	**Șcheia**	3.2	6.3	**15.9**	**17.5**	**12.7**	11.1	9.5	9.5	3.2	3.2	4.8	3.2

If we make an analysis of the frequency of maximum monthly flow in Suceava River basin during 1981-2005, it can be seen that in some days were exceeded several times the threshold – value considered for that station than in other days (Fig. 4).

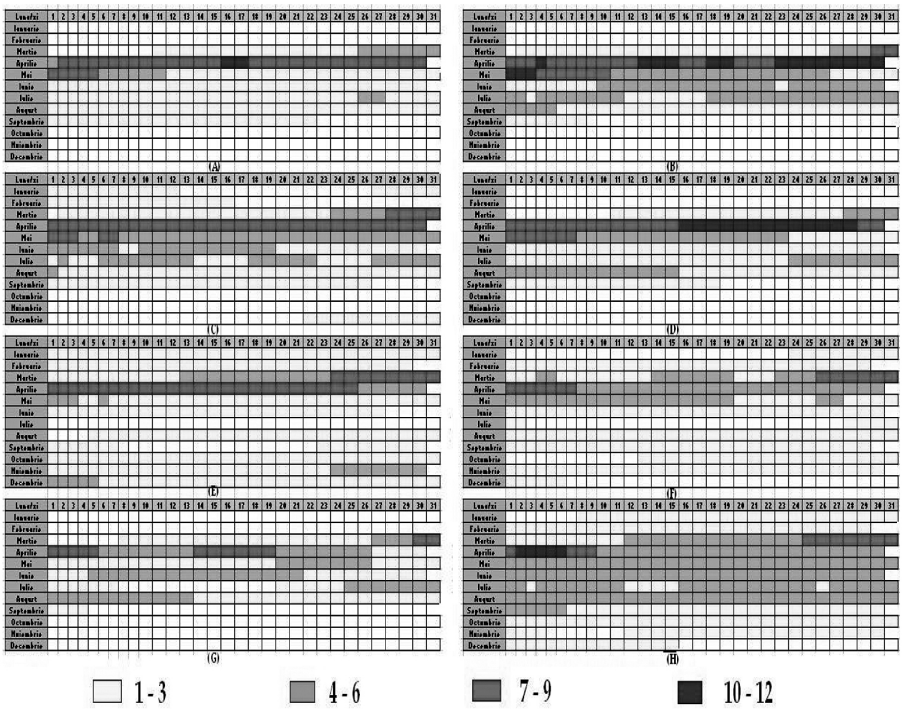

Figure. 4. Number of cases when the threshold value was exceeded in the interval 1981-2005 at the hydrometric stations: Brodina 2 (A), Țibeni (B), Ițcani (C), Brodina 1 (D), Horodnic (E), Părhăuți (F), Putna (G) and Șcheia (H)

Thus, it can be seen that in April are recorded the most cases of exceeding threshold value at all stations, most days occurring at stations on the main course, where the maximum flow lasts longer due to the overlap of floods and high waters on the incoming tributaries, and also at Brodina 1 station (10-12 of exceeding the threshold value). A lower frequency of threshold value exceeding (7-9 of exceeding the threshold value) is recorded in late March for stations located in the transition and plateau sectors or early May for stations located in the mountain sectors. At Țibeni and Ițcani stations, on the main course, are under the influence of the river's tributaries from the mountain sectors, but also on the influence of those in the transition and plateau sectors, occurs between 7 and 9 exceeding of the threshold value from late March to early May.

Seasonal frequency. In *winter* are recorded the lowest frequencies of maximum flow, since most large amounts of water are stored in solid form. At the mountain stations the maximum flow values are very low (between 2.9% at Brodina 1 station and 4.2% at Brodina 2 station), and at the stations in the transition and plateau sectors it reaches 13% at Horodnic and Șcheia stations (Fig. 5).

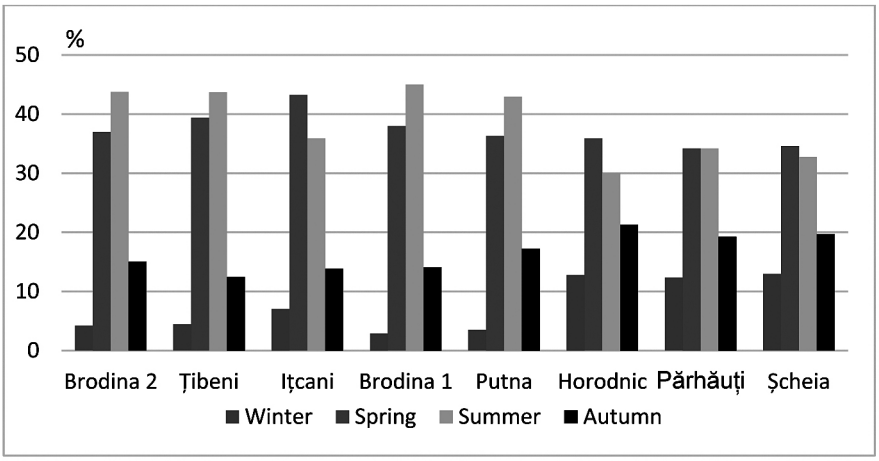

Figure. 5. Seasonal frequency (in %) of maximum flow

In *spring* high waterss prevail, in some cases overlapping flash floods caused by the sudden melting of the snow in the mountain area. The highest percentage values of periods with maximum flow are recorded at stations in the transition and plateau sectors (43.2% Ițcani station), which is most affected by high rainfall in spring. The lowest values are recorded at Părhăuți (34%) and Șcheia stations (35%).

Seasonal frequency with maximum flow is recorded in *summer*, when the highest frequency values occur at the stations from the mountain sector, where later snow melting determines the delaying of maximum flow period appearance. The

values in this season varies between 30% at Horodnic station and 45% Brodina 1 station.

In *autumn*, the frequency of periods with maximum flow is lower than in the preceding seasons, with the highest percentage values on the rivers from the plateau sector (21% at Horodnic station and 20% at Şcheia station), and the lowest recorded at Ţibeni station (12%).

3.2.2.Quantitative parameters

The quantitative parameters of maximum flow on the rivers from Suceava river basin are represented by the maximum daily discharge and the maximum volume registered during 1981-2005.

Maximum daily discharge. Daily maximum discharge in the period 1981 - 2005 at the hydrometric stations from Suceava river basin was recorded during the biggest floods occurred in these years (Table 8). The value of this discharge depended on the size of the catchment, the highest values being recorded on the main water course. It can be seen that some years are more common, such as 1995, when was the recorded the highest flood on Suceava river basin in this period, which affected mostly the mountain sector and main water course.

Table 8. Maximum absolute discharges appeared in the interval 1981-2005 at the hydrometric stations from Suceava river basin

River	Station	Maximum absolute discharge	Date of appearance
Suceava	Brodina 2	168	28.06.1995
Suceava	Ţibeni	373	29.06.1995
Suceava	Iţcani	552	17.08.2002
Brodina	Brodina 1	144	28.06.1995
Putna	Putna	34,8	29.06.1995
Pozen	Horodnic	17,9	05.08.2001
Soloneţ	Părhăuţi	118	29.07.1991
Şcheia	Şcheia	10,4	17.07.1988

Maximum volume. The intensity of maximum flow is calculated by using the volume of water drained during floods and high waters, calculated from daily discharges. This volume depends on the length of time it is recorded, but also on the amount of water drained during the period. He also is directly proportional to the surface of each river basin, with bigger values at the stations from the main water course. The largest volume of water drained occurred in years with most floods (1991, 2002, 2005) and corresponded to periods of different time lengths, ranging between 26 and 76 days (Table 9). They have appeared both in spring and in the summer.

Table 9. Average and maximum water volume registered at the hydrometric stations from Suceava river basin.

River	Station	Average volume	Maximum volume	Date of appearance
Suceava	**Brodina 2**	4.6	68.39	17.07-28.08.2002
Suceava	**Țibeni**	14.6	171.47	25.04-17.06.1984
Suceava	**Ițcani**	21.1	232.58	03.04-21.05.1996
Brodina	**Brodina 1**	2.1	34.52	17.07-30.09.2002
Putna	**Putna**	0.6	10.77	02.05-22.06.1984
Pozen	**Horodnic**	0.6	8.52	05.08-07.09.2005
Soloneț	**Părhăuți**	1.4	26.71	28.07-22.08.1991
Șcheia	**Șcheia**	0.1	2.73	16.07-7.09.1991

Case study – Țibeni Station

Țibeni hydrometric station is located in the plateau sector of Suceava river basin, in the middle sector of the river, with water discharges that are not influenced by manmade constructions.

The water flow variation from Suceava River on this station over the years shows how were distributed in one year the periods with maximum flow. In Figure 5 it can be seen the complete absence of periods of maximum flow in winter (days 1-60, 335-365), when minimum flow prevailed on Suceava River.

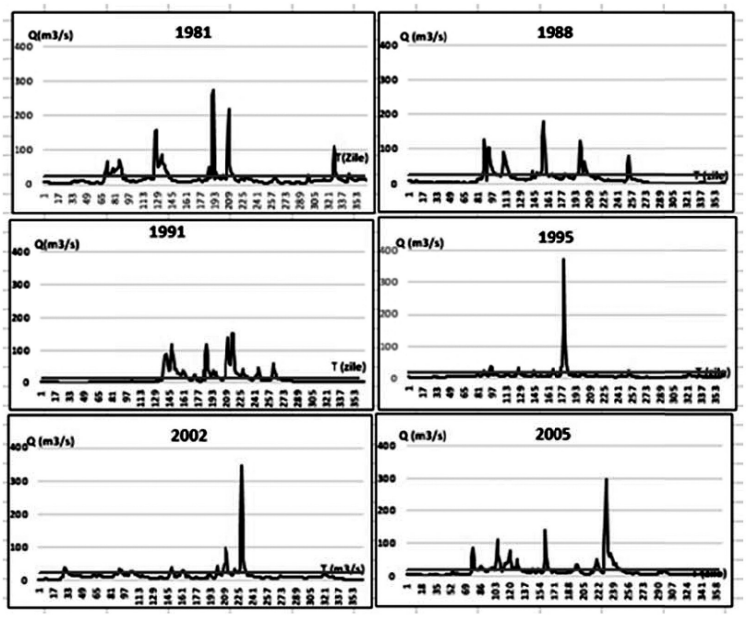

Figure 6. Daily flow variation of Suceav River at Țibeni Station in some characteristic years and the threshold value for maximum flow.

In the first part of spring, high waters prevailed, sometimes overlapping floods, lower rates of floods than those in summer, caused by snow melt overlapping with the fall of large amounts of rainfall.

In summer there appeared a decrease in the frequency and intensity of periods of high water periods, being replaced with floods of big discharges, especially in the middle and towards the end of this season. Sometimes between two large floods may appear a period of high waters caused by rainfall maintained at high levels due to the presence of an extended rainy periods for a long time (eg. 1991).

During autumn, the maximum flow has a low frequency at this station, in some cases appeared isolated at the beginning or the end of the season (September and November).

CONCLUSIONS

In Suceava river basin, the maximum flow has a distribution concentrated mainly in spring and summer, when is recorded the highest water flow in the basin, due in particular large amounts of precipitation fallen during these seasons in the basin; in the autumn and winter, maximum flow presents significantly lower values, in these seasons prevailing low waters periods, due to lower amounts of precipitation and to air temperatures decrease, which causes frost in the mountain.

High waters occur mainly in April and May, with variations depending on hydrometric stations' positioning in the basin. This is consistent with the general characteristics of the water flow regime in the Eastern Romanian Carpathians (Ujvari, 1972), and it is in total contradiction with water basins from Transylvania and the western part of Romania, where maximum flow occurs with greater frequencies in winter.

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