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CHARACTERISTICS OF FLOODS IN VALEA CERBULUI CATCHMENT

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Abstract

Floods are the most violent phenomena both through their manifestation and the damages upon the society. Valea Cerbului is a mountainous basin, located on the eastern slope of Bucegi Mountains. Their morphological, morphometric and climatic features are favoring the production of flash floods. Studying the causes of production and the characteristics of floods in this basin is important in order to mitigate the risk induced by these phenomena, especially in the inferior sector which overlaps the Buşteni town (renowned mountainous tourist resort) and where there are located elements of road and international and national railway infrastructure. After emphasizing the main control factors of floods in the study area, we determined and analyzed the monthly and seasonal frequency of the floods and the characteristic elements of some representative floods (growth, decreasing and total duration of the flood wave, volume and water layer drained). The study is based on statistical processing of the hydrological data series (monthly and annual maximum discharges from 1961 to 2010, daily and hourly discharges during the analyzed floods) from Buşteni hydrometric station on Valea Cerbului river. In order to determine the weather conditions that led to the floods, there have been used climatic data during their manifestation (daily average temperature and daily precipitation) from weather stations in the vicinity and within the basin (Vf. Omu - 2505 m, Sinaia - 1510 m and Predeal - 1090 m) (data from ECA&D database and the National Meteorological Administration). The analysis of floods shows that specific to Valea Cerbului Catchment are the flash floods, with rapid rise in water, esspecially when produced by heavy rainfalls. The long term precipitation or the rainfalls associated with the snow melting, are causing floods with longer durations. The annual maximum discharges have a maximum frequency from June to August: 19,2% of cases in June, 19,2% of cases in July, 23,1% in August (for the period 1961-2010). This fact shows the mainly pluvial origin of the annual floods: they are produced as a consequence of the heavy rainfalls, which are generating flash floods, with important destructive impact.

Keywords: floods, flood control factors, probabilities, Valea Cerbului Catchment.

1. INTRODUCTION

Due to their mode of manifestation and to the scale of damages produced to the environment and to the human community, floods can be considered one of the most violent hasards. They determine imbalances in riverbeds, as well as in social and ecological systems. Therefore, monitoring the watercourses is necessary for defense against floods to be made accordingly to physico-geographical and socio-economic features of each catchment. The aim of this paper is to analyze the frequency of flood occurrence and the their characteristics in Valea Cerbului Catchment - a small basin (26 km^2), whose main collector (Valea Cerbului River) - is an important right tributary of the Upper Prahova. The confluence of the two rivers is situated in the Buşteni town area - resort crossed by traffic routes of national and international importance (road: DN1 / E60 and railway route 200). Being a mountainous basin, with a significant relief energy, floods are common and can affect both the built up areas and the infrastructure and the human/ socio-economic activities (e.g. tourism and recreation in the lower sector of Valea Cerbului River). Given the importance of areas exposed to the flooding risk and the lack of studies that assess specifically aspects related to maximum flow and floods in Valea Cerbului Catchment, we considered necessary to approach this issue. In order to analyze the main characteristics of floods (time of growth, time of decreasing and total time, total volume and water layer drained, maximum discharge etc.) from Valea Cerbului Basin, after a brief overview of the factors influencing the production of peak flows and floods, we will detail aspects of: maximum discharges from 1961 to 2007, discharges with different probabilities of exceeding/ return time and frequency of floods exceeding the alert thresholds. Then we will summarize the characteristics of 42 floods considered from the interval 1986-2010.

2. DATABASE AND METHODOLOGY

This study is based on statistical processing of hydrological data series recorded at Buşteni gauging station on Valea Cerbului River. The data are obtained through the "Romanian Waters" National

Administration (RWNA) and refers to: annual maximum discharges (during 1961-2010), maximum monthly discharges, daily and hourly discharges during floods (between 1993-2010). Annual maximum discharges were used to estimate the maximum discharges with the probabilities of exceedance of 0.1%, 1%, 2%, 5% and 10%, using Pearson III theoretical binomial distribution. Flood characteristics were calculated for 42 floods from the period 1986-2010, using a program developed in Microsoft Excel, used in the operational activity carried out within RWNA.

For the flood with the highest peak discharge recorded during the period 1961-2010, we analyzed the climatic conditions (daily temperature and precipitation recorded before and during the flood) in order to establish the causes that have brought it. Climatic data are recorded at weather stations (W.S.) from the basin area and its vicinity: Vf. Omu WS (2505 m), Sinaia WS (1510 m), Predeal WS (1090 m). They were taken from the ECA&D database and by the means of the National Meteorological Administration (NMA).

Morphometrical data on the basin and on the river system are partly those published in *Atlasul Cadastrului Apelor din România* (1992), partly calculated using GIS. To obtain information through GIS, there has been used the topographic map, scale 1: 25,000 (published in 1985), and the geological map, scale 1: 200,000 (published in 1967).

3. GENERAL DATA ON STUDY AREA

Valea Cerbului Catchment is a small (26 km^2) mountainous basin, located on the eastern slopes of Bucegi Mountains (figure 1). The maximum altitude of the basin is 2505 m a.s.l. (Omu Peak), while the minimum is 861 m a.s.l. (at the confluence of Valea Cerbului with Prahova, in Buşteni town) - hence a relief energy of 1644 m. The mean altitude is 1536 m. The basin is monitored through the gauging station Buşteni, located at approx. 1 km upstream the confluence of Valea Cerbului with Prahova and it controls 96% of the basin's area.

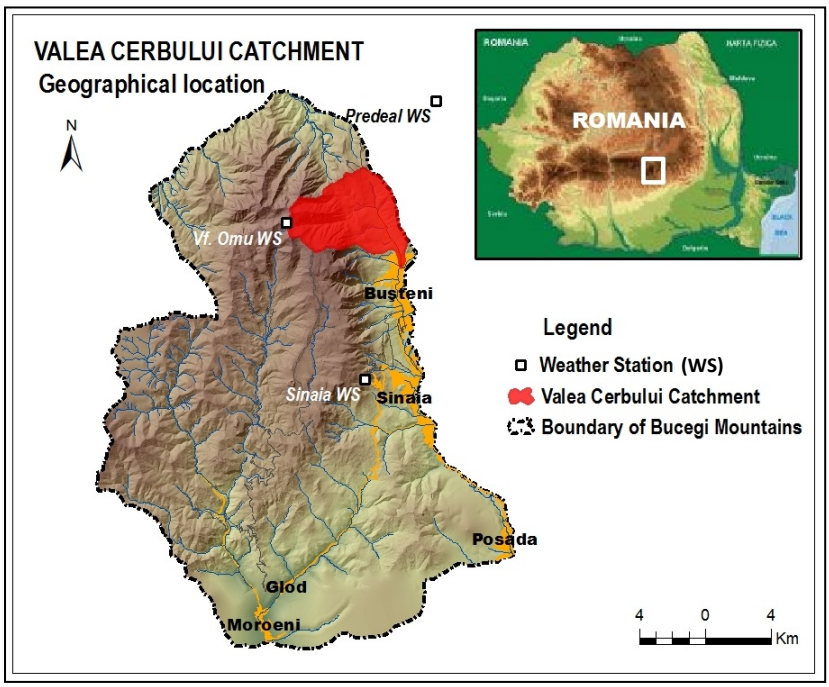

Figure 1. Geographical location of Valea Cerbului Catchment

Valea Cerbului Catchment has a well individualized river system, with an average density of 0.32 km/km^2, without being considered the intermittent (torrential) watercourses, which strongly fragment the relief – particularly in the high region, on the upper sectors of the main rivers (figure 2). The main collector has a total length of approx. 9.5 km, only the last 5.6 km having a permanent regime (values resulting from GIS). The longitudinal profile of Valea Cerbului has a mean slope of 80 m/km.

From the climatic point of view, the most important influencing factors for liquid flow are the precipitations and the air temperature, to which are added the snow layer and the winter phenomena on rivers.

Due to significant relief energy, the climatic parameters have notable spatial differences.The consequences of this fact are reflected in the monthly flow regime. Thus, the mean monthly precipitations in the basin area are: 976.8 mm at Vf. Omu Weather Station (W.S.), 945,7 mm at Predeal W.S. and 1031,2 mm at Sinaia W.S.. The mean annual temperature decreases from 4.9°C at Predeal W. S., to -2.5°C at Vf. Omu W. S. (1961-2006, according to NMA). The mean depth of the snow layer increases from 137 days/year at Predeal, to 145 days/year ar Sinaia and 220 days/year at Vf. Omu. The highest monthly average thickness is recorded in January (approx. 45 cm) at weather stations from lower altitudes and in June at Vf. Omu (88.3 cm) (*Clima României*, 2008).

In the alpine area, snow depth increases until June (due to heavy rainfall during winter) and its melting is delayed compared to lower areas. Thus, by late spring and early summer the flow is often very rich, to heavy rainfall being added the sudden snow melt. During this period, pluvio-nival floods are particularly common.

Lithological and morphological characteristics, together with land cover, influence, in their turn, the occurrence of floods and their features. At altitudes above 1500 m there are calcareous conglomerates (Bucegi Conglomerates) and sandstones, while at lower altitudes, there are calcarenites and sandstones (Comarnic layers). On the left bank of Valea Cerbului, in the lower sector, the lithology includes: marls, sandstones and spilites (Sinaia layers) (Cristea & Dumitriu, 1964). The lithology favors the infiltration of precipitations and diminishes the flow. From morphological point of view, the higher area, occupied by calcareous conglomerates, corresponds, generally, to slopes with gradients between 45° and 80°, the drainage of precipitation water being rapid.

In the lower sector of Valea Cerbului River slopes are smoother, not exceeding 25°, and even 10° in the floodplane (values derived from slope map made through GIS, after topographic map 1: 25,000). The sudden change of slopes inclination results in accumulation of alluvia in the riverbed of Valea Cerbului and at the confluences with the other streams, which may favor the raise of the water level and river overflow. On the other hand, the basin shape, rather round than elongated, favors rapid concentration of volumes of water and increases the frequency and the magnitude of flash floods. Valea Cerbului Catchment is more than 70% covered by forests (value obtained through GIS, after CLC-2006). They influence the flow regime through interception, by delaying and reducing the maximum flows and by reducing soil erosion. At high altitudes (over 1700 m), where slopes are generally exceeding 40°, there are herbaceous plant associations, pastures and rocky areas, which favors the flow and regressive erosion.

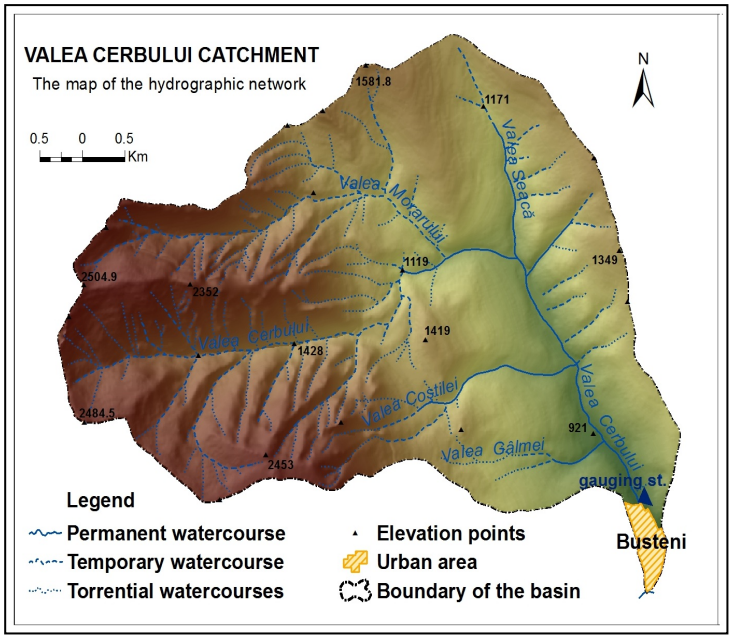

Figure 2. Valea Cerbului Catchment

4. SPECIFIC FEATURES OF MAXIMUM FLOW AND FLOODS

4.1. The variability of annual and monthly maximum discharge

As a result of the small size of the basin, the annual mean discharge of Valea Cerbului is only 0.511 m^3/s (for the period 1961-2010, according to RWNA). The coefficient of variation is approximately equal to 1 (Cv = 1). The mean flow regime is rich in spring and summer, with highest values in June and July (0.8 m^3/s, respectively 0.89 m^3/s). The interval March – August totals, on average, over 70% of the mean annual water volumes transited in basin (Perju, 2012). In these conditions, the highest values of maximum monthly discharges are specific to the summer : June - 62.3 m^3/s, July - 22.4 m^3/s, August - 24.7 m^3/s (1993-2010) (figure 3). They are the consequence of heavy rainfall. For June, heavy rainfall can be associated with late snow melting from the peaks or valleys sheltered from direct solar radiation.

The annual maximum discharge values are ranging between 1.03 m^3/s and 62.3 m^3/s (for 1961-2010 period). The average of the maximum discharges is 11.5 m^3/s, threshold exceeded in 34% of cases in the period under review. The linear trend of the maximum discharges is ascending and statistically significant according to Mann-Kendall test (with a level of sgnificance of 0,01) (figure 3).

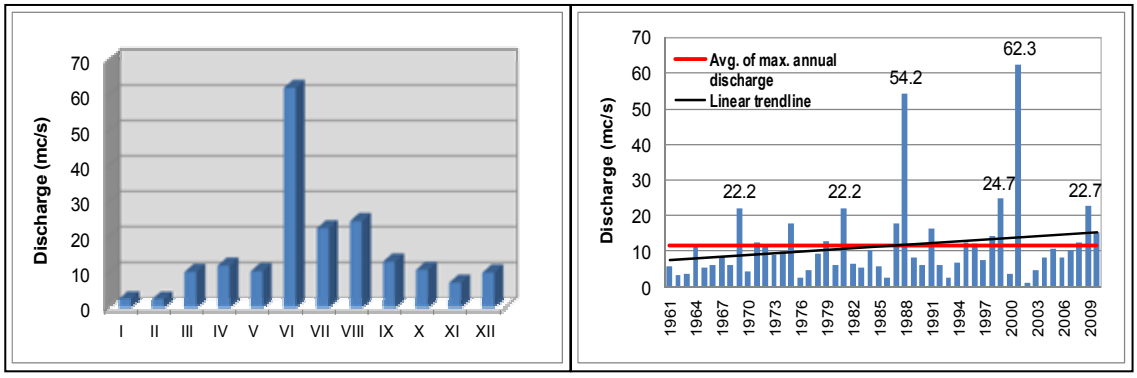

Figure 3. Maximum monthly discharge (1993-2010) (left) and maximum annual discharge (1961-2010) (right) at Buşteni gauging station, on Valea Cerbului River (according to RWNA data)

4.2. The frequency of floods

The annual floods have a maximum frequency in the summer months: 19.2% in June, respectively in July and 21.3% of cases in August. The minimum frequency of annual floods is specific for the interval November - February. In the analysed period there were no annual floods in January (figure 4).Seasonally, the minimum number of annual floods is in winter (3.8%) and the maximum number in summer (61.5%) (figure 4).

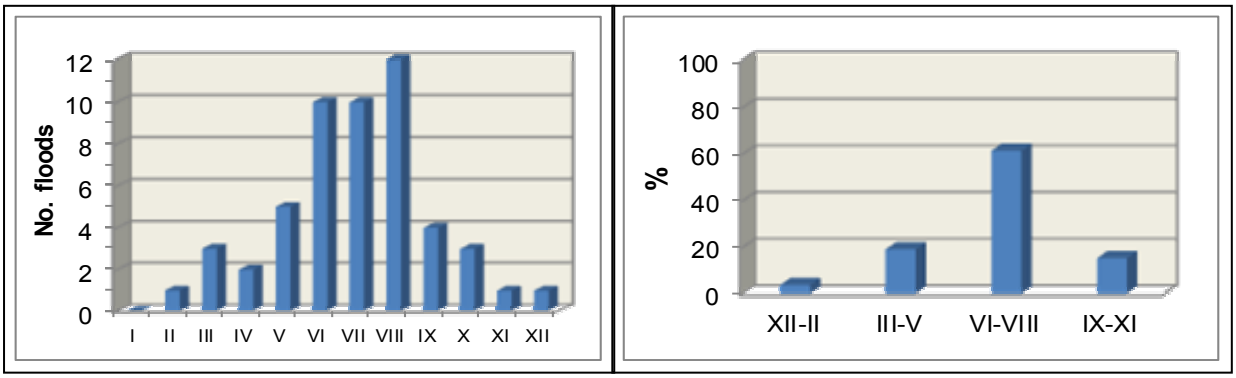

Figure 4. Monthly frequency (left) and seasonal frequency (right) of the annual floods at Buşteni gauging station, on Valea Cerbului River (1961-2010)

For a more rigorous analysis of monthly and annual frequency of floods there have been considered the alert thresholds and 42 floods (representing the annual floods and other major floods during the year - obtained from RWNA), which are recorded during 1986-2010, at Buşteni gauging station, on Valea Cerbului River. Therefore, we determined the number of cases in which the threshold values of the discharges were exceeded by the peak discharges of the floods considered. The alert thresholds are used in operational activity for establishing areas affected by large floods and for the adoption of measures to prevent flooding. Setting these thresholds depends on physico-geographical features of the basin, on the one hand, and on the position of socio-economic and infrastructure sectors, on the other (Stănescu and Drobot, 2002). For Valea Cerbului river, the discharges equivalent with the alert thresholds are: 9.4 m^3/s - warning discharge, 16.0 m^3/s - flooding discharge, 30.8 m^3/s - danger discharge (according to RWNA).

Floods with peak discharges superior to the alert thresholds are common from March to September. Their maximum frequency is specific for the period June - August (in June, 5 of the floods analyzed exceeded the attention threshold - of these, 3 had a discharge superior to the flooding threshold and one has exceeded the danger threshold: June 2001). The flooding discharge was exceeded in six of the cases reviewed, only in summer months and the danger discharge was exceeded twice in June and July (figure 5).
At annual level, there is a highly irregular frequency of the discharges superior to the alert thresholds. In three years, there have been two floods by year with more than 9.4 m^3/s. The flooding threshold was exceeded six times out of the 42 floods considered, two of which have exceeded the danger threshold (in July 1988 and in June 2001).

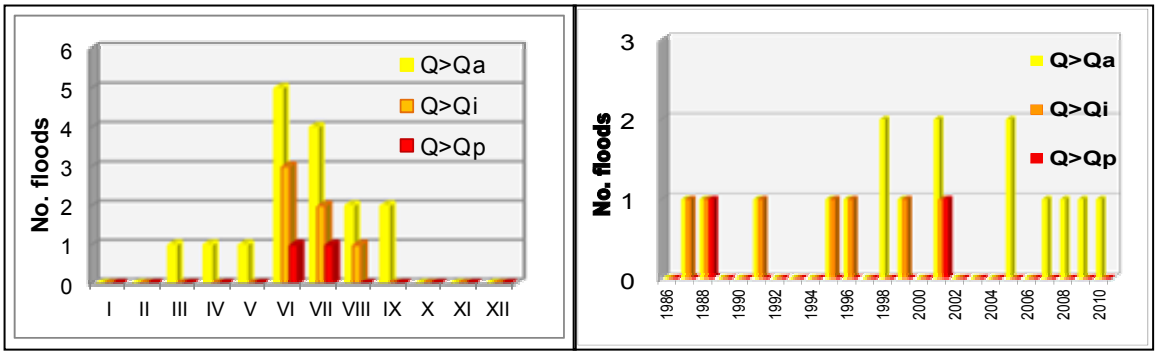

Figure 5. Monthly frequency of floods exceeding the alert thresholdings (left) and the annual number of floods exceeding the alert thresholfings (right) at Buşteni gauging station, on Valea Cerbului River (alert thresholds: Q – flood discharge; Qa – warning discharge, Qi – flooding discharge, Qp – danger discharge) (1986-2010)

4.3 Maximum discharges with different exceedence probabilities

Estimating flows with different probabilities of exceedance is necessary for the design of hydrotechnical and flood protection works (Kritsky and Menkel, 1969). Unlike the alert thresholds, these ones do not capture the particularities of each sector of river in part and the socio-economical factor (for example: the existence of communication routes, of built and cultivated areas etc.). The exceedence probabilities take into account only the recorded maximum flows for which is made a statistical analysis based on the use of distribution functions. To estimate the maximum discharge with different probabilities of exceedance for Valea Cerbului River, we used the theoretical Pearson III distribution curve, for assurances of: 0.1%, 1%, 2%, 5% and 10%. For the asymmetry coefficient there was chosen the calculated value (Cs ≈ 3), because the probabilities thus obtained are closer to the empirical curve values.

The discharge with the probability of 5% (33.56 mc / s) is close to the discharge corresponding to the danger threshold (30.8 m^3/s) (Table 1). This value was exceeded twice: during the historical flood of June 2001 (Q = 62.3 m^3/s) when the discharge exceeded the assurance of 1% (58.14 m^3/s) and in July 1988 (Q = 54.2 m^3/s), when there was an average return period of 50 years (57.05 m^3/s).

Table 1. Maximum discharges (m^3/s) with different exceedence probabilities (p%)/ average return periods (years) for Valea Cerbului River, at Buşteni gauging station (1961 – 2010)

p%/ years	0.1%/ 1000	1%/ 100	2%/ 50	5%/ 20	10%/ 10
Q (cm/s)	95.19	58.14	47.05	33.56	23.61

4.4 Characteristics of floods

The characteristics of flood waves provides information on floods' manifestation and therefore, on their possible impact. The characteristics of floods are influenced by several factors such as: amount of rainfall, lithology, relief energy and basin's degree of inclination, basin shape, type of vegetation.

The maximum flow (for the period 1961-2010) on Valea Cerbului was recorded during the flood of June.18-25.2001. The water level increased in only one hour and a half from a water level of 75 cm (3.19 m^3/s) to 220 cm and an equivalent discharge of 62.3 m^3/s (figure 6). The total duration of the flood was of 24 hours. The total water volume transited during the flood was of 1.56 mil. m^3, which corresponds to a specific discharge of 2396.2 l/s·km and a water layer of 47.2 mm. The cause of this flood was the heavy rainfall fallen in the catchment area, especially on June 19, when there were recorded 83.5 mm at Vf. Omu WS, 100.4 mm at Sinaia WS and 75.4 mm at Predeal WS. The rising temperature that caused the complete melting of the snow layer from the peaks, associated with the rainfall recorded between 12 and 16 of June, have represented favoring factors for its generation. The saturation of the underlying layer with water coming from the melted snow and from the liquid precipitation intensified its magnitude.

For the analysis of flood caracteristics we considered 42 floods. These floods were recorded within the hydrometric network in the period 1986-2010. Of these, 19 are annual floods. On average the total duration of analysed floods is 39,2 hours, while the average growth time is 14.2 hours.

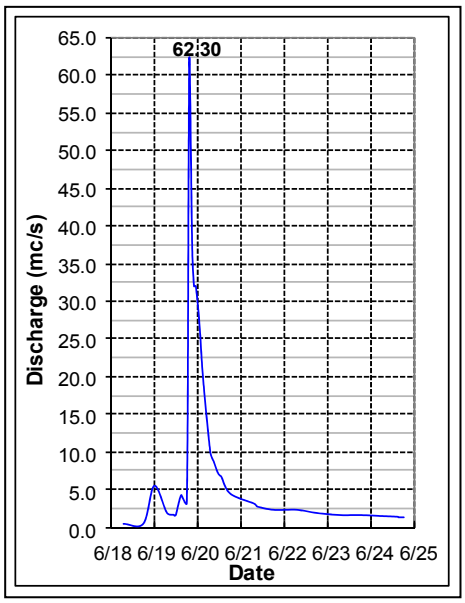

Figure 6. The flood of 6.18-25.2001, on Valea Cerbului, at Buşteni gauging st.

But flash floods are frequent, thus the minimum duration of floods from the outbreak of the flood, until reaching the peak discharge is one hour (August 2010), the minimum decreasing time is of 0.83 hours – value recorded in July 2004 when also the total duration of the flood was minimal: 2.5 hours. The reduced growth time shows the speed of growth of the discharges and the power of altering the riverbed by erosion and alluvia transport.

The flood with the largest growth time (52 hours) was recorded in August 2006. The highest specific discharge was recorded during the historical flood of June 2001, namely 2396.2 l/s·km. The average height of the water layer is about 11,5 mm. The largest volume of water transited during a flood (1,888 mil. m^3) and the maximum water layer drained (51 mm) were recorded in July 2009.

CONCLUSIONS

The physico-geographical conditions of Valea Cerbului Catchment (such as prevalence of watercourses with a torrential regime, the abundant precipitations, the high relief energy, the accentuated slopes, the lithology etc.) are favorable for the occurence of floods. Certain features of the basin (eg.: the round shape, the existence of bare rocks and herbaceous vegetation on the high slopes, the torrential rainfalls during summer) favor the formation of rapid and violent floods. In these conditions, floods have often reduced growth time (1 to 10 hours). They frequently occur between April to September, especially in summer months, when the frequency of annual floods is maximum (61.5%). The maximum discharges recorded during the summer floods exceed generally the discharges equivalent with the alert thresholds. The value of the discharge equivalent with the danger water level (30.8 m^3/s) is close to that of the average return period of 20 years (33.56 m^3/s), both being exceeded twice in the period under review: in June 2001 - 62.3 m^3/s (when it was exceeded the probability of 1%) and in July 1988 - 54.2 m^3/s (when it was exceeded the probability of 2%). On the basis of studies that asses such issues there can be made several considerations regarding the protective measures (taken or necessary) against the risk induced by these. In the case of Valea Cerbului Catchment, the knowledge of maximum flow features is even more important because floods can cause damage to the economic objectives of national and international importance, such as E60 (DN1) and rail route 200. Meanwhile, Valea Cerbului basin is a tourist destination of a local importance and floods affect both, the human community from Buşteni town and the activities specific for this urban settlement (for e.g.: camping in the lower sector of Valea Cerbului River, hiking/ trekking).

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